International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Enhancing peak-to-average power ratio performance in orthogonal frequency division multiplexing based wireless communication system

D. O. Njoku[a], *C. T. Ikwuazom*[b], *C. G. Onukwugha*[a], *E. J. Jibiri*[b]

[a]**Department of Computer Science, Federal University of Technology Owerri, Owerri, Nigeria**
[b]**Department of Information Technology, Federal University of Technology Owerri, Owerri, Nigeria**

A B S T R A C T

Optimal parameters have been used to carried out analysis of signal distortion techniques for Peak-to-Average Power Reduction (PAPR) in Orthogonal Frequency Division Multiplexing (OFDM) based wireless network. An OFDM system that uses Discrete Fourier Transform (DFT) precoding algorithm to code the OFDM signal and after which Clipping and Filtering process was performed repeatedly for four times in order to effectively reduced the PAPR effect on the signal. Simulations were performed in MATLAB environment using Quadrature Phase Shift Keying (QPSK) modulation. The results from the simulations carried out using optimum parameters revealed that the PAPR of OFDM signal was reduced to 2.80 dB, which is 73.4% improvement from the original or conventional OFDM signal.

Keywords: DFT precoding, OFDM signal, PAPR, RCF

Introduction

In exploiting the numerous benefits channel fading robustness, diversity in multipath fading environment, high data rate, spectral efficiency and energy efficiency, systems with Orthogonal Frequency Division Multiplexing (OFDM) (which is a multicarrier) modulation and Multiple Input Multiple Output (MIMO) plus OFDM (simply referred to as MIMO-OFDM) are now considered potential candidate in wireless communication networks such as Digital Audio Broadcasting (DAB), Worldwide interoperability for Microwave Access (WiMAX), Long Term Evolution (LTE), Digital Video Broadcasting (DVB), high speed Wireless Local Area Network (WLAN) and many other applications. In fact, in many wireless networks such as Digital Video Broadcasting Terrestrial (DVB-T) DVB-T2, Integrated Services Digital Broadcasting (ISDB) for Microwave Access, (ISDB-T), LTE and etc, OFDM has been accepted (Thakur and Jain, 2015; Proakis, 2011). A very important advantage of OFDM is that it can overcome the effect of severe channel conditions such as interference, attenuation and multipath fading without complex equalization filters (Thakur and Jain, 2015).

Despite the observed significant improvement in the performance of OFDM systems, intensive research in MIMO-OFDM is still being performed (Jayakumar, 2010). These areas of research interest include carrier offset and drift sensitivity, high Peak-to-Average Power Ratio (PAPR), receiver complexity and the use of complex computational scheme (Agwah and Aririguzo, 2020). However, the interest of this paper is on PAPR reduction. With several techniques already proposed and implemented in literature resulting in considerable reduction in PAPR of OFDM signal, the problem of computational complexity due to the sub-blocks associated with signal scrambling schemes such as selective level mapping (SLM) and partial transmit sequence (PTS), and also the in-band noise associated with signal distortion methods is still being addressed. In this study, a combination of signal distortion schemes with finest simulation parameters is employed for minimizing PAPR in OFDM system.

In this paper optimal parameters for PAPR reduction collected from literature are implemented in this paper to validate the system.

Material and Methods

This section presents the approaches taken to realizing the objective of this paper. The material or tool used in this paper is the MATLAB. The mathematical descriptions are presented to describe OFDM and PAPR problem.

System Model

The model of the system used for the PAPR reduction in OFDM system is shown in Fig. 1. In the model, the OFDM is initially coded using precoding discrete Fourier Transform precoder before the RCF algorithm scheme is applied. It should be noted that the block diagram as shown in Fig. 1, represents the transmit side of OFDM system because it is the transmitter that PAPR occurs.

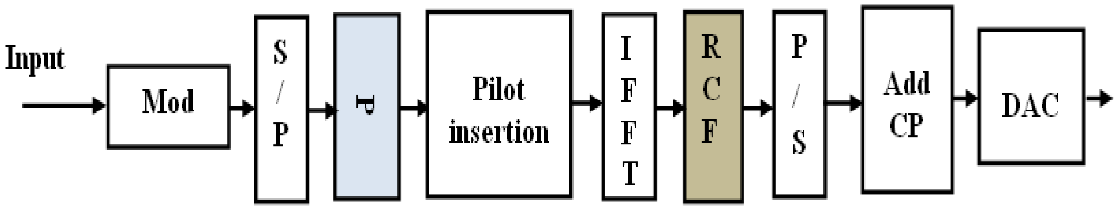

Fig. 1 - PAPR reduction model for OFDM system

Precoding scheme

In Fig. 1, the input data binary data stream are grouped and mapped into multi-amplitude-multi-phase signals. Precoding scheme based on DFT is applied after parallel conversion. Pilot carrier insertion is performed and after that the modulated and DFT coded complex band OFDM signal with N subcarriers is performed.

The precoding matrix P of $N \times N$ dimension that is implemented prior to Inverse Fast Fourier Transform (IFFT) is given by (Dubey and R. Gupta, 2016; Aboul-Dahab et al., 2013):

$$P = \begin{bmatrix} P_{00} & P_{01} & \cdots & P_{0(N-1)} \\ P_{10} & P_{11} & \cdots & P_{1(N-1)} \\ \vdots & \vdots & \ddots & \vdots \\ P_{(N-1)0} & P_{(N-1)1} & \cdots & P_{(N-1)(N-1)} \end{bmatrix}$$

(1)

Adding the P matrix to the OFDM system results in complex band OFDM signal with N subcarriers given by:

$$x(t) = x(t) = \sqrt{\frac{1}{N}} \times \sum_{k=0}^{N-1} P.X_k e^{j2\pi k\Delta f t} \qquad 0 \le t \le NT$$

(2)

where Δf is the subcarrier spacing and NT is the useful block period.

The modulated OFDM vector signal with N subcarriers can be expressed given by:

$$x_N = IFFT\{P.X_N\}$$

(3)

The PAPR of OFDM signal in can be expressed given by:

$$PAPR = \frac{\max |x(t)|^2}{E[|x(t)|^2]} \qquad (4)$$

The DFT of a sequence of length N and IDFT can be expressed given by (Aboul-Dahab et al., 2013):

$$X(k) = \sum_{n=0}^{N-1} x(n).e^{-j2\pi nk}, \quad k = 0,1...N-1 \qquad (5)$$

$$x(n) = \frac{1}{N} \sum_{n=0}^{N-1} x(n).e^{j2\pi nk}, \quad k = 0,1...N-1 \qquad (6)$$

where, $p_{mn} = e^{-j2\pi mn/N}$, *m* and *n* are integers from 0 to N-1.

Clipping and Frequency Filtering

With the operation of IFFT performed, next stage is clipping and filtering process performed repeatedly, which is simply called repeated clipping and filtering (RCF). This process is repeated depending on the number of iterations, which is often chosen between 1 and 4. Flow chart of RCF technique is shown in Fig. 2. In RCF, the original signal is clipped in the time domain (Devi and Ramprabhu, 2018). Mathematical description of the clipping is given by:

$$C = \begin{cases} \sqrt{CR * E[|x|^2]} * \frac{x}{|x|} & |x|^2 > C_m \\ x & |x|^2 \leq C_m \end{cases}$$

(7)

where C represents the time domain signal of the output, $|x|^2$ is the signal absolute power, $E[|x|^2]$ is the mean signal power, CR is the clipping ratio, which is the defined as the ratio of the clipping level to the mean power of the unclipped baseband signal, and C_m is the threshold clipping level is given by:

$$C_m = CR * E[|x|^2]$$

(8)

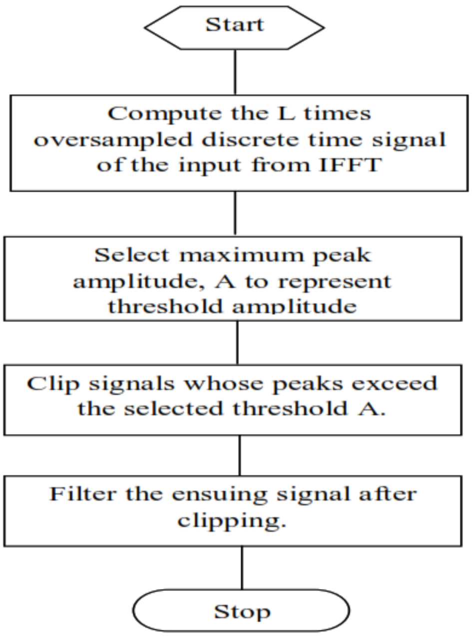

Fig. 2- Flow chart of RCF technique

Simulation Results

The selection of optimal values for clipping ratio (CR), number of iteration, oversampling factor (L), and the $\mu - \text{Law}$ companding is based on previous reports in literature. The time domain signal must meet this criteria, $L > 2$ (or $L \geq 4$) (Yu and Wei, 2010; Mowla et al., 2014) with L = 4 usually considered to be sufficient to reach the peaks (Yi and Iinfeng, 2009). The CR can be any positive value from 0.8 to 4. However, in practical system, by setting CR = 1.2, the system performance will be nearly optimal (Yu and Wei, 2010). The number of iteration is chosen based on the fact that with 4 iterations, the best performance of RCF is achieved as shown from simulations carried out by (Agwah et al., 2020).

Other simulation parameters are QPSK modulation scheme, FFT size of 256, spacing of 15 kHz, band width of 1250 kHz, cyclic prefix (CP) of 0.25 of FFT size, number of symbol is 1000, sampling frequency of 192 MHz, sampling period of 192×10-6 s, and maximum Doppler frequency shift of 0 Hz. Simulations were conducted in MATLAB considering conventional OFDM signal with RCF technique and coded OFDM signal with RCF.

OFDM signal with RCF

Simulation is carried out in this case by enhancing the PAPR performance of OFDM signal with RCF scheme as shown in Fig. 3. The essence of this simulation is to show the effectiveness of the RCF technique when combined alone with OFDM system. The performance analysis based on the PAPR values for each iteration at CCDF of 10-3 is shown in Table 1.

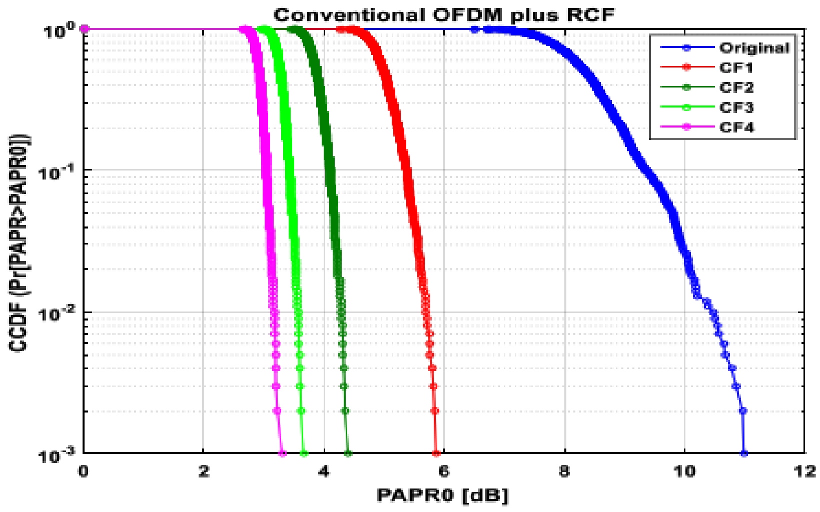

Fig. 3 - PAPR of OFDM with RCF

Table 1 -Performance analysis of uncoded OFDM signal with RCF technique

Parameter	PAPR Value (dB)
Original	**10.98**
One Clipping and Filtering (CF1)	**5.86**
Two Clipping and Filtering (CF2)	**4.40**
Three Clipping and Filtering (CF3)	**3.65**
Four Clipping and Filtering (CF4)	**3.30**

.

Coded OFDM signal with RCF Technique

The simulation performance of PAPR in OFDM system model with precoding and RCF algorithms is presented in Fig. 4. This simulation is conducted to show the effectiveness of precoding with RCF technique in reducing PAPR of OFDM signal. Table 3 shows the numerical values

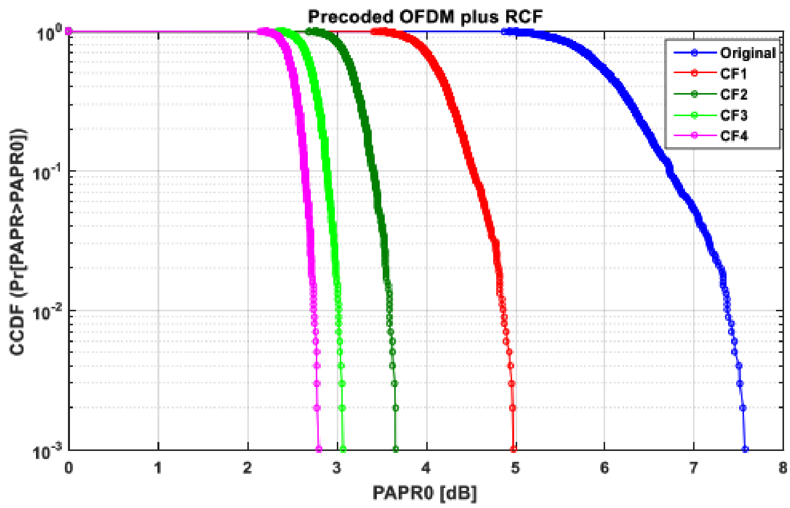

Fig. 4 - PAPR of coded OFDM with RCF

Table 2 -Performance analysis of coded OFDM signal with RCF technique

Parameter	PAPR Value (dB)
Original	**7.57**
One Clipping and Filtering (CF1)	**4.97**
Two Clipping and Filtering (CF2)	**3.65**
Three Clipping and Filtering (CF3)	**3.07**
Four Clipping and Filtering (CF4)	**2.80**

The performance of the coded OFDM system with repeatedly performed clipping and filtering algorithm for PAPR reduction in OFDM signal has been examined using finest parameters. The results obtained showed that the introduction of the algorithm provided reduction in PAPR of OFDM signal. The PAPR of uncoded OFDM signal was initially 10.51 dB. With the addition of RCF, the PAPR value was reduced to 3.30 dB, which is 68.6% reduction. Then, by coding the OFDM signal and adding RCF, the PAPR was reduced to 2.80 dB, which is 73.4% reduction.

Conclusion

The performance of coded OFDM signal with clipping and filtering process performed iteratively for four times using optimum parameters in litertature has been presented. Simulation results have shown that PAPR was minimized for improved OFDM signal. The performance of the system using optimal values in literature for oversampling factor, clipping ratio, repeated clipping and filtering, with QPSK modulation scheme revealed the effectiveness of the proposed system.

Acknowledgements

References

1. Aboul-Dahab, M. A., Hagras, E. A. A. A., & A. A. Elhaseeb (2013). PAPR Reduction based on DFT precoding for OFDM Signals. International Journal of Future Computer and Communication, 2(4), 325-328. https://doi.org/10.7763/IJFCC.2013.V2.177
2. Agwah, B. C. & Aririguzo, M. I. (2020). MIMO-OFDM System in Wireless Communication: A Survey of Peak to Average Power Ratio Minimization and Research Direction. International Journal of Computer Science Engineering, 9(4), 219-234.
3. Agwah, B. C., Nwabueze, C. A., & Akaneme, S. A. (2020). Hybrid Algorithm for Optimizing Peak to Average Power Ratio Performance in MIMO-OFDM System. World Journal of Engineering Research and Technology, 6(3), 625-640.
4. Devi, N. & Ramprabhu, G. (2018). Peak-to-average power ratio reduction in OFDM using repeated frequency domain filtering and clipping (RFC). SSRG International Journal of Electronics and Communication Engineering, Special Issue ICETSST April 2018, 102-108.
5. Dubey, S. & Gupta, R. (2016). PAPR reduction in OFDM using precoding method, precoding with repeated clipping and filtering (RCF) method and precoding with clipping method. Advances in Computer Science and Information Technology (ACSIT), 3(3), 174-177.
6. Jayakumari, J. (2010). MIMO-OFDM for 4G Wireless Systems. International Journal of Engineering Science and Technology, 2(7), 2886-2889.
7. Mowla, M., Ali, Y., &. Hasan, S. M. R (2014). A modified design Of RCF operation for reducing PAPR of OFDM Signal. International Journal of Next_Generation Networks, 6(1), 31-42.
8. Proakis, J. G. (2011). Digital Communications (4th ed.). McGraw-Hill Book Co., New York.
9. Thakur, J.J. & Jain, S. (2015). A Review of MIMO-OFDM Systems for LTE Environment. International Journal of Electrical, Electronics and Computer Engineering, 4(2), 13-18.
10. Yi, W. & Iinfeng, G. (2009). An investigation of peak-to-average power reduction in MIMO-OFDM systems. Master Thesis, Blekinge Institute of Technology.
11. Yu, H. & Wei, G. (2007). Choosing the Optimal Clipping Ratio for and Filtering PAR-Reduction Scheme in OFDM, IEEE Xplore, 460-463. DOI:10.1109/WICOM.2007.121