Proceedings of CONF-MPCS 2025 Symposium: Mastering Optimization: Strategies for Maximum Efficiency
DOI: 10.54254/2753-8818/2025.CH22273

OFDM Encryption Transmission System Based on PLIS (pso-logistic-ipts-slm)

Yiting Liu

School of Information Science and Technology, Northwestern University, Xi'an, China
2799317712@qq.com

Abstract: In the context of the booming development of wireless communication technology today, although orthogonal frequency division multiplexing (OFDM) technology is widely used, the high peak-to-average power ratio (PAPR) issue significantly constrains its performance enhancement. This paper is dedicated to studying the OFDM transmission system based on PLIS (Particle Swarm Optimization-Logistic mapping-Improved Partial Transmit Sequence-Selected Mapping) to overcome this problem. First, this study had sorted out the relevant theories and previous achievements, and accurately located the defects of existing research in solving the PAPR problem of OFDM system. Then, the system model was constructed in detail and the research method was introduced, covering precise parameter settings and rigorous data processing procedures. Experimental results demonstrate that the proposed PLIS-based method achieves remarkable improvements in reducing PAPR, improving bit error rate and improving spectrum efficiency, and its advantages are obvious compared with traditional methods. Finally, the research findings are deeply discussed, the limitations are analyzed, the important contributions to theory and practice are explained, and the future research directions such as performance optimization under frequency-selective fading channels and algorithm hardware implementation are prospected, providing valuable reference and reference for the sustainable development of OFDM technology.

Keywords: PLIS, OFDM, particle swarm optimization, SLM, Logistic mapping

1. Introduction

In the information age, wireless communication technology is advancing rapidly, and people's demand for high-speed and reliable data transmission is on the rise. Orthogonal frequency division multiplexing (OFDM) has become a core technology in modern wireless communication systems because of its high spectrum utilization and strong multipath fading resistance. It's widely used in 4G, 5G, and future communication systems. However, the OFDM system has a key issue: the peak to average power ratio (PAPR). When the signal with high PAPR passes through the power amplifier, it incurs nonlinear distortion. This not only diminishes the power efficiency of the system but also has the potential to trigger spectrum expansion, out-of-band radiation, heightened adjacent-channel interference, and a deteriorated bit-error-rate performance, severely undermining the communication quality. For OFDM signals $x(n)$, the PAPR calculation formula is:

DOI: 10.54254/2753-8818/2025.CH22273

$$\mathrm{PAPR} = \frac{\max_{0 \le n \le N-1} |x(n)|^2}{E\left[|x(n)|^2\right]} \tag{1}$$

Where, N is the number of sampling points in the OFDM symbol, $\max_{0 \le n \le N-1} |x(n)|^2$ indicates the maximum instantaneous power of signal $x(n)$ within an OFDM symbol, $E[|x(n)|^2]$ represents the average power of the signal $x(n)$. Therefore, how to effectively reduce the PAPR of the OFDM system while ensuring good system performance has become a research hotspot and difficulty in the field of wireless communications [1].

The main purpose of this study is to propose an OFDM transmission system based on PLIS (pso-logistic-ipts-slm), which innovatively combines selective mapping (SLM), interleaved partitioning (IPTS) [2], logistic mapping and particle swarm optimization algorithm [3-4] to effectively reduce the PAPR of the OFDM system and improve the system's bit error rate performance and spectrum efficiency. This research has important theoretical and practical significance. Theoretically, it helps to understand the PAPR problem in OFDM systems, helps to enrich the OFDM theory, and helps to provide a basis for further research. Practically, the proposed method can optimize wireless communication systems, cut costs and power consumption, enhance performance and reliability, and promote the application of wireless communication in areas like mobile, IoT, and IoV to meet high - speed data transmission demands, thus having great application value and broad prospects. The paper is organized in the following manner. Chapter 2 conducts a comprehensive review of relevant theories and prior research on OFDM systems, PAPR reduction techniques, and the particle swarm optimization algorithm, pinpointing the existing research lacunae. Chapter 3 elaborates on the research methodologies, covering system models, parameter settings, and data sources. Chapter 4 showcases and analyzes the experimental results regarding PAPR, bit - error - rate, and spectrum efficiency. Chapter 5 concludes the paper by summarizing the research work and findings, while underscoring its significance.

2. Literature review

2.1. About the PAPR reduction technology of OFDM system

Pushkarev et al. proposed a PTS - SLM hybrid algorithm for OFDM signal PAPR reduction. Analyzing traditional SLM and PTS issues, they combined the two with different phase search algorithms, reducing system complexity and achieving better PAPR reduction under certain conditions [5]. Xiao et al. combined chaos with SLM to propose CSLM for 16 - QAM OFDM signal PAPR reduction. Using chaotic sequences to control the phase rotation factor, experiments demonstrated its effectiveness in reducing PAPR and improving system receiving sensitivity and bit - error - rate performance [6]. Yang et al. proposed a chaotic encryption algorithm for optical OFDM to resist chosen - plaintext attacks. Employing chaotic subcarrier allocation scrambling, phase rotation, and training sequences, they created a large key space for OFDM transmission encryption [7]. Tarik HADJ ALI and Abdelkrim HAMZA applied the TLBO algorithm to enhance SLM for OFDM signal PAPR reduction. The algorithm cuts calculation amount without needing specific parameters. Simulations show its superiority over traditional SLM and other algorithms in PAPR reduction and computational complexity [8]. Hongmei Wang et al. proposed MDPSO - PTS, an improved PTS algorithm based on DPSO. Using a dynamic time - varying learning factor to prevent premature convergence, it outperforms traditional DPSO - PTS in PAPR reduction with similar complexity and reduces complexity significantly compared to traditional PTS with little performance loss [9].

DOI: 10.54254/2753-8818/2025.CH22273

2.2. About OFDM encrypted transmission security performance

Hou Yanli proposed a dual - chaotic - encryption transmission scheme for OFDM systems. Scrambling the signal constellation with a chaotic matrix and controlling phase rotation with a composite discrete chaotic sequence, it enhanced system security and reduced the cooperative receiver's bit - error - rate [10]. Zong et al. demonstrated a real - time secure optical OFDM system with chaotic data encryption. Using an FPGA board for real - time encryption and decryption, they ensured physical - layer confidentiality and successfully transmitted a 435 Mb/s encrypted 16 - QAM optical OFDM signal over 22 km of standard single - mode fiber [11].

2.3. About OFDM system optimization and improvement

Litvinenko and Aboltins proposed an OFDM modulation with linear precoding using OCT. The method enhanced multipath resistance and reduced PAPR, and its effectiveness in communication systems was verified experimentally [12]. Fathy et al. combined SLM - WOFDM with the PSO algorithm for OFDM signal PAPR reduction. The PSO searched for the optimal phase rotation factor, and experiments showed its superiority over traditional methods in PAPR reduction [13]. Ma Yan'e and Li Ruijin proposed a DFT - S - OFDM - based network security encryption method. Leveraging DFT - S - OFDM's low - frequency features, they achieved vector encryption via key encryption and elliptic curve equations. Simulation verified its strong anti - attack ability, low information leakage, and high overall efficiency [14].

2.4. Other related research

Renuka and Naganjaneyulu studied F - OFDM PAPR in 5G and improved it with PTS. Simulation compared F - OFDM and traditional OFDM in PAPR, bit - error - rate, and spectrum efficiency, providing a reference for 5G system design [15]. Hong - Jie Chou et al. proposed an improved SLM - PTS hybrid algorithm. By linearly combining and exchanging PTS sub - blocks, it created more OFDM signal sequences, achieving better PAPR reduction with lower complexity under the same IFFT and phase rotation sequences [16]. MESHARI H. ALANAZI et al. proposed PSO - based PTS and SLM for OTFS 6G waveform PAPR reduction. Analyzing PAPR, bit - error - rate, etc. for different subcarrier numbers under Rayleigh and Ricean channels, the results showed its effectiveness in adjusting phase - weighting factors and reducing PAPR [17].

2.5. Theoretical Assumptions of This Study

Based on relevant theories and previous studies, this study proposes theoretical assumptions. First, combining SLM, IPTS, Logistic mapping, and PSO can fully utilize their advantages for better PAPR reduction. SLM offers multiple candidate signals, IPTS partitions the signal, and Logistic - generated chaotic sequences provide a richer search space and better PSO initial population. PSO can find the optimal phase - factor combination to further reduce PAPR. Second, the Logistic - generated chaotic sequence's randomness and ergodicity prevent PSO from getting trapped in local optima, enhancing the algorithm's convergence speed and global search ability, and thus improving system performance. Third, properly setting PSO parameters (e.g., particle number, iteration number, learning factor) can optimize PAPR reduction and system performance under different system parameters (e.g., subcarrier number, modulation mode, sub - block number). While ensuring PAPR reduction, optimizing the algorithm process and parameters can keep computational complexity acceptable for practical applications.

DOI: 10.54254/2753-8818/2025.CH22273

3. Research Methods

3.1. Overview of PLIS-OFDM encrypted transmission system architecture

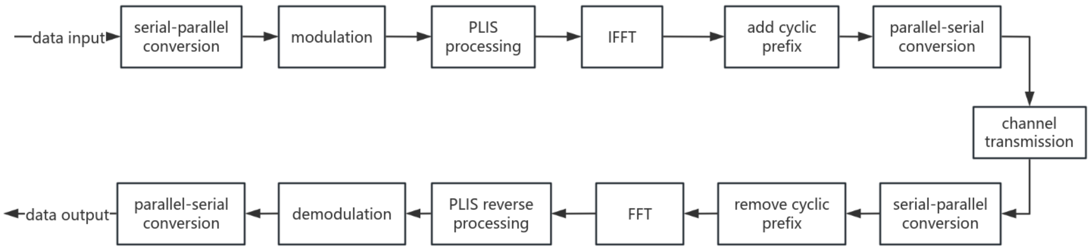

Figure 1: OFDM system model based on PLIS

Figure 1 shows the signal processing flow of the OFDM encrypted transmission system based on PLIS. The process involves multiple key steps from data input to output, ensuring efficient and stable data transmission through close coordination among these steps.

The signal processing flow of the OFDM encrypted transmission system based on PLIS includes three parts: the transmitter, channel transmission and receiver processing. The transmitter converts the input data into serial-to-parallel data, modulates it with 16-QAM, and processes it through PLIS to reduce the PAPR. Then, it is sent into the channel after IFFT, adding a cyclic prefix and parallel-to-serial conversion. Channel transmission is affected by noise and other factors. While the research simulates an ideal AWGN channel, real-world channels are more complex. The receiver performs parallel-to-serial conversion, FFT, cyclic prefix removal, PLIS inverse processing, demodulation, and serial-to-parallel conversion, ultimately outputting the data.

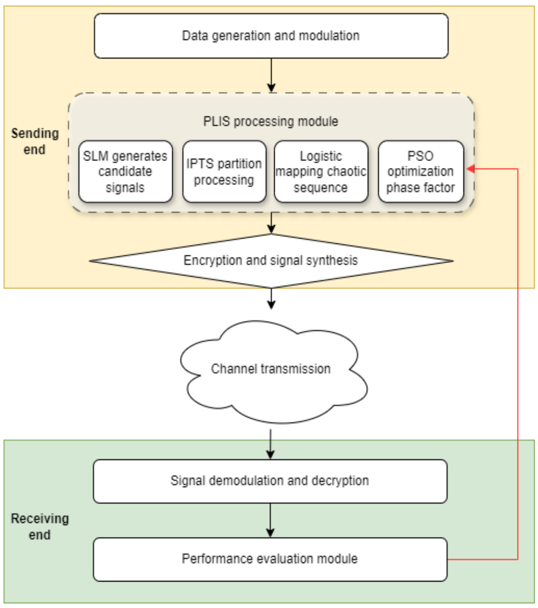

Figure 2: PLIS-based OFDM encryption transmission system module function schematic

Figure 2 illustrates the flow of a PLIS-based OFDM encrypted transmission system. The transmitter first generates and modulates the data, and then passes through the PLIS processing module, in which SLM generates candidate signals, IPTS partitioning, Logistic mapping provides chaotic sequences, PSO optimizes phase factors, and enters the channel after encryption and signal

DOI: 10.54254/2753-8818/2025.CH22273

synthesis. The signal is demodulated and decrypted at the receiving end, and finally evaluated by the performance evaluation module. This process complements the previous system model and presents the whole process from data input to output and performance evaluation, which is helpful to understand the working mechanism of the system.

3.2. Parameter settings

3.2.1. OFDM system parameters

Number of subcarriers (N = 64): The number of subcarriers determines the bandwidth and data transmission rate of the OFDM system. Although a larger number of subcarriers improves spectrum utilization, it also increases system complexity and PAPR. In this study, considering system performance and complexity, 64 was selected as the number of subcarriers to explore the performance of the OFDM transmission system based on PLIS under this condition. Number of symbols (S = 200): After weighing the pros and cons, 200 was finally determined as the number of symbols, which ensures that the experimental results can reflect the real performance of the system as much as possible while ensuring a certain experimental efficiency. Modulation mode is 16-QAM ((M = 16)): 16-QAM exhibits high spectrum utilization, but also leads to high PAPR. Choosing this modulation mode can better demonstrate the effectiveness of the PAPR reduction method proposed in this study when dealing with high PAPR modulation modes. Number of sub - blocks (V): It is set as a variable parameter with a value range of [8,16,32]. This research aim to investigate the influence of different numbers of sub - blocks on PAPR reduction and system performance. Varying numbers of sub - blocks will have an impact on the performance and computational complexity of the IPTS method. Through testing these specific values, this research can more precisely analyze the correlation between the number of sub - blocks and system performance. Oversampling ratio (O = 4): Oversampling can improve the spectral resolution of the signal, reduce spectral leakage, and more accurately calculate performance indicators such as PAPR. In this study, 4 times oversampling is used to ensure the accuracy of performance indicator calculation. Partitioning method: Use interleaved partitioning (Partition = 2). After comparing the effects of adjacent partitioning and interleaved partitioning on system performance, it was found that interleaved partitioning is more conducive to improving system performance under the system model of this study, so the interleaved partitioning method is used by default for subsequent experiments. Weight factor length (W = 1): In the particle swarm optimization algorithm, the weight factor is used to balance the impact of the particle's historical optimal position and the group's optimal position on the current speed. In this study, it is set to 1, which is a common setting.

3.2.2. Particle swarm optimization algorithm parameters

Number of particles (Num_Particle = 100): After many experiments and analyses, 100 particles were determined to be the number of particles, which ensures the algorithm's search capability while keeping the computational complexity within an acceptable range. Maximum number of iterations (Gn = 200): The number of iterations determines the convergence speed and performance of the algorithm. Considering the algorithm performance and calculation efficiency, the maximum number of iterations is set to 200.

Learning factor (c1 = 2.05), (c2 = 2.05): The learning factor controls the step size of the particle moving to its own optimal position and the group's optimal position, which has an important impact on the convergence speed and search accuracy of the algorithm. After reviewing numerous related studies and considering the specific context of this research, the learning factor was fine-tuned and set to 2.05 to optimize the performance of the particle swarm optimization algorithm.

DOI: 10.54254/2753-8818/2025.CH22273

Maximum speed (Vmax = 0.3): Limits the speed range of particles to prevent particles from moving too fast in the search space and missing the optimal solution. Setting a reasonable maximum speed helps the algorithm explore the solution space more effectively process and improves search efficiency. Maximum inertia weight (wmax = 0.9), minimum inertia weight (wmin = 0.4): The inertia weight is used to balance the impact of the particle's current speed and historical speed on the next speed. As the number of iterations increases, the inertia weight decreases linearly from (wmax) to (wmin), that is, (w = wmax - (wmax - wmin) / Gn * (1: Gn)). This setting can improve the global search capability in the early stage of the algorithm and the local search capability in the later stage, so that the algorithm can better adapt to the search needs of different stages. In the particle swarm optimization algorithm, the velocity update formula of particle i at the tth iteration is:

$$v_i^{t+1} = wv_i^t + c_1 r_1 (pbest_i^t - x_i^t) + c_2 r_2 (gbest_i^t - x_i^t) \tag{2}$$

The position update formula is:

$$x_i^{t+1} = x_i^t + v_i^{t+1} \tag{3}$$

Among them, v_i^t and x_i^t represent the velocity and position of particle i at the tth iteration respectively, w is the inertia weight, c_1 and c_2 are learning factors, r_1 and r_2 are random numbers in the interval [0, 1]. $pbest_i^t$ is the historical optimal position of particle i, and $gbest_i^t$ is the global optimal position of the entire particle swarm. In this study, these formulas are used to iteratively update the speed and position of the particle to find the optimal phase combination to reduce PAPR.

3.3. Data sources and sample selection

3.3.1. Data generation

At the transmitting end, `Datatx = floor (rand(length (Position_data), NumSymb) *M)` is used to generate random integer data as transmission data, and the functions and variables involved are used to simulate the data distribution in the actual communication system. Then `DataMap = qammod (Datatx, M)` is used to perform 16-QAM modulation on the data to obtain the modulated symbol data.

3.3.2. Sample selection

To obtain reliable experimental results and statistical characteristics, multiple independent experiments are conducted for each parameter setting (e.g., the number of sub-blocks, signal-to-noise ratio, etc.). For example, when analyzing the impact of the number of sub-blocks on PAPR, for each number of sub-blocks (each value in (V)), multiple (such as 100) independent experiments are conducted, each experiment generates 200 symbols (i.e. (S = 200)), and then calculates performance indicators such as average PAPR, BER, and spectrum efficiency. Assuming that the number of bits sent is N_{total} and the number of bits correctly received by the receiving end is $N_{correct}$, the bit error rate BER is calculated as: $BER = \frac{N_{total} - N_{correct}}{N_{total}}$

DOI: 10.54254/2753-8818/2025.CH22273

4. Results

4.1. Data presentation and analysis

4.1.1. Peak to Average Power Ratio (PAPR) Results

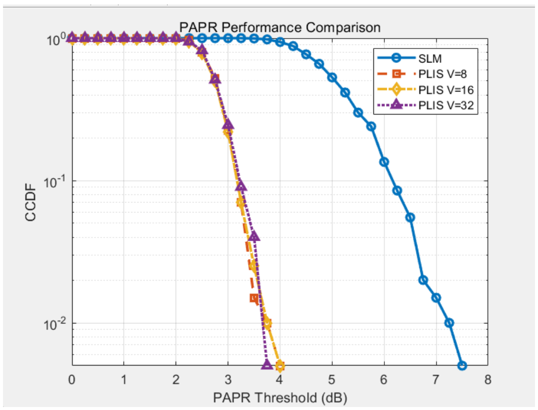

Figure 3: PAPR performance comparison of SLM alone and PLIS designed in this paper under different numbers of sub-blocks

Figure 3 shows the PAPR complementary cumulative distribution function (CCDF) curves of the traditional SLM method and the ipts-slm-logistic based particle swarm optimization method (PLIS) under different numbers of sub-blocks (V). The horizontal axis is PAPR (dB) and the vertical axis is the CCDF value, which represents the probability that the PAPR is greater than a certain value.

Under the same CCDF value, the PAPR value corresponding to the PLIS method remains almost unchanged as the number of sub-blocks increases, indicating a stable CCDF curve. For example, when the CCDF value is 0.1, the PAPR value corresponding to the PLIS method is lower than the SLM value when V = 8/16/32. This demonstrates that the PLIS method significantly reduces PAPR compared to the traditional SLM method, particularly when V = 32, where the advantage is more pronounced in the low PAPR region. For example, when the CCDF value is 0.1, the PAPR value corresponding to the traditional SLM method is about 6.2 dB, while the PAPR value corresponding to the PLIS method when V = 8/16/32 is significantly and stably lower than 3.5 dB. This shows that the PLIS method can reduce the PAPR more effectively and reduce the risk of the signal peak power exceeding the linear operating range of the power amplifier.

The PLIS method integrates a variety of techniques to effectively reduce PAPR. When the number of sub-blocks increases, IPTS makes the phase adjustment of each sub-block more flexible, and the particle swarm optimization algorithm can better optimize the phase. Moreover, the particle swarm optimization algorithm can find a better combination instead of random selection, so compared with the traditional SLM method, the PAPR reduction effect is better under the same CCDF value, and the advantage is also extremely stable after the number of sub-blocks increases .

DOI: 10.54254/2753-8818/2025.CH22273

4.1.2. Bit Error Rate (BER) Results

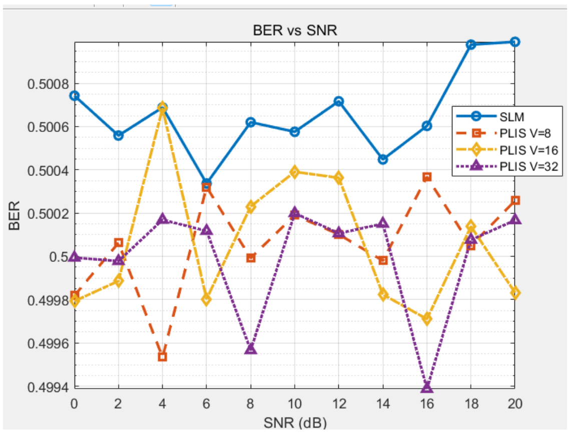

Figure 4: BER vs SNR comparison of SLM alone and PLIS designed in this paper with different numbers of sub-blocks

Figure 4 shows the relationship curves between the bit error rate (BER) and the signal-to- noise ratio (SNR) under different methods, including the traditional SLM method and the ipts-slm-logistic based particle swarm optimization method (PLIS) when the number of sub-blocks V is 8, 16, and 32, respectively.

In the low SNR range (e.g., SNR < 6 dB), the BER differences between PLIS schemes with different numbers of sub-blocks and between PLIS as a whole and SLM are small. However, as the SNR increases, the PLIS scheme with the number of sub-blocks V = 32 exhibits a lower BER than SLM. For example, at SNR = 16 dB, the BER of PLIS V = 32 is about 0.4994, while the BER of SLM is about 0.5006. This shows that increasing the number of sub-blocks can help further reduce the BER, and the advantage is more obvious under high SNR conditions.

PLIS method collaborates multiple algorithms to reduce signal transmission bit error rate. Increasing the number of sub-blocks (such as increasing V from 8 to 32) makes the signal processing more refined, and the particle swarm optimization algorithm has more parameters to adjust, which can more accurately find the optimal phase factor combination, thereby further reducing BER under high signal-to-noise ratio. Overall, the PLIS method is superior to the traditional SLM method in bit error rate performance, and increasing the number of sub-blocks can significantly improve the bit error rate performance under high signal-to-noise ratio conditions.

4.1.3. Spectral efficiency results

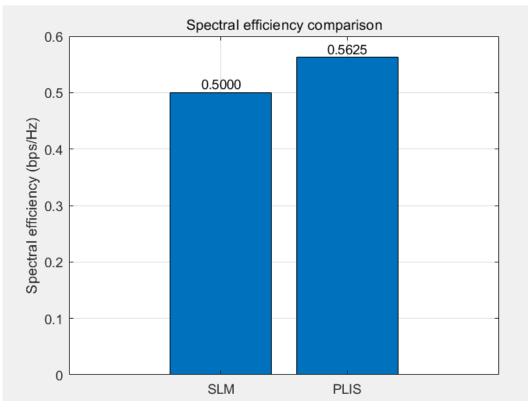

Figure 5: Comparison of the spectrum efficiency of SLM alone and the PLIS designed in this paper

DOI: 10.54254/2753-8818/2025.CH22273

Figure 5 shows the spectrum efficiency comparison between the traditional SLM method and the particle swarm optimization method (PLIS) based on ipts-slm-logistic. It can be clearly seen from the figure that the PLIS method has a significant advantage in spectrum efficiency. Since the SLM method requires 3 bits of sideband information, its number of effective data subcarriers is `length (Position_data) - ceil(3/mapsize)`, while the PLIS method has no additional overhead and the number of effective data subcarriers is `length(Position_data)`. According to the spectrum efficiency calculation formulas `SE_SLM = (effective_data_SLM * mapsize) / NumCarr` and `SE_PLIS = (effective_data_PLIS * mapsize) / NumCarr`, the results show that the spectrum efficiency of the PLIS method is higher, which is 0.5625, while the spectrum efficiency of SLM is 0.5. This means that under the same system resource conditions, the PLIS method can more effectively utilize spectrum resources for data transmission. Compared with the traditional SLM method, it can transmit more data per unit time, thereby improving the efficiency of data transmission and providing strong support for achieving high-speed and efficient communications.

4.2. Hypothesis Testing

This study conducted three hypothesis tests on the PLIS method. In the PAPR reduction test, it can be seen from the PAPR-CCDF curve in Figure 3 that under the same CCDF value, the PAPR of PLIS is lower than that of the traditional SLM method when the number of sub-blocks (V=8, 16, 32) is different, and the effect is more significant when the number of sub-blocks increases. For example, when CCDF is 0.1, the PAPR of the traditional SLM method with V=32 is about 6.2dB, and that of PLIS is about 3.2dB; at the same time, although the computational complexity of PLIS has increased, it is still acceptable. For example, to process 1000 symbols, the traditional SLM takes an average of about 0.5 seconds, while PLIS takes about 0.65 seconds when V=32, indicating that it can effectively reduce PAPR. In terms of bit error rate performance test, the relationship between BER and SNR in Figure 4 shows that under the same SNR, especially at high signal-to-noise ratio, PLIS has a lower bit error rate. For example, when SNR = 16dB, the BER of the PLIS method with V = 32 is 0.4994, while that of the traditional SLM method is 0.5006, which verifies that its bit error rate performance is better. In the spectrum efficiency test, in theory, PLIS can improve spectrum efficiency because there is no additional overhead. Figure 5 shows that its spectrum efficiency is 0.5625, while that of the traditional SLM is 0.5, and the advantage still exists after changing the system parameters. For example, when the number of subcarriers is 128 and the number of symbols is 300, the spectrum efficiency of PLIS is higher, which verifies the hypothesis.

5. Conclusion

This study successfully constructed an OFDM transmission system based on ipts-slm-logistic particle swarm optimization, and fully verified its excellent effectiveness in reducing the peak-to-average power ratio (PAPR), improving the bit error rate and spectrum efficiency through experiments. With reasonable configuration of key parameters, including the number of subcarriers, symbols, modulation method, subblocks, and particle swarm optimization algorithm parameters, the system can significantly reduce the PAPR of the OFDM signal and effectively reduce the nonlinear distortion of the signal in the power amplifier. Additionally, the system maintains a low bit error rate and high spectrum efficiency across different SNR conditions, enhancing energy efficiency and overall performance. Compared with the traditional selective mapping (SLM) method, the PLIS method proposed in this study has significant advantages. As the number of sub-blocks increases and particle swarm parameters are optimized, the PLIS method becomes increasingly effective in reducing PAPR. Compared to traditional SLM, the PLIS method achieves lower PAPR under the same CCDF value and a lower bit error rate across all SNR ranges, ensuring signal integrity. It also

DOI: 10.54254/2753-8818/2025.CH22273

improves spectrum efficiency, enabling higher data transmission under the same system resources and supporting high-speed communication. Subsequent research can be carried out in the following directions. First, in complex channels like multipath fading and time - varying ones, integrate channel estimation and equalization techniques to boost system robustness and practicality; second, conduct in-depth research on algorithm optimization, design efficient particle swarm optimization algorithm variants, simplify related processing procedures, reduce computational complexity, and study its efficient implementation methods on hardware platforms; third, expand the research to multi-user and multi-antenna systems, analyze the collaboration mechanism and resource allocation strategy between users, and optimize system performance; fourth, explore the integrated application of this method with new technologies such as millimeter wave communication, artificial intelligence, and blockchain to meet the diverse communication needs of the future.

References

[1] Zhang, Yiqun, Ning Jiang, Anke Zhao, Shiqin Liu, Jiafa Peng, Lu Chen, Martin P. J. Lavery, Hasan T Abbas, and Kun Qiu. 'Security Enhancement in Coherent OFDM Optical Transmission with Chaotic Three-Dimensional Constellation Scrambling'. Journal of Lightwave Technology 40, no. 12 (15 June 2022): 3749–60.

[2] FANG Zhijing,CHEN Yuan,WANG Junjie. Improved PTS peak-to-average ratio suppression method for visible light communication systems[J]. Systems Engineering and Electronics,2024,46(07):2509-2514.

[3] Jain, Meetu, Vibha Saihjpal, Narinder Singh, and Satya Bir Singh. 'An Overview of Variants and Advancements of PSO Algorithm'. Applied Sciences 12, no. 17 (23 August 2022): 8392.

[4] Hu, Feng, Hong Xu, Libiao Jin, JianBo Liu, Zhiping Xia, Guoting Zhang, and Jingting Xiao. 'Continuous-Unconstrained and Global Optimization for PSO-PTS Based PAPR Reduction of OFDM Signals'. Physical Communication 55 (December 2022): 101825.

[5] Pushkarev, P.A., Kwan-Woong Ryu, Kook-Yeol Yoo, and Yong-Wan Park. 'A Study on the PAR Reduction by Hybrid Algorithm Based on the PTS and SLM Techniques'. In The 57th IEEE Semiannual Vehicular Technology Conference, 2003. VTC 2003-Spring., 2:1263–67. Jeju, South Korea: IEEE, 2003.

[6] Xiao, Yaoqiang, Ming Chen, Fan Li, Jin Tang, Yi Liu, and Lin Chen. 'PAPR Reduction Based on Chaos Combined with SLM Technique in Optical OFDM IM/DD System'. Optical Fiber Technology 21 (January 2015): 81–86.

[7] Yang, Xuelin, Zanwei Shen, Xiaonan Hu, and Weisheng Hu. 'Chaotic Encryption Algorithm against Chosen-Plaintext Attacks in Optical OFDM Transmission'. IEEE Photonics Technology Letters 28, no. 22 (15 November 2016): 2499–2502.

[8] Hadj Ali, Tarik, and Abdelkrim Hamza. 'Low-Complexity PAPR Reduction Method Based on the TLBO Algorithm for an OFDM Signal'. Annals of Telecommunications 76, no. 1–2 (February 2021): 19–26.

[9] Wang, Hongmei, Yunbo Chen, Jiahui Dai, Shiyin Li, Faguang Wang, and Minghui Min. 'Improved Algorithm of Partial Transmit Sequence Based on Discrete Particle Swarm Optimization'. Mathematics 12, no. 1 (25 December 2023): 80.

[10] Hou Yanli,Li Zilong.A double chaotic encryption secure transmission scheme in OFDM system[J/OL]. Microelectronics and Computers,1-10[2025-02-07].

[11] Zong, Jianyou, Adnan A.E. Hajomer, Liuming Zhang, Weisheng Hu, and Xuelin Yang. 'Real-Time Secure Optical OFDM Transmission with Chaotic Data Encryption'. Optics Communications 473 (October 2020): 126005.

[12] Litvinenko, Anna, and Arturs Aboltins. 'Chaos Based Linear Precoding for OFDM'. In 2015 Advances in Wireless and Optical Communications (RTUWO), 13–17. Riga, Latvia: IEEE, 2015.

[13] Fathy, Sameh A., Mohamed S. El-Mahallawy, and Esam A. A. Hagras. 'C8. SLM Technique Based on Particle Swarm Optimization Algorithm for PAPR Reduction in Wavelet-OFDM Systems'. In 2015 32nd National Radio Science Conference (NRSC), 163–70. 6th of October City, Giza Province, Egypt: IEEE, 2015.

[14] Ma Yan'e,Li Ruijin. Simulation of secure encrypted transmission of network information based on DFT-S-OFDM[J]. Computer Simulation,2022,39(01):358-361+393.

[15] Renuka, N., and P. V. Naganjaneyulu. 'Filtered OFDM PAPR Performance for 5G Communications Is Improved Utilizing PTS'. International Journal of Health Sciences, 26 April 2022, 6115–24.

[16] Chou, Hong-Jie, Ping-You Lin, and Jung-Shan Lin. 'PAPR Reduction Techniques with Hybrid SLM-PTS Schemes for OFDM Systems'. In 2012 IEEE 75th Vehicular Technology Conference (VTC Spring), 1–5. Yokohama, Japan: IEEE, 2012.

[17] Alanazi, Meshari H., Arun Kumar,etc. 'Reducing Papr in Otfs 6g Waveforms Using Particle Swarm Optimization-Based Pts and Slm Techniques with 64, 256, and 512 Sub-Carriers in Rician and Rayleigh Channels'. Fractals 32, no. 9n10 (December 2024): 2540018.