Received: May 11, 2022. Revised: July 5, 2022.

International Journal of
Intelligent Engineering & Systems

http://www.inass.org/

Prime Learning Ant Lion Optimization with Precoding and Companding for PAPR Reduction in MIMO-OFDM

Abdul Azeez[1]* **Suraiya Tarannum[1]**

[1] *HKBK College of Engineering, Bangalore, India*
* Corresponding author's Email: abdulazeez.ec@hkbk.edu.in

Abstract: To meet the increasing demand for wireless applications requires efficient performance in orthogonal frequency division multiplexing (OFDM) and multi-input multi-output (MIMO). The existing methods involve applying various optimization techniques to increase the performance of the partial transmit sequence (PTS) and OFDM system to reduce the peak average to power ratio (PAPR). This research proposes prime learning ant lion optimization (PL-ALO) method to reduce the PAPR and bit error rate (BER) of the system. The tournament selection technique is applied to increase the exploitation related to the best fitness agent that improves the PL-ALO model performance. The tournament selection technique randomly performs tournaments among the best fitness search agent in the system. The square-root raised cosine (SRC) precoding and Mu law companding techniques were applied to improve the efficiency of the system. The comparison between discrete cosine transform (DCT) and fast fourier transform (FFT) techniques was carried out in the performance analysis. The DCT-based method has higher efficiency than FFT-based techniques in the system. The PL-ALO method has higher efficiency than existing techniques of particle swarm optimization (PSO)- grey wolf optimization (GWO) and multi-objective mayfly algorithm (MOMA). The average PAPR of selective mapping (SLM) is 8.243, PTS-ant lion optimization (ALO) is 3.962, MAMO is 5.279, PSO-GWO is 5.854, and PL-ALO is 3.099.

Keywords: Prime learning ant lion optimization, Mu law companding, Orthogonal frequency division multiplexing, Partial transmit sequence, Square-root raised cosine.

1. Introduction

The OFDM is a common multi-carrier transmission method that is an effective and simple solution for wideband communication based on single carrier transmission systems, which is related to longer symbol durations of the channel that is divided into sub-channels of narrowband [1]. Several sub-bandwidths are divided from the available bandwidth of the OFDM system, whereas low data rates streams are parallel modulated and sub-bandwidths are carried over. The symbol duration increases based on parallel transmission thus decreasing the dispersion amount prorated from multi-path delay spread in time resulting [2]. This technology faces challenges due to power consumption and high cost when employing hardware components, cells, and multiple antennas. Researchers continuously seek to provide solutions to accommodate the demand for quality of service (QoS) requirements and diverse data rates for wireless communications [3]. However, the OFDM system has a limitation of high PAPR, especially with many sub-carriers. Many PAPR reduction techniques are used in existing methods to reduce PAPR such as iterative clipping and filtering (ICF), signal distortion technique, partial transmit sequence (PTS), selective mapping (SLM), tone reservation (TR), tone injection (TI), probabilistic techniques, multiple signaling, Turbo coding and linear block coding, and hybrid methods [4, 5].

Meta-heuristic algorithms have increasingly popular in many optimization methods with simple concept advantages, easy implementation, and no need for gradient information. Commonly applied algorithms for PAPR reduction are bat inspired algorithm (BA), genetic algorithm (GA), grey wolf optimizer (GWO), whale optimization algorithm

(WOA), and artificial bee colony (ABC), and particle swarm optimization [6, 7]. high cubic metric (CM) is mitigated using partial transmit sequence (PTS) in OFDM signals and original PTS faces high computational complexity due to phase factor possible combinations. Less search complexity in several optimization algorithms has been recently applied to optimize the PTS technique for the reduction of CM and PAPR in OFDM systems [8 - 10]. The objectives and contribution of this research are discussed as follows:

1. An prime learning ALO method is proposed to increase the efficiency of the OFDM system and reduces PAPR. The tournament selection method is applied in the PL-ALO method to increase the search efficiency of the model.
2. Tournament selection technique is applied in ALO model to carried out tournament among the best solutions and find optimal solution from the tournament. This technique helps to improve the exploitation of the model.
3. Hybrid SRC precoding and Mu law companding technique is applied to further reduces the PAPR in the model.
4. Mu law companding technique is applied to balance the PAPR and BER in the MIMO-OFDM system. DCT technique is applied to convert the signal from spatial domain to frequency domain in the system.
5. The PL-ALO method shows higher efficiency in PAPR reduction than existing methods in the MIMO-OFDM system.

The organization of the paper is given as follows: The Literature survey is provided in section 2 and the explanation of the PL-ALO method is given in section 3. The result and discussion are given in section 4. The conclusion of this research work is given in section 5.

2. Literature survey

The OFDM has been extensively studied in many communication systems due to its low-complexity implementation, simple equalization, and high spectral efficiency. The high PAPR is the main problem in multi-input multi-output (MIMO) – OFDM system and various optimization techniques were applied to improve its performance.

Sharifi and Emami [11] applied improved flower pollination (IFP) with the PTS technique to minimize search complexity. The IFP method is derived from the pollination behavior of flowers to find the optimal solution for the system. The OFDM system was applied with the IFP-PTS technique in asymmetrical clipped optical and the performance of the method was evaluated. The IFP method was applied with a new local pollination operator that increases the search capability of the model. The IFP method increases the exploitation ability and the exploration process was improved by the modified global pollination phase. The modified global pollination phase balance the exploration and exploitation of the developed method. The IFP algorithm has poor exploitation ability and premature convergence in optimization.

Abed [12] used IFFT and a dummy sub-carriers insertion (DSI) system using the PSO technique. The dummy algorithm with the PSO technique sends data to PAPR using a specific threshold of dummy sub-carrier and data sequence. PAPR and BER metric was used to evaluate the channel environment in additive white gaussian noise. The dummy sequence-based PSO method reduces PAPR more than the conventional system and clipping technique. The PSO-based method was applied in OFDM systems in the sub-carrier’s creation. Side information was not required in the PSO method for sender transmit information and sub-carriers amplitude was adapted in the PSO method that requires the computational cost of PAPR and less iteration numbers. The PSO method easily fall into local optima in high dimensional data and low convergence.

Bai and Yang, [13] applied an adaptive PSO (APSO) method combined with the PTS technique to reduce PAPR. The phase factor of the best combination was effectively found using adaptive inertia factor and particle position discretizing. The simulation analysis shows that model has better global convergence ability, lower computational complexity, and better robustness. The PTS method is based on a probabilistic technique to suppress PAPR that does not affect the BER of the system. The two-dimensional APSO model PTS phase exhaustive the search and reduce model complexity. The APSO method has lower exploitation due to position discretizing.

Aghdam and Sharif, [14] applied ACO and PTS to reduce the PAPR and computational cost of OFDM systems. The improved ACO method was combined with the PTS method to explore the phase rotation optimal compound. The ACO-based PTS method significantly reduces PAPR and improves the computational cost. The ACO-PTS method has higher performance than existing methods of GWO, PSO, and GA in terms of PAPR. The PTS problem was applied with a new mapping technique by representing phase factors as a graph. The developed method effectively discovers the space of all sequences of a given phase factor. The improved

Received: May 11, 2022. Revised: July 5, 2022.

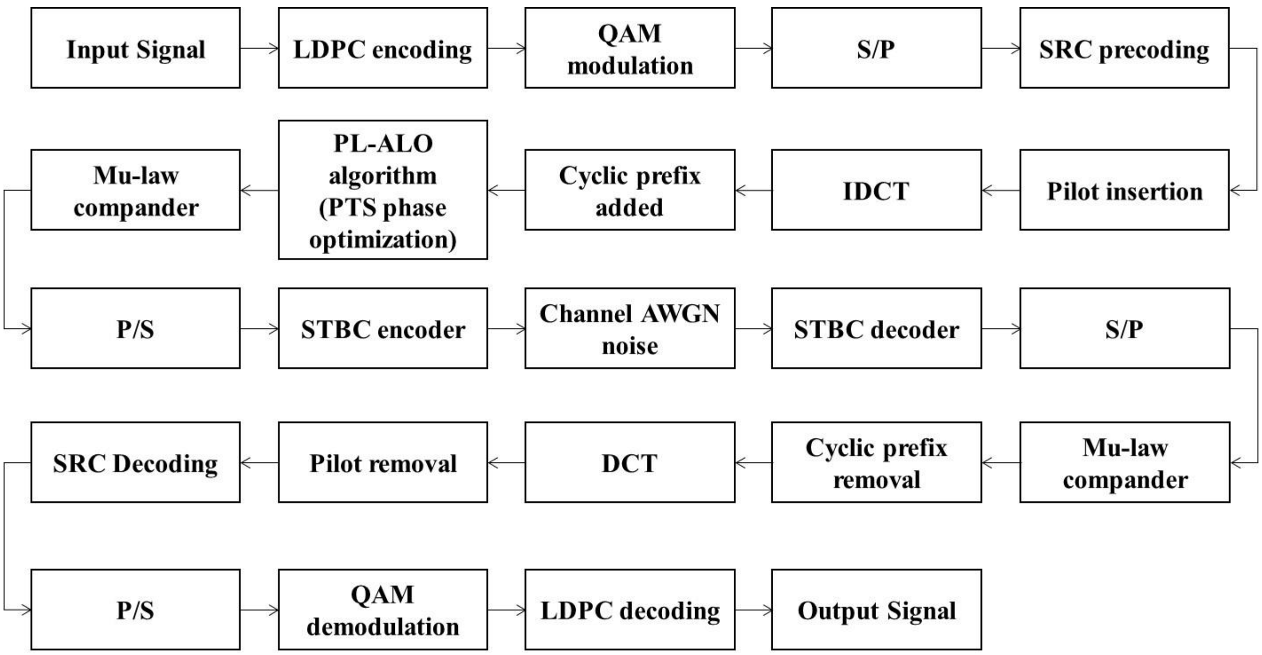

Figure. 1 The PL-ALO method for the MIMO-OFDM system

ACO method has lower convergence, lower exploitation rate and stagnation phase.

Sarkar [15] applied twin symbol hybrid optimization based on cyclic prefix OFDM and PTS method. The slap swarm optimization (SSO) and bald eagle search (BES) are applied to optimally analyze the PTS method phase factor. The discrete fourier transform (DFT) of data transmission in the physical layer of security for digital chaos sequences for sub-carrier allocation. The developed method has a quicker convergence rate and computational complexity based on optimal phase factor estimation. The SSO method suffers from unbalance exploration-exploitation and lower convergence.

3. Proposed method

The PL-ALO method for MIMO-OFDM system is shown in Fig. 1.

3.1 OFDM system

Discrete symbols are converted by input bit-streams in the original OFDM system using the digital modulation technique [26, 27]. Frequency domain OFDM symbols are performed on an OFDM system and the signal is real and positive. The Hermitian symmetry operation is used to generate a unipolar signal and OFDM signal in real value. Domain length of Each frequency OFDM block k, $\mathbb{x} = [X_0, X_1, \dots, X_{K-1}]^T$ is applied with Hermitian symmetry (HS) in an ACO-OFDM system and symbols of a new block with $4K$ length are achieved, as given in Eq. (1).

$$x = [0, x_0, 0, X_1, \dots, 0, X_{K-1}, 0, X_{K-1}^*, 0, \dots, 0, X_1^*, 0, X_0^*]^T \quad (1)$$

Data symbols of odd sub-carriers are communicated and sub-carriers even are set to zero. Sequence X of inverse fast fourier transform (IFFT) procedure and symbols of time-domain $x = [x_0, x_1, \dots, x_{N-1}]^T$ is generated. The PL-ALO method signal of discrete-time of n^{th} sample is given in Eq. (2).

$$x_n = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X_k e^{\frac{j2\pi}{N} kn}, \quad 0 \le n \le N-1 \qquad (2)$$

Where oversampling operation is denoted as ℓ and $N = 4K\ell$. The original PAPR is approximate oversampling and accurately OFDM signals. The real x signal and antisymmetry property are given in Eq. (3).

$$x_n = -x_{n+\frac{N}{2}}, \quad 0 \le n \le \frac{N}{2} - 1 \qquad (3)$$

The OFDM signals amplitude variations are known as the PAPR and the ratio of the peak power to average power is given in Eq. (4).

$$PAPR = \frac{\max\{|x_n|^2\}}{E\{|x_n|^2\}}, \quad 0 \le n \le N-1 \qquad (4)$$

Where mathematical expectation operation is denoted as $E\{.\}$.

The complementary cumulative distribution function (CCDF) is depicted in PAPR. The CCDF illustrates the PAPR probability in an OFDM frame such that $PAPR_0(CCDF = Pr\ (PAPR > PAPR_0))$ and Monte Carlo simulation is used to determine.

3.2 Discrete cosine transform

For image and data compression for signal compression, discrete cosine transform (DCT) is widely used [28]. Conversion of spatial domain to frequency domain, DCT is used for a signal that provides better de-correlation performance. Fourier transform is a special case in DCT that avoids Fourier transform complex operation and the real number domain is in transform.

Once the signal is applied with DCT and coefficients are divided into some altering components (AC) and a direct component (DC). Average brightness is represented by the DC component and original image block of main energy in the concentrated AC component. In signal processing, DCT plays a major role.

One-dimensional DCT is used to perform two-dimensional DCT. The matrix A size of DCT coefficients is obtained after performing 2D-DCT, as in Eqs. (5-7).

$$F(u,v) = c(u)c(v) \times \left[\sum_{x=0}^{M-1}\sum_{y=0}^{N-1} f(x,y) \times \cos\left(\frac{(2x+1)u\pi}{2M}\right)\cos\left(\frac{(2y+1)v\pi}{2N}\right)\right] \quad (5)$$

among them,

$$c(v) = \begin{cases} \sqrt{\frac{1}{N}}\, v = 0 \\ \sqrt{\frac{2}{N}}\, v = 1,2,\ldots,N-1 \end{cases} \quad (6)$$

$$c(u) = \begin{cases} \sqrt{\frac{1}{M}}\, u = 0 \\ \sqrt{\frac{2}{M}}\, u = 1,2,\ldots,M-1 \end{cases} \quad (7)$$

The spatial domain of sampling values is denoted as x and y and the pixel value at position (x,y) is $f(x,y)$. The frequency-domain of sampling values is denoted as u and v, and the spatial domain corresponding position of the pixel value is (x,y). In the frequency domain, the frequency coefficient is $F(u,v)$ at position (u,v) and after 2D-DCT. A square pixel matrix is used that is $M = N$.

The inverse transform of 2D-DCT (2D-IDCT) is given in Eq. (8).

$$f(x,y) = c(u)c(v) \times \left[\sum_{u=0}^{M-1}\sum_{v=0}^{N-1} F(u,v) \times \cos\left(\frac{(2x+1)u\pi}{2M}\right)\cos\left(\frac{(2y+1)v\pi}{2N}\right)\right] \quad (8)$$

3.3 Precoding – SRRC

Nyquist pulses of the square-root raised cosine (SRRC) [29] with power spectral density is given in Eq. (9).

$$G_{SRRC}(\alpha, f) = \begin{cases} T_c & \|f\| \le \frac{1-\alpha}{2T_c} \\ \frac{T_c}{2}\left\{1 + \cos\left[\frac{\pi T_c}{\alpha}\left(\|f\| - \frac{1-\alpha}{2T_c}\right)\right]\right\} & \frac{1-\alpha}{T_c} \le \|f\| \le \frac{1+\alpha}{2T_c} \\ 0 & \|f\| > \frac{1+\alpha}{2T_c} \end{cases} \quad (9)$$

3.4 Partial transmit sequence (PTS)

Several sub-frames are splits from the PTS input data frame, corresponding phase factor is rotated for each sub-frame that returns phase factors permutation such that combined sub-frames of PAPR are minimized [30, 31]. Input data block X Partitioned into V sub-frames disjoint $\mathbb{X}^v(v = 1,2,\ldots,V)$, as in Eq. (10).

$$\mathbb{X} = \sum_{v=1}^{V} \mathbb{X}^v \quad (10)$$

Each sub-frame $X(v) \in C^K$ of Hermitian symmetry and achieve a new sub-frame as $X(v) \in C^{4K}$. The ℓ times oversampling with IFFT operation is applied for each sub-frame $X(v)$ and a length of $N = 4K\ell$ of time-domain sequence $x(v)$. Sub-frame each center is padded with $(\ell - 1)4K$ zeros in an oversampling process. Independently rotating the partial sequences of phase factors is denoted as $b_v \in \{e^{\frac{j2\pi}{wk}};\ k = 0,1,\ldots,w-1\}$. The phase factors selection is applied to reduce computational complexity that is limited to $\{+1,-1\}$ $(w = 2)$. The PAPR is minimized with a transmitted signal as given in Eq. (11).

$$\tilde{x} = \sum_{v=1}^{V} b_v x^v \quad (11)$$

The factor of the first phase is applied as $b_1 = 1$ and selected $V - 1$ factors. Explore phase factor sequences of w^{V-1} and exponentially increases search complexity with a number of sub-frames V. The partitioned sub-frames V and phase factors w numbers highly depend on PAPR reduction.

Received: May 11, 2022. Revised: July 5, 2022.

3.5 Prime learning ant lion optimization for PTS

Fitness value combination, antlions selection mechanism, ants hunting, and random walk improvements are developed in original ALO [32 – 34]. In the original ALO algorithm, the random walking technique provides ant's model based on the modelling technique and maximum iteration number that affects algorithm run time. The random walk distance reduces in the ALO algorithm. The 20 % distance value is used for the maximum iteration number at this distance, as in Eq. (12).

$$X(t) = [0, cumsum(2r(t_1) - 1), \ldots, cumsum(2r(t_n) - 1)], \quad n = 1,2,\ldots, MaxIter/5 \tag{12}$$

The ALO algorithm has a long-running time that is considered and shortened in random walkways innovation. PL-ALO algorithm in some test functions runs faster than the original ALO method. At a certain rate of slippage, the ants are shifting towards antlion. Existing ALO model only consider the threshold of more than 0.5 and this tends to loss potential solutions and causes lower exploration. The PL-ALO model partition option in four thresholds and increases exploration. In PL-ALO, throwing sand is used to shifting of ants and antlion's pit, explained in the mathematical model as given in Eqs. (13-14).

$$c_i^t = \begin{cases} Antlion_i^t + c^t, & for\ 0.75 < option < 1 \\ Antlion_i^t - c^t, & for\ 0.5 < option < 0.75 \\ -Antlion_i^t + c^t, & for\ 0.25 < option < 0.5 \\ -Antlion_i^t - c^t, & for\ option < 0.25 \end{cases} \tag{13}$$

$$d_i^t = \begin{cases} Antlion_i^t + d^t, & for\ 0.75 < option < 1 \\ Antlion_i^t - d^t, & for\ 0.5 < option < 0.75 \\ -Antlion_i^t + d^t, & for\ 0.25 < option < 0.5 \\ -Antlion_i^t - d^t, & for\ option < 0.25 \end{cases} \tag{14}$$

Where the randomly chosen variable is an option that updates these shift rates based on conditions of faster hunting mechanism and provides a more accurate has been established. More precise results are achieved in retrieving ant search space of redirection space.

The best antlion is updated in the original ALO method at each iteration end. The antlion and ant populations are combined that are ranked based on their fitness values. Combining population half is considered as antlion position for the next iteration. The improvement of the selection method is ant and antlion-ant each pair is compared with the antlion's fitness value for sorting and combining the population. If the ant's fitness value is better than the antlion's fitness, the ant antlion position is updated as the ant position, as in Eq. (15).

$$Antlion_i^t = Ant_i^t \ if\ f\left(Ant_i^t\right) < f(Antlion_i^t \tag{15}$$

Where the position of antlion is denoted as $Antlion_i^t$, t is iteration, i is antlion, antlion fitness is $f\ (Antlion)_i^t$, the fitness of ants is $f\ (Ant)_i^t$, and the position of the ant is Ant_i^t. In PL-ALO, ants go out of the search area and the original ALO method has the search of space boundary checking method. The population of this algorithm is located at the same boundary points for most search agents. In ALO, a new technique is applied instead of the boundary technique. Ants re-enter search space once ants exist search space, unlike the original ALO algorithm. The search performance of the model is increased in the PL-ALO method. The ants were randomly applied in search space based on the mathematical model, as in Eq. (16).

$$Ant_i^t = b_{low} + rand \times \left(b_{up} - b_{low}\right) \ if\ Ant_i^t > b_{up} or\ Ant_i^t < b_{low} \tag{16}$$

Where the random number in the interval is denoted as $rand$, the lower boundary is blown and the search space upper boundary is b_{up}. The roulette wheel method is applied to every ant for moves around an antlion. Some algorithms considered the roulette wheel method as an alternative. Some applied techniques such as ranking selection, linear, tournament selection, exponential ranking selection, etc. A tournament is conducted for randomly selected individuals of the best fitness and population in tournament selection. The tournament parameter is the size or tour of the tournament and tournament size varies from 2 to population size.

The roulette wheel technique is used in Mirjalili's work for less efficient minimization problems. The tournament selection technique is much more useful in minimizing problems than the roulette wheel technique. Randomly considered two groups from the population in tournament method and division of population size to tournament size is groups size.

Received: May 11, 2022. Revised: July 5, 2022.

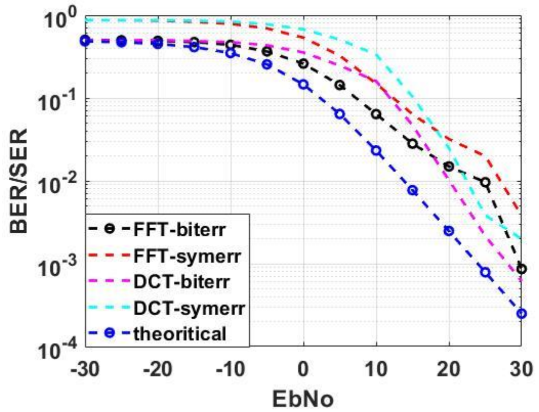

Figure. 2 BER/SER of PL-ALO for M=32

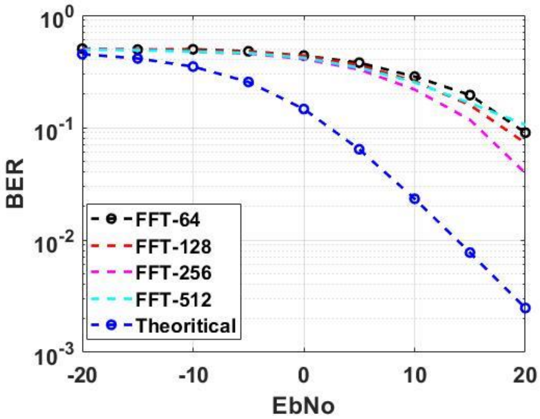

Figure. 3 BER/SER of PL-ALO for M=64

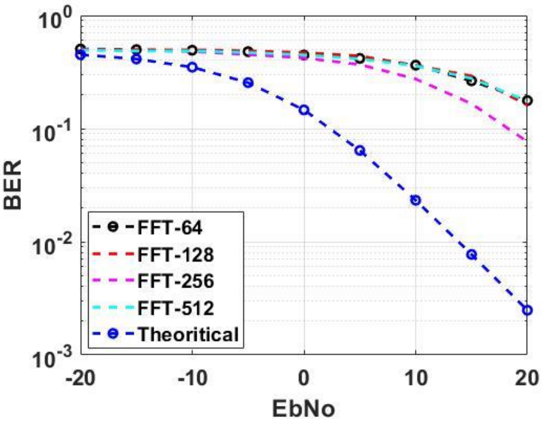

Figure. 4 BER/SER of PL-ALO for M=128

3.6 Mu-law compander

Companding is an efficient PAPR reduction technique that is used to reduce PAPR in OFDM signals in higher amplitude signals by compressing and expanding lower signals [35]. The companding technique is capable to reduce PAPR without expanding upon bandwidth. Two important characteristics are simple implementation and low computational complexity. The inverse companding

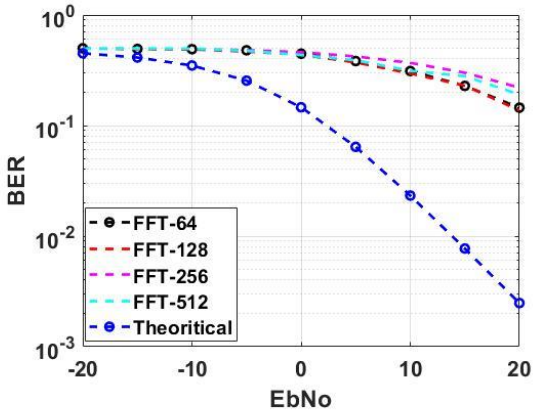

Figure. 5 BER/SER of PL-ALO for M=256

function is applied to retrieve the original signal in the receiver. Side information is not required in companding and the bit rate is reduced. A non-linear companding transform is based on μ law companding and speech signal processing is based on this method. The μ law companding output is provided mathematically as in Eq. (17).

$$Y(z) = \frac{F}{\log(1+\mu)} \log\left(1 + \frac{\mu|z|}{F}\right) sgn(z) \tag{17}$$

Where signum function is denoted as $sgn(.)$, μ is denoted as companding level, and signal maximum amplitude z is signified by F.

The μ law decompanding is expressed in Eq. (18).

$$Y(r) = \frac{F}{\mu}\left(e^{\frac{|r|\log(1+\mu)}{F}} - 1\right) \tag{18}$$

Where the received signal is denoted as r. The increasing value of μ effectively reduces μ law companding scheme. The performance of system error is degraded due to signal average power level in the OFDM technique. The μ law companding technique favorable trade-off between PAPR and BER.

4. Results

The PL-ALO method is compared with existing methods in terms of PAPR and BER in the MIMO-OFDM system.

4.1 Performance in terms of BER

The PL-ALO method is evaluated with various FFT values and DCT in terms of BER to analyze the performance.

The PL-ALO method comparison for DCT and FFT in 32 modulation order in terms of BER and

Received: May 11, 2022. Revised: July 5, 2022.

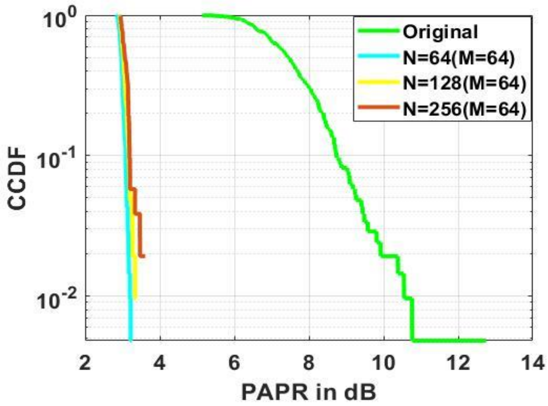

Figure. 6 PAPR of PL-ALO method for M=64 various FFT values

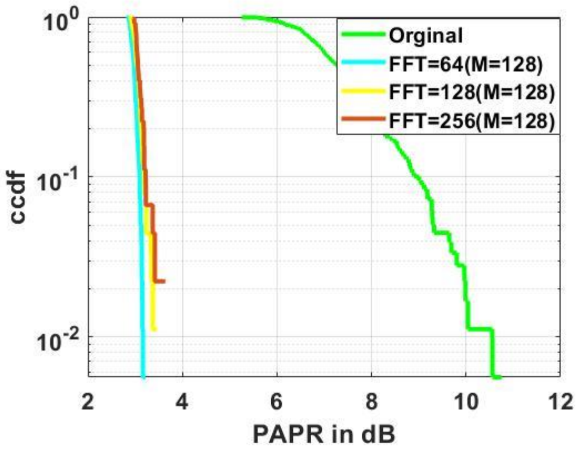

Figure. 7 PAPR of PL-ALO method for M=128 and various FFT values

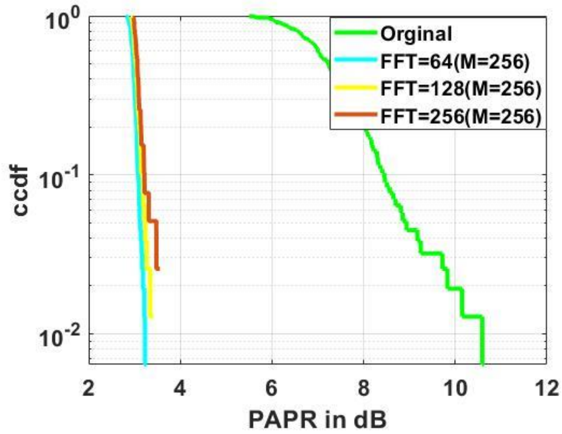

Figure. 8 PAPR of PL-ALO method for M=256 and various FFT values

symbol error rate (SER) is given in Fig. 2. The PL-ALO method with the DCT method has higher efficiency than the FFT technique in terms of BER and SER. The PL-ALO method reduces the error in the transmission due to its tournament selection technique which increases the exploitation process. The tournament selection method selects the potential solution from the best fitness value of antlion that increases the exploitation process.

The PL-ALO method of BER/SER is analyzed for various Modulation orders, as given in Fig. 2 to Fig. 5. The PL-ALO method analysis shows that 256 FFT modulation provides higher performance than other FFT values. In M=64, the FFT 256 value has a lower bit error rate than other FFT values. The 512 FFT value has a higher error rate than FFT 256 value in the system. In M=128, the FFT 256 has a higher performance than other FFT values in the system. The FFT values of 64, 128, and 512 provide performance almost equal to each other in the system. In M = 256, the FFT 64 and FFT 256 has almost similar BER value for the PL-ALO method.

4.2 Performance analysis in terms of PAPR

The PL-ALO method is evaluated with DCT and various FFT values in terms of PAPR to test the performance.

The PAPR of the PL-ALO method for various modulation orders and FFT values are given in Fig. 6 to Fig. 8. In M=64 in the system, the PL-ALO method reduces the PAPR value to less than 4 for the MIMO-OFDM system. The FFT 64 values have lower PAPR values than FFT 128 and 256 values in the system. In M = 128 system, the PL-ALO method PAPR value is evaluated for various FFT values. The PL-ALO method reduces the PAPR value to less than 4 for the MIMO-OFDM system. The PL-ALO method shows more significant performance than the original MIMO-OFDM system. In M = 256 system, the PL-ALO method with FFT 64 value shows higher performance than other FFT values.

4.3 Comparative analysis

The PL-ALO method is compared with PTS, SLM, and existing methods related to optimization of the MIMO-OFDM system.

The PL-ALO method is compared with SLM and PTS techniques in the MIMO-OFDM system, as shown in Fig. 9. This shows that the PTS-ALO method has a lower PAPR value than SLM and PTS techniques. The PTS precoding method has a lower PAPR value than the SLM technique in the system. The PL-ALO method has the advantage of applying a tournament selection process to increase exploitation in the system.

The comparison of DCT and FFT with the IACO method in terms of PAPR is shown in Fig. 10. The DCT method reduces the PAPR value more than the FFT technique in the MIMO-OFDM system.

Received: May 11, 2022. Revised: July 5, 2022.

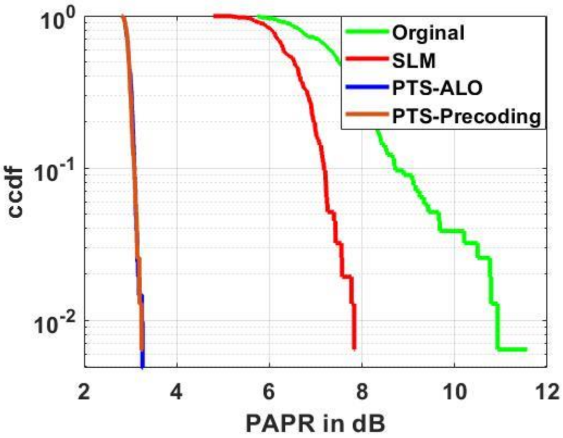

Figure. 9 Comparison of SLM and PTS

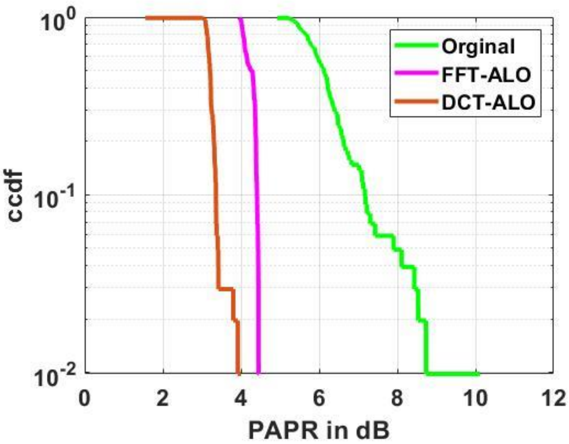

Figure. 10 Comparison of DCT and FFT

The PL-ALO method is compared with existing methods of PSO-GWO, and multi-objective mayfly algorithm (MOMA), as shown in Fig. 11 and 12. The PL-ALO method shows significantly less PAPR value than MOMA and PTS- PL-ALO methods. The tournament selection in the PL-ALO method helps to increase the exploitation process that improves the performance of the method.

The average PAPR of SLM is 8.243, PTS-ALO is 3.962, MAMO is 5.279, PSO-GWO is 5.854, and PL-ALO is 3.099. The average convergence rate of PTS-PL-ALO is 2.846, MOMA is 6.084, and PSO-GWO is 5.943.

The PL-ALO method and existing Improved ACO [14], DIWO-PTS [16], and PTS-DPSO-TH [17] were compared in Table 1. The improved ACO [14] method has limitation of lower convergence, lower exploitation rate, and stagnation phase. The DIWO [16] method has limitation of local optima trap, and PTS-DPSO-TH [17] has lower convergence. The PL-ALO method significantly reduces the PAPR of the model due to its efficiency in tournament for selecting the features and increases the exploitation.

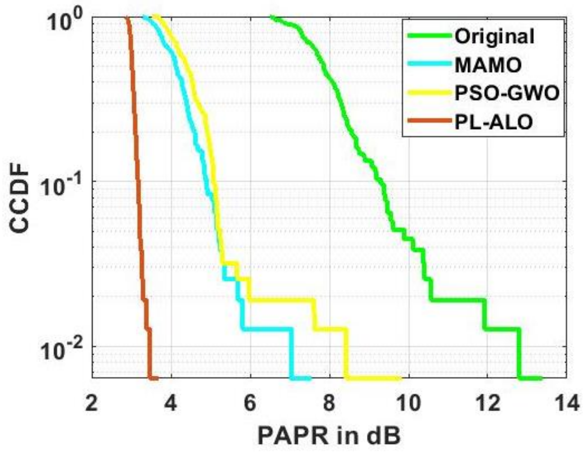

Figure. 11 PL-ALO method and existing method comparison on M=64

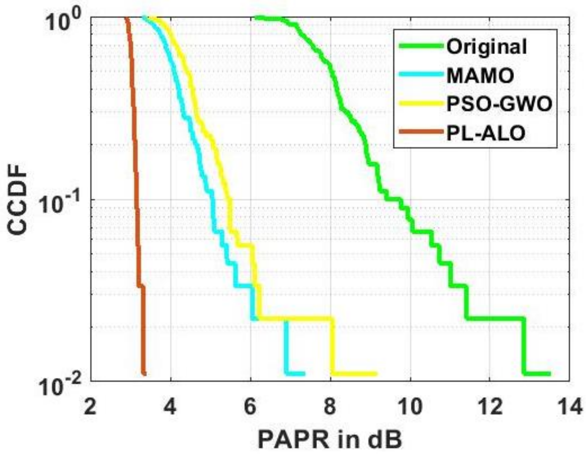

Figure. 12 PL-ALO method and existing method comparison on M=128

Table 1. Comparative analysis

Methods	PAPR (dB)
Improved ACO [14]	6.12
DIWO-PTS [16]	6.45
PTS-DPSO-TH [17]	6.23
ALO	3.96
PL-ALO	3.09

5. Conclusion

The OFDM system has many advantages in a communication system such as immune to impulse interference, robustness to channel fading, and high spectral efficiency. The existing methods have a limitation of local optima trap in the system that degrades the performance. This research proposed the PL-ALO method to increase the exploitation that improves the performance of the model. The tournament selection technique is applied in the PL-ALO method that performs tournaments among the best search agents to increase the exploitation. The tournament selection method helps to find the potential solution to overcome the local optima trap and increase the system efficiency. The PL-ALO method has higher efficiency than existing optimization methods such as PSO-GWO and MOMA in the optimization of the MIMO-OFDM system. The average convergence rate of PTS- PL-ALO is 2.846, MOMA is 6.084, and PSO-GWO is 5.943. The proposed algorithm-based antenna grouped with the PTS technique can be implemented in a massive MIMO system in the future for the improvement of the present system. The blind channel estimation can be included in the future work of this model to improve its efficiency.

Notation

Symbol	Description
b_{up}	upper boundary
b_v	partial sequences of phase factors
$f\ (Ant)_i^t$	fitness of ants
$f\ (Antlion)_i^t$	antlion fitness
$F(u, v)$	frequency coefficient
i	Antlion
k	Block
l	oversampling operation
n^{th}	Sample
r	received signal
$sgn(.)$	signum function
t	Iteration
u and v	frequency-domain of sampling values
V	sub-frames
X	Sequence
x	symbols of time-domain
$x(v)$	time-domain sequence
z	signal maximum amplitude

Conflicts of Interest

The authors declare no conflict of interest.

Author Contributions

The paper background work, conceptualization, methodology, dataset collection, implementation, result analysis and comparison, preparing and editing draft, visualization have been done by first. The supervision, review of work and project administration, have been done by second author.

References

[1] N. Taşpınar and Ş. Şimşir, “Pilot tones design using particle swarm optimization for OFDM–IDMA system”, *Neural Computing and Applications*, Vol. 31, No. 9, pp. 5299-5308, 2019.

[2] A. Mohammed, T. Ismail, A. Nassar, and H. Mostafa, “A novel companding technique to reduce the high peak to average power ratio in OFDM systems”, *IEEE Access*, Vol. 9, pp. 35217-35228, 2021.

[3] H. Li, W. Cai, Y. Liu, M. Li, Q. Liu, and Q. Wu, “Intelligent reflecting surface enhanced wideband MIMO-OFDM communications: From practical model to reflection optimization”, *IEEE Transactions on Communications*, Vol. 69, No. 7, pp. 4807-4820, 2021.

[4] K. Liu and Y. A. Liu, “Adjustable nonlinear companding transform based on scaling of probability density function for PAPR reduction in OFDM systems”, *IEEE Transactions on Broadcasting*, Vol. 67, No. 2, pp. 524-537, 2021.

[5] N. Taşpınar and Ş. Şimşir, “Dual symbol optimization-based partial transmit sequence technique for PAPR reduction in WOLA-OFDM waveform”, *International Journal of Communication Systems*, Vol. 32, No. 14, p. e4081, 2019.

[6] R. Jiang, X. Wang, S. Cao, J. Zhao, and X. Li, “Joint compressed sensing and enhanced whale optimization algorithm for pilot allocation in underwater acoustic OFDM systems”, *IEEE Access*, Vol. 7, pp. 95779-95796, 2019.

[7] Y. Huang and B. Su, “Circularly pulse-shaped precoding for OFDM: A new waveform and its optimization design for 5G new radio”, *IEEE Access*, Vol. 6, pp. 44129-44146, 2018.

[8] H. Emami and A. A. Sharifi, “An improved backtracking search optimization algorithm for cubic metric reduction of OFDM signals”, *ICT Express*, Vol. 6, No. 3, pp. 258-261, 2020.

[9] Y. Wang, Y. Wang, and Q. Shi, “Optimized signal distortion for PAPR reduction of OFDM signals with IFFT/FFT complexity via ADMM approaches”, *IEEE Transactions on Signal Processing*, Vol. 67, No. 2, pp. 399-414, 2018.

[10] Z. Na, X. Wang, J. Shi, C. Liu, Y. Liu, and Z. Gao, “Joint resource allocation for cognitive OFDM-NOMA systems with energy harvesting in green IoT”, *Ad Hoc Networks*, Vol. 107, p. 102221, 2020.

[11] A. A. Sharifi, and H. Emami, “PAPR reduction of asymmetrically clipped optical OFDM signals: Optimizing PTS technique using

improved flower pollination algorithm", *Optics Communications*, Vol. 474, p. 126057, 2020.

[12] A. K. Abed, R. Mansoor, and A. K. Abed, "Particle Swarm Optimization-based dummy sub-carriers insertion for peak to average power ratio reduction in OFDM systems", *ICT Express*, Vol. 8, No. 1, pp. 135-141, 2022.

[13] J. Bai, and S. Yang, "In UOWC systems: A combined PAPR reduction method by PTS approach based on improved particle swarm optimization", *Optik*, Vol. 232, p. 166581, 2021.

[14] M. H. Aghdam, and A. A. Sharifi, "A novel ant colony optimization algorithm for PAPR reduction of OFDM signals", *International Journal of Communication Systems*, Vol. 34, No. 1, p. e4648, 2021.

[15] M. Sarkar, A. Kumar, and B. Maji, "PAPR reduction using twin symbol hybrid optimization-based PTS and multi-chaotic-DFT sequence-based encryption in CP-OFDM system", *Photonic Network Communications*, Vol. 41, No. 2, pp. 148-162, 2021.

[16] S. Şimşir and N. Taşpınar, "An improved PTS scheme based on a novel discrete invasive weed optimization algorithm for PAPR reduction in the UFMC signal", *Neural Computing and Applications*, Vol. 33, No. 23, pp. 16403-16424, 2021.

[17] L. Li, L. Xue, X. Chen, and D. Yuan, "Partial transmit sequence based on discrete particle swarm optimization with threshold about PAPR reduction in FBMC/OQAM system", *IET Communications*, Vol .16, No. 2, pp. 142-150, 2022.

[18] F. A. Zeidabadi, S. A. Doumari, M. Dehghani, and O. P. Malik, "MLBO: Mixed Leader Based Optimizer for Solving Optimization Problems", *International Journal of Intelligent Engineering and Systems*, Vol. 14, No. 4, pp. 472- 479, 2021, doi: 10.22266/ijies2021.0831.41.

[19] F. A. Zeidabadi, M. Dehghani, and O. P. Malik, "TIMBO: Three Influential Members Based Optimizer", *International Journal of Intelligent Engineering and Systems*, Vol. 14, No. 5, pp. 121-128, 2021, doi: 10.22266/ijies2021.1031.12.

[20] M. Dehghani, Z. Montazeri, H. Givi, J. M. Guerrero, and G. Dhiman, "Darts Game Optimizer: A New Optimization Technique Based on Darts Game", *International Journal of Intelligent Engineering and Systems*, Vol. 13, No. 5, pp. 286-294, 2020, doi: 10.22266/ijies2020.1031.26.

[21] S. A. Doumari, F. A. Zeidabadi, M. Dehghani, and O. P. Malik, "Mixed Best Members Based Optimizer for Solving Various Optimization Problems", *International Journal of Intelligent Engineering and Systems*, Vol. 14, No. 4, pp. 384-392, 2021, doi: 10.22266/ijies2021.0831.34.

[22] M. Dehghani, Z. Montazeri, A. Dehghani, R. A. R. Mendoza, H. Samet, J. M. Guerrero, and G. Dhiman, "MLO: Multi Leader Optimizer", *International Journal of Intelligent Engineering and Systems*, Vol. 13, No. 6, pp. 364-373, 2020, doi: 10.22266/ijies2020.1231.32.

[23] F. A. Zeidabadi, M. Dehghani, and O. P. Malik, "RSLBO: Random Selected Leader Based Optimizer", *International Journal of Intelligent Engineering and Systems*, Vol. 14, No. 5, pp. 529-538, 2021, doi: 10.22266/ijies2021.1031.46.

[24] Q. T. Nguyen and M. P. Bui, "Performance of Equilibrium Optimizer for the Traveling Salesman Problem", *International Journal of Intelligent Engineering and Systems*, Vol. 14, No. 5, pp. 46-55, 2021, doi: 10.22266/ijies2021.1031.05.

[25] B. K. Kihel, S. K., Kihel, and S. Chouraqui, "Immune Grey Wolf Optimizer for Attribute Reduction: Application for Medical Systems", *International Journal of Intelligent Engineering and Systems*, Vol. 14, No. 4, pp. 35-43, 2021, doi: 10.22266/ijies2021.0831.04.

[26] M. R. Khan and B. Das, "Multiuser detection for MIMO-OFDM system in underwater communication using a hybrid bionic binary spotted hyena optimizer", *Journal of Bionic Engineering*, Vol. 18, No. 2, pp. 462-472, 2021.

[27] C. He, Z. Ahmed, and S. Collins, "Signal pre-equalization in a silicon photomultiplier-based optical OFDM system", *IEEE Access*, Vol. 9, pp. 23344-23356, 2021.

[28] Z. A. Qasem, H. A. Leftah, H. Sun, and H. Esmaiel, "Precoded IM-OFDM-SS for Underwater Acoustic Communication", *Wireless Communications and Mobile Computing*, Vol. 2022, 2022.

[29] P. Biswas, S. Rathore, and M. R. Khan, "A novel approach of various QAM with roll off factor variation using raised cosine filter and SRRC filter for analysis of BER and SNR", *Materials Today: Proceedings, In Press*, 2021

[30] N. A. Harthi, Z. Zhang, D. Kim, and S. Choi, "Peak-to-average power ratio reduction method based on partial transmit sequence and discrete Fourier transform spreading", *Electronics*, Vol. 10, No. 6, p. 642, 2021.

[31] T. Alameri, N. S. Ali, M. L. Attiah, M. S. Talib, and J. K. Mezaal, "Low Complexity Rotation Algorithm for PAPR Reducing Performance in Partial Transmits Sequence", *Wireless Personal*

Communications, Vol. 124, pp. 1169–1190, 2022.

[32] Q. Li, D. Li, K. Zhao, L. Wang, and K. Wang, "State of health estimation of lithium-ion battery based on improved ant lion optimization and support vector regression", *Journal of Energy Storage*, Vol. 50, p. 104215, 2022.

[33] L. Abualigah, and A. Diabat, "A novel hybrid antlion optimization algorithm for multi-objective task scheduling problems in cloud computing environments", *Cluster Computing*, Vol. 24, No. 1, pp. 205-223, 2021.

[34] L. M. E. Bakrawy, M. A. Cifci, S. Kausar, S. Hussain, M. A. Islam, B. Alatas, and A. S. Desuky, "A Modified Ant Lion Optimization Method and Its Application for Instance Reduction Problem in Balanced and Imbalanced Data", *Axioms*, Vol. 11, No. 3, p. 95, 2022.

[35] Z. T. Ibraheem, K. K. Ahmed, Y. Fazea, M. Madi, F. Mohammed, and A. Q. Ali, "Boosted PTS Method with Mu-Law Companding Techniques for PAPR Reduction in OFDM Systems", *Wireless Personal Communications*, Vol. 124, pp. 423-436, 2022.