Received: December 10, 2020. Revised: January 18, 2021.

International Journal of
Intelligent Engineering & Systems

http://www.inass.org/

An improved ASOICF algorithm for PAPR Reduction in OFDM systems

Vijaya Kumar Padarti[1]* **Venkateswara Rao Nandhanavanam[2]**

[1]*Department of Electrical and Computer Engineering, ANU College of Engineering and Technology, Acharya Nagarjuna University, Vijayawada, India*
[2]*Bapatla Engineering College, Bapatla, India*
* Corresponding author's Email: vijay.kumartanguturu@gmail.com

Abstract: Orthogonal Frequency Division Multiplexing (OFDM) is an extensively used technology in broadband wireless communications. However, it also poses some drawbacks. The critical limitation which affects the quality of the service (QoS) is a peak-to-average power ratio (PAPR). This high PAPR problem results in the degradation of the power efficiency of the RF amplifier. Among the PAPR reduction schemes, Iterative clipping and filtering (ICF) gained a lot of attention due to its simplicity of implementation in the mitigation of PAPR in OFDM systems. ICF technique drives Fast-Fourier transform (FFT) / inverse FFT (IFFT) signal processing blocks multiple numbers of times to attain the prescribed level of PAPR, which leads to high system power consumption and add on computational time. In addition, the ICF technique was unable to control the in-band and out-of-band radiation. Therefore, we introduce an improved Adaptive Simplified Optimized Iterative Clipping and Filtering (ASOICF) algorithm to reduce PAPR in OFDM systems. The algorithm exploits Lagrange Multiplier optimization (LMO), the advantage of choosing LMO is to belittle the number of iterations in a customized fashion. We have found that our adaptive algorithm significantly reduces the PAPR in OFDM signals. The effectiveness of the proposed algorithm reveals it outperforms the existing techniques with a 4dB improvement in the simulation results and with reduced computational complexity.

Keywords: OFDM, PAPR, Improved ASOICF, ICF, Simplified optimized ICF (SOICF), LMO.

1. Introduction

OFDM technology [1] is a promising technique employed in wireless applications like smart grid systems, Digital Audio Broadcasting (DAB), LTE, 4G, and 5G systems. OFDM has been largely used to control the frequency-selective fading [2]. The major issue associated with OFDM signals is that they are more susceptible to high PAPR, which results in large envelope variations in the signal. This PAPR problem results in the degradation of power efficiency [3] of the RF amplifier. Also to control the in-band and out-of-band radiation [4] in the signal, minimizing the high PAPR is essential. The transmitter section requires high resolution [5] digital to analog (DAC) converters and linear power amplifiers are required to support high PAPR, which is a very costly affair [6]. If the antennas count increases developing such systems is impractical. Hence, efficient PAPR reduction [7] methods are essential for high data rate communication [8]. Also, a large PAPR reduction results in a reduction of hardware implementation cost [9] and leads to an increase in power efficiency levels. Many PAPR mitigation techniques [10] have been proposed and developed by authors in the literature. Among them the prominent techniques [11] includes clipping, [12] tone reservation (TR), precoding [13], active constellation extension (ACE) [14] , partial transmission sequence (PTS) [15], peak insertion techniques and [16] selected mapping (SLM). These techniques [17] are categorized into multiple signalling, signal distortion, probabilistic techniques, and coding techniques [18]. Currently, authors working with state of art techniques like machine learning and deep learning for controlling PAPR in the simulation environment. In [19] authors presented that clipping has been an easy method to reduce PAPR in OFDM systems. One of the most commonly used techniques to reduce PAPR is ICF

[20]. The major drawback with this method is peak re-expansion [21], which is capable of increasing the power level of symbols. In authors [22] presented, ICF uses more iterations and system resources to achieve the desired PAPR level [23, 24]. So ICF technique consumes more iteration to approach a specified PAPR threshold value. Increasing the power level leads to a drop in bit error rate performance, which increases the number of errors. The [24] authors applied methods like ICF, OICF, and SOICF suffers from an inherent peak regrowth problem. OICF also consumes more iteration to reach the PAPR threshold value. SOICF cannot avoid in-band and out-of-band radiation, though it is able to consume less number of iterations to reach the specified threshold PAPR value. In conventional ICF by setting constant threshold leads to in-band distortion which adversely impact BER performance of the system. SOICF utilizes adaptive threshold which greatly reduces PAPR and with good improvement in BER, but consumes more number of iterations to achieve the target value. In the literature survey [24], authors have taken the parameter Error Vector Value (EVV) which measures in-band and out-of-band radiation. Also suggested minimizing the EVV is essential in reducing the radiation and PAPR level significantly which results in less BER. We added an additional PAPR vector into the problem to convert a non-convex problem into a convex problem and also applied LMO to belittle the number of iterations in a customized fashion. The LMO optimization results in scaling down the computational complexity. The effectiveness of the proposed algorithm reveals it outperforms the existing techniques with a 4dB improvement in the simulation results and with reduced computational complexity. So the proposed method is good at adaptive threshold level calculation, minimizes the number of iterations, controls in-band and out-of-band radiation. The proposed method is attractive in achieving a good balance between PAPR and BER, additionally with LMO optimization controls the in-band radiation and achieves the target PAPR value in fewer numbers of iterations. The convergence rate is improved, additionally it offers a trade-off between power consumption and processing time. Eqs. (19, 20) are the equations obtained after application of LMO which mathematically justifies the above explanation.

The paper is organized as follows, the second section presents the literature work, the third section represents the block diagram of the OFDM system, the fourth section portrays the existing methods like ICF and SOICF, the fifth section illustrates an analysis of the proposed method and performance of the proposed method compared to other modern methods. Finally, the last part contains the relevant conclusion and scope for the future.

2. System model

OFDM is a widely employed for high data rate communication over channels which frequently undergo frequency selective fading. In frequency domain OFDM symbols are given as $X[k] = [x_0, x_1, x_2, \ldots x_L]$ with length L. On application of IDFT to $X[k]$, the obtained sequence is given as

$$x(n) = \frac{1}{\sqrt{LN}} \sum_{k=0}^{LN-1} X[K] e^{\frac{j2\pi kn}{LN}} n = 0,1,2,..LN-1 \quad (1)$$

Where N is oversampling rate factor ($N \geq 4$).

For mathematically complex OFDM symbols, amplitude value is obtained as $|x(n)| = \sqrt{{x_r}^2 + {x_i}^2}$ where x_r and x_i denotes the real and imaginary parts of the x[n], respectively.

2.1 PAPR

The major issue associated with OFDM signals is that they are more susceptible to high PAPR, which results in large envelope variations in the signal. This PAPR problem [24] results in the degradation of the power efficiency of the RF amp-amplifier. Also to control the in-band and out-of-band radiation in the signal, minimizing the high PAPR is essential. At the transmitter side high resolution DAC converters and linear power amplifiers are required to support high PAPR, which is a very costly affair. If the antennas count increases developing such systems is impractical. PAPR is mathematically expressed as

$$PAPR(x(n)) = 10log \frac{max|x(n)|^2}{Expectation\{|x(n)|^2\}} \quad (2)$$

Complementary cumulative distribution function (CCDF) is formulated as

$$CCDF_{|x(n)|} = Pr(PAPR > Threshold\ Value) \quad (3)$$

$$Pr(PAPR > Threshold\ Value) = 1 - ((PAPR \leq Threshold\ Value)) \quad (4)$$

2.2 ICF

In the ICF technique, clipping is performed on the peak amplitude of the signal in connection with threshold level. It is mathematically expressed as

Received: December 10, 2020. Revised: January 18, 2021.

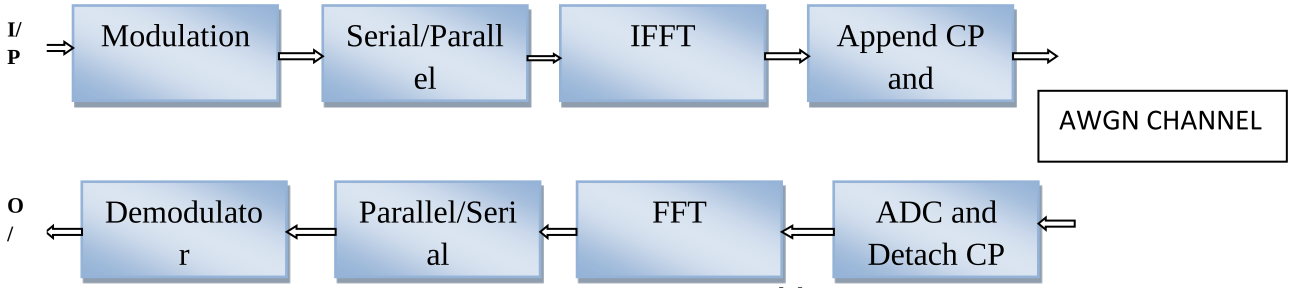

Figure. 1 OFDM system model

$$\overline{x(n)} = \begin{cases} T \times e^{j\emptyset(n)} & if\ |x(n)| \\ x(n) & else \end{cases} \quad (5)$$

$\emptyset(n)$ denotes the angle of x(n) and

$$T = ClippingValue \times \sqrt{Average\ Power} \quad (6)$$

Clipping Value is mathematically defined as

$$Clipping\ Value = \frac{AMP_{max}}{AMP_{avg}} \quad (7)$$

Amp represents amplitude of the OFDM signal,

$$AMP_{max} = argmax\{x(n)\}\ \ \forall\ 0 < n < LN - 1 \quad (8)$$

$$AMP_{avg} = \frac{1}{LN}\sum_{n=0}^{LN-1}|x(n)| \quad (9)$$

$$Average\ Power = \frac{1}{LN}\sum_{n=0}^{LN-1}|x(n)|^2 \quad (10)$$

In ICF method [16] the authors applied rectangular window for filtering followed by clipping operation. Rectangular window is defined as

$$W_R[n] = \begin{cases} 1 & 0 \le n \le N-1 \\ 0 & elsewhe \end{cases} \quad (11)$$

is used for filtering. This window has negligible role in nullification of in-band and out of -band radiation. This method failed to control the in-band and out-of-band radiation effects on the OFDM signal. The conventional ICF method limits the PAPR with the more number of the iterations which consumes system power and processing time heavily.

2.3 Description and analysis of OICF and SOICF

The ICF method is one of the clipping based methods that focus on clipping of the signal based on fixed threshold value. In [12] ICF method, convex optimization is utilized along with the rectangular window. This idea able to lower the PAPR level with a fewer number of iterations but failed to control in-band radiation. In the OICF technique, a function EVV is defined to measure the amount of radiation deteriorated the OFDM symbols after clipping method.

EVV $(\alpha)$is the difference between original vector and in-band and out-band vector. *EVV* is defined as

$$\alpha = \|X - IO\|^2 \quad (12)$$

Where *X* is the input vector and *IO* is the in-band and out-of-band vector. To lower the BER minimization of EVV is essential. A simplified version of OICF have been presented to lower the computational complexity of the SOICF [12] algorithm.

3. Description and analysis of proposed improved adaptive SOICF technique

The methods ICF, OICF, SOICF [9, 12] which suffer from an inherent peak regrowth problem. Increasing the power level leads to a drop in bit error rate performance, which increases the number of errors. In addition, these techniques significantly reduced PAPR by introducing in-band and out-of-band radiation into the signal with more computational complexity. The major concern with ICF is that the clipping threshold level is fixed and constant. Therefore, we introduced an improved ASOICF algorithm to reduce PAPR in OFDM systems. The algorithm exploits LMO, the advantage of choosing LMO is to belittle the number of iterations in a customized fashion. The LMO function has an ability to optimize or minimize the multivariable function loaded with constraints in a limited number of iterations. It has ability to updates the clipping threshold adaptively until it is below a defined value. After every iteration clipping value is updated adaptively. Let the clipping noise vector is defined as *D* = *X-IO* and every iteration, then normalized EVV is

$$\alpha = \frac{\|D^2\|_2}{\|X^2\|_2}. \quad (13)$$

Received: December 10, 2020. Revised: January 18, 2021.

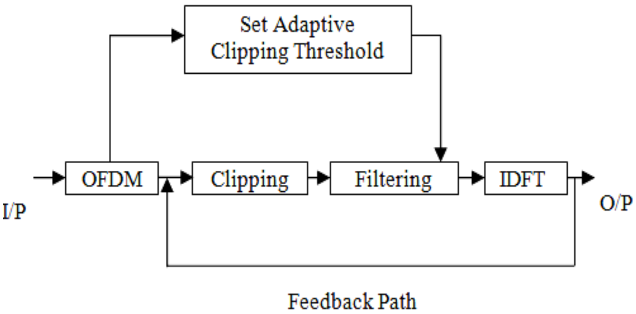

Figure. 2 System model with clipping threshold level

$$min(\alpha) = \frac{\|D^2\|_2}{\|X^2\|_2} \quad (14)$$

EVV function is minimized subjected to constraints out of band radiation and required PAPR level.

$$min(\alpha) = \frac{\|D^2\|_2}{\|X^2\|_2} \quad \text{Subjected to}$$

$IO^I = IO.W_R$ represents in-band radiation component. (15)

IO^0 represents out-of-band radiation component (16)

$$x_{m+1} = IDFT(\overline{x_m}) \quad (17)$$

$$\frac{\|x_{m+1}\|_\infty}{\|x_{m+1}\|_{2/\sqrt{LN}}} \leq \sqrt{PAPR_{max}} = Clipping\ Value (18)$$

The Eqs. (13-17) represents the constraint functions for PAPR and out-of-band radiation parameters respectively. Implementing LMO optimization function and then by equating for minimum EVV applying (14) the obtained equation

$$LMO(D,l) = \frac{\|D^2\|}{\|X^2\|} + l(|X_L - D_{L+1}|^2 - \frac{Clipping\ Value^2\|\bar{x}\|^2}{\sqrt{LN}}) \quad (19)$$

Where l is the multiplier of LMO technique.
Optimized clipping level

$$T^1 = \frac{Clipping\ Value^2\|\bar{x}\|^2}{\sqrt{LN}} \quad (20)$$

Eq. (14) is used to nullify the out-of-band radiation and to maintain good EVV which effectively reduces PAPR value.

The process of step by step calculation of clipping optimized clipped level and EVV is given in the form of sequence of steps.

Proposed Improved Adaptive SOIACF Algorithm:

START
Step1.Define the clipping level with number of iterations
Step 2.Model the vector R as R=[1, 1,…1L,0,0,….0L(N-1)] /) $\sqrt{N}$
Step 3. Calculate the updated threshold applying Eq. (14)
Step 4. Compute the EVV value using Eq. (11)
Step 5. Transform obtained value in step 4 into frequency domain and multiply with the crest factor
Step 6.Transform the obtained one into time domain
Step 7.Calculate for decreased PAPR value
Step 8.If the value obtained in step 7 matches the target value
Step 9.Otherwise repeat steps from 2 t0 8
END

4. Performance analysis

In this section, we evaluate the performance with proposed technique through simulations test compared to existing methods. Fig. 3 shows the

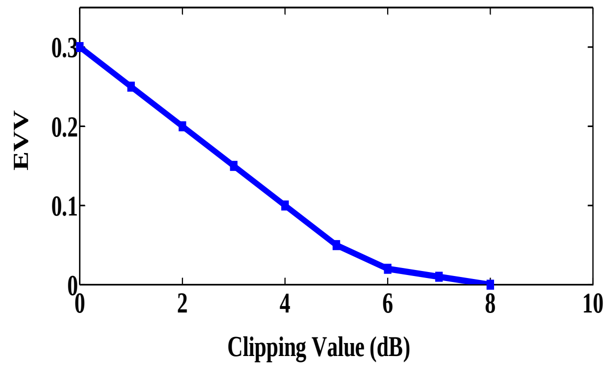

Figure. 3 Variation of EVV w.r.t clipping value

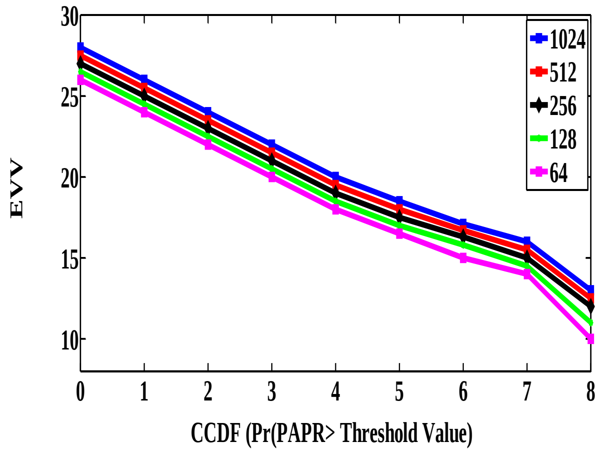

Figure. 4 EVV vs. CCDF curves for different carriers

 DOI: 10.22266/ijies2021.0430.32

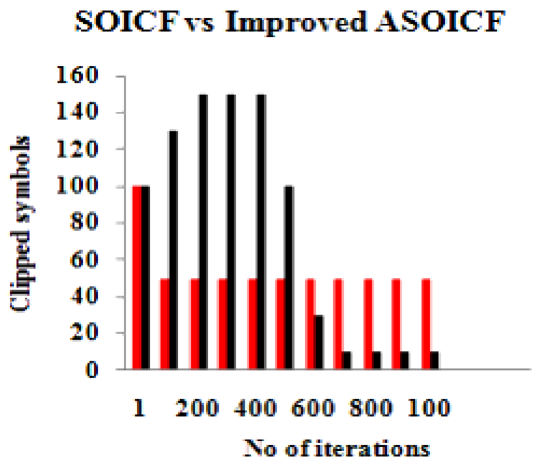

Figure. 5 Clipping symbols vs. no of iterations comparison of SOICF and Improved ASOICF technique

Simulation Parameters	Types/Value
Applied subcarriers (N)	128
FFT/IFFT blocks	512
Oversampling factor	4
Type of modulation	QPSK
Channel	AWGN
Optimization clipping algorithm	Improved ASOICF
Software	MATLAB

variation of EVV w.r.t clipping value,

$$E(EVV) = \{exp^{-(clipping\ value)^2} - \sqrt{\pi} \times clipping\ value \times erfc(clipping\ value)\}^{0.5} \quad (21)$$

For each iteration, the number of clipped symbols increases, which shows that the clipping level is significantly reduced over several iterations. This implies that the peak power is decreasing, which indicates that the PAPR reduction is better exploited by the improved ASOICF method over the SOICF and ICF methods. The level decreases over several iterations compared to other algorithms.

This section deals the performance of the proposed ASOICF algorithm. Fig. 6 gives an example of CCDF of amplitude OFDM signals with 128 sub-carriers and QPSK modulation. As can be seen from the Fig. 6 with the improved ASOICF PAPR reduction achieved very quickly with lesser number of iterations and for 3-level clip it is 4dB better compared to existing SOICF 3-clip method. For the clipping level or clipping value equal to 3.01 dB calculated from the equations PAPR reduction is optimum for this value. A sample comparison table is formed from Fig. 6, for a given CCDF PAPR reduction for different methods is tabulated in the form of table. Visibly the proposed method the

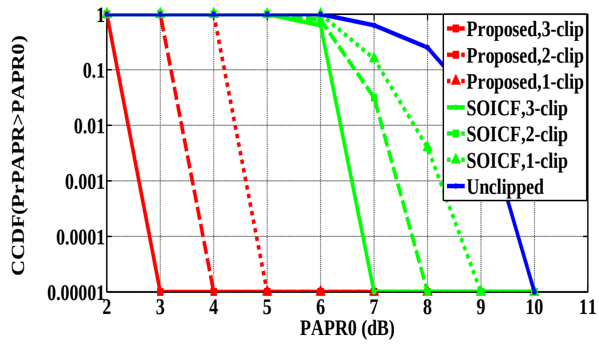

Figure. 6 CCDF vs PAPR0 for different methods with various clipping levels

Table 1. CCDF vs. threshold value for clipping value of 3.01dB

	Proposed			SOICF [9, 24]			Unclipped [10,30]
	1-clip	2-clip	3-clip	1-clip	2-clip	3-clip	
CCDF	10^0	10^0	10^0	10^0	10^0	10^0	10^0
PAPR0 (dB)	5	4	3	9	8	7	10

Table 2. BER vs SNRO for clipping value of 3.01 dB

	Proposed			SOICF[9,24]			Unclipped [10, 30]
	1-clip	2-clip	3-clip	1-clip	2-clip	3-clip	
BER	10^0	10^0	10^0	10^0	10^0	10^0	10^0
SNR0 (dB)	7.5	8	8.5	9	9.5	10	4.6

achieved reduced PAPR value with fewer number of iterations compared to other existing methods. The proposed 3-clip achieved better PAPR reduction compared with 2-clip and 1-clip.

This section deals the performance of the proposed ASOICAF algorithm to other algorithms to optimize the parameters like PAPR reduction, reduction of in-band and out-of-band radiation and maintaining good BER. Fig. 7 gives an example of BER vs SNRO with 128 sub-carriers and QPSK modulation. As can be seen from the Fig. 7 BER performance of the proposed method is little bit degraded compared to unclipped signal.

Table 3 illustrating theqe computational complexity of proposed algorithm in comparison to existing methods. Clearly the proposed method

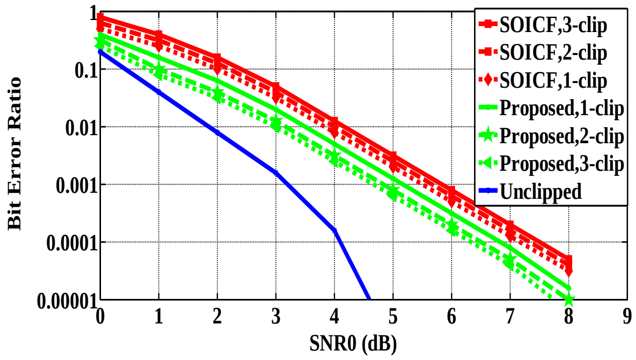

Figure. 7 BER vs SNRO for different methods with various clipping levels

Table 3. Computational complexity of techniques

Method	Multiplications	Additions
ICF [9, 12]	SLNlog(SL)+2SLN	2SLNlog2(SL)+SLN
SOICF [9]	2(SLlog(SL)+SL)	2(SLlog(SL)+SL)
Proposed	2SLlog2SL+4SLN	4SLlog2SL+3SLN

S is the number of subcarriers, *L* is filter length, and *N* is the oversampling factor.

Table 4. Performance comparison of power spectral density

Method	Over Sampling Factor (N)	PSD (dB)
OFDM Signal	4	-28.9
ICF [9, 12]	4	-35.1
SOICF [9, 12]	4	-48.9
Proposed	4	-95.1

provides less computational complexity compared to existing ICF and SOICF methods.

Table illustrating the power spectral density (PSD) of proposed algorithm in comparison to existing methods

The proposed method PSD is drastically reduced compared with original OFDM signal, ICF and SOICF. Clearly the proposed improved ASOICF performs better compared to existing methods interms of PSD reduction.

The proposed method is attractive in achieving a good balance between PAPR and BER, additionally with LMO optimization controls the in-band radiation and achieves the target PAPR value in fewer numbers of iterations. The convergence rate is improved, additionally it offers a trade-off between power consumption and processing time. Eqs. (19, 20) are the equations obtained after application of LMO which mathematically justifies the above explanation

5. Conclusion

In industry and academia, with the development of smart grid systems and reliable multiuser communication, many researchers have focused more on the mitigation of PAPR for OFDM signals. The proposed method is an optimized version of existing methods. The proposed technique achieves the target PAPR value with fewer numbers of iterations compared to existing methods which is tabulated in Table 4. Additionally, the LMO method controls noise due to distortion which influences PAPR and BER. PAPR value is mitigated to a good extent and it delivers better by a 4 dB at all clip levels. Also, the proposed method provides less computation complexity and controls in-band and out-of-band radiation. The proposed technique can be further extended to control inband distortion by applying optimal methods and also can be extended to design flexible hardware which will be useful in 4G / 5G.

Conflicts of Interest

The authors declare no conflict of interest.

Author Contributions

The paper conceptualization, methodology, software, validation, formal analysis, investigation, resources, data curation, writing—original draft preparation, writing—review and editing, visualization, have been done by 1st author. The supervision, and project administration, has been done by 2nd author

Notation List

EVV-Error Vector Value
LMO-Lagrange Multiplier Optimization
Erfc(x)-Complementary Error Function
CCDF-Complementary Cumulative Distribution Function
PAPR-Peak-to-Average Power Ratio
N-Over Sampling Factor
L-Symbol Length
Amp-Amplitude Level
E-Expectation Operator
Avg-Average Value
Max-Maximum Value
$\| \ \|^2$-Normalized Square of function
||-Absolute Value

References

[1] J. Bingham, "Multicarrier modulation for data transmission: an idea whose time has come",

IEEE Commun. Mag., Vol.28, No. 5, pp. 5-114, 1990.

[2] T. Jiang and Y. Wu, “An Overview: Peak-to-Average Power Ratio Reduction Techniques for OFDM Signals”, *IEEE Trans. Broadcasting*, Vol. 54, No. 2, pp. 257-268, 2008.

[3] T. Jiang, M. Guizani, H. Chen, W. Xiang, and Y. Wu, “Derivation of PAPR Distribution for OFDM Wireless Systems Based on Extreme Value Theory”, *IEEE Trans.Wireless Communications*, Vol. 7, No. 4, pp. 1298-1305, 2008.

[4] D. Singh and R. Sarin, “Computationally efficient variational bayesian method for papr reduction in multiuser mimo-ofdm systems”, *ETRI Journal*, Vol. 41, No. 3, pp. 298–307, 2019.

[5] K. Anoh, “Advances in PAPR reduction for OFDM systems with machine learning”, *In: Proc. of International Conf. on Future Networks and Distributed Systems*, Australia, pp. 1-4 ,2018

[6] M. Kim, W. Lee, and D. Cho, “A novel PAPR reduction scheme for OFDM system based on deep learning”, *IEEE Commun. Lett.* Vol. 22, No. 3, pp. 510-513, 2018.

[7] L.Hao, D. Wang, Y. Tao, W. Chung, J. Li, and Z. Liu, “The Extended SLM Combined Auto encoder of the PAPR Reduction Scheme in DCO-OFDM Systems”, *MDPI Journal of Applied Science*, Vol. 9, No. 5, pp. 852-862, 2019.

[8] S. Stephen and P. DelMarco, “A Constrained Optimization Approach to Compander Design for OFDM PAPR Reduction”, *IEEE Letters*, Vol. 64, No. 2, pp. 307-318, 2018.

[9] K. Anoh, C. Tanriover, B. Adebisi, and M. Hammoudeh, “A new approach to iterative clipping and filtering papr reduction scheme for ofdm systems”, *IEEE Access*, Vol. 6, No. 1, pp. 533–544, 2018.

[10] L. Wang and C Tellambura, “A simplified clipping and filtering technique for PAR reduction in OFDM Systems”, *IEEE Signal Processing Letters*, Vol. 12, No. 6, pp. 453-456, 2005.

[11] J. Armstrong, “Peak-to-average power reduction for OFDM by repeated clipping and frequency domain filtering”, *IEEE Electronic Letters*, Vol. 38, No. 5, pp. 246-247, 2002.

[12] V. Nandalal, and S. Sophia, “PAPR reduction of OFDM signal via custom conic optimized iterative adaptive clipping and filtering”, *Wireless Pers. Commun*. Vol. 78, No. 2, pp. 867–880, 2014.

[13] Y. Wang and Z. Luo, “Optimized iterative clipping and filtering for PAPR reduction of OFDM signals”, *IEEE Trans. Commun*., Vol. 59, No. 1, pp. 33– 37, 2011.

[14] X. Zhu, W. Pan, H. Li, and Y. Tang, “Simplified approach to optimized iterative clipping and filtering for PAPR reduction of OFDM signals”, *IEEE Trans. Commun*., Vol. 61, No. 5, pp. 1891–1901, 2013.

[15] A. Gurung, F. Al-Qahtani, A. Sadik, and Z. Hussain, “One-Iteration-Clipping-filtering scheme for PAPR reduction of OFDM signals”, In: *Proc. of International Conf.On Advanced Technol. Commun.*, Hanoi, Vietnam pp. 207–210, 2008.

[16] B. Lee, and Y. Kim, “An adaptive clipping and filtering technique for PAPR reduction of OFDM signals”, *Circuits Syst. Signal Process*, Vol. 32, No. 3, pp. 1335–1349, 2013.

[17] P. VijayaKumar and R. Nandhanavanam., “Performance evaluation of coexistence of Wi-Fi and LTE licensed –assisted access to unlicensed spectrum using markov chain analytical model”, *International Journal of Engineering and Advanced Technology*, Vol. 8, No. 6, pp. 2032-203, 2019.

[18] Y. Wang, J. Ge, L. Wang, J. Li, and B. Ai, “Nonlinear Companding Transform for Reduction of Peak-to-Average Power Ratio in OFDM systems”, *IEEE Trans. Broadcast*, Vol. 59, No. 2, pp. 369–375, 2013.

[19] G. Wunder, R. Fischer, H. Boche, S. Litsyn, and J. No, “The PAPR Problem in OFDM Transmission: New Directions for a Long-Lasting Problem”, *IEEE Signal Process. Mag*., Vol. 30, No. 6, pp. 130–144, 2013.

[20] K. Anoh, R. Abd-Alhameed, J. Noras, and S. Jones, “Wavelet packet transform modulation for multiple input multiple output applications”, *Intl. J. Comput. Appl.*, Vol. 63, No.7, pp. 0975-8887, 2013.

[21] P. V. Kumar and R. Nandhanavanam., “Performance Analysis of OFDM based Massive MIMO Downlink system”, *International Journal of Recent Technology & Engineering*, Vol. 8, No. 3, pp. 7161-7165, 2019.

[22] P. VijayaKumar and R. Nandhanavanam., “A novel method for joint- PAPR mitigation in OFDM based massive MIMO downlink systems”, *International Journal of Engineering & Technology*, Vol. 7, No. 3, pp. 1185-1188, 2018.

[23] H. Yeh, “Architectures for MIMO-OFDM Systems in Frequency Selective Mobile Fading

Received: December 10, 2020. Revised: January 18, 2021.

Channels", *IEEE, Trans. on Circuits Syst. II, Exp.Briefs*, Vol. 62, No. 5, pp. 1189- 1193, 2015.

[24] V. K Padarti and N. V Rao, "Adaptive SOICAF Algorithm for PAPR Mitigation in OFDM Systems", *Wireless Personal Communication*, Vol. 113, No. 7, pp. 927–943, 2020