Indonesian Journal of Electrical Engineering and Computer Science
Vol. 40, No. 3, December 2025, pp. 1698~1706
ISSN: 2502-4752, DOI: 10.11591/ijeecs.v40.i3.pp1698-1706

Low complexity blind selective mapping in orthogonal frequency division multiplexing: utilizing linear combination

Aeizaal Azman Abdul Wahab[1], Nur Qamarina Muhammad Adnan[1], Firdaus Mohamad Hamzah[2]
[1]School of Electrical and Electronic Engineering, Universiti Sains Malaysia, Nibong Tebal, Pulau Pinang, Malaysia
[2]Pusat Asasi Pertahanan, Universiti Pertahanan Nasional Malaysia, Kem Sungai Besi, Malaysia

Article Info

Article history:

Received Dec 26, 2024
Revised Oct 23, 2025
Accepted Nov 23, 2025

Keywords:

Blind receiver
Linear combination
OFDM
PAPR
Selective mapping

ABSTRACT

Orthogonal frequency division multiplexing (OFDM) is a cornerstone in wireless communications for its spectral efficiency and robustness against multipath fading. However, its deployment is constrained by the high peak-to-average power ratio (PAPR), which demands complex power amplifiers and increases system costs. Selective mapping (SLM) is a popular distortion less method for PAPR reduction but suffers from high computational complexity and data rate losses due to side information (SI) transmission. This paper proposes a low-complexity, blind SLM method utilizing linear combination, which reduces computational complexity by generating alternative candidate signals without additional inverse fast fourier transform (IFFT) operations. A maximum likelihood estimation (MLE)-based blind receiver recovers transmitted signals without SI, preserving data rate integrity. The proposed method achieves comparable PAPR and bit error rate (BER) performance to conventional SLM (C-SLM) while significantly reducing computational operations. Simulations demonstrate the efficiency of the method across various configurations, making it a strong candidate for next-generation communication systems like 5G and beyond.

Corresponding Author:

Aeizaal Azman Abdul Wahab
School of Electrical and Electronic Engineering, Universiti Sains Malaysia
143000 Nibong Tebal, Pulau Pinang, Malaysia
Email: aeizaal@usm.my

1. INTRODUCTION

Orthogonal frequency division multiplexing (OFDM) has emerged as a foundational technology in modern broadband wireless communication systems. It underpins numerous standards, including 5G NR, LTE, Wi-Fi, and various IoT protocols, owing to its efficient spectrum utilization and resilience to inter-symbol interference in multipath environments [1]–[3]. Despite these advantages, OFDM systems inherently suffer from a high peak-to-average power ratio (PAPR) [4], which forces power amplifiers to operate inefficiently in their linear region. This leads to excessive energy consumption, reduced coverage, and signal degradation due to spectral spreading and nonlinear distortions [5], [6]. Such inefficiencies are particularly critical in mobile uplink transmissions, where device energy budgets and amplifier design constraints are tightly coupled. A wide array of techniques has been proposed to mitigate PAPR, categorized into signal distortion methods, coding-based methods, and probabilistic schemes [7], [8]. Distortion methods like clipping and filtering can reduce peaks but introduce in-band distortion and out-of-band radiation [9]–[11]. Coding-based approaches avoid distortion but typically require large lookup tables or redundancy overhead. Probabilistic techniques, such as selective mapping (SLM) and partial transmit sequence (PTS), modify OFDM symbols' phase structures to achieve PAPR reduction without signal distortion. Among these, SLM is particularly attractive for its BER-preserving nature; however, it suffers from high computational complexity due to multiple IFFT operations and data rate loss from side information (SI) transmission [12]–[17].

Recent efforts have sought to overcome these challenges through blind SLM (BSLM) schemes, eliminating the need for SI transmission [18]-[20]. Maximum Likelihood Estimation (MLE)-based blind receivers [21], [22] enable signal recovery without SI but may introduce receiver-side complexity. Parallel research has explored reducing computational burden by generating additional candidate signals through linear combinations of existing subcarrier sequences [23]–[25], notably in methods such as odd-even sequence combination (OEOSC). These strategies achieve computational savings but sometimes degrade PAPR performance, particularly with higher subcarrier counts or in non-ideal channels.

Despite these advancements, a gap remains: many existing methods either retain high complexity or compromise BER performance under challenging conditions. This paper addresses these limitations by proposing a novel low-complexity blind SLM method that: (i) generates multiple candidate signals using linear combinations without additional IFFT operations, (ii) introduces an MLE-based blind receiver to eliminate SI transmission, (iii) maintains or improves PAPR and BER performance compared to traditional C-SLM and GreenOFDM methods, and (iv) demonstrates robustness under both AWGN and Rayleigh fading channels. In wireless communication systems—particularly in energy- and bandwidth-constrained environments such as mobile devices and IoT nodes—the ability to reduce transmitter complexity while preserving system performance is crucial. The proposed technique aims to offer an efficient and scalable solution for next-generation OFDM-based wireless systems.

2. METHOD

This section provides a step-by-step description of the proposed low-complexity blind SLM method. The methodology includes standard procedures such as PSK modulation, FFT/IFFT operations, and channel modeling (AWGN and Rayleigh fading), alongside novel elements including linear combination-based candidate generation and MLE-based blind detection. Key parameters for the system include subcarrier counts of 128, 256, 512, and 1024; modulation using QPSK; and binary phase sequences (1 and -1). To generate candidate signals, the frequency-domain OFDM symbols are multiplied elementwise with phase sequences, followed by IFFT. Instead of multiple new IFFT operations, candidate signals are generated through linear combinations of odd and even sequences. Scalar coefficients for combinations are set to unity to minimize additional processing. The selection of the best candidate is based on minimizing PAPR as evaluated via the complementary cumulative distribution function (CCDF). At the receiver, MLE detection is applied by comparing the received signal with all possible candidates to identify the transmitted sequence without requiring SI. This step-by-step design ensures efficient, blind recovery of transmitted signals while maintaining computational practicality.

2.1. Transmitter design

The transmitter design focuses on leveraging the linear combination property of IFFT to generate additional candidate signals without requiring additional IFFT operations. This approach significantly reduces the computational burden associated with traditional SLM methods. The OFDM input signal X is modulated phase shift keying (PSK). The signal is then transformed into the frequency domain and multiplied elementwise with a set of predefined pseudorandom phase sequences $P_i(i = 1,2, \dots, U)$, where U denotes the number of phase sequences. The resulting signals X_i are expressed as:

$$X_i = X \cdot P_i \tag{1}$$

Where represents elementwise multiplication. After applying IFFT to each X_i, the resulting time-domain signals S_i are partitioned into odd and even sequences:

$$S_{odd}[n] = \begin{cases} S[n], n \text{ is odd} \\ 0, n \text{ is even} \end{cases} \tag{2}$$

$$S_{even}[n] = \begin{cases} 0, n \text{ is odd} \\ S[n], n \text{ is even} \end{cases} \tag{3}$$

These partitions enable the generation of new candidate signals through linear combinations. To generate additional candidate signals, each row of the odd and even matrices is linearly combined. If S_{odd}^i and S_{even}^j represent the odd and even matrices for the i-th and j-th phase sequences, the combined candidate signal $S_{combined}^{ij}$ is:

$$S^{ij}_{combined} = \alpha \cdot S^{i}_{odd} + \beta \cdot S^{j}_{even} \quad (4)$$

where α and β are scalar coefficients, typically chosen as 1 to minimize computational overhead. This process produces 2^P candidate signals, where P is the number of phase sequences. The CCDF is used to evaluate the PAPR of each candidate signal. The signal with the lowest PAPR is selected for transmission:

$$S_{selected} = \arg\min_{i} PAPR(S_i) \quad (5)$$

The selected signal is then appended with a cyclic prefix (CP) and transmitted over the wireless channel. Figure 1 visualized the design of the proposed transmitter.

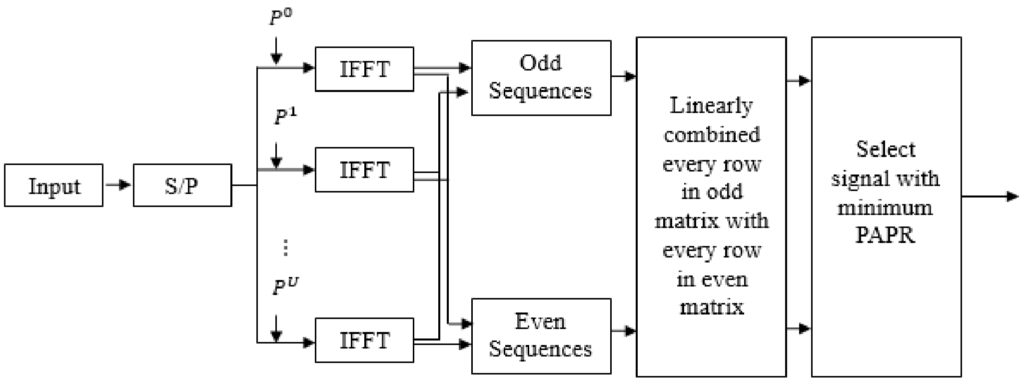

Figure 1. Design of the proposed transmitter

2.2. Receiver design

The receiver employs a MLE-based blind detection method to recover the transmitted signal without requiring SI. This eliminates the data rate loss typically associated with SI transmission. The received signal Y is modeled as:

$$Y = H \cdot S_{selected} + W \quad (6)$$

where H is the channel response, and W is additive white gaussian noise (AWGN). After removing the cyclic prefix, the signal undergoes FFT to transform it back into the frequency domain. The output is then partitioned into odd and even sequences, mirroring the transmitter's approach, Y_{odd}, Y_{even}. The MLE method estimates the transmitted phase sequence by minimizing the Euclidean distance between the received signal and all possible phase-modulated signals:

$$\hat{P} = \arg\min_{P_i} \|Y - H \cdot P_i \cdot X\|^2 \quad (7)$$

where $\hat{P}$ is the estimated phase sequence, and X represents the original constellation diagram. Figure 2 visualized the design of the proposed receiver.

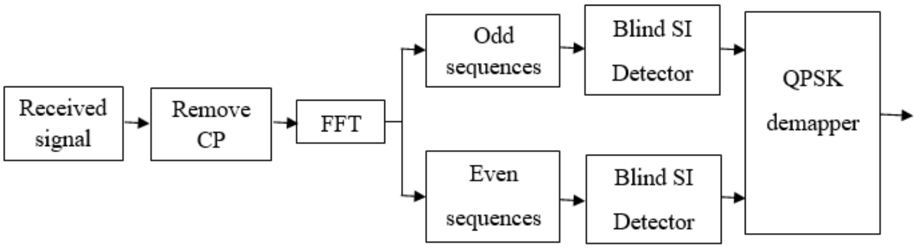

Figure 2. Design of the porposed receiver

3. PERFORMANCE ANALYSIS

The proposed method significantly reduces computational complexity compared to traditional SLM and GreenOFDM methods. Traditional SLM requires U IFFT operations for U candidate signals. The proposed method generates 2^P candidates using only P IFFT operations. By leveraging the sparsity of odd and even matrices, the number of additions and multiplications required for linear combinations is minimized. The computational complexity reduction ratio (CCRR) is quantified as:

$$CCRR = \left(1 - \frac{Complexity\ of\ Proposed\ SLM}{Complexity\ of\ Conventional\ SLM}\right) \times 100\% \quad (8)$$

The methodology is evaluated using the following performance metrics; PAPR reduction, BER performance and computational complexity. PAPR reduction was assessed using CCDF plots, comparing the proposed method with C-SLM and GreenOFDM. BER performance was simulated under AWGN and Rayleigh fading channels to ensure robustness. The computational complexity was measured in terms of IFFT operations and arithmetic operations required. The proposed methodology is implemented and evaluated using MATLAB.

4. RESULTS AND DISCUSSIONS

Table 1 shows the number of complex multiplications and complex additions required by C-SLM, GreenOFDM, and the Proposed SLM for a given number of candidate signals U and subcarriers N. The formula represents the complex multiplications in the conventional selective mapping (C-SLM) approach. The term N corresponds to the length of the IFFT, $\frac{N}{2}\log_2 N$ is the number of multiplications required for a fast fourier transform (FFT) operation, and U is the number of candidate signals. So, for C-SLM, the number of complex multiplications grows linearly with both the number of subcarriers N and the number of candidate signals U. In GreenOFDM, there's an additional term $\frac{U^2}{4}N$ that accounts for extra operations involved in optimizing the phase sequences used for subcarrier grouping. This results in more multiplications, making GreenOFDM computationally more expensive than C-SLM. The Proposed SLM method also has a term U^2N, which corresponds to the linear combination of phase sequences (as discussed earlier). The Proposed SLM method increases the number of candidate signals generated without requiring extra IFFT operations, which results in fewer IFFTs being performed compared to GreenOFDM.

The C-SLM method requires complex additions proportional to the number of subcarriers N, the number of candidates U, and the logarithmic factor $\log_2 N$ that arises from the FFT operation. In GreenOFDM, the additional term $\frac{U^2}{4}N$ represents the extra additions involved in the optimization step. This makes GreenOFDM slightly more computationally intensive than C-SLM in terms of additions. Proposed SLM also includes the U^2N term, representing the additional complexity of generating more candidate signals via the linear combination approach. However, unlike GreenOFDM, the Proposed SLM does not require a significant increase in additions compared to C-SLM, as it avoids the quadratic complexity of GreenOFDM. The Proposed SLM reduces the number of IFFT operations for the same number of candidate signals compared to C-SLM and GreenOFDM, making it computationally more efficient. The proposed method achieves this by utilizing linear combinations rather than performing additional IFFTs. While GreenOFDM and C-SLM show similar growth in their computational complexity with respect to the number of candidate signals, Proposed SLM achieves a significant reduction in computational cost by minimizing the number of IFFT operations needed. Both GreenOFDM and proposed SLM involve U^2N terms, but Proposed SLM maintains a better balance between generating multiple candidate signals and keeping the operations efficient, ensuring reduced overall complexity. The proposed SLM method offers a substantial advantage in terms of reducing both complex multiplications and complex additions compared to C-SLM and GreenOFDM, thanks to the optimization via linear combinations and the reduction of IFFT operations. This makes the proposed SLM a more efficient approach for reducing PAPR in OFDM systems while maintaining comparable performance.

Table 1. Computational complexity analysis

	Complex multiplications	Complex additions
C-SLM	$(N + \frac{N}{2}\log_2 N)U$	$UN\log_2 N$
GreenOFDM	$(N + \frac{N}{2}\log_2 N)U + \frac{U^2}{4}N$	$UN\log_2 N + \frac{U^2}{4}N$
Proposed SLM	$(N + \frac{N}{2}\log_2 N)U + U^2N$	$UN\log_2 N + U^2N$

Table 2 compares the CCRR for the Proposed SLM method against the C-SLM and GreenOFDM methods. The CCRR values represent the percentage reduction in complex multiplications and complex additions achieved by the Proposed SLM compared to C-SLM and GreenOFDM for different numbers of candidate signals. The number of Candidate Signals (C) column shows the number of candidate signals considered in the method. For each method (C-SLM, GreenOFDM, and Proposed SLM), two different scenarios are presented: 16 and 25 candidate signals. Complex Multiplications column shows the CCRR for complex multiplications, i.e., the percentage reduction in the number of complex multiplications when using the Proposed SLM compared to C-SLM and GreenOFDM. Complex Additions column shows the CCRR for complex additions, i.e., the percentage reduction in the number of complex additions when using the Proposed SLM compared to C-SLM and GreenOFDM.

For C-SLM, when the number of candidate signals increases from 16 to 25, the CCRR of complex multiplications increases from 50.00% to 55.00%. The CCRR of complex additions increases from 58.33% to 63.33%. This indicates that as the number of candidate signals increases, the Proposed SLM reduces more complex multiplications and additions compared to C-SLM. For GreenOFDM, when the number of candidate signals increases from 16 to 25. The CCRR of complex multiplications decreases from 33.33% to 30.77%. The CCRR of complex additions decreases from 37.50% to 35.29%. The Proposed SLM reduces complex multiplications and additions more effectively than GreenOFDM, especially as the number of candidate signals increases. The Proposed SLM shows a greater reduction in both complex multiplications and complex additions compared to C-SLM at both 16 and 25 candidate signals. The Proposed SLM outperforms GreenOFDM by a larger margin, providing a higher reduction in both complex multiplications and complex additions for both 16 and 25 candidate signals. The Proposed SLM method demonstrates significant computational savings over C-SLM and GreenOFDM, especially when the number of candidate signals increases. The Proposed SLM achieves a higher percentage reduction in computational complexity, making it more efficient in terms of both complex multiplications and complex additions. This reduction in computational complexity is a key advantage, particularly for power-constrained devices in real-time applications like 5G and IoT.

Table 2. CCRR of the proposed SLM over C-SLM and GreenOFDM

	Number of candidate signal $\boldsymbol{C}$	Complex multiplications	Complex additions
C-SLM	16	50.00%	58.33%
	25	55.00%	63.33%
GreenOFDM	16	33.33%	37.50%
	25	30.77%	35.29%

Figure 3 illustrated CCDF performance of Original OFDM signal, C-SLM and proposed SLM. Both C-SLM and Proposed SLM show reduced PAPR as the number of candidates U increases. This is because increasing U provides more opportunities to select a signal with lower PAPR. The Proposed SLM achieves comparable PAPR reduction to C-SLM but with significantly fewer IFFT computations. For example, to achieve performance like C-SLM ($U = 25$), the Proposed SLM only requires $U = 5$, reducing the computational complexity by 80%. The Proposed SLM is ideal for applications where computational efficiency is critical (e.g., resource-constrained devices like mobile systems). However, for systems where computational resources are not a concern, C-SLM can achieve better PAPR reduction. This graph effectively illustrates the trade-off between PAPR reduction and computational complexity for C-SLM and Proposed SLM. The Proposed SLM offers a more computationally efficient solution with acceptable PAPR reduction, making it a practical choice for real-time and resource-limited applications.

Compared to the conventional SLM (C-SLM) method, the proposed linear combination-based blind SLM technique achieves a significant reduction in transmitter complexity by minimizing the number of required IFFT operations. While C-SLM necessitates one IFFT per candidate signal, our method generates multiple candidates through linear combinations, requiring substantially fewer IFFT executions. Furthermore, although GreenOFDM also reduces complexity, it incurs additional processing overhead due to optimization steps do not present in our approach. Simulation results confirm that the proposed method maintains comparable PAPR and BER performance to C-SLM and GreenOFDM, while achieving up to 55% and 30% greater computational complexity reduction, respectively, particularly when the number of candidate signals increases. This demonstrates the superior scalability and practicality of the proposed method for next-generation OFDM-based communication systems.

Figure 4 illustrated the BER performance of the receiver with SI and the proposed blind receiver. Both receivers achieve very low BER, close to 10^{-3}, indicating excellent performance in high SNR conditions. Across the SNR range, the blind receiver closely matches the performance of the receiver with SI, especially at moderate to high SNR levels (e.g., above 20 dB). Despite lacking SI, the blind receiver achieves a BER performance within a small margin of the receiver with SI, showcasing its robustness. At high SNR values (above 40 dB), the blind receiver achieves nearly identical BER to the receiver with SI, reaching values as low as 110^{-3}. This highlights that blind decoding can be as effective as side-information-based decoding when the signal is strong, and noise is minimal. The blind receiver avoids the overhead associated with transmitting and processing SI, making it ideal for systems where bandwidth efficiency is critical or where transmitting SI is impractical. By not relying on SI, the blind receiver simplifies system design, reducing the need for additional signaling or synchronization. This makes it more adaptable for real-world scenarios where resources or communication overhead are constrained. While the receiver with SI benefits from additional information, the blind receiver proves to be a highly capable alternative. Its performance is only marginally lower, making it an attractive choice in scenarios where simplicity, bandwidth efficiency, or minimal overhead are priorities.

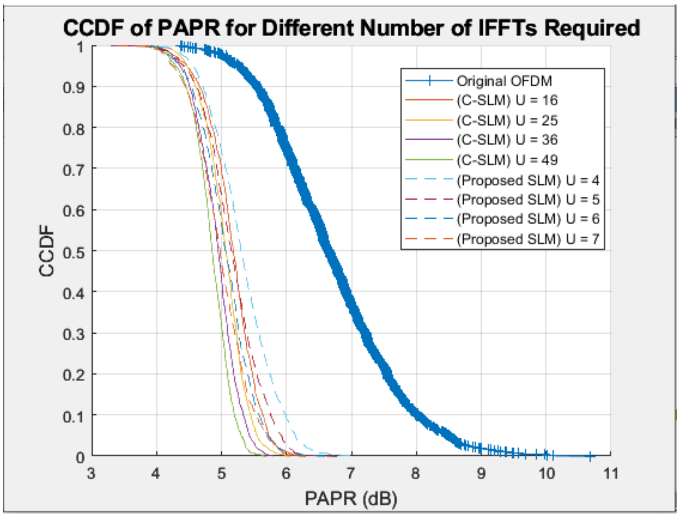

Figure 3. CCDF performance of original OFDM, C-SLM and proposed SLM

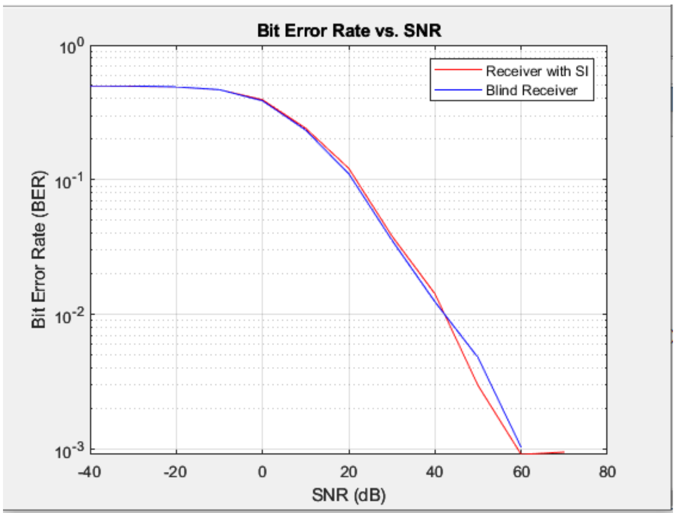

Figure 4. BER performance of the receiver with SI and the blind receiver

The findings demonstrate that the proposed method achieves substantial computational savings, with up to 55% complexity reduction compared to C-SLM and up to 30% compared to GreenOFDM, while maintaining comparable PAPR and BER performance. These results imply that the proposed blind SLM technique is highly suitable for power- and bandwidth-constrained applications such as mobile uplink transmissions, internet of things (IoT) sensors, and real-time edge computing devices. Furthermore, eliminating the need for SI transmission enhances system throughput and reliability, which is critical in modern wireless environments with tight latency and bandwidth requirements. For future work, the proposed method can be extended to higher-order modulation schemes (e.g., 16-QAM, 64-QAM) to further assess scalability. Additionally, integrating adaptive linear combination weights based on channel conditions or applying machine learning-based blind detection techniques may offer further performance enhancements under dynamic wireless environments.

5. CONCLUSION

This study advances the field of low-complexity, bandwidth-efficient OFDM communication systems by proposing a novel blind SLM technique. By utilizing linear combinations to generate multiple candidate signals without additional IFFT operations and employing a MLE-based blind receiver to eliminate SI transmission, the proposed method addresses two critical challenges: transmitter complexity and data rate degradation. Compared to conventional methods like C-SLM and GreenOFDM, the proposed approach achieves better scalability to high subcarrier counts and greater computational efficiency while maintaining comparable or improved PAPR and BER performance. Simulation results confirm substantial reductions in computational operations, demonstrating the method's suitability for next-generation wireless applications such as 5G uplink transmissions, IoT devices, and real-time edge computing platforms where power and processing resources are constrained. These findings not only validate the feasibility of blind SLM strategies under practical system conditions but also open new pathways for designing lightweight, adaptive, and high-efficiency wireless protocols. Future research may explore extensions to higher-order modulation schemes (e.g., 16-QAM, 64-QAM) and dynamic adjustment of linear combination weights to further enhance robustness in varying channel environments. In conclusion, this work contributes to the development of more efficient, scalable, and practical PAPR reduction techniques, supporting the broader objective of making OFDM more viable for modern, real-time communication systems.

FUNDING INFORMATION

This project was supported by "Ministry of Higher Education Malaysia for Fundamental Research Grant Scheme" with project code FRGS/1/2020/TKO/USM/02/21.

AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Aeizaal Azman Abdul Wahab	✓	✓		✓	✓		✓			✓		✓	✓	✓
Nur Qamarina Muhammad Adnan	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
Firdaus Mohamad Hamzah				✓	✓		✓					✓	✓	✓

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

INFORMED CONSENT

We have obtained informed consent from all individuals included in this study.

ETHICAL APPROVAL

The research related to human use has been complied with all the relevant national regulations and institutional policies in accordance with the tenets of the Helsinki Declaration and has been approved by the authors' institutional review board or equivalent committee; or: The research related to animal use has been complied with all the relevant national regulations and institutional policies for the care and use of animals.

DATA AVAILABILITY

The authors confirm that the data supporting the findings of this study are available within the article.

REFERENCES

[1] M. Mounir, M. I. Youssef, and A. M. Aboshosha, "Low-complexity selective mapping technique for PAPR reduction in downlink power domain OFDM-NOMA," *EURASIP Journal Adv Signal Process*, vol. 2023, no. 1, 2023, doi: 10.1186/s13634-022-00968-y.

[2] A. A. A. Wahab, N. Q. M. Adnan, S. S. N. Alhady, W. A. F. W. Othman, and H. Husin, "On optimization of selective mapping and clipping hybrid scheme using firefly algorithm for PAPR reduction," *In IT Applications for Sustainable Living*, 2023, doi: 10.1007/978-3-031-40751-2_8.

[3] N. Qamarina, A. A. A. Wahab, W. A. F. W. Othman, S. S. N. Alhady, and H. Husin, "PAPR reduction of OFDM system using selective mapping (SLM) and firefly algorithm (FA)," in *Lecture Notes in Electrical Engineering*, 2022, doi: 10.1007/978-981-16-2406-3_20.

[4] A. A. A. Wahab, S. S. N. Alhady, W. A. F. W. Othman, H. Husin, and N. Q. M. Adnan, "Improved partial transmit sequence (PTS) for PAPR reduction in OFDM system," in *Lecture Notes in Electrical Engineering*, 2022, doi: 10.1007/978-981-16-8129-5_39.

[5] S. Carcangiu, A. Fanni, and A. Montisci, "A closed form selected mapping algorithm for PAPR reduction in OFDM multicarrier transmission," *Energies (Basel)*, vol. 15, no. 5, 2022, doi: 10.3390/en15051938.

[6] B. H. S. Faraj and A. I. Siddiq, "Overview on PAPR reduction techniques in OFDM-IM," *Multidiszciplináris tudományok*, vol. 12, no. 2, 2022, doi: 10.35925/j.multi.2022.2.11.

[7] R. Niwareeba, M. A. Cox, and L. Cheng, "PAPR reduction in optical OFDM using lexicographical permutations with low complexity," *IEEE Access*, vol. 10, 2022, doi: 10.1109/ACCESS.2021.3138193.

[8] B. D. Timande and M. K. Nigam, "PAPR reduction an effective approach for next frontier MIMO-OFDM systems," *Journal of Engineering Research (Kuwait)*, vol. 9, 2021, doi: 10.36909/JER.11379.

[9] B. Bakkas, R. Benkhouya, I. Chana, and H. Ben-Azza, "Palm date leaf clipping: A new method to reduce PAPR in OFDM systems," *Information (Switzerland)*, vol. 11, no. 4, 2020, doi: 10.3390/info11040190.

[10] K. Venkateswarlu, C. Sravanya, M. Nyalapogula, M. Anudheep, and P. Sairam, "Performance analysis of PAPR minimization in OFDM system using clipping, SLM and PTS techniques," *International Journal of Research in Science and Engineering*, no. 32, 2023, doi: 10.55529/ijrise.32.33.45.

[11] S. R. Abdulridha and F. S. Hasan, "Palm clipping and nonlinear companding techniques based PAPR reduction in OFDM-DCSK system," *Journal of Engineering and Sustainable Development*, vol. 25, no. 4, 2021, doi: 10.31272/jeasd.25.4.8.

[12] Y. A. Al-Jawhar, K. N. Ramli, M. A. Taher, N. S. M. Shah, S. A. Mostafa, and B. A. Khalaf, "Improving PAPR performance of filtered OFDM for 5G communications using PTS," *ETRI Journal*, vol. 43, no. 2, 2021, doi: 10.4218/etrij.2019-0358.

[13] M. M. Albogame and K. M. Elleithy, "Enhancement orthogonal frequeney division multiplexing (OFDM) in wireless communication network by using PTS (Partial transmit sequences) technique," in *29th International Conference on Computers and Their Applications, CATA 2014*, 2014.

[14] X. Song *et al.*, "SCMA-OFDM PON based on chaotic-SLM-PTS algorithms with degraded PAPR for improving network security," *Optics Letters*, vol. 47, no. 20, 2022, doi: 10.1364/ol.471658.

[15] J. Li, X. Zeng, C. Yin, Q. Luo, and G. Li, "A low-complexity CRC-based decoding algorithm for SLM-ML OFDM systems," *IEEE Wireless Communications Letters*, vol. 10, no. 6, 2021, doi: 10.1109/LWC.2020.3042676.

[16] R. Niwareeba, M. A. Cox, and L. Cheng, "Low complexity hybrid SLM for PAPR mitigation for ACO OFDM," *ICT Express*, vol. 8, no. 1, 2022, doi: 10.1016/j.icte.2021.10.002.

[17] S. R. Abdulridha and F. S. Hasan, "Enhanced SLM based OFDM-DCSK communication system for PAPR reduction," *Bulletin of Electrical Engineering and Informatics*, vol. 11, no. 1, 2022, doi: 10.11591/eei.v11i1.3549.

[18] D. S. Pawar and H. S. Badodekar, "Review of PAPR reduction techniques in wireless communication," in *Proceedings - 2018 IEEE Global Conference on Wireless Computing and Networking, GCWCN 2018*, 2018, doi: 10.1109/GCWCN.2018.8668631.

[19] A. B. Kotade, A. B. Nandgaonkar, and S. L. Nalbalwar, "Peak-to-average power ratio reduction techniques in OFDM: a review and challenges," in *2018 International Conference on Advances in Communication and Computing Technology, ICACCT 2018*, 2018. doi: 10.1109/ICACCT.2018.8529645.

[20] S. A. Fathy, M. Ibrahim, S. El-Agooz, and H. El-Hennawy, "Low-complexity SLM PAPR reduction approach for UFMC systems," *IEEE Access*, vol. 8, 2020, doi: 10.1109/ACCESS.2020.2982646.

[21] S. Y. Zhang and B. Shahrrava, "A SLM scheme for PAPR reduction in polar coded OFDM-IM systems without using side information," *IEEE Transactions on Broadcasting*, vol. 67, no. 2, 2021, doi: 10.1109/TBC.2020.3039696.

[22] L. Yang, Y. M. Siu, K. K. Soo, and S. Q. Li, "New construction scheme to reduce the PAPR of M-QAM OFDM signal," *Wireless Personal Communications*, vol. 80, no. 3, 2015, doi: 10.1007/s11277-014-2083-6.

[23] R. Niu and L. Wang, "Threshold selection PTS method for PAPR reduction in OFDM systems," in *International Conference on Communication Technology Proceedings, ICCT*, 2020, doi: 10.1109/ICCT50939.2020.9295881.

[24] C. Hu, L. Wang, and Z. Zhou, "A modified SLM scheme for PAPR reduction in OFDM systems," in *ICEIEC 2020 - Proceedings of 2020 IEEE 10th International Conference on Electronics Information and Emergency Communication*, 2020, doi: 10.1109/ICEIEC49280.2020.9152350.

[25] W. W. Hu, "PAPR reduction in DCO-OFDM visible light communication systems using optimized odd and even sequences combination," *IEEE Photonics Journal*, vol. 11, no. 1, 2019, doi: 10.1109/JPHOT.2019.2892871.

BIOGRAPHIES OF AUTHORS

Aeizaal Azman Abdul Wahab is Senior Lecturer at School of Electrical and Electronic Engineering at Universiti Sains Malaysia, Penang, Malaysia. He holds a Ph.D. degree in Wireless Communication. His research areas are signal processing, digital communication networks, advanced and emerging methods, coding and information theory and mathematics software. He can be contacted at email: aeizaal@usm.my.

Nur Qamarina Muhammad Adnan is Ph.D. student at School of Electrical and Electronic Engineering at Universiti Sains Malaysia, Penang, Malaysia. She holds a master's degree in electronic system design engineering and bachelor's degree in electronic engineering. Her research area is wireless communications. She can be contacted at email: qamarashvin96@gmail.com.

Prof. Ts. Gs. Dr. Firdaus Mohamad Hamzah is Professor of Pusat Asasi Tahanan at Universiti Pertahanan Malaysia, Kuala Lumpur, Malaysia. He holds a Ph.D. degree in Environmental, Hydrological, and Ecological Statistical. His research areas are applied statistics, data science, environmental science, and civil engineering. He can be contacted at email: firdaus.hamzah@upnm.edu.my.