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PAPR Reduction, and BER Performance in MIMO OFDM Using Conventional Techniques with Modified PTS and SLM

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Abstract

Multiple-Input Multiple-Output Orthogonal Frequency Division Multiplexing (MIMO-OFDM) is a widely adopted transmission technique in modern wireless communication systems due to its high data rate and robustness against multipath fading. However, high Peak-to-Average Power Ratio (PAPR) remains a major drawback, leading to nonlinear distortion, degraded Bit Error Rate (BER), This paper presents a comparative study between conventional PAPR lessening techniques and a low-complexity PAPR reduction approach using a Modified Partial Transmit Sequence (PTS) scheme with a Hybrid Artificial Bee Colony–Firefly (ABC–FF) algorithm. The comparison is carried out in terms of PAPR reduction capability, BER performance, and computational complexity. Simulation results demonstrate that the proposed Modified PTS with Hybrid ABC–FF algorithm achieves superior PAPR reduction, improved BER performance, compared to conventional methods, making it suitable for next-generation wireless communication systems. To progress the existing PAPR reduction techniques, we have incorporated ideal SLM and PTS based PAPR reduction strategy in parallel. By utilizing, the OGWO algorithm Moreover, the OGWO optimization based PAPR reduction technique will provide better performance and it was been promoted as an uncomplicated way for PAPR reduction. The proposed approach will be analyzed with various novel PAPR reduction schemes to show the effectiveness

Keywords: MIMO-OFDM, PAPR Reduction, BER Performance, Computational Complexity, Modified PTS, Hybrid ABC–FF, OGWO Algorithm

1. Introduction

MIMO-OFDM technology plays a crucial role in modern wireless standards such as 4G, 5G, and beyond due to its high spectral efficiency and resistance to frequency-selective fading. Despite these advantages, MIMO-OFDM systems suffer from a significant limitation known as Peak-to-Average Power Ratio (PAPR), which arises from the superposition of multiple subcarriers.High PAPR forces the High Power Amplifier (HPA) to operate in its nonlinear region, causing signal distortion, spectral spreading, and increased Bit Error Rate (BER). To overcome this issue, several PAPR reduction techniques such as clipping, companding, Selective Mapping (SLM), and Partial Transmit Sequence (PTS) have been proposed. However, these methods often introduce distortion, require side information, or increase computational complexity.

Recently, intelligent optimization-based techniques have been explored to reduce PAPR effectively with lower complexity. In this paper, a comparative analysis is performed between conventional PAPR lessening execution methods and a Modified PTS scheme optimized using a Hybrid ABC–FF algorithm, focusing on PAPR, BER, and computational complexity.

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. 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. This focuses on traditional PAPR reduction techniques that have been widely used to address this issue, particularly in MIMO-OFDM systems [1]. The study explores three well-known methods, Partial Transmit Sequence (PTS), Selected Mapping (SLM), and Clipping and Filtering (C&F). 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. SLM generates multiple OFDM candidate signals using different phase sequences and selects the one with the lowest PAPR for transmission, balancing complexity and performance. 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. This paper is concerned with the Orthogonal Frequency Division Multiplexing (OFDM) system that is adopted by a wireless communication system for transmitting multicarrier modulated signals simultaneously with robustness against interference and noise facing the system. It presents a significant issue related to the OFDM system known as the raise of Peak to Average Power Ratio (PAPR) that is the high peaks of OFDM signals compared to its average power. Increasing the PAPR yields in the component devices of the OFDM system does not cope with the high peaks resulting in distortion and signal losses. Therefore, the objective of this article is to review different approaches of PAPR reduction techniques and compare them to select the best technique for a particular system. The approaches are mainly of three classifications; distortion, probabilistic, and coding schemes with each including several techniques [2]. Orthogonal Frequency Division Multiplexing (OFDM) is one of the multi-carrier modulation techniques which divides the available spectrum into many carriers; each one is modulated by a low data rate stream [3]. OFDM is used for high data rate wireless communications because of its robustness to frequency selective fading, high spectral efficiency and low computational complexity [4] [5]. It is employed in wireless applications such as Digital Audio Broadcasting (DAB), Digital Video Broadcasting (DVB-T), the ETSI HIPERLAN/2 standard, the IEEE 802.11a standard for Wireless Local Area Networks (WLAN) and the IEEE 802.16a standard for Wireless Metropolitan Area Networks (WMAN) [6]. One of the main limitations of OFDM system is the high Peak to Average Power Ratio (PAPR) of the transmitted signal [7]. The high peaks of an OFDM signal are produced due to the addition of sub symbols of each subcarrier coherently. So these signals may cause many problems including a severe power penalty at the transmitter [8]. Therefore, it is necessary to reduce the PAPR of an OFDM signal [9]. Many techniques have been proposed to overcome the PAPR problem in the OFDM [10], which are classified into two types namely, distortion based techniques and redundancy-based techniques. The distortion-based techniques such as direct clipping, peak windowing, Recursive Clipping and Filtering (RCF) etc., are used to reduce the PAPR of the OFDM symbol by adding distortion to the signal points in the subcarriers. The redundancy-based techniques such as coding, Selective Mapping (SLM), Partial Transmit Sequences (PTS), Tone Reservation (TR) and Tone Injection (TI), etc. are used to increase the average power due to the introduction of redundancy. Among these methods, the PTS is one of the most emerging schemes because of high-quality PAPR reduction performance with no limitation to the number of subcarriers. In the PTS scheme, the input data block of N symbols is divided into many disjoint sub blocks. After that, each sub block is transformed to obtain the corresponding time-domain signal using Inverse Fast Fourier Transform (IFFT) and each one is multiplied by a rotation phase factor. The objective of the PTS technique is to select the phase factor of the combined signal to minimize the PAPR. This requires a number of iterations to be performed to find the optimum combination of phase factors for sub blocks, which results in the search complexity and increases exponentially with the number of sub blocks. Multiple Input Multiple Output (MIMO) technology has numerous advantages including the ability to improve the system capacity and increasing the communication reliability through the diversity gain. For high data rate wireless applications such as in IEEE 802.16 d/e WIMAX, OFDM is combined with MIMO technology. Like OFDM, a serious problem in MIMO-OFDM system is, its high Peak to Average Power Ratio (PAPR).

2. System Model of MIMO-OFDM

In a MIMO-OFDM system, input data bits are modulated using schemes such as QPSK or QAM. The modulated symbols are converted into parallel streams and transformed into time-domain signals using the Inverse Fast Fourier Transform (IFFT). These signals are transmitted through multiple antennas over a fading channel.

3. Conventional PAPR Lessening Execution

3.1 Conventional Techniques

- Clipping and Filtering: Simple implementation but causes in-band distortion and BER degradation.
- Companding: Reduces PAPR but increases sensitivity to noise.
- Selective Mapping (SLM): Provides better PAPR reduction but requires multiple IFFT operations.
- Conventional PTS: Effective but computationally complex due to exhaustive phase factor search.

3.2 Performance Characteristics

- PAPR Reduction: Moderate
- BER Performance: Often degraded
- Computational Complexity: High

4. Proposed Methodology: Modified PTS with Hybrid ABC–FF and (OGWO) Algorithm

4.1 Modified Partial Transmit Sequence (PTS)

In the Modified PTS scheme, the frequency-domain data block is divided into multiple disjoint sub-blocks. Each sub-block is multiplied by an optimized phase factor before combining them to generate the OFDM signal.

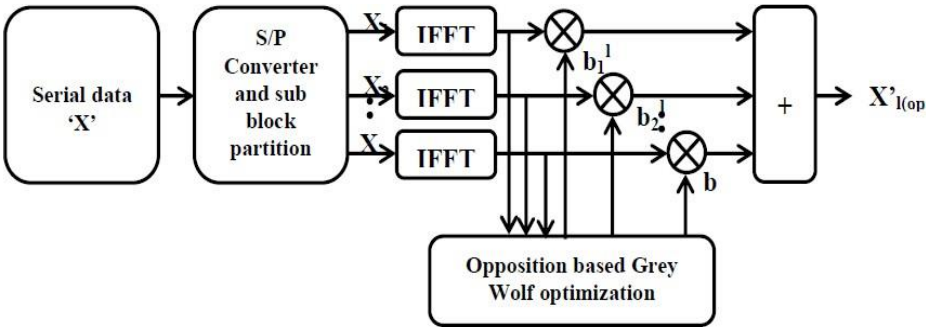


Figure 1. Block diagram of PTS

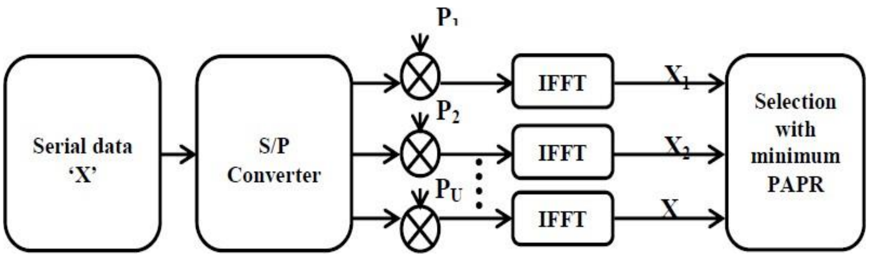


Figure 2: Block diagram of SLM

4.2 Hybrid ABC–FF Algorithm

The Hybrid Artificial Bee Colony–Firefly algorithm combines:

- **ABC algorithm** for global exploration of optimal phase factors
- **Firefly algorithm** for fast local convergence

This hybrid approach efficiently finds optimal phase factors that minimize PAPR while preserving BER performance.

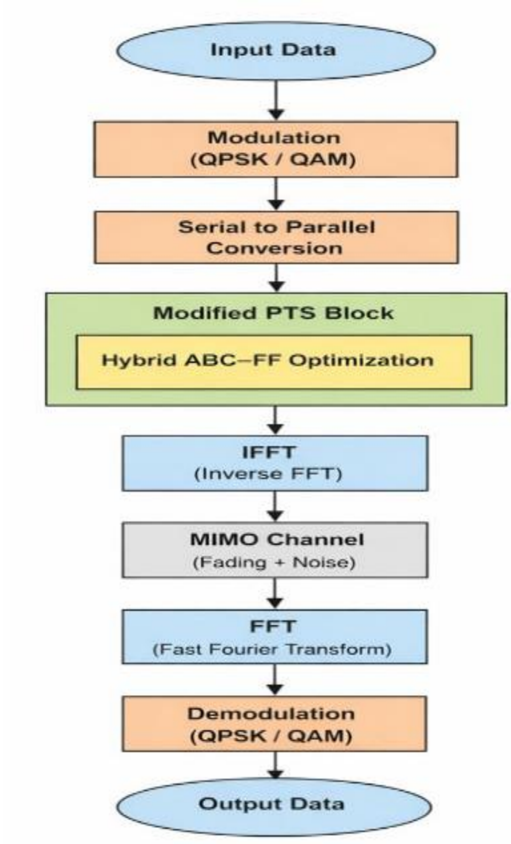
4.3 Objective Function

The PAPR of a signal is expressed by the following formula:

$$PARP_{dB} = 10\log\left(\frac{\max[b(t)b*(t)]}{E[b(t)b*(t)]}\right)$$

5. Block Diagram

5.1Proposed MIMO-OFDM with Modified PTS and Hybrid ABC–FF



5.2PROPOSED WOLF OPTIMIZER (GWO)

The GWO calculation, proposed is hopeful with the chasing conduct and social administration of dim posers. It resembles other meta-heuristics, and in GWO calculation the pursuit begins by a populace of discretionarily made wolves (competitor arrangements). Keeping in mind the end goal to imagine the social chain of command of wolves when planning GWO, in this calculation the populace is part into four gatherings: alpha (α), beta (β), delta (δ), and omega (ω). Through the traverse of accentuations, the underlying three best arrangements are called α,, and δ, separately. Whatever is left of the hopeful arrangements are named as ω. The social predominant progression is instanced as in figure. 3

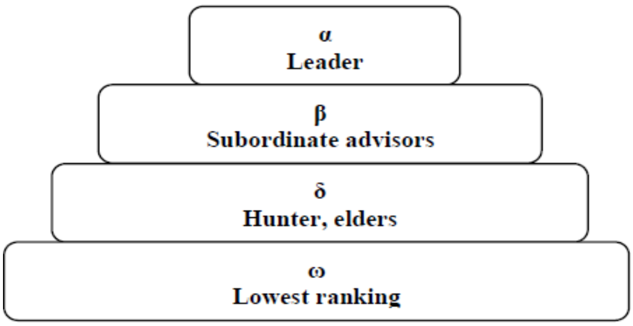


Figure3. Social hierarchy of wolf

Results and Performance Analysis

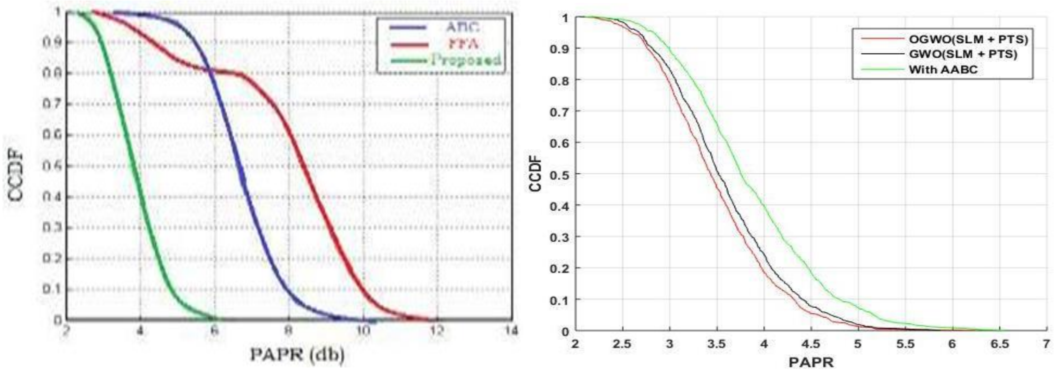


Table 1: PAPR Comparison of Conventional Techniques with Modified PTS and SLM

Algorithms	PAPR (db)
ABC	9.9
FFA	11.9
Hybrid (ABC+FFA)	6
GWO	**5.5**
OGWO	**5.2**

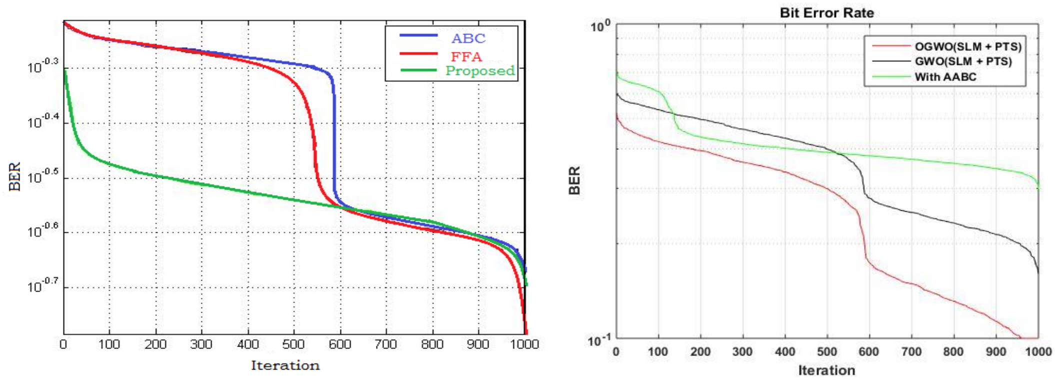


Figure 6: Bit Error Ratio

Table 2: BER,SER Comparison of Conventional Techniques with Modified PTS and SLM

Algorithms	**BER**	**SER**
ABC	$10^{-0.29}$	$10^{-0.27}$
FFA	$10^{-0.3}$	$10^{-0.28}$
Hybrid(ABC+FFA)	$10^{-0.54}$	$10^{-0.29}$
GWO	$10^{-0.60}$	$10^{-0.31}$
OGWO	$10^{-0.65}$	$10^{-0.32}$

PAPR Performance

Simulation results show that the proposed Modified PTS with Hybrid ABC–FF, OGWO algorithm significantly reduces PAPR compared to conventional techniques. The CCDF curve shifts left by approximately **3–4 dB**, indicating better power efficiency.

BER ,SER Performance

The proposed method achieves lower BER,SER across all SNR values due to reduced nonlinear distortion caused by lower PAPR.

Conclusion

This paper presented a comparative analysis of PAPR,BERand SER lessening execution techniques Modified PTS,SLM scheme using a Hybrid ABC–FFand OGWO algorithm in MIMO-OFDM systems. The proposed method achieves superior PAPR reduction, improved BER ,SER performance, compared to conventional approaches. Therefore, the proposed scheme is highly suitable for future high-data-rate and energy-efficient wireless communication systems.

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