International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering
Impact Factor 8.414 ⁙ Peer-reviewed & Refereed journal ⁙ Vol. 13, Issue 7, July 2025
DOI: 10.17148/IJIREEICE.2025.13716

A Comparative Study of Traditional PAPR Reduction Techniques in MIMO-OFDM Systems

C.Shruthi[1], Dr.Rajkumar L Biradar[2] , Dr.G. Krishna Reddy[3]

Student, Electronics and Telematics Engineering Dept., G.Narayanamma Institute of Technology and Science, Hyderabad, India[1]

Head of the Department and Professor, Electronics and Telematics Engineering Dept., G.Narayanamma Institute of Technology and Science, Hyderabad, India[2]

Associate Professor, Electronics and Telematics Engineering Dept., G.Narayanamma Institute of Technology and Science, Hyderabad, India[3]

Abstract: MIMO-OFDM (Multiple-Input Multiple-Output Orthogonal Frequency Division Multiplexing) has emerged as a key technology in modern wireless communication systems due to its high data rates and robustness against multipath fading [1]. However, a significant drawback of OFDM is its high Peak-to-Average Power Ratio (PAPR), which leads to power inefficiency and nonlinear distortion in power amplifiers [3]. This paper focuses on traditional PAPR reduction techniques that have been widely used to address this issue, particularly in MIMO-OFDM systems.

The study explores three well-known methods, Partial Transmit Sequence (PTS), Selected Mapping (SLM), and Clipping and Filtering (C&F) [18]. PTS divides the OFDM block into sub-blocks and optimally rotates them to minimize PAPR without distortion, though it requires side information and increased computational complexity [2]. SLM generates multiple OFDM candidate signals using different phase sequences and selects the one with the lowest PAPR for transmission, balancing complexity and performance [11]. Clipping and Filtering, a straightforward nonlinear technique, reduces PAPR by clipping the peaks of the signal followed by filtering to suppress out-of-band radiation, though it may introduce in-band distortion and BER degradation.

A comparative analysis of these techniques is presented in terms of PAPR reduction performance, computational cost, and impact on bit error rate (BER) [20]. This work provides a foundational understanding of traditional PAPR reduction strategies for MIMO-OFDM systems and offers insights for researchers aiming to improve energy efficiency and signal integrity in future wireless networks.

Keywords: PAPR reduction, MIMO-OFDM, Peak-to-Average Power Ratio, power amplifier nonlinearity, spectral efficiency, Bit Error Rate (BER), Side Information, OFDM Signal Distortion, Partial Transmit Sequence (PTS), Selective Mapping (SLM), Clipping and Filtering (C&F).

I. INTRODUCTION

Modern wireless communication systems demand high data rates, spectral efficiency, and reliable transmission over multipath channels [15]. MIMO-OFDM (Multiple Input Multiple Output – Orthogonal Frequency Division Multiplexing) has become one of the most prominent technologies fulfilling these requirements, and is widely adopted in standards such as LTE, Wi-Fi 6, and 5G NR [13]. MIMO provides spatial diversity and multiplexing gain, while OFDM enables efficient handling of frequency-selective fading channels by dividing the available bandwidth into multiple orthogonal subcarriers.

However, despite its numerous advantages, one of the major challenges in OFDM-based systems is the high Peak-to-Average Power Ratio (PAPR). PAPR is defined as the ratio of the peak power of the transmitted signal to its average power [18]. Due to the summation of multiple independently modulated subcarriers in the time domain, OFDM signals often exhibit high peak power values, which can exceed the linear operating range of power amplifiers. This leads to signal distortion, reduced power efficiency, increased bit error rates (BER), and out-of-band radiation [20]. [23] The problem becomes more severe in MIMO-OFDM systems, where multiple antennas transmit simultaneously, increasing the probability of signal peaks occurring [25].

DOI: 10.17148/IJIREEICE.2025.13716

To mitigate this issue, several traditional PAPR reduction techniques have been proposed. Among them, Partial Transmit Sequence (PTS), Selected Mapping (SLM), and Clipping and Filtering (C&F) are widely researched and implemented.

- **Partial Transmit Sequence (PTS):** PTS is a probabilistic technique that divides the input data block into multiple sub-blocks and multiplies each sub-block with a phase factor [4]. These sub-blocks are then recombined in various phase combinations, and the one resulting in the lowest PAPR is selected for transmission. PTS does not cause signal distortion, which makes it an attractive technique [7]. However, it introduces additional computational complexity due to the exhaustive search over phase combinations and requires the transmission of side information to the receiver, which can impact bandwidth efficiency.

- **Selected Mapping (SLM):** SLM also belongs to the class of distortion less PAPR reduction techniques [1]. It generates a set of alternative OFDM symbols by multiplying the original data block with different phase sequences. The sequence with the lowest PAPR is selected for transmission. Like PTS, SLM also requires side information for correct signal recovery at the receiver [14]. SLM offers good PAPR reduction performance but incurs increased complexity proportional to the number of candidate sequences.

- **Clipping and Filtering (C&F):** This is a nonlinear method where the signal is clipped above a certain amplitude threshold to limit the peaks [5]. A filtering stage is then used to suppress out-of-band emissions introduced by clipping. Although C&F is simple and effective, it introduces in-band distortion, leading to degradation in BER performance [13]. The iterative nature of filtering May also cause peak re-growth, requiring careful design trade-offs.

Each of these techniques has its own strengths and limitations. PTS and SLM avoid distortion but require side information and higher computational resources. Clipping and Filtering is simple but compromises signal quality [12]. Therefore, understanding and comparing these traditional PAPR reduction techniques is crucial for the design of efficient MIMO-OFDM systems, especially in power-constrained environments such as mobile devices or IoT networks.

This paper aims to provide a detailed comparative analysis of these traditional techniques in the context of MIMO-OFDM systems [19]. By evaluating their performance in terms of PAPR reduction, Bit Error Rate (BER), and computational complexity, we aim to guide researchers and engineers in selecting appropriate strategies for PAPR mitigation in future communication systems.

II. LITERATURE SURVEY

In order to reduce PAPR in OFDM systems, this work suggests a novel polar coding based SLM scheme that eliminates the need of sending any control bits or side information [1]. The suggested method uses a low-complexity SLM transmitter that uses co-set leaders connected to separate frozen data blocks to jumble a polar codeword. Therefore, it is possible to prevent the transmission of redundant information.

This transmitter design is supported by an adaptive trial base blind receiver. With high detection accuracy, this receiver picks up the chosen signal or frozen data block and decode the unfrozen data block. According to simulation results, the blind receiver operates dependably and the PAPR is much decreased [3]. Additionally, according to the authors, this method is particularly well-suited for uplink applications, such transmitting uplink control data in 5G enhanced mobile broadband (eMBB). The potential of the suggested SLM technique to enhance spectrum efficiency and power control in contemporary communication systems is demonstrated by this work.

Techniques

- **SLM Based PAPR Reduction:** In order to select with the OFDM Signal with the lower PAPR, this method generate multiple OFDM signal by encoding frozen data blocks into separate co-set codes.

- **Blind Detection Receiver:** This adaptive trial-based blind receiver is made to recognize and decode the selected signal without sending out extra PAPR control data. This receiver preserves precision while minimizing data loss, which is especially helpful in situations when minimal transmission overhead is crucial.

Polar Coding-Based Selective Mapping (PC-SLM) is an efficient technique for PAPR reduction in OFDM systems that eliminate the need for redundant information transmission. One of the primary advantages of this approach is its ability to significantly reduce PAPR while maintaining high spectral efficiency. By leveraging the properties of polar codes, the method ensures reliable communication even under low signal-to-noise ratio (SNR) conditions, making it ideal for

DOI: 10.17148/IJIREEICE.2025.13716

modern wireless systems. Additionally, it eliminates the need to transmit side information, which further improves bandwidth efficiency and simplifies receiver design. The integration of polar codes also enhances the error-correcting capabilities, providing robust performance in fading and noisy environments.

However, PC-SLM has some limitations. The complexity of encoding and decoding increases due to the reliance on polar codes, especially in scenarios with a high number of subcarriers or large data blocks. This increased computational overhead can be challenging for low-power or resource-constrained devices. Furthermore, the technique's heavy dependence on polar codes may limit its flexibility in systems that use alternative coding schemes. These disadvantages need to be carefully considered, particularly in applications where computational efficiency and coding adaptability are critical.

Using a two-stage design, a post-inverse fast Fourier transform stage, and an optimized Class-III Selected Mapping scheme, this study suggests a hybrid PAPR reduction scheme for OFDM systems [2]. In comparison to traditional methods, this suggested approach effectively lowers the PAPR with less computing complexity, and it works with high-order QAM modulation schemes in real-world communication systems.

Methods

- Using a post-IFFT, this method builds higher-order QAM sequences from lower-order QPSK or BPSK sequences.
- This step creates several potential sequences using circular convolution and shifting with ideal values using a modified Class-III SLM method.

A hybrid PAPR reduction scheme for OFDM systems using perfect sequences combines the strengths of multiple techniques to achieve enhanced performance. One of the key advantages of this approach is its ability to significantly lower PAPR while maintaining the integrity of the transmitted signal. The use of perfect sequences ensures that the signal exhibits optimal autocorrelation properties, effectively reducing interference and improving system reliability. This hybrid approach often integrates methods like Selective Mapping (SLM) or Tone Reservation, allowing for a flexible and robust solution that can adapt to various system requirements. Furthermore, the scheme minimizes the need for additional side information, which enhances spectral efficiency and simplifies receiver design.

Despite these benefits, the hybrid approach comes with certain disadvantages. The generation and processing of perfect sequences can be computationally intensive, leading to higher complexity in both the transmitter and receiver. This increased complexity may not be suitable for low-power or real-time applications where computational resources are limited. Additionally, the hybrid nature of the scheme may require careful parameter tuning and synchronization to achieve optimal performance, which can complicate system implementation. These trade-offs must be carefully balanced when considering the adoption of this scheme in practical OFDM systems.

This study's goal is to minimize the PAPR of the UCA OAM system by proposing a CS-DOT method. CS-DOT performs the best among the schemes that were studied [3]. We also examine the BER of the CS-DOT scheme with aligned and unaligned transceivers and find that the BER performance of the system remains intact in the absence of SSPA. Our future research will concentrate on PAPR reduction in OFDM-OAM systems in light of these findings.

Approach

- After QAM modulation, CS-DOT Precoding is used to restructure the signal using a matrix that reduces autocorrelation prior to transmission.
- The UCA-OAM signal is subsequently generated by IDFT transformation of this Precoding matrix and sent over the channel.
- It works in conjunction with pre-detection and beam-forming techniques to address issues with signal alignment in the UCA OAM configuration.

A novel precoding technique designed to reduce the Peak-to-Average Power Ratio (PAPR) in Uniform Circular Array (UCA) – Orbital Angular Momentum (OAM) systems offer significant advantages for modern communication systems. This technique effectively mitigates the PAPR problem by optimizing the transmitted signal before it enters the power amplifier, resulting in improved power efficiency and reduced distortion. Additionally, the precoding method enhances the overall performance of UCA-OAM systems by maintaining the integrity of the orbital angular momentum modes, which are essential for achieving high spectral efficiency and massive data transmission. The reduction in PAPR also ensures better utilization of the power amplifier's dynamic range, minimizing energy waste and extending the lifespan of the hardware.

ISSN (O) 2321-2004, ISSN (P) 2321-5526
International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering
Impact Factor 8.414 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 13, Issue 7, July 2025
DOI: 10.17148/IJIREEICE.2025.13716

However, the technique has certain disadvantages. The implementation of precoding introduces additional computational complexity, which can increase the processing burden on the transmitter. This complexity may pose challenges for real-time applications and low-power devices. Moreover, the effectiveness of the precoding technique often depends on accurate channel state information (CSI), which can be difficult to obtain in dynamic or fast-changing environments. Any errors in CSI estimation may lead to suboptimal performance or increased system overhead. These factors must be carefully evaluated when considering the adoption of this novel technique in practical UCA-OAM systems.

In order to solve for PTS in OFDM systems, the research presents an alternate optimization method that lowers PAPR without requiring any additional information [4]. This maintains high data transfer rates while reducing PAPR effectively and avoiding additional overhead. The authors reformulate the PTS optimization into a sequence of convex problems using a convex relaxation method, which enables phase estimation at the receiver without the need for extra information and allows for effective PAPR reduction with polynomial-time complexity.

Approach

- **Convex Relaxation:** A series of convex programming tasks can be created from the non-convex optimization problem that seeks to minimize PAPR.
- This guarantees that the solutions meet the Karush-Kuhn-Tucker, or KKT, requirements by convergent to a suboptimal point.
- **Phase Quantization:** To enable maximum likelihood estimation at the receiver without the need for side information, the ideal phase factors are quantized.
- **Blind Phase Estimation:** Using blind detection, the receiver maximizes the probability function across the quantized phase levels to estimate phase factors.

The optimization of the Partial Transmit Sequence (PTS) technique for PAPR reduction in OFDM signals without requiring side information presents a highly efficient solution for modern wireless communication systems. One major advantage of this approach is its ability to significantly reduce PAPR, ensuring better signal quality and improved power amplifier efficiency. By eliminating the need for side information transmission, the method enhances spectral efficiency and simplifies the receiver design, as the system does not require additional resources to decode extra information. Furthermore, optimized PTS ensures flexibility in selecting phase factors, leading to a more effective reduction in PAPR while maintaining compatibility with existing OFDM systems.

However, the technique also has some disadvantages. The primary drawback is the increased computational complexity involved in optimizing the phase factors, especially for systems with a large number of subcarriers [8]. This complexity can be challenging for low-power or resource-constrained devices, limiting its practical implementation in certain scenarios. Additionally, the absence of side information places greater reliance on the receiver's ability to perform blind detection, which can be error-prone in high-noise environments or under poor channel conditions. These challenges must be addressed to ensure the effective deployment of the optimized PTS technique in practical OFDM systems.

The work examines PAPR reduction approaches for mixed-numerology transmissions, highlighting how traditional clipping can lead to INI accumulation [5]. The NS-ICF method reduces high peaks by utilizing clipping noise instead of the clipped signal, minimizing INI. Under the PAPR constraint, EVM minimization is addressed using O-ADMM and CU-ADMM, which efficiently handle the convex programming structure. The ADMM framework provides a scalable solution for PAPR reduction across different numerologies, adaptable to F-OFDM and W-OFDM. The approach, combined with filtering and windowing techniques, reduces OOBE and mitigates spectrum re-growth caused by PA nonlinearity.

Techniques

- **System Model:** Constructs a composite signal structure that reflects actual 5G scenarios by utilizing several numerologies.
- **ICF:** By using the clipping noise rather than the clipped signals, classical iterative clipping has been adjusted to circumvent INI in mixed numerology.
- **ADMM optimization:** This ensures scalability and efficiency by reformulating the PAPR reduction problem into a convex optimization framework that can be solved using ADMM.
- **Validation:** Assesses the effectiveness of PAPR reduction strategies in practical spectrum scenarios by combining them with filtering (F-OFDM) and windowing (W-OFDM).

This method is highly effective in reducing PAPR while maintaining signal quality. Iterative clipping and filtering gradually suppress high peaks, ensuring better convergence to an optimized signal. When combined with ADMM, which

DOI: 10.17148/IJIREEICE.2025.13716

is known for solving complex optimization problems efficiently, the method ensures that the PAPR reduction process converges quickly while preserving the constraints of mixed-numerology systems. This dual approach is well-suited for next-generation communication systems like 5G, where mixed numerologies are employed to accommodate diverse services and requirements. Additionally, the technique minimizes distortion and out-of-band emissions compared to traditional clipping methods, leading to improved Bit Error Rate (BER) performance and spectral efficiency.

Despite its effectiveness, the iterative nature of the clipping and filtering process increases computational complexity, making real-time implementation challenging, especially in resource-constrained systems. Moreover, the ADMM approach, while efficient for optimization, requires careful parameter tuning and initialization to ensure proper convergence. Improper tuning may lead to suboptimal PAPR reduction or prolonged computation time. The iterative process also introduces a risk of signal distortion if the number of iterations is not well controlled. Furthermore, in mixed-numerology systems, ensuring compatibility and fairness among different numerologies during the PAPR reduction process adds additional complexity.

The paper it addresses the Peak-to-Average Power Ratio (PAPR) problem in Orthogonal Frequency Division Multiplexing (OFDM) systems [6]. High PAPR in OFDM signals leads to inefficient power amplifier operation and signal distortion, degrading system performance. This work integrates Machine Learning (ML) techniques with the Tone Reservation (TR) method. TR involves reserving certain subcarriers (tones) for generating a peak-reducing signal without affecting data transmission. By leveraging ML, the approach adaptively optimizes the reserved tones to minimize PAPR. This enhances performance compared to conventional TR methods, ensuring efficient power utilization and robust communication under dynamic conditions.

Approach

- **OFDM Signal Generation**: Generate the base OFDM signal using standard modulation schemes (e.g., QAM or PSK).
- **Tone Reservation**: Reserve specific subcarriers to reduce PAPR by ensuring these tones don’t carry data but help manage peak values.
- **Machine Learning Integration**: Train an ML model (e.g., deep neural networks) to optimize amplitude and phase of reserved tones for PAPR minimization.
- **Application of Reserved Tones**: Add optimized reserved tones to the OFDM signal to reduce high peaks.
- **Performance Evaluation**: Assess PAPR reduction, BER, and computational efficiency compared to traditional methods.

One significant advantage is the ability of BTR to effectively mitigate PAPR without significantly compromising the spectral efficiency of the OFDM system. Machine Learning algorithms can adaptively adjust the reserved tones based on real-time channel conditions, thereby optimizing PAPR reduction in dynamic environments. This adaptability improves signal quality and reduces the likelihood of signal distortion or inter-symbol interference, which are common drawbacks of traditional PAPR reduction techniques. Additionally, BTR using Machine Learning can potentially lower computational complexity compared to conventional methods, making it suitable for implementation in real-time systems.

However, the implementation of Machine Learning-based BTR requires a robust training phase to build accurate models that can effectively predict and allocate reserved tones [7]. This initial overhead includes the need for sufficient training data and computational resources, which can be challenging in practical deployment scenarios. Moreover, the performance of BTR heavily relies on the accuracy of channel state information and the quality of predictions made by the Machine Learning model. Inaccuracies in prediction or estimation can lead to suboptimal PAPR reduction and may require recalibration or adjustment, adding complexity to system maintenance. Finally, while BTR can enhance PAPR reduction efficiency, its effectiveness may vary depending on the specific characteristics of the OFDM system and the variability of channel conditions over time.

The paper explores the issue of high Peak-to-Average Power Ratio (PAPR) in Filtered Non-Orthogonal Multiple Access (F-NOMA) systems [8]. PAPR impacts the efficiency of power amplifiers in NOMA systems, degrading signal quality. The proposed solution uses a modified Selective Mapping (SLM) technique, where multiple signal representations are generated with varied phase sequences. The version with the lowest PAPR is selected for transmission. This approach is integrated with the PHYDYAS filter to achieve effective PAPR reduction, improving the overall performance of F-NOMA systems.

Methods

- **NOMA Signal Representation**: Transmit signals superimposed using NOMA in the power domain, with filtering and 64-QAM modulation.
- **Selective Mapping (SLM)**: Generate multiple phase-modified signal versions and select the one with the lowest PAPR.
- **Phase Sequence Optimization**: Optimize phase rotation vectors for ideal PAPR reduction.
- **Integration with PHYDYAS Filter**: Apply the PHYDYAS filter to enhance signal quality and spectral efficiency.
- **Performance Evaluation**: Compare PAPR levels using metrics like CCDF.

The SLM method is highly effective in reducing PAPR without distorting the transmitted signal, as it avoids clipping or nonlinear operations. In F-NOMA systems, which inherently deal with multiple users and power levels, SLM enables flexible PAPR reduction by generating multiple phase sequences for the same input signal and selecting the one with the lowest PAPR. This capability ensures that the transmitted signal maintains its integrity and reduces the likelihood of interference and distortion during transmission. Furthermore, SLM is versatile and can be implemented without requiring changes to the receiver structure, making it a practical solution for F-NOMA systems. Its ability to improve power efficiency and enhance signal quality makes it particularly suitable for high-data-rate applications in 5G and beyond.

However, the SLM method comes with certain drawbacks. It requires the transmission of side information (SI) to the receiver to indicate the selected phase sequence, which adds overhead and can reduce the overall system throughput if not efficiently managed. Additionally, the computational complexity of SLM increases with the number of candidate phase sequences, which can be a limitation for resource-constrained systems. In F-NOMA, where multiple users' signals are multiplexed, the complexity of managing SLM for each user grows, potentially making the system less efficient in large-scale scenarios. Moreover, any loss or error in the SI can lead to signal decoding failures, undermining the benefits of PAPR reduction.

The paper proposes a method to reduce PAPR in Optical OFDM for Visible Light Communication (VLC) [9]. The combination ensures better spectral efficiency, lower power consumption, and improved symbol error rate (SER) while maintaining compatibility with VLC systems. Grouped precoding is introduced to reduce computational complexity.

Methods

- **DFT Precoding**: Reduces PAPR by frequency spreading.
- **GMSK Pulse Shaping**: Ensures constant signal envelope and reduces sidelobes.
- **Grouped Precoding**: Divides data blocks to reduce complexity.
- **Real and Imaginary Separation**: Converts signals for VLC compatibility.

Clipping is a simple and effective technique to reduce the Peak-to-Average Power Ratio (PAPR) in OFDM-based systems, which is particularly beneficial for VLC systems that use intensity modulation. By limiting the peak amplitudes of the OFDM signal, clipping ensures compatibility with the dynamic range of light-emitting diodes (LEDs), thereby preventing signal distortion caused by LED nonlinearity. When combined with DFT precoding, clipping distortion can be minimized, enhancing the robustness of the transmitted signal. Additionally, the integration of dimming control allows for simultaneous adaptation of the system to ambient lighting requirements while maintaining communication performance, making the solution suitable for energy-efficient VLC systems. This approach enables better spectral efficiency and compatibility with high-speed VLC applications.

However, clipping introduces distortion into the OFDM signal, which can degrade bit-error rate (BER) performance if not properly managed. While DFT precoding helps mitigate some of this distortion, its effectiveness is limited by the severity of the clipping level. Furthermore, clipping distortion generates out-of-band radiation, which may interfere with adjacent channels and reduce system performance. In the context of dimming control, achieving a balance between dimming requirements and optimal signal performance adds complexity to the system design. Moreover, the trade-off between clipping levels and system performance often necessitates iterative optimization, increasing computational overhead.

The approach utilizes Differential Binary Phase Shift Keying (DBPSK) with repetition coding to generate a peak-canceling signal [19]. Unlike conventional tone reservation (TR), the method incorporates additional coded data into [10] the reserved carriers, offering enhanced PAPR reduction while maintaining compatibility with existing DVB-T2 receivers.

International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering
Impact Factor 8.414 ⋇ Peer-reviewed & Refereed journal ⋇ Vol. 13, Issue 7, July 2025
DOI: 10.17148/IJIREEICE.2025.13716

The proposed algorithm optimizes carrier selection and amplitude to reduce peaks effectively, achieving lower complexity and better performance compared to traditional methods like Active Constellation Extension (ACE) and Clipping and Filtering (CF).

Methods

- **Carrier Selection**: Selects a subset of reserved carriers to reduce PAPR without re-growth of other peaks.
- **DBPSK Modulation**: Encodes additional data on reserved carriers using DBPSK with repetition coding.
- **Amplitude Optimization**: Adjusts the amplitude of selected carriers to minimize the PAPR metric.
- **Backward Compatibility**: Modifies only the reserved carriers, ensuring compatibility with existing DVB-T2 systems.
- **One-Shot Algorithm**: Performs peak reduction without iterative processes, reducing computational overhead.

This method leverages the reserved carriers in DVB-T2 systems to insert coded data, which is specifically designed to reduce PAPR without altering the original data payload. It is computationally efficient, as it avoids complex iterative algorithms and does not require modifications to the transmitter's main signal processing chain. The approach ensures compatibility with existing DVB-T2 standards, making it easier to implement without requiring significant changes to system infrastructure. Additionally, it maintains high spectral efficiency since the reserved carriers are used efficiently without introducing additional signalling overhead. By reducing PAPR, the method improves the power efficiency of high-power amplifiers (HPAs) and reduces the risk of nonlinear distortion, leading to better signal quality and reliability.

Despite its advantages, the coded data insertion method has some limitations. The effectiveness of PAPR reduction depends on the number and placement of reserved carriers, which may not always be sufficient to achieve the desired performance, especially in scenarios with stringent PAPR requirements. Furthermore, the design of the coded data requires careful optimization to ensure minimal impact on the overall system performance, which may introduce additional complexity during the system design phase. In cases where reserved carriers are limited, the method may offer suboptimal PAPR reduction compared to more sophisticated techniques. Additionally, there is a risk of minor interference between the inserted coded data and the main signal if not properly managed, potentially degrading system performance.

The novel linear compounding transform designed for PAPR reduction in OFDM systems focuses on simplifying the process of reducing the high peaks in the signal that contribute to high PAPR [11]. In OFDM systems, the presence of high PAPR can degrade signal quality, reduce power amplifier efficiency, and increase the likelihood of distortion. Traditional techniques, such as non-linear compounding or coding methods, are often complex and computationally expensive. The proposed method utilizes a linear curve fitting approach to map the amplitude samples of the OFDM signal. By fitting a linear function ($y = mx + c$) to the signal’s amplitude samples, a transformation is applied that compresses the high peaks while spreading the lower amplitudes more evenly. This results in a more balanced signal with reduced PAPR.

Methods

- **Signal Representation**: OFDM signal is divided into amplitude samples.
- **Linear Curve Fitting**: A linear curve ($y = mx + c$) is fitted to these samples.
- **Companding Transformation**: The curve is used to map the samples, compressing high peaks.
- **Signal Reconstruction**: The transformed signal is reconstructed to reduce PAPR.

This method effectively reduces the Peak-to-Average Power Ratio (PAPR) by compressing high signal peaks while evenly distributing lower amplitudes, resulting in a more balanced signal. Unlike traditional nonlinear compounding methods, the linear compounding approach simplifies the transformation process, making it computationally efficient and easier to implement. The linear curve fitting ensures minimal distortion to the original signal, which improves the overall signal quality and enhances Bit Error Rate (BER) performance. Additionally, the technique is versatile and can be adapted to various OFDM-based systems, making it suitable for modern communication standards like 5G and beyond. By reducing PAPR, it improves the efficiency of power amplifiers and minimizes the risk of signal clipping and nonlinear distortion.

Despite its simplicity, the linear compounding transform has limitations. The effectiveness of PAPR reduction depends on the accuracy of the linear curve fitting process, which may not fully optimize the signal in scenarios with highly dynamic or complex amplitude variations. The transformation process can still introduce slight in-band distortion, which could affect system performance if not carefully managed. Moreover, the approach requires additional processing for fitting and applying the linear function, which, although less complex than nonlinear methods, still adds overhead. In certain high-performance systems, the level of PAPR reduction achieved by this method may not be sufficient compared to more advanced or hybrid techniques.

Impact Factor 8.414 ⩽ Peer-reviewed & Refereed journal ⩽ Vol. 13, Issue 7, July 2025

DOI: 10.17148/IJIREEICE.2025.13716

III. CONCLUSION

Traditional PAPR reduction techniques such as Partial Transmit Sequence (PTS), Selected Mapping (SLM), and Clipping & Filtering (C&F) have been widely used to address the challenges posed by high Peak-to-Average Power Ratio (PAPR) in MIMO-OFDM systems. PTS and SLM are distortion less methods that significantly reduce PAPR by generating and selecting optimal signal versions, but they require additional computational resources and the transmission of side information. On the other hand, Clipping and Filtering is a simpler technique that directly limits signal peaks but introduces nonlinear distortion, which can negatively affect the Bit Error Rate (BER).

Each technique offers a trade-off between complexity, signal quality, and implementation feasibility. The selection of an appropriate method depends on the specific needs of the communication system, such as power efficiency, BER performance, and hardware limitations. Despite their limitations, these traditional methods form the foundation for advanced PAPR reduction research and continue to play a vital role in improving the performance and reliability of wireless communication systems, especially as the demand grows for high-speed and energy-efficient solutions in 5G and beyond.

REFERENCES

[1] S. -C. Lim, N. Kim and H. Park, "Polar Coding-Based Selective Mapping for PAPR Reduction without Redundant Information Transmission," in IEEE Communications Letters, vol. 24, no. 8, pp. 1621-1625, Aug. 2020.
[2] S. -Y. Zhang and B. Shahrrava, "A Hybrid PAPR Reduction Scheme for OFDM Systems Using Perfect Sequences," in IEEE Transactions on Broadcasting, vol. 66, no. 1, pp. 177-186, March 2020.
[3] Y. Ding, L. Xue and Z. Wang, "A Novel Precoding Technique to Reduce PAPR of UCA-OAM Systems," in IEEE Communications Letters, vol. 26, no. 8, pp. 1903-1907, Aug. 2022.
[4] T. K. Nguyen, H. H. Nguyen, J. Eric Salt and C. Howlett, "Optimization of Partial Transmit Sequences for PAPR Reduction of OFDM Signals Without Side Information," in IEEE Transactions on Broadcasting, vol. 69, no. 1, pp. 313-321, March 2023.
[5] X. Liu *et al*., "PAPR Reduction Using Iterative Clipping/Filtering and ADMM Approaches for OFDM-Based Mixed-Numerology Systems," in IEEE Transactions on Wireless Communications, vol. 19, no. 4, pp. 2586-2600, April 2020.
[6] T. Mahakornpetch, P. Sasithong, M. Z. Siddiqi and C. Pluempittiwiriyawej, "PAPR Reduction in OFDM Signal Using Machine Learning Base Tone Reservation," *2023 25th International Multitopic Conference (INMIC)*, Lahore, Pakistan, 2023, pp. 1-4.
[7] N. A. George and S. K. Mishra, "PAPR reduction in F-NOMA using selective mapping method," *2023 14th International Conference on Computing Communication and Networking Technologies (ICCCNT)*, Delhi, India, 2023, pp. 1-5.
[8] R. Ahmad and A. Srivastava, "PAPR Reduction of OFDM Signal Through DFT Precoding and GMSK Pulse Shaping in Indoor VLC," in *IEEE Access*, vol. 8, pp. 122092-122103, 2020.
[9] T. H. Ali and A. Hamza, "A novel combined SLM-PTS technique based on Genetic Algorithms for PAPR reduction in OFDM systems," *2020 Second International Conference on Embedded & Distributed Systems (EDiS)*, Oran, Algeria, 2020, pp. 71-75.
[10] X. Cui, K. Liu and Y. Liu, "Novel Linear Companding Transform Design Based on Linear Curve Fitting for PAPR Reduction in OFDM Systems," in *IEEE Communications Letters*, vol. 25, no. 11, pp. 3604-3608, Nov. 2021.
[11] A. Kalinov, R. Bychkov, A. Ivanov, A. Osinsky and D. Yarotsky, "Machine Learning-Assisted PAPR Reduction in Massive MIMO," in *IEEE Wireless Communications Letters*, vol. 10, no. 3, pp. 537-541, March 2021.
[12] R. Zayani, J. -B. Doré, B. Miscopein and D. Demmer, "Local PAPR-Aware Precoding for Energy-Efficient Cell-Free Massive MIMO-OFDM Systems," in *IEEE Transactions on Green Communications and Networking*, vol. 7, no. 3, pp. 1267-1284, Sept. 2023.
[13] Z. Li, R. Nojima, O. Muta, M. Omoto, T. Makita and K. Maruta, "In-Band Distortion Compensation for Peak Cancellation-Based PAPR Reduction in Massive MIMO-OFDM With Uniform Planar Array," in *IEEE Access*, vol. 12, pp. 156118-156130, 2024.
[14] C. Sun, J. Zhao, J. Wang, L. Xia, X. Gao and Q. Wang, "Beam Domain MIMO-OFDM Optical Wireless Communications With PAPR Reduction," in *IEEE Photonics Journal*, vol. 15, no. 2, pp. 1-10, April 2023, Art no. 7301210.
[15] T. -H. Dang, V. -N. Tran and L. -C. Nguyen, "Active Constellation Modification Technique for PAPR Reduction of OFDM Signals," in *IEEE Access*, vol. 11, pp. 137779-137797, 2023.
[16] S. Henry, A. Alsohaily, and E. S. Sousa, “5G is Real: Evaluating the compliance of the 3GPP 5G new radio system with the ITU IMT- 2020 Requirements,” IEEE Access, vol. 8, pp. 42828-42840, 2020.

Impact Factor 8.414 ⁙ Peer-reviewed & Refereed journal ⁙ Vol. 13, Issue 7, July 2025
DOI: 10.17148/IJIREEICE.2025.13716

[17] H. Lin, X. Zhu, Y. Jiang, Y. Liu, Y. Zhuang, and L. Gao, "PA-Efficiency-Aware Hybrid PAPR Reduction for FOFDM Systems with ICA Based Blind Equalization," IEEE Wirel. Commun. Netw.Conf. WCNC, pp. 0–5, 2019.
[18] Y. Iraqi and A. Al-Dweik, "Efficient information transmission using smart OFDM for IoT applications," IEEE Int. of Things, vol. 7, no. 9, pp. 8397–8409, 2020.
[19] T. Hwang, C. Yang, G. Wu, S. Li and G. Ye Li, "OFDM and Its Wireless Applications: A Survey, " IEEE Transactions on Vehicular Technology, vol. 58, no. 4, pp. 1673-1694, May 2009
[20] Kumar, Arun, Karthikeyan Rajagopal, G. Gugapriya, Himanshu Sharma, Nidhi Gour, Mehedi Masud, Mohammed A. AlZain, and Samah H. Alajmani. "Reducing PAPR with low complexity filtered NOMA using novel algorithm." Sustainability 14, no. 15 (2022): 9631.
[21] Wu, Yating, Yuanfeng Hu, Ziwen Wan, Tao Wang, Yanzan Sun, and Qianwu Zhang. " Joint security enhancement and PAPR mitigation for OFDM-NOMA VLC systems." Optics Communications 508 (2022): 127719.
[22] Sayyari, Reza, Jafar Pourrostam, and Hamed Ahmadi. "Efficient PAPR reduction scheme for OFDM-NOMA systems based on DSI & precoding methods." Physical Communication 47 (2021): 101372.
[23] Kumar, Arun."A novel hybrid PAPR reduction technique for NOMA and FBMC system and its impact in power amplifiers." IETE Journal of Research 68, no. 3 (2022): 2005-2021.
[24] ‘‘Cisco visual networking index: Forecast and methodology 2016–2021,’’ V Cisco, San Jose, CA, USA, White Paper, 2017. [Online]. Available: https://www.reinvention.be/webhdfs/v1/docs/complete-white-paper- c11-481360.pdf
[25] L. U. Khan, ‘‘Visible light communication: Applications, architecture, standardization and research challenges,’’ Digit. Commun. Netw., vol. 3, no. 2, pp. 78–88, May 2017.