Peak -to - Average Power Ratio Reduction in OFDM using Repeated Frequency Domain Filtering and Clipping (RFC)

S . Nandhini Devi
Dept of ECE,
Annamalai University
Chidambaram, India

G. Ramprabhu
Dept of ECE,
Annamalai University
Chidambaram, India

Abstract— *Orthogonal Frequency Division Multiplexing is a Key Broadband Wireless Technology, Which supports high data rates in both cellular and LAN standard. One of the main drawbacks in OFDM system is the high Peak to Average Power Ratio (PAPR).In OFDM, when the peak deviation about average is significantly high, the signal level moves outside the dynamic linear range. This results in amplifier saturation, thus leading to severe Inter carrier Interferenec (ICI) and so on. In this work a simple method is used for reducing Peak-to-Average Power Ratio in OFDM is presented. Repeated frequency domain filtering and clipping (RFC) and this compare with Repeated clipping and frequency domain filtering. This paper highlights the performance and advantages of proposed technique. The simulation shows an improved PAPR and Bit Error Rate.*

Keywords—*OFDM,PAPR,BER,RFC*

I. Introduction

In this Smart world, demand for the multimedia data services has grown drastically and this trends are expected to continue in future.Orthogonal Frequency Division Multiplexing (OFDM) is the latest wireless technology and it is the both multiplexing and modulation technique. Were, OFDM is the basis for two keys in wireless communication systems. They are 4G (fourth generation) and WIMAX (world wide interoperability fro microwave access) because, the reason is OFDM is a Broadband Wireless Technology. This supports data rates in excess of 100Mbps. Not only cellular standard and also OFDM is the basis for Wireless LAN standard like IEEE 802.11 a /g /n here, the data rates supports up to 200Mbps.

OFDM architecture uses efficient algorithms in transmission scheme. Which is IFFT and FFT, so Inverse Fast Fourier Transform at the Transmitter and Fast Fourier Transform at the Receiver can be Performed in a very fast fashion, there is no matrix inversion, it just adds to the complexity. So, employing cyclic prefix, inter symbol interference has been removed in the frequency domain.

But, 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.

PAPR has a pernicious effect on battery lifetime in mobile applications. In many cut - rate applications, the problem of high PAPR may exceed the all potential benefits of multicarrier transmission systems.

II. Peak-To-Average Power Ratio

PAPR is the most critical factor in OFDM. The high PAPR value means use of high power amplifier (HPA) on a large linear scale at the transmitter end. This nonlinearity of high power amplifier gives in-band distortion, which allows system to increase its BER to out-of-band (OOB) distortion,which in turn gives to high adjacent channel interference. The major drawback of a high PAPR are increase intricacy in the analog to digital and digital to analog converter then, reduction is efficiency of RF amplifiers.

Peak to Average Power Ratio (PAPR) is defined as ratio of maximum power to the average power of complex signal. Mathematically it is given by

$$\mathrm{PAPR}\{x(t)\} = \frac{\max |x(t)|^2}{E\{|x(t)|^2\}} \qquad (1)$$

Reducing the max |x (t)| is the principle goal of PARP reduction techniques. In the time past, discrete- time signals are dealt with many systems, most of the PAPR techniques are carry out to deal with samples of amplitude of x (t). Due to the symbol spaced output in the first equation we find some of the peaks missing which can be compensated by oversampling the equation by some factor to give the true PAPR value.

II. Distribution of PAPR

To design and develop an effectual PAPR reduction technique, it is very important to exactly identify the issue of PAPR in OFDM systems.

The distribution of PAPR plays an vital role in the whole OFDM system. The distribution of PAPR can be used in determining the proper output back-away of the HPA to minimize the total degradation. It can be used to directly calculate the BER and to estimate the reasonable information rates.

The Cumulative Distribution Function (CDF) is one of the mostly used parameters, the Complementary CDF (CCDF) is used instead of CDF, which is used to measure the efficiency of any PAPR technique. Conventionally, this helps us to measure the probability that the PAPR of a certain data block run over the given threshold.

By executing the Central Limit Theorem for a multicarrier signal with a large number of sub-carriers, the real and imaginary part of the time domain signals have a mean of zero and a variance of 0.5 and follow a Gaussian distribution. the amplitude of OFDM symbols followed Rayleigh distribution, where as a central chi-square distribution with two degrees of freedom is followed for the power distribution of the system.

The CDF of the amplitude of a signal sample is given by

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

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:

$$FZ_{max}(z) = P(z_{max} > z)$$

$$= 1 - P(Z_{max} \leq z)$$

$$= 1 - F_{max}(Z)$$

$$= 1 - (1 - e^{z^2})^N \quad (3)$$

Where, z is the given reference level.

III. RCF and RFC Techniques for PAPR Reduction

A. *Repeated Clipping and Frequency Domain Filtering (RCF)*

In the clipping technique hard limiting is applied to the amplitude of the complex values of the output. The filtering technique is designed to alleviate or cancel Out Of Band (OOB) distortion dependent on oversampling value but cannot correct in-band distortion.

The input vector $A_i = a_0, a_1, \ldots. a_{N-1}$ is first transformed using an oversize IFFT,N is the number of subcarriers in each OFDM symbol. For each oversampling factor of I_1, the input vector is extended by adding $N(I_1-1)$ zeros in the middle of the vector. This results in trigonometric interpolation of time domain signal. Trigonometric interpolation gives perfect interpolation when the original signal consists of integral frequencies over the FFT window. This is the case for OFDM.. The interpolated signal is then clipped.

In this technique, hard-limiting is applied to the amplitude of the complex values at the IFFT output. After an IFFT, the original signal is clipped in the time domain. The clipping can be described as shown below

$$C = \sqrt{CR * E(x^2) * \frac{x}{|x|}} \quad (4)$$

Where , $|x|^2 > Cm$

$$C = x$$

Where, $|x|^2 \leq Cm$

Where C represents output of time domain signal

$$Cm = CR * E(|x|^2) \quad (5)$$

Where Cm represents threshold clipping level, $|x|^2$ represents signal power and E ($|x|^2$) represents mean signal power. The clipping ratio (CR) is defined as the ratio of the clipping level to the mean power of the unclipped baseband signal

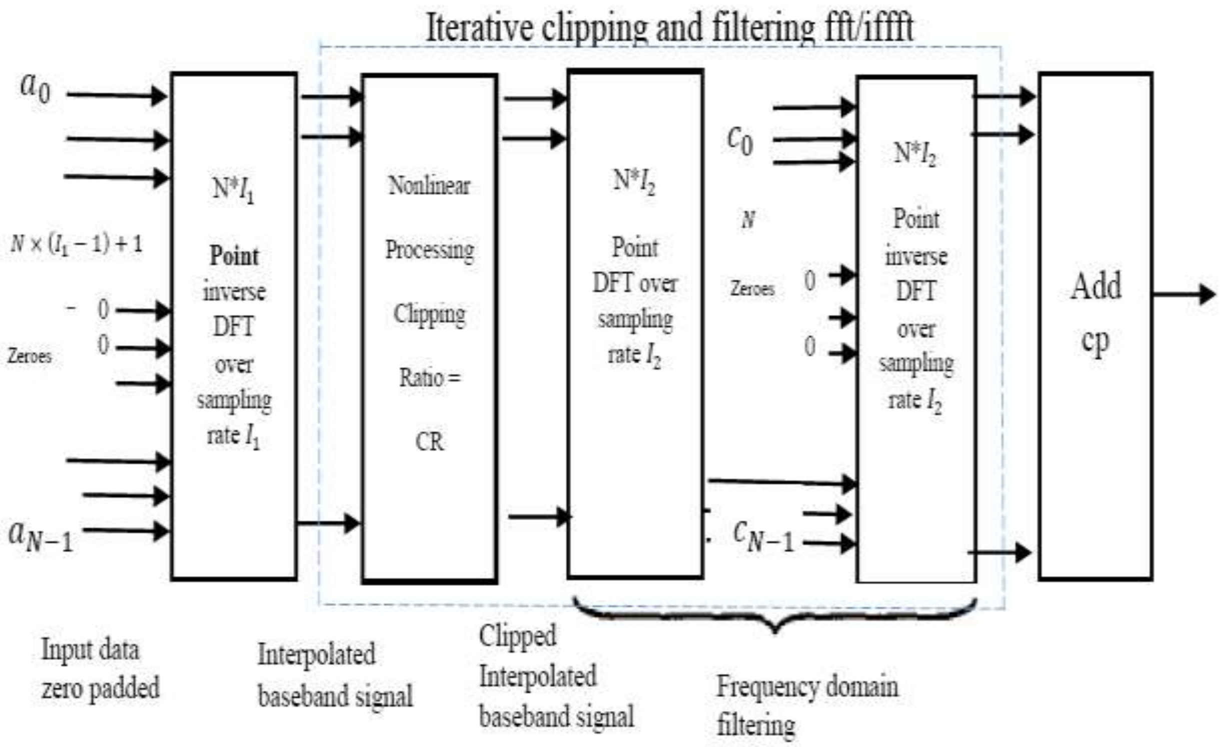

Figure 1 Block diagram of Repeated Clipping and Filtering technique

As shown in the equation (4), the discrete time domain signals are 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. To reduce OOB power caused by clipping, the clipping is followed by frequency domain filtering. The filter consists of two FFT operations. 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 $_{0,i}$,$C_{N/2-1}$,$C_{NI1-N/2+1}$,…,C_{NI1-1} are passed unchanged to the inputs of the second IFFT while the OOB components, $_{=}C_{N2+1}$,…,C_{NI1-N2} are nulled [1 and 5] 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, before interpolation, this is very less than for clipping.

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.

B. Repeated Frequency Domain Filtering and Clipping (RFC)

This 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.

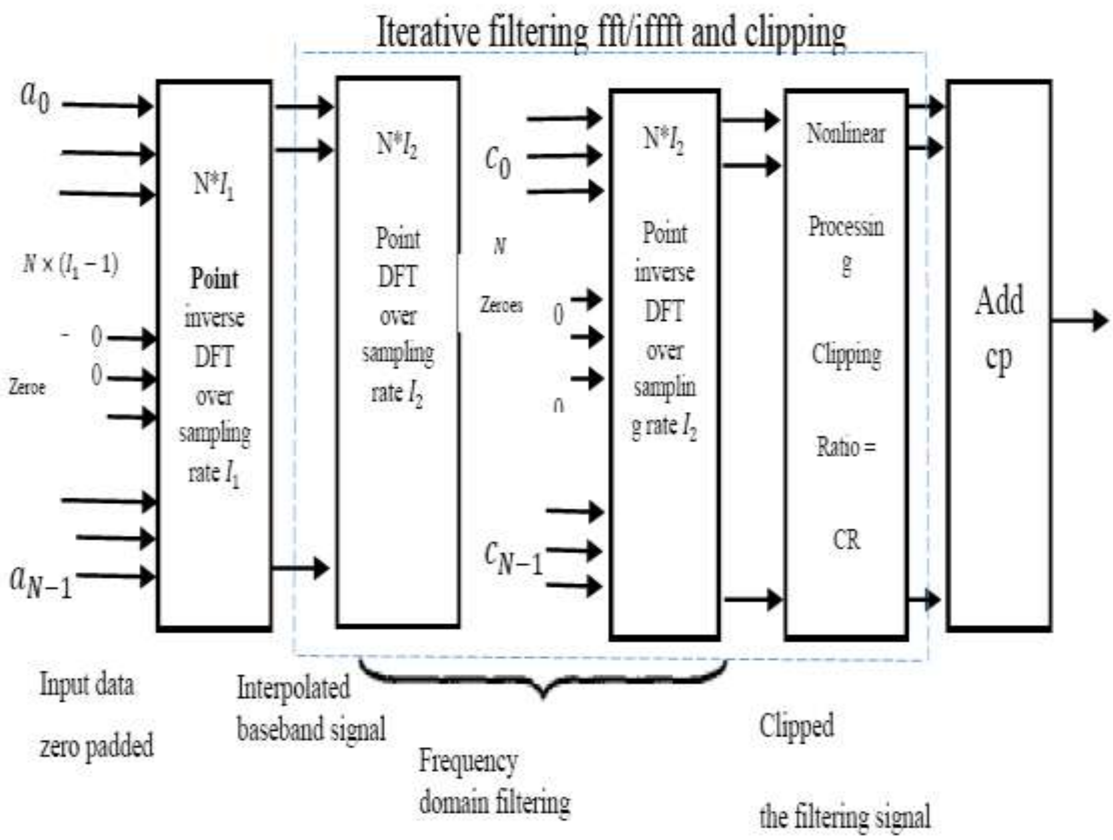

Figure2 Block Diagram Of Repeated Frequency Domain Filtering and Clipping RFC

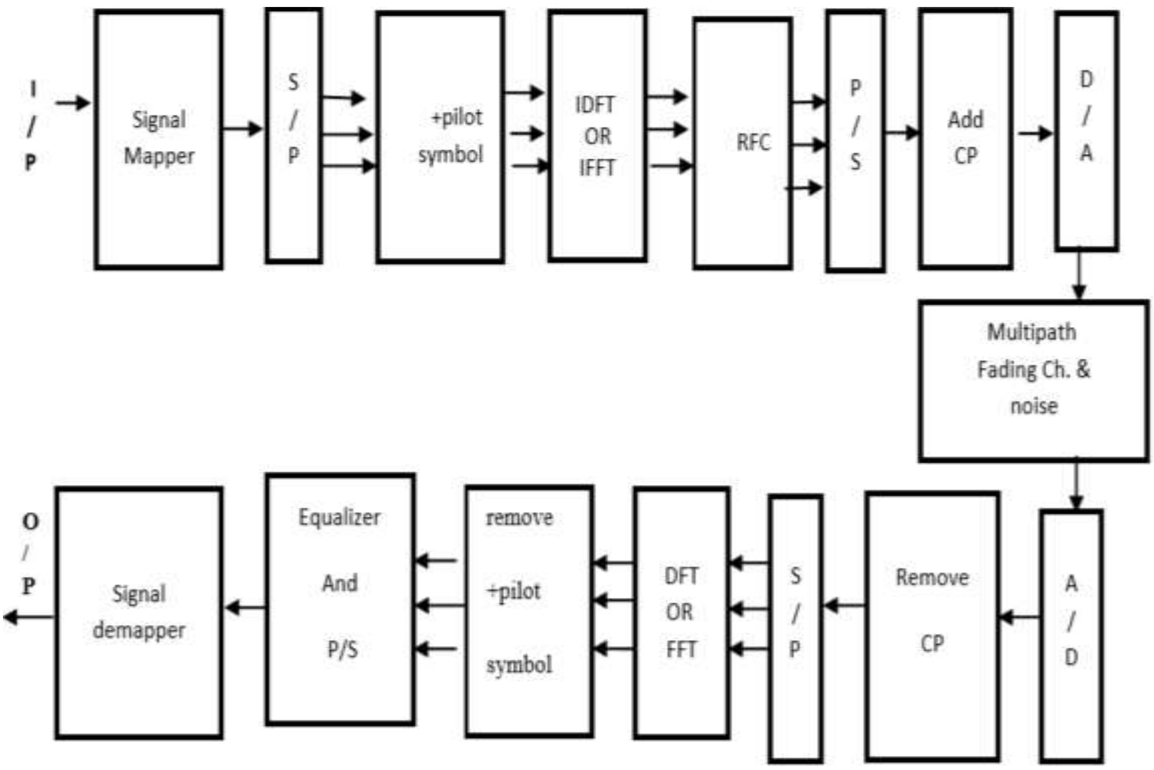

Figure 3 OFDM System Model With RFC

V. SIMULATION RESULTS AND DISCUSSION

The results are simulated using MATLAB and OFDM Parameters chosen for simulating the results are

- Number of sub-carriers: 128.
- FFT length: 128.
- Number of OFDM frames: 200.
- Channel model: Rayleigh multi-path fading channel.
- No. of. Iterations for clipping and filtering : 4
- Interpolation factor : 2

PAPR can be computed using equation (1)

CCDF (Complementary Cumulative Distribution Function) computes the power complementary to complementary distribution function from a time domain signal. The CCDF curve shows the average power level of the measured signal, or equivalently, the probability that the signal power will be above the average power level.

The PAPR performance (CCDF) of RCF technique with different clipping ratios are shown in figure 4 and 5

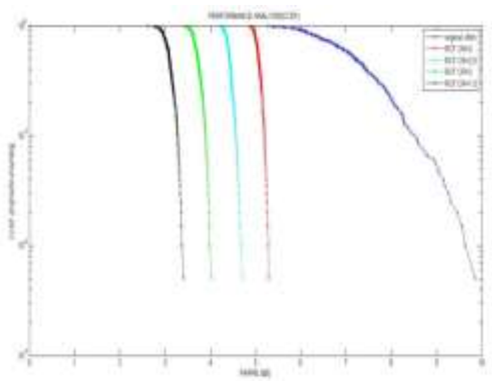

Figure 4 PAPR performance (CCDF) analysis using QPSK modulation.

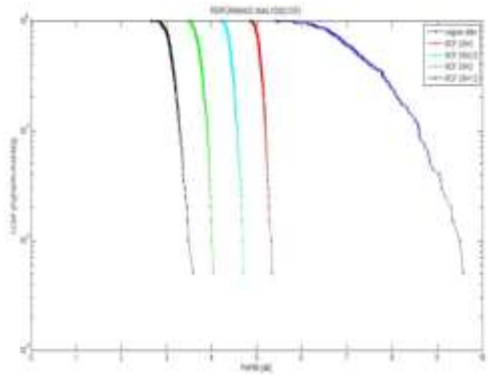

Figure 5 PAPR performance (CCDF) analysis using 16 QAM modulation.

CCDF performance analysis of OFDM using QPSK and 16 QAM modulation for different clipping ratios. Performance increases with reduction in clipping ratio. CCDF performance of QPSK and QAM is almost same hence PAPR performance of RCF technique is independent of modulation level.

The receiver Bit Error rate performance of RCF technique with different Clipping ratios are shown in figure 6 and 7

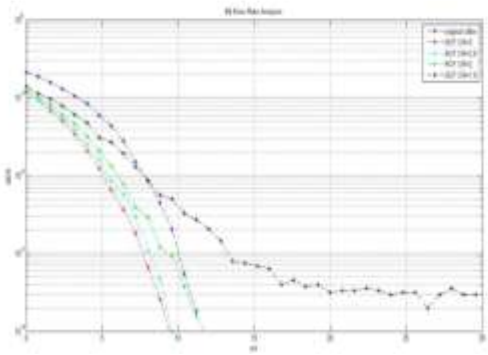

Figure 6 BER Performance analysis using QPSK modulation

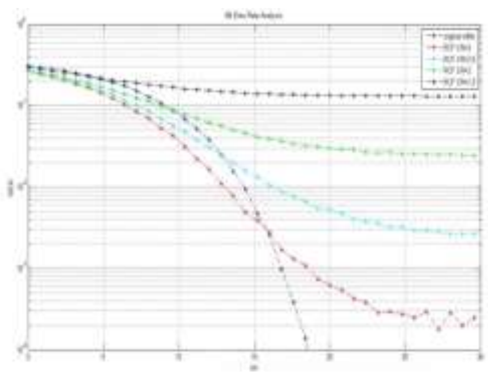

Figure 7 BER Performance analysis using 16-QAM modulation

BER performance degrades with decrease in Clipping Ratio as oppose to PAPR performance. BER performance degrades with increase in the modulation level also.

Figure 8 and 9 shows the comparison of PAPR and BER performance of RCF technique with oversampling factor (interpolation factor) of 2 and without oversampling for QPSK modulation (CR =3)

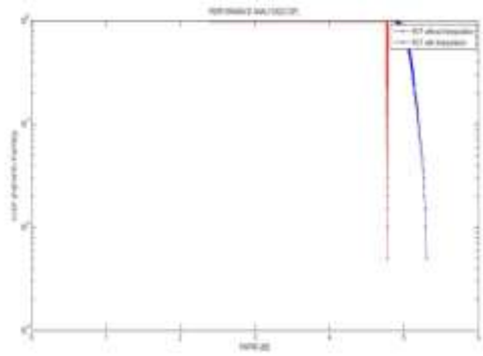

Figure 8 PAPR performance (CCDF) Comparison of RCF with and without Interpolation

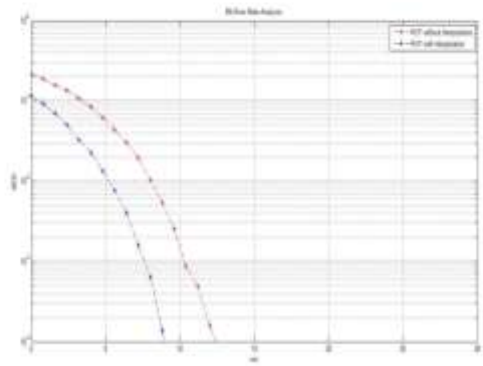

Figure 9 BER performance Comparison of RCF with and without Interpolation

Bit error rate performance of RCF technique increases with increase in interpolation factor while PAPR performance decreases with increase in interpolation factor.

Simulated results of RFC technique for PAPR reduction.

The PAPR and BER performance of RFC technique using QPSK modulation with CR =3 is shown and compared with RCF in figure 10 and 11

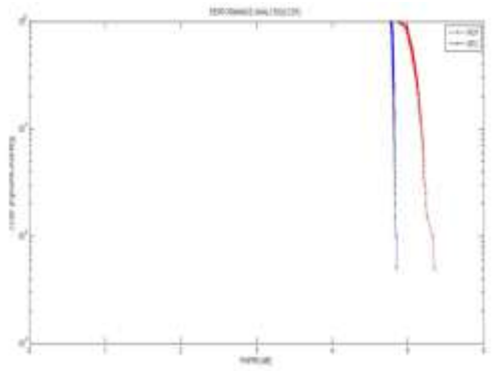

Figure 10 PAPR performance (CCDF) comparisons of RCF and RFC techniques

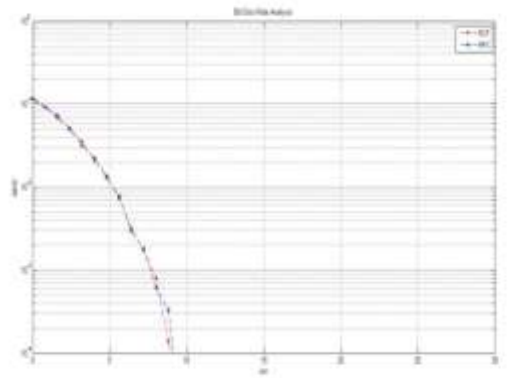

Figure 11 BER performance comparisons of RCF and RFC techniques.

RFC technique has better PAPR performance without degradation in BER performance.

VI. CONCLUSION

This method based on Repeated Clipping and Filtering technique (RCF) and Repeated Frequency domain filtering and Clipping techniques (RFC) for PAPR reduction was presented and performance in term of CCDF and BER was evaluated. Both the techniques reduce PAPR without any increase in the out –of –band power.

The PAPR performance of both techniques increases with decrease in the Clipping ratio and BER performance degrades with decrease in the Clipping ratio, so selection of optimum clipping ratio is vital. Further BER performance of the both techniques shows better improvement when interpolation factor is increased.RFC is better than RCF in performance especially when interpolation factor is greater than two.

References

[1] J. Armstrong. “Peak-to-average power reduction for OFDM by repeated clipping and frequency domain filtering,” IEEE Electronics Letters, vol. 38, pp. 246 - 247, Feb 2002.

[2] Zainab saad Hadi and Buthaina mosa Omran. “ Peak to Average power reduction using Repeated frequency domain filtering and clipping” , International Journal of Computer Applications (0975 – 8887) Volume 122 – No.11, July 2015.

[3] Sayed Shoaib Anwar, S.L. Kotgire, S.B. Deosarkar and D. Elizabeth Rani, “New Improved Clipping and Filtering Technique Algorithm For Peak-To-Average Power Ratio Reduction of OFDM Signals”, International Journal of Computer Science and Communication Vol. 3, No. 1, January-June 2012, pp. 175-179.

[4] R. Prasad. OFDM for Wireless Communications Systems. Artech House Publishers, August 2004.

[5] J. Armstrong “Peak-to-Average Power Reduction in Digital Television Transmitters,” Digital Image Computing Techniques and Applications, pp.1-6, January 2002.

[6] K. Fazel and S. Kaiser, Multi-Carrier and Spread Spectrum Systems: From OFDM and MC-CDMA to LTE and WiMAX, 2nd Edition, John Wiley & Sons, 2008.

[7] G. Wunder, R. F. H. Fischer, H. Boche, S. Litsyn, J,-S. No, “The PAPR Problem in OFDM Transmission: New Directions for a Long-Lasting Problem,” *IEEE Signal Processing Magazine*, vol. 20, no. 6, pp. 130-144, November 2013.

[8] K. Takeda and F. Adachi “A PAPR Reduction Scheme Without Side Information For OFDM Signal Transmissions,” IEEE Transactions on Signal Processing, vol. 60, pp. 3657- 3669, July 2012.

[9] T. Jiang, and Y. Wu, “An Overview: Peak-to-Average Power Ratio Reduction Techniques for OFDM Signals,” IEEE Transactions on Broadcasting, vol. 54, no. 2, pp.257-268, June 2008.

[10] Leonard J Cimini Jr and Nelson R Sollenberger. “Peak-to-average power ratio reduction of and OFDM signal using partial transmit sequences,” Communications Letters, IEEE, 4(3):86–88, 2000.

[11] Y. Cho, J. Kim, W. Yang, and C. Kang, MIMO- OFDM Wireless Communication with MATLAB. Wiley,2010.

[12] M. M. Mowla , and S.M. M. Hasan “Performance Improvement of PAPR Reduction for OFDM Signal In LTE System,” International Journal of Wireless & Mobile Networks , vol. 5, no. 4,pp. 35-47,August 2013.

[13] Prasanta Kumar Pradhan, Satyendra Singh Yadav, SaratKumar Patra, “PAPR reduction in OFDM systems” IEEE India Conference (INDICON),2014. 12

[14] . JijinaN., and S. S. Pillai. “Linear Precoding Schemes for PAPR Reduction in Mobile WiMAX OFDMA System,” International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, vol. 3,pp. 88738884, April 2014.