https://doi.org/10.31436/iiumej.v24i1.2625

MULTI-OBJECTIVE MAYFLY OPTIMIZATION IN PHASE OPTIMIZATION OF OFDM

ABDUL AZEEZ* AND SURAIYA TARANNUM

Department of Electronics and Communication Engineering, HKBK College of Engineering, Bangalore, 560045, India

**Corresponding author: abdulazeez.ec@hkbk.edu.in*

(Received: 10th October 2022; Accepted: 8th November 2022; Published on-line: 4th January 2023)

ABSTRACT: Communication systems have been used tremendously in recent years which results in the need for high data transmission rates. Orthogonal Frequency Division Multiplexing (OFDM) provides robust performance in frequency selective fading due to high bandwidth efficiency and inter-symbol interference. Various optimization techniques were applied in existing research to increase the efficiency of OFDM in a communication system. The existing research has a limitation of considering a single objective to improve the efficiency of OFDM and also has a local optima trap. This research proposes a Multi-Objective Mayfly algorithm (MOMF) to consider multi-objective and provides a proper trade-off between exploration and exploitation. The Partial Transmit Sequence (PTS) is applied in the model to test the performance. The FFT sizes and modulation orders are varied to evaluate the performance of the MOMF technique in phase optimization. The MOMF technique effectively increases the performance of the model than other existing optimization techniques. The MOMF technique provides a non-dominated solution to escape from local optima trap. The MOMF model considers PAPR, BER, and SER in MIMO-OFDM system to increase the efficiency of the system. The exploration-exploitation trade-off helps to improve the convergence and overcome local optima trap. The MOMF in OFDM phase optimization was evaluated using BER, SER, and Peak-to-Average Power Ratio (PAPR) metrics. The MOMF method has PAPR of 3.95 dB and PSO-GWO method has 4.92 dB of PAPR.

ABSTRAK: Sistem komunikasi telah digunakan secara meluas sejak beberapa tahun ini dan dapatan kajian menunjukkan keperluan pada kadar transmisi data yang tinggi. Pemultipleksan Bahagian Frekuensi Ortogon (OFDM) menyediakan prestasi berkesan dalam pemilihan pemudaran frekuensi berdasarkan keberkesanan lebar jalur tinggi dan gangguan antara-simbol. Pelbagai teknik optimum digunakan pada kajian sebelum ini bagi meningkatkan keberkesanan OFDM dalam sistem komunikasi. Kajian tersebut mempunyai kekurangan dalam memilih satu objektif bagi membaiki keberkesanan OFDM dan juga mempunyai perangkap optima setempat. Kajian ini mencadangkan algoritma Mayfly Objektif-Pelbagai (MOMF) bagi memilih objektif-pelbagai dan menyediakan keseimbangan yang wajar antara eksplorasi dan eksploitasi. Urutan Pancar Separa (PTS) telah digunakan dalam model ini bagi menguji prestasi. Saiz FFT dan turutan modulasi dipelbagaikan bagi menguji keberkesanan teknik MOMF pada fasa pengoptimuman. Teknik MOMF dengan berkesan menaikkan prestasi model ini berbanding teknik-teknik sedia ada yang lain. Teknik MOMF menyediakan solusi kepada teknik bukan-dominasi bagi mengelak perangkap optima setempat. Model MOMF ini mengambil kira PAPR, BER, dan SER dalam sistem MIMO-OFDM bagi meningkatkan kecekapan sistem. Keseimbangan yang wajar antara eksplorasi-eksploitasi membantu dalam membaiki penumpuan dan mengatasi perangkap optima setempat. MOMF dalam fasa optimanisasi OFDM telah dinilai menggunakan BER, SER, dan matrik Nisbah Kuasa Puncak-kepada-Purata (PAPR). Kaedah MOMF mempunyai nilai PAPR sebanyak 3.95 dB dan kaedah PSO-GWO mempunyai PAPR 4.92 dB.

KEYWORDS: *exploration; multi-objective mayfly algorithm; OFDM phase optimization; partial transmit sequence*

1. INTRODUCTION

Smart grid systems, Digital Audio Broadcasting (DAB), LTE, 3GPP, Wi-MAX, Wireless LAN, and Terrestrial Digital Video Broadcasting (DVB-T) of various wireless broadband communication systems are applied with the OFDM technique to improve their efficiency. OFDM systems have superior qualities and have a limitation of high PAPR for RF signals. OFDM has amplitude variation in the time domain due to its multicarrier nature and also has a large dynamic range or PAPR [1]. The OFDM signal is clipped when applied to a non-linear High-Power Amplifier (HPA) if high PAPR degrades the in-band distortion and out-of-band radiation. A wide dynamic range of expensive linear HPA is required in OFDM transmitters for efficient performance [2]. The many PAPR reduction methods of OFDM systems include Selective Mapping (SLM), PTS, tone reservation and tone injection, non-linear companding, coding, and clipping [3]. The PTS and SLM are popular distortionless techniques that received substantial attention due to decrease in PAPR without BER degradation. High computation complexity and Side Information (SI) are major limitations in these techniques. The complexities of the PTS and SLM PAPR reduction methods are compared, in which the comparison shows that the PTS method has lower complexity and the SLM method has high PAPR reduction [4,5].

Less search complexity of several optimization methods has been recently developed to optimize the PTS method for CM reduction and PAPR reduction in OFDM systems. Some of the optimization methods are Grey Wolf Optimization (GWO), Tabu Search (TS), Harmony Search (HS), Adaptive Particle Swarm Optimization (APSO), and Hybrid Genetic Algorithm (HGA) [6,7]. OFDM of Multiple-Input Multiple-Output (MIMO) has received wide attention due to its advantages such as channel fading robustness, fading environment diversity, spectral efficiency and high data rate. However, the OFDM-MIMO also suffers from disadvantages such as high envelope fluctuations in a transmitted signal called PAPR that decreases the HPA efficiency, increases complexity of non-linear elements and Bit Error Rate (BER) degradation occurs from out-of-band radiation [8-10]. The contribution of this research is discussed below.

- The MOMF method is proposed to consider PAPR, BER, and SER in the MIMO-OFDM system to increase the efficiency of the model. The MOMF method provides a proper exploration-exploitation trade-off that improves the efficiency of the optimization.
- The exploration-exploitation trade-off process improves the convergence rate of the method and escapes from local optima trap. The MOMF method has higher efficiency compared to existing methods in optimization of MIMO-OFDM systems.

2. LITERATURE REVIEW

OFDM is a reliable and robust multicarrier modulation method that is sufficient for broadband communication. Various methods applied in OFDM for phase optimization are discussed in this section.

Lavanya et al. [11] applied Improved Monarch Butterfly Optimization (IMBO) method for PAPR reduction in the OFDM framework. The IMBO method was efficient for optimal character fusion of phase rotation factor for minimizing computation. The IMBO method provides efficient search optimization, and using optimum phase factor and phase weighting method with less complexity. The IMBO method significantly reduces the PAPR and computational complexity. Sorting was carried out twice with the Monarch Butterfly Optimization method during every generation. The IMBO method applies Random Local Perturbation (RLP) and Opposition-Based Learning (OBL) to solve the sorting problem.

Ali and Hamza [12] applied Teaching Learning Based Optimization (TLBO) for PAPR reduction in OFDM optimization. The TLBO method has the advantage of less computational effort and no algorithm-specific parameter requirement. The TLBO consists of two-phases, teacher and learner phases, for learning the input data. The interaction between teacher and student is the teaching phase, and the interaction between the learners is the learning phase. The TLBO based method was applied to obtain the phase factor of optimum rotation in the SLM method for PAPR reduction. The TLBO-SLM method achieved considerably better performance in PAPR reduction.

Sharif and Emami [13] proposed the Improved Flower Pollination (IFP) algorithm to reduce the search complexity of Partial Transmit Sequence (PTS). The ACO-OFDM method was applied with PTS technique to reduce high PAPR in the system. The IFP method was derived from flower pollination behaviors and an asymmetrical clipped optical OFDM system was applied in IFP. The IFP method increased the optimization capability of standard flower pollination using a local pollination operator to increase exploitation ability and the global pollination phase was applied to increase exploration. The IFP method balanced the exploitation and exploration capacity of the optimization method. The IFP method had less computational complexity than the existing method in OFDM optimization.

Emami and Sharif [14] applied a Tree Growth Optimization (TGO) method to reduce the computational complexity for the selection of optimal phase factors in PTS. The TGO method was efficient in reducing the high PAPR of optical OFDM signals. The TGO consists of three operators: seed scattering, root spreading, and competition. The solution population was updated by these operators to find near-optimal solutions for optimization problems. The TGO-PTS method dramatically decreased the PAPR of the OFDM signal and had higher performance than existing methods in terms of convergence rate and solution quality.

Emami and Sharif [15] applied a Chaotic Differential Search Algorithm (CDSA) with an efficient and fast convergence optimizer for OFDM optimization. The CDSA method was an optimization technique to solve non-linear, largescale, and complex problems. The CSA method was compared with several optimization methods in terms of mitigation performance and search complexities. The CDSA and PTS were combined to solve the search complexity problem in the conventional method and to control a few parameters for exploring phase factors for the optimal set. The CDSA method had considerable performance in phase optimization than existing methods.

An improved Adaptive Simplified Optimized Iterative Clipping and Filtering (ASOICF) technique has been shown by Padarti and Nandhanavanam [16] to lower PAPR in OFDM systems. Due to its ease of application in the PAPR minimization in OFDM, ICF, between these PAPR reduction techniques, drew a lot of interest. The approach uses Lagrange Multiplier Optimization (LMO), which has the benefit of reducing the number of iterations in a specific way. It was discovered that the PAPR in OFDM signals was greatly reduced by the adaptive technique. The results clearly showed that the suggested approach performed better in terms of computational complexity. The peak of the clipped OFDM affected the noise overhead, therefore, it decreased the BER.

A Regularization Optimization Based Flexible Hybrid Companding and Clipping technique (ROFHCC) employed for PAPR reduction in OFDM systems was developed by Xing et al. [17]. The companding function comprised two components to lessen the complexity of the design. In order to achieve both peak power reduction and small power compensation, it limited the signal samples whose amplitudes exceeded a certain value to a constant value. Signals were extended using a linear companding function for samples below a specified amplitude. In order to jointly optimize the companding distortion and the continuity of the companding function, a regularization optimization model was developed. Nonetheless, the proposed method could not confirm the average power as constant.

3. RESEARCH METHOD

The input signal is applied to LDPC encoding to encode the signal and apply for its modulation. The pilot insertion of the signal is transformed with IFFT and the pilot insertion information is provided as input to the proposed MOMF optimization to find optimal parameter settings. The optimal parameter settings of the MOMF optimization method are applied in the STBC encoder as well as in the AWGN noise channel. The STBC decoding is carried out and cyclic prefix removal is applied. The FFT is applied in the signal and pilot removal is carried out to process the output signal. The block diagram of the MOMF method in phase optimization of OFDM is shown in Fig. 1 and Fig. 2.

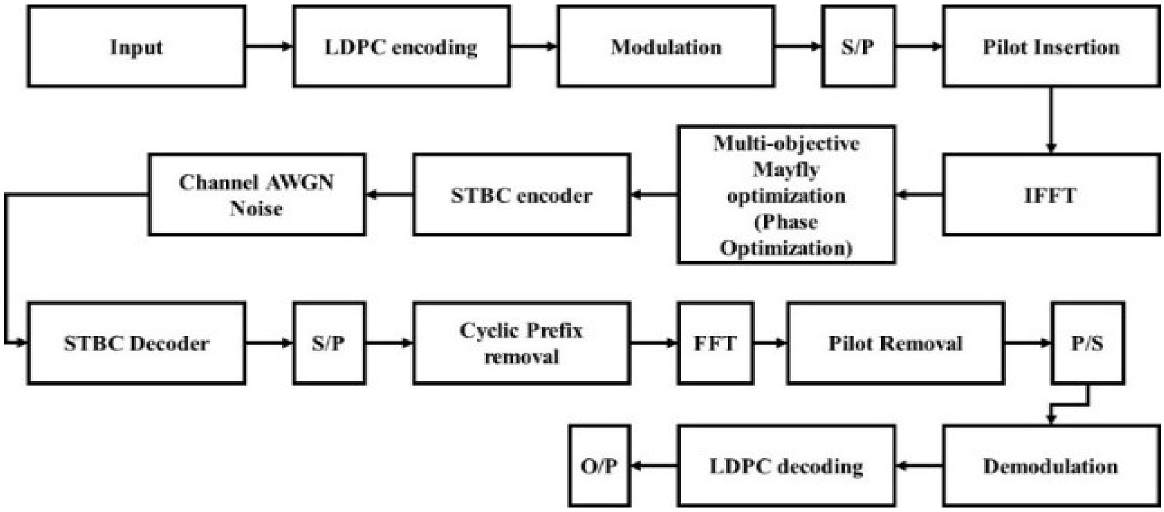

Fig. 1: The MOMF optimization in pilot insertion.

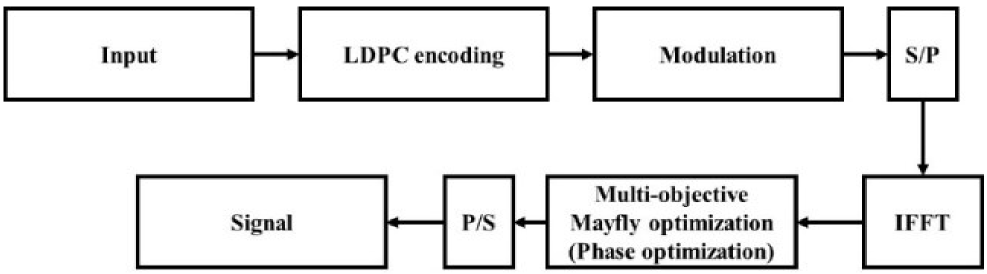

Fig. 2: The MOMF optimization in phase factor of OFDM.

3.1 PAPR in MIMO-OFDM

The subcarriers arrangement of relating subcarriers are adjusted to each signal surrounding the subcarriers M of OFDM data [13], [18], [19]. The MIMO-OFD structure of Orthogonal M subcarriers is over the period of $0 \le p \le G$ where the primary data signal period is denoted as G and the near sub-carriers repeat partitioning is denoted as $T0 = 1/G$. The OFDM movement of complex baseband in M subcarriers is given in Eq. (1).

$$s(p) = \frac{1}{\sqrt{M}} \sum_{n=0}^{M-1} A_n e^{j2\pi n T_o p}, 0 \le p \le G \tag{1}$$

The discrete time adaptation is mentioned as $G_c = G/M$ and substitutes $p = mG_c$ which is expressed in Eq. (2),

$$s(m) = \frac{1}{\sqrt{M}} \sum_{n=0}^{M-1} A_n e^{\frac{j2\pi mn}{DM}}, \quad m = 0, 1, \ldots, MD-1 \tag{2}$$

Wherein, the oversampling element is denoted as D.

Spikes are not found in the inspection of the signal; therefore, it provides optimistic results for PAPR. Fourier change in the OFDM transmits the ordinary power and quick power of PAPR which is given as (p), as in Eq. (3).

$$PAPR = \frac{max_{0 \le p \le G} |a(p)|^2}{E\left[\left|a(p)^2\right|\right]} \tag{3}$$

Wherein, the desire expectation is $E[.]$.

The consistent time of PAPR is not unquestionably registered in the Nyquist inspecting rate which completely depends on OFDM signal. The OFDM signals of PAPR in the Complementary Cumulative Distribution Function (CCDF) are used to improve PAPR reduction accurately. The CCDF probability outperforms the edge of PAPR and is represented in Eq. (4).

$$CCDF\left(PAPR\left(a(t)\right)\right) = p_q\left(PAPR\left(a(t)\right)\right) > PAPR_0 \tag{4}$$

3.2 Partial Transmit Sequences (PTS)

The PAPR diminish technique based on fractional transmit arrangement is PTS. This is based on the original OFDM sequence which is divided into sub-grouping experts and each sub-progression weight is varied until the expert is in optimal value [13,20-22].

Random space of data information is separated into W sub-pieces of non-covering and has comparable size S of each sub-square. The S/W non-zero segments are present in each sub piece and the real part is zero. The sub-squares are given in Eq. (5).

$$\hat{A} = \sum_{W=1}^{W} c_w a_w \tag{5}$$

Here, $c_w = e^{r\partial_w}\left(\partial_w \in [0, 2\pi]\right)\{w = 1, 2, \ldots, w\}$.

Stage pivot of weighting part is denoted as c_w and time range of the signal is applied using IFFT operation on a_w.

A proper part mix $c = [c_1,\ c_2 \ldots c_w]$ is applied to measure the optimal value for PAPR reduction, as in Eq. (6).

$$c = arg \underset{(c_1, c_2, \ldots, c_w)}{min} \left(\underset{1 \le m \le M}{max} \left| \sum_{W=1}^{W} c_w, a_w \right|^2 \right) \tag{6}$$

Wherein, best estimation is found using the condition of $arg\ min(*)$ and by remembering the ultimate objective of c for PAPR execution redesign. Most of the complication arises on the downside and IFFT operations are performed for an extra $W-1$ times.

3.3 Multi-objective Mayfly Algorithm

In Mayfly, the nuptial dance and random flight operations help an algorithm escape local optimums and improve the harmony between its exploitation and exploration features. In this way, Mayfly efficiently identifies the space of each and every sequence of a given phase factor set. While considering the PSO in high-dimensional space, it falls into local optimum and attains a lower convergence rate in the iterative process. Therefore, the proposed MOMF optimization method is applied in the phase factor of OFDM to improve the efficiency of the model, BER, and PAPR. Mayfly group behavior is mimicked to develop the Mayfly algorithm with mating behavior [23-30]. Female and male mayflies are randomly divided from the population at the initial stage of algorithm. All mayflies are randomly scattered in d-dimensional space and $\xi = (\xi_1,\ \xi_2,\ \cdots,\ \xi_d)$ expression is considered for the selection of candidate solutions. The position change $\varpi = (\varpi_1,\ \varpi_2,\ \cdots,\ \varpi_d)$ is represented by the velocity vector.

1) Male mayflies' movement: i^{th} male Mayfly with the position of ξ_i^t at time t and velocity is denoted as ξ_i^t to change i^{th} individual position. Male mayflies $\xi(t+1)$ of position $t+1$ is expressed in Eq. (7).

$$\xi_i^{t+1} = \xi_i^t + \varpi_{i,male}^{t+1} \tag{7}$$

The velocity for j^{th} dimension of i^{th} mayfly is denoted in Eq. (8).

$$\begin{aligned} \varpi_{ij,male}^{t+1} = \varpi_{ij,male}^{t} + a_1 \exp\left(-\beta \rho_p^2\right) \times \left(pbest_{ij} - \xi_{ij}^t\right) + \\ a_2 \exp\left(-\beta \rho_g^2\right) \times \left(gbets_j - \xi_{ij}^t\right) \end{aligned} \tag{8}$$

The position and velocity of j^{th} dimension of i^{th} mayfly are denoted as ξ_{ij}^t and $\varpi_{ij,male}^t$, respectively. The positive attraction constants are denoted as $a_i\ (i = 1,2)$ that respond based on social components and cognitive rules. The global optimal and local optimal positions are $gbest_j$ and $pbest_{ij}$, respectively. A fixed visibility coefficient is denoted as β, that controls individual visibility to other individuals. Cartesian distance is denoted as ρ_p and ρ_g from i^{th} mayfly, respectively for local and global optimal solutions. The global optimal value $gbest_j$ and local optimal value $pbest_{ij}$ are calculated using Eq. (9 & 10).

$$pbest_i = \begin{cases} \xi_i^{t+1} & , \quad if\ \{\phi_{1,\ldots,c}\left(\xi_i^{t+1}\right) < \{\phi_{1,\ldots,c}\left(pbest_i\right)\}\} \\ kept\ the\ same\ , & \qquad otherwise \end{cases} \tag{9}$$

$$gbest \in \left\{ pbest_1, pbest_2, \ldots, pbest_N | \phi_{1,\ldots,c}\left(cbest\right) \right\} = dominate\left\{ \left\{ \phi_{1,\ldots,c}\left(pbest_1\right) \right\}, \left\{ \phi_{1,\ldots,c}\left(pbest_2\right) \right\}, \ldots, \left\{ \phi_{1,\ldots,c}\left(pbest_N\right) \right\} \right\} \tag{10}$$

Wherein, objective functions are represented as $\phi_{1,\ldots,c} : R^n \to R$. To ensure effective operation of the algorithm, the population of optimal mayflies constantly perform the up and down nuptial dance. The optimal mayflies' velocities are changed in the following Eq. (11).

$$\varpi_{ij,male}^{t+1} = \varpi_{ij,male}^{t} + d \times \rho \tag{11}$$

Wherein, the position for j^{th} dimension of i^{th} male mayfly is denoted as $\varpi_{ij,male}^{t}$, a random number of ρ is in the range of [-1, 1], and the nuptial dance coefficient is denoted as d.

2) Movement of female mayflies: For breeding, female individuals move toward males and male mayflies gather in swarms. The corresponding velocity and current position at time t of i^{th} female mayfly are denoted as $\varpi_{i,female}^{t+1}$ and ψ_i^t, respectively. The female mayflies of $(t+1)^{th}$ positions are given in Eq. (12).

$$\psi_i^{t+1} = \psi_i^t + \varpi_{i,female}^{t+1} \tag{12}$$

A deterministic scheme is used to define the attraction process in the Mayfly Algorithm optimization process. The fitness function is used by an optimal female and sub-optimal females to provide a tendency toward male individuals and sub-optimal male individuals. The j^{th} dimension of i^{th} female mayfly velocity is used for a minimization problem, as in Eq. (13).

$$\varpi_{ij,female}^{t+1} = \begin{cases} \varpi_{ij,female}^{t} + a_2 \exp\left(-\beta \rho_{mf}^2\right) \times \left(\xi_{ij}^t - \psi_{ij}^t\right), & if\, \phi\left(\psi_i\right) > \phi\left(\xi\right) \\ \varpi_{ij,female}^{t} + fl \times \rho & , \quad if\, \phi\left(\psi_i\right) \le \phi\left(\xi_i\right) \end{cases} \tag{13}$$

Wherein, the position and velocity for j^{th} dimension of i^{th} female mayfly are denoted as $\varpi_{ij,female}^{t}$ and ψ_{ij}^{t} respectively. The Cartesian distance of i^{th} male mayfly to i^{th} female mayfly is denoted as ρ_{mf}. The random walk coefficient is denoted as fl.

3) Mating of mayflies: Female and male populations are selected as two parents. As per the mating principle, the best male mates with the best female, that creates two offspring as shown in Eq. (14) and Eq. (15).

$$offspring1 = \mu \times male + \left(1 - \mu\right) \times female \tag{14}$$

$$offspring2 = \mu \times female + \left(1 - \mu\right) \times male \tag{15}$$

Wherein, the random value of male and female individuals in the previous generation is represented as $\mu \in \left(0, 1\right)$. Initial individual velocities in the current generation are 0.

4) Multi-objective Mayfly Algorithm: The MOMF is a multi-objective variant of the Mayfly Algorithm based on roulette wheel selection, the strategy of non-dominated sorting, and the archive mechanism. Non-dominated Pareto optimal solution is applied to generate the present iteration and to archive the upper limit. Once a non-dominated

https://doi.org/10.31436/iiumej.v24i1.2625

solution is achieved, it is compared with the present solution. The least values are eliminated and a better solution is archived. Most populated neighborhoods are eliminated using $Pro_i = N_i / \chi,\ \chi > 1$ and when the archive is full, i^{th} individual number of members is denoted as N_i and χ is a constant. The roulette wheel method is used to develop solutions that are added to MOMF. The probability of the roulette wheel is set in Eq. (16).

$$Pro_i = \chi / N_i \tag{16}$$

A solution is selected from a set of non-dominated solutions using a multiple-criteria selection method. Fitness function values are normalized for male and female mayflies in Eq. (17).

$$Fitness_j^{i} = \frac{\left[Fitness_j^{i} - \min_{i \le j \le N} \right]}{\left[\max_{l \le j \le N} \left(Fitness^{i} \right) - \min_{l \le j \le N} \right]} \tag{17}$$

The i^{th} fitness function of normalized value is denoted as $Fitness_j^{i}$ measured from j^{th} female or male mayfly and population size is denoted as N.

The j^{th} female or male mayfly is computed using multiple-criteria (Mc), as in Eq. (18).

$$Mc_j = \sum_{i=1}^{m} Fitness_j^{i} \tag{18}$$

The Mc values are used to sort male and female mayflies in MOMF; the lowest Mc values of mayfly's optimal male and female are obtained from individuals and non-dominated solution.

4. RESULTS AND DISCUSSION

This research applies the MOMF algorithm in phase optimization of OFDM to improve its efficiency. The OFDM parameters are given in Table 1 and parameter settings of MOMF are given in Table 2. Various FFT sizes of 64, 128, 256, 512, and 1024 were used to evaluate MOMF algorithm in OFDM phase optimization.

Table 1: OFDM parameters

FFT size	64, 128, 256, 512, 1024
User carriers	52, 104, 156, 208, 260
Pilot carriers	12, 24, 48, 60, 72
Antenna	2X2, 2X4, 4X2, 4X4
Cyclic prefix or guard time	0 to 2e-6s
Modulation	8 QAM, 16 QAM, 32 QAM, 64 QAM, 256 QAM
Oversampling factor	1e6 HZ
Channel type	Rayleigh Channel
Noise	AWGN

Table 2: MOMF Algorithm

Number of iteration	100
Population Size (males and females)	25 & 25
nPareto (Repository Size)	30
LowerBound	-3
UpperBound	6
g (Inertia Weight)	1
gdamp (Inertia Weight Damping Ratio)	1
a1 (Personal Learning Coefficient)	1.5
a2 & a3 (Global Learning Coefficient)	1.5 & 1.5
beta (Distance sight Coefficient)	0.99
dance (Mutation Coefficient)	0.77
dance_damp (Mutation Coefficient Damping Ratio)	0.77
f1 (Random flight)	0.77
f1_damp (Random flight Damping Ratio)	0.99
% Mating Parameters	-
nCrossover (Number of Parnets (Offsprings))	4
nMutation (Number of Mutants)	round (0.4*nPop)
mu (Mutation Rate)	0.001

The MOMF optimization method is applied in the phase factor of OFDM to improve the efficiency of the model and BER is shown in Fig. 3. The DCT and FFT techniques have higher efficiency in MOMF methods. The DWT has lower efficiency in the phase optimization of OFDM.

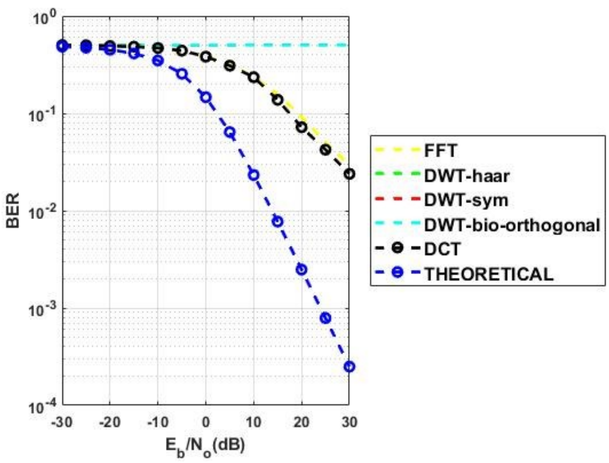

Fig. 3: The BER of MOMF optimization with various techniques.

Figures 4, 5 and 6 show BER, SER and PAPR of MOMF in FFT 128 M8 modulation of OFDM phase optimization. The MOMF has a higher convergence rate and overcomes local optima trap. The existing GWO method has a trap in local optima and PSO has lower convergence in optimization. The MOMF method reduces the PAPR compared to existing methods in OFDM phase optimization.

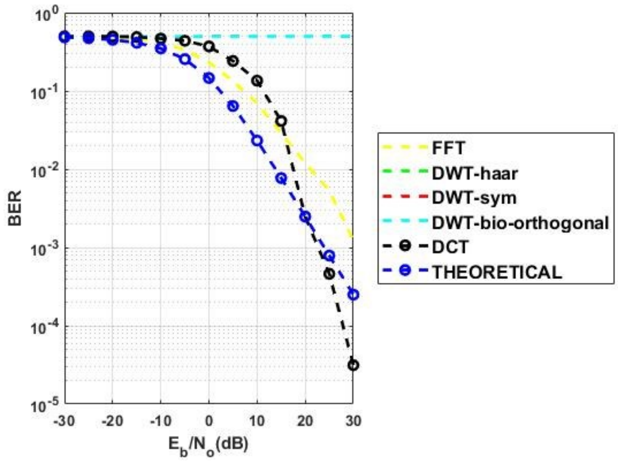

Fig. 4: BER of FFT 128 M8 modulation.

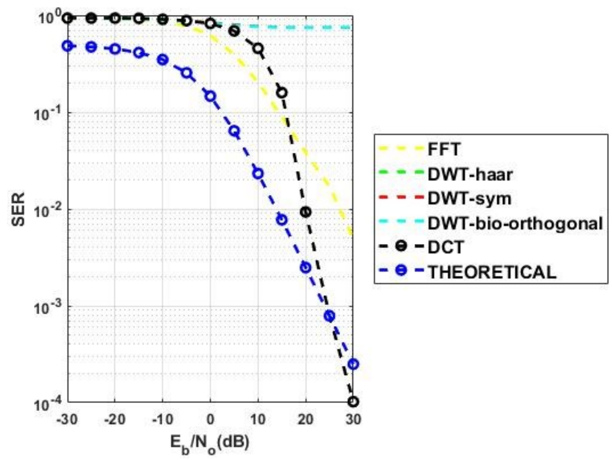

Fig. 5: Symbol error rate of FFT 128 M8 modulation.

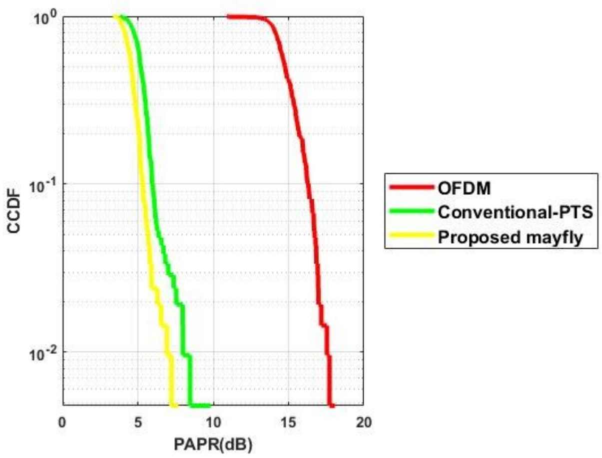

Fig. 6: MOMF PAPR of FFT 128 M8 modulation.

Table 3 shows the difference in PAPR reduction achieved by various methods including PTS, PSO, GWO, PSO-GWO and Proposed MOMF. Table 3 clearly shows that the PAPR reduction of proposed MOMF achieved a value of 3.9537 dB which is much better when compared to specified methods.

Table 3: Results of PAPR on FFT 64 M16 modulation

Methods	PAPR (dB)
MIMO-OFDM	7.8345
PTS	5.0140
PSO	5.0168
GWO	5.1163
PSO-GWO	4.9222
Proposed MOMF	3.9537

The MOMF optimization method is measured with BER and PAPR in FFT 128 M256 modulation, as in Fig. 7 and Fig. 8. The MOMF method provides higher efficiency in FFT 128 compared to existing methods. The MOMF method has the advantages of high convergence and overcoming local optima trap.

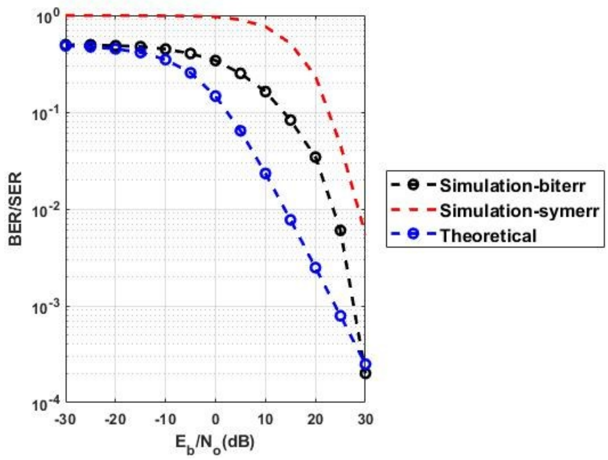

Fig. 7: MOMF BER of FFT 128 M256 modulation.

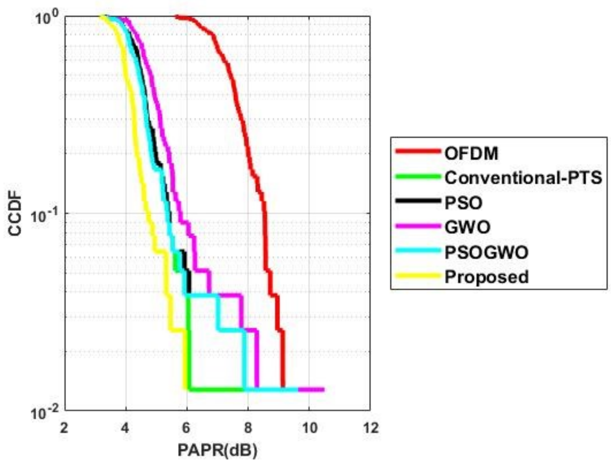

Fig. 8: MOMF PAPR of FFT 128 M256 modulation.

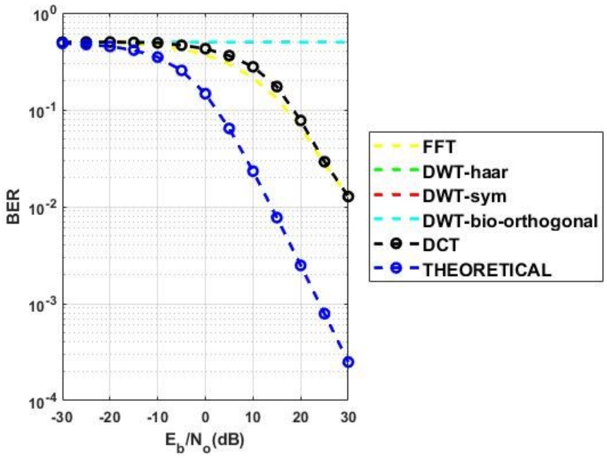

Fig. 9: MOMF BER of FFT 512.

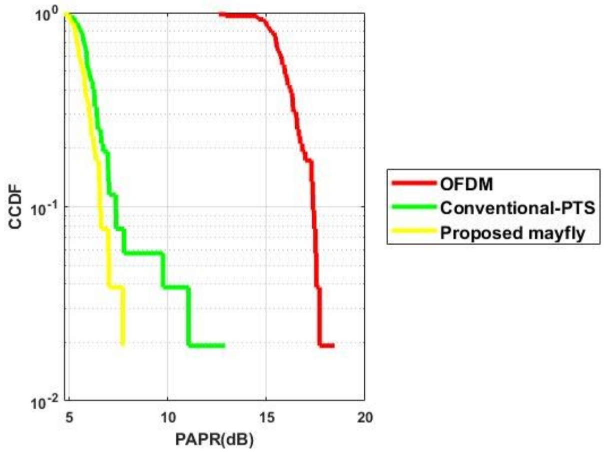

Fig. 10: MOMF PAPR of FFT 512.

The MOMF BER and PAPR in FFT 512 in OFDM phase optimization are given in Fig. 9 and Fig. 10. The MOMF method has the advantages of higher convergence and overcoming local optima trap. The GWO method is easily trapped into local optima and PSO method has lower convergence.

The MOMF method in OFDM phase optimization for M8 and M64 modulation are shown in Fig. 11 and Fig. 12. The MOMF method provides a higher efficiency in both modulations than existing methods.

The MOMF BER and PAPR of FFT 1024 in OFDM phase optimization are shown in Fig. 13 and Fig. 14. The MOMF method considers various parameters in OFDM to reduce BER, SER and PAPR. The existing methods consider a single objective and have a limitation of local optima trap.

The MOMF BER of FFT 1024 M128 modulation in OFDM phase optimization is given in Fig. 15. The MOMF method has lower BER due to the consideration of multi-objective optimization and has higher convergence.

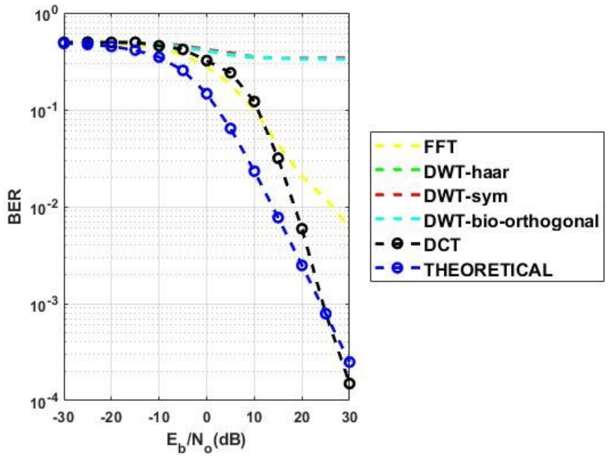

Fig. 11: MOMF BER of FFT 512 M8 modulation.

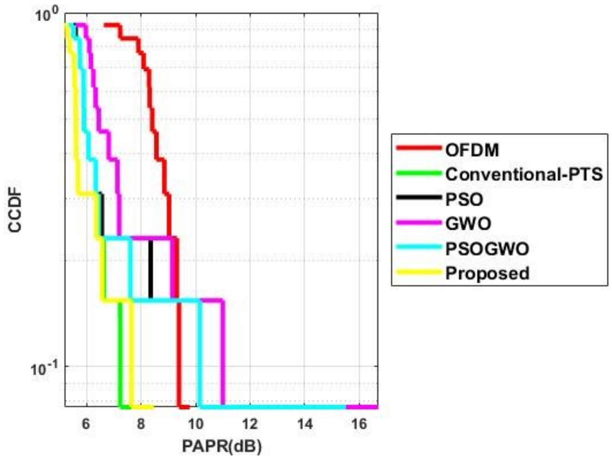

Fig. 12: MOMF PAPR of FFT 512 M64.

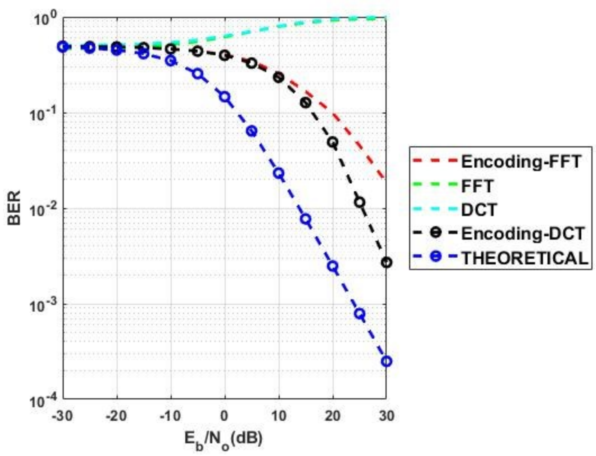

Fig. 13: MOMF BER of FFT 1024.

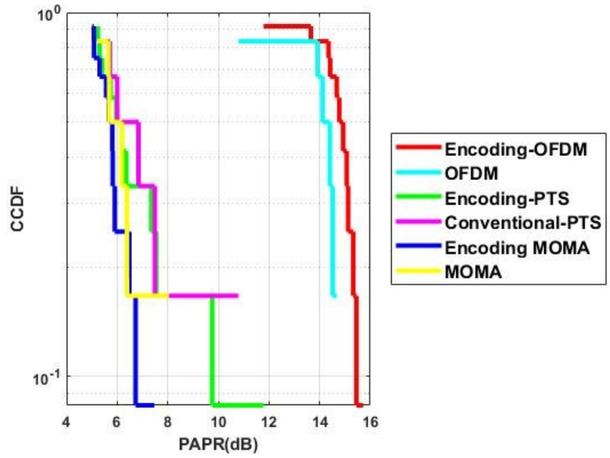

Fig. 14: MOMF PAPR of FFT 1024.

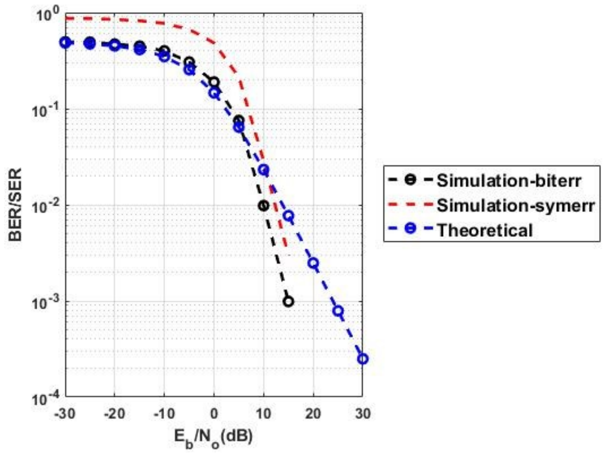

Fig. 15: MOMF BER of FFT 1024 M128.

In order to properly balance exploration and exploitation, this research suggests using the Multi-Objective Mayfly algorithm (MOMF), which takes many objectives into account. The model applies the Partial Transmit Sequence (PTS) to test performance. To assess the effectiveness of the MOMF technique in phase optimization, several FFT widths and modulation orders are used. When compared to other optimization strategies, the proposed MOMF technique significantly improves model performance. From the result analysis, it clearly shows that various FFT sizes of 64, 128, 256, 512, and 1024 are used to evaluate MOMF algorithm in terms of BER and PAPR. The proposed strategy is a better way to achieve a better trade-off between PAPR reduction and computing complexity, according to simulation results.

5. CONCLUSION

The existing methods in OFDM apply optimization methods to improve the efficiency of the OFDM. The existing methods have limitations of considering a single objective in optimization and also have a local optima trap. This research proposes the MOMF algorithm to increase the efficiency of OFDM phase optimization by considering multiple objectives. The MOMF method balances the exploration and exploitation in the search process of optimization. The MOMF method considers three objectives for OFDM phase optimization: BER, SER, and

PAPR. The MOMF method is evaluated in various FFT and modulations in the OFDM. The MOMF method provides higher performance in the OFDM phase optimization than existing methods. The GWO method has the limitation of a local optima trap and the PSO method has lower convergence. The MOMF method balances the trade-off between exploration and exploitation that increases the convergence and overcomes the local optima trap. The future work of this research involves applying the enhanced Artificial Bee Colony method to improve the efficiency of the MIMO-OFDM system.

REFERENCES

[1] Singh M, Patra SK. (2018) On the PTS optimization using the firefly algorithm for PAPR reduction in OFDM systems. IETE Tech. Rev., 35(5): 441-455. https://doi.org/10.1080/02564602.2018.1505563.

[2] Aghdam MH, Sharifi AA. (2019) PAPR reduction in OFDM systems: An efficient PTS approach based on particle swarm optimization. ICT Express, 5(3): 178-181. https://doi.org/10.1016/j.icte.2018.10.003.

[3] Wu W, Cao Y, Wang S, Wang Y. (2018) Joint optimization of PAPR reduction based on modified TR scheme for MIMO-OFDM radar. Digital Signal Process., 80: 27-36. https://doi.org/10.1016/j.dsp.2018.05.008.

[4] Ahmed MS, Boussakta S, Al-Dweik A, Sharif B, Tsimenidis CC. (2019) Efficient design of selective mapping and partial transmit sequence using T-OFDM. IEEE Trans. Veh. Technol., 69(3): 2636-2648. doi: 10.1109/TVT.2019.2928361.

[5] Hu W, Li F, Jiang Y. (2021) Phase Rotations of SVD-Based Precoders in MIMO-OFDM for Improved Channel Estimation. IEEE Wireless Commun. Lett., 10(8): 1805-1809. DOI: 10.1109/LWC.2021.3081583.

[6] Emami H, Sharifi AA. (2020) An improved backtracking search optimization algorithm for cubic metric reduction of OFDM signals. ICT Express, 6(3): 258-261. https://doi.org/10.1016/j.icte.2020.03.001.

[7] Sarkar M, Kumar A, Maji B. (2021) PAPR reduction using twin symbol hybrid optimization-based PTS and multi-chaotic-DFT sequence-based encryption in CP-OFDM system. Photonic Network Communications, 41(2): 148-162. https://doi.org/10.1007/s11107-020-00923-7.

[8] Amhaimar L, Ahyoud S, Elyaakoubi A, Kaabal A, Attari K, Asselman A. (2018) PAPR reduction using fireworks search optimization algorithm in MIMO-OFDM systems. J. Electr. Comput. Eng., 2018: 3075890. https://doi.org/10.1155/2018/3075890.

[9] Geetha MN, Mahadevaswamy UB. (2020) Performance evaluation and analysis of peak to average power reduction in OFDM signal. Wireless Personal Communications, 112(4): 2071-2089. https://doi.org/10.1007/s11277-020-07140-5.

[10] Du J, Xu W, Zhao C, Vandendorpe, L. (2019) Weighted spectral efficiency optimization for hybrid beamforming in multiuser massive MIMO-OFDM systems. IEEE Trans. Veh. Technol., 68(10): 9698-9712. DOI: 10.1109/TVT.2019.2932128.

[11] Lavanya P, Satyanarayana P, Mohatram M. (2022) Peak to average power ratio reduction of ZT DFT-s-OFDM signals using improved monarch butterfly optimization-PTS scheme. J. Ambient Intell. Hum. Comput. https://doi.org/10.1007/s12652-022-03954-2.

[12] Ali TH, Hamza A. (2021) Low-complexity PAPR reduction method based on the TLBO algorithm for an OFDM signal. Ann. Telecommun., 76(1): 19-26. https://doi.org/10.1007/s12243-020-00777-0.

[13] Sharifi AA, Emami H. (2020) PAPR reduction of asymmetrically clipped optical OFDM signals: Optimizing PTS technique using improved flower pollination algorithm. Opt. Commun., 474: 126057. https://doi.org/10.1016/j.optcom.2020.126057.

[14] Emami H, Sharifi AA. (2020) A novel bio-inspired optimization algorithm for solving peak-to-average power ratio problem in DC-biased optical systems. Opt. Fiber Technol., 60: 102383. https://doi.org/10.1016/j.yofte.2020.102383.

[15] Emami H, Sharifi AA. (2020) Optimizing cubic metric in orthogonal frequency division multiplexing systems using chaotic differential search algorithm. Phys. Commun., 43: 101231. https://doi.org/10.1016/j.phycom.2020.101231.
[16] Padarti VK, Nandhanavanam VR. (2021) An improved ASOICF algorithm for PAPR reduction in OFDM systems. Int. J Intell. Eng. Syst., 14: 352-360. https://doi.org/10.22266/ijies2021.0430.32
[17] Xing Z, Liu K, Rajasekaran AS, Yanikomeroglu H, Liu Y. (2021) A hybrid companding and clipping scheme for PAPR reduction in OFDM systems. IEEE Access, 9: 61565-61576. https://doi.org/10.1109/ACCESS.2021.3074009
[18] Yuan Y, Wei S, Luo X, Xu Z, Guan X. (2022) Adaptive PTS scheme based on fuzzy neural network for PAPR reduction in OFDM system. Digital Signal Process., 126: 103492. https://doi.org/10.1016/j.dsp.2022.103492.
[19] Carcangiu S, Fanni A, Montisci A. (2022) A Closed Form Selected Mapping Algorithm for PAPR Reduction in OFDM Multicarrier Transmission. Energies, 15(5): 1938. https://doi.org/10.3390/en15051938.
[20] Murad M, Tasadduq IA, Otero P. (2022) Ciphered BCH Codes for PAPR Reduction in the OFDM in Underwater Acoustic Channels. J. Mar. Sci. Eng., 10(1): 91. https:// doi.org/10.3390/jmse10010091.
[21] Aghdam MH, Sharifi AA. (2021) A novel ant colony optimization algorithm for PAPR reduction of OFDM signals. Int. J. Commun. Syst., 34(1): e4648. https://doi.org/10.1002/dac.4648.
[22] Wu Y, Hu Y, Wan Z, Wang T, Sun Y, Zhang Q. (2022) Joint security enhancement and PAPR mitigation for OFDM-NOMA VLC systems. Opt. Commun., 508: 127719. https://doi.org/10.1016/j.optcom.2021.127719.
[23] Kumar C, Karpurapu A, Singh YP. (2022) Reduction of PAPR for FBMC-OQAM system using Ant Colony Optimisation technique. Soft Comput., 26(9): 4295-4302. https://doi.org/10.1007/s00500-021-06503-9.
[24] Elaziz MA, Senthilraja S, Zayed ME, Elsheikh AH, Mostafa RR, Lu S. (2021) A new random vector functional link integrated with mayfly optimization algorithm for performance prediction of solar photovoltaic thermal collector combined with electrolytic hydrogen production system. Appl. Therm. Eng., 193: 117055. https://doi.org/10.1016/j.applthermaleng.2021.117055.
[25] Shaheen MAM, Hasanien HM, El Moursi MS, El Fergany AA. (2021) Precise modeling of PEM fuel cell using improved chaotic MayFly optimization algorithm. Int. J. Energy Res., 45(13): 18754-18769. https://doi.org/10.1002/er.6987.
[26] Liu Z, Jiang P, Wang J, Zhang L. (2021) Ensemble forecasting system for short-term wind speed forecasting based on optimal sub-model selection and multi-objective version of mayfly optimization algorithm. Expert Syst. Appl., 177: 114974. https://doi.org/10.1016/j.eswa.2021.114974
[27] Adnan RM, Kisi O, Mostafa RR, Ahmed AN, El-Shafie A. (2022) The potential of a novel support vector machine trained with modified mayfly optimization algorithm for streamflow prediction. Hydrol. Sci. J., 67(2): 161-174. https://doi.org/10.1080/02626667.2021.2012182
[28] Wei D, Ji J, Fang J, Yousefi N. (2021) Evaluation and optimization of PEM Fuel Cell-based CCHP system based on Modified Mayfly Optimization Algorithm. Energy Rep., 7: 7663-7674. https://doi.org/10.1016/j.egyr.2021.10.118
[29] Liu Y, Chai Y, Liu B, Wang Y. (2021) Bearing Fault Diagnosis Based on Energy Spectrum Statistics and Modified Mayfly Optimization Algorithm. Sensors, 21(6): 2245. Doi: 10.3390/s21062245
[30] Tamilmani G, Devi VB, Sujithra T, Shajin FH, Rajesh P. (2022) Cancer MiRNA biomarker classification based on Improved Generative Adversarial Network optimized with Mayfly Optimization Algorithm. Biomed. Signal Process. Control, 75: 103545. https://doi.org/10.1016/j.bspc.2022.103545