PAPR Reduction and Encryption Based On Hybrid Optimized PTS and Chaotic-DFT Sequences in OFDM System

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***Abstract:** In high-speed wireless applications, because of the high-speed compatibility of the OFDM, it is a significant signal processing approach. In general, an efficient spectral multi-carrier modulation strategy is named OFDM, which gets impact via the issues of high PAPR. Because of the limited BW availability, the demand for high-speed applications is increasing. Due to the high data requirement, the various subcarriers are increased in OFDM, hence it made the difficult with PAPR (peak-to-average power ratio). To achieve better results by reducing the PAPR is the foremost problem on OFDM. In this paper, a hybrid optimized PTS is used to decrease the PAPR and the data will be encrypted by the DFT based chaotic sequences. A new Hybrid Whale Optimization and Moth Flame Optimization (HWOMFO) is introduced in this paper. It will generate a weighting factor for the PTS. PTS is the foremost strategy in OFDM for reducing the PAPR with low distortion. The minimum performance on computational complexity and PAPR achieved by this paper. The new combination of optimization approaches provides efficient best combination of phase rotational factors. The new hybrid optimization gives fast convergence quality and low complex and also this combination provides better than others. The proposed scheme is executed in MATLAB simulation and performance will be evaluated using parameters such as BER regards to SNR, complementary cumulative distribution function (CCDF) of PAPR and the outputs are associated depends on computation time. However, the experimental results show that compared with existing approaches, our proposed strategy gives better PAPR reduction with respect to SNR.*

***Keywords:** Wireless application, Partial Transmit Sequence (PTS), chaotic sequence, orthogonal frequency division multiplexing (OFDM) and Signal to noise ratio (SNR).*

I. INTRODUCTION

In various wireless communication schemes, the foremost famous approach used for transmission of data is OFDM. Due to the various advantages, (e.g. high BW efficiency, low complexity, great data rate and strong to fading in multipath) of OFDM, it is said to be a very attractive approach [1]. Therefore, various applications named, Digital Audio Broadcasting (DAB), Worldwide Interoperability for Microwave Access (WiMAX), Asymmetric Digital Subscriber Line (ADSL), IEEE802.11a/g wireless LANs, Digital Video Broadcasting (DVB), etc. are adopted with the multicarrier system of OFDM [2] [3]. Miserably, OFDM is a multicarrier modulation approach makes a number of independent symbols subject to high PAPR. Hence, by reducing the operating point, the efficiency of high power amplifiers (HPAs) also reduces [4].

In every non-linear devices named HPA, mixers and also digital-to-analog converters (DACs), the OFDM with high PAPR comes to be highly sensitive [5]. By reducing the PAPR through the available characteristics, the benefits of OFDM has been preserved. In order to reduce the power amplifier and to improve the transmitter power efficiency, the low PAPR is used [6]. Selected mapping, partial transmit sequence, tone reservation (TR) [7], and iterative clipping and filtering (ICF) are the methods available for denoting the PAPR problem [8]. For the OFDM system, there are several types of PAPR reduction approaches have been reported [9]. Out of all, the selective mapping (SLM) and ICF approach have low complexity [10].

The data blocks are separated into several split sub-blocks in PTS approach. In order to obtain reduced PAPR value, each sub-blocks are changed by traditional rotation factors. A few bits of the code word is used to decrease PAPR and increase the BER in coding technique [11-12]. The Inverse Fast Fourier Transforms (IFFT) of all these sub-blocks are then obtained and multiplied by various combinations from a set of phase rotation vectors [13]. To suppress the high PAPR in OFDM systems, an excellent PTS system is utilized. To get the optimal phase factors set a detailed search to be processed in an optimal PTS scheme, cause unbearable complexity. Hence, the computational complexity has been reduced by the various sub-optimal PTS schemes [14] [15].

The high PAPR of transmitted sequences is one of the chief issues for multiple-input multiple OFDM (MIMO-OFDM) systems and furthermore, communication channels get nonlinear distortion [16]. Followed by two modes namely, Conventional PTS and by using Cross-Correlation on PTS, the PTS can be implemented [17]. The PAPR calculation is equal to the optimal phase selection at most approaches, achieved by Cross-Correlation concept [18] [19]. When the subcarrier's number increased the simulation outcomes shows that the proposed approach obtained enhanced performance [20].

The foremost contributions of this paper are given below:

- The idea of the PTS technique is adopting in this scheme. The proposed scheme employs PTS accompanied by a

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meta-heuristic optimization algorithm called Hybrid Whale Optimizer.

- In this proposed system, the hybrid version of Whale optimizer is considered as a complexity decrease approach. The goals which prime to a combinatorial optimization issue to be answered is achieving low complexity and peak power reduction.
- To ensure the security in data transmission, the information bits are encrypted by the chaotic sequences. Hence, the information correctly decrypts by the legitimate user.

The organization of the remaining section has organized as follows: Section 2 gives some of the recent related works related to the PAPR reduction in wireless communication. Section 3 explains the designed task in terms of a problem statement, system design and proposed scheme. The results obtained from the experimentation is shown in section 4 and the conclusion part given in section 5.

II. RELATED WORKS

Some of the recent related works related to the PAPR reduction in wireless applications

An iterative smoothing filtering method was proposed by Shu-Ping Lin et al. [21] for the purpose of PAPR decrease in OFDM by clipping noise-assisted signals. Based on ICF the authors introduced a novel method with clipping signals. In order to reduce PAPR and attain the least magnitude error vector, the optimized filter was utilized. The simulated results were shown that the efficiency of the proposed approach.

Xinjin Lu et al. [22] introduced a strategy combined physical level encryption and lessening method of PAPR. The proposed approach was depending on chaotic sequences and polar codes in OFDM. Achieve high data transmission and solve PAPR issue were the main aim of the proposed method in this paper. The results from simulation and the theoretical approach gives that the designed scheme reach high security as well as reduce PAPR in OFDM. It produces the output without increasing the system latency and complexity.

In OFDM, Sanjana Prasad and Ramesh Jayabalan [23] were designed a PAPR reduction utilizing scaled PSO created PTS method. A scaled PSO was employed to PTS strategy to choose the phase vectors. At quick convergence rate and lower computational complexity, it reduces PAPR. The designed strategy reduces the PAPR by using scaled PSO-PTS and applicable for applications with 64-QAM modulation.

Necmi Taşpınar and Şakir Şimşir [24] were proposed a dual symbol optimization-PTS (DSO-PTS) method. With lowest PAPR, if searching, our proposed scheme considers both two adjacent symbols for the optimum data block. Likewise, the method of C-PTS optimized the adjacent symbols separately. The proposed DSO-PTS approach produced a great PAPR reduction and PSD performance by the implementation shown in performance analysis.

To decrease PAPR of OFDM signal the complexity reduction of PTS method has designed by Hocine Merah et al. [25]. A remarkable strategy has been monitored in this proposed approach, mainly in the random access memory it was relying on analyze the obtainable data. The results analysis gives a complete high presentation that PTS approach suggests in respect to mutually the PAPR and the reduction of BER.

III. PROPOSED METHODOLOGY

Due to the high-speed compatibility of the OFDM, it is considered as the significant signal processing approach. The availability of the limited BW source increases the demand for high-speed applications. In OFDM, the number of sub-carriers is increased due to high data requirement which generates problems with the PAPR. Fig 1 illustrates the schematic diagram of the designed methodology. According to the schematic diagram, initially, we encode the generated input bits. The encoded data be modulated using QAM Modulator and this data be the input of serial to parallel converter.

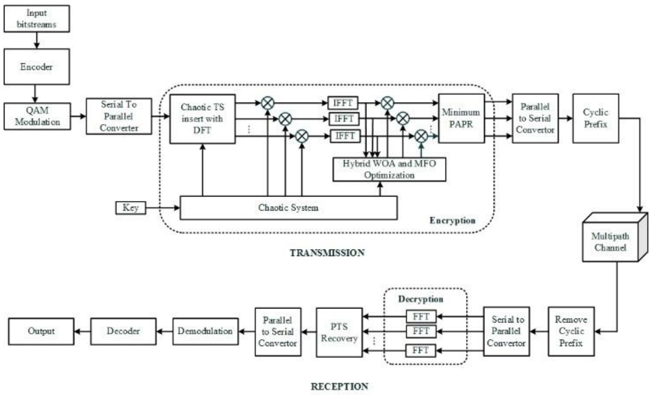

Fig 1: Schematic Diagram of Proposed Methodology

After that, we are calculating the PAPR using Chaotic DFT PTS technique. Here the chaotic sequence is generated using a key value. The weight value is updated using the HWOMFO Algorithm and we are reducing the PAPR value using this algorithm. The encrypted data be given to the parallel to serial converter. Then we are applying the OFDM steps such as adding cyclic prefix and insertion of a pilot. Then we define the multipath channel for transmission. The data be hand on through the channel and is get by the receiver. It will remove the cyclic and pilot data. This data be again given to the serial to parallel converter for decryption. After decryption, the data be again given to parallel to serial converter. This data be demodulated using QAM demodulator. Then we receive the original data by decoding the demodulated data with minimum error.

A. Problem Statement

PAPR is the ratio between the immediate powers to the average powers of the signals in the OFDM systems. PAPR occurs during the pre-processing phase of the OFDM where the signals are enhanced. High PAPR leads to the application of the high-power amplifiers which increases the complexity of the system. There are many approaches for the reduction of PAPR such as companding and clipping, which degrades the bit error rate and introduces self-interference. A combined arrangement is considered based on PTS based PAPR encryption and reduction to reduce the problems.

B. System Model: OFDM and PAPR

By using M-array QAM (i.e. a digital modulation), the input binary sequence is presented to certain constellation points. The modulated symbols are separated and given via a serial-to-parallel converter perform the IFFT process. Next, through an IFFT block the torrent of modulated symbols X_k are passed and OFDM baseband signal is created. The n^{th} model of a discrete-time using N number of subcarriers transferred OFDM signal can be [26]:

$$x_n = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X_k e^{j\frac{2\pi}{N}kn}; \quad 0 \le n \le -1 \tag{1}$$

The ratio of the highest power to the power on average is known as the PAPR of the transmitted signal shown by the following equation:

$$PAPR = \frac{\max\left\{ \left| x(k) \right|^2 \right\}}{Exp\left\{ \left| x(k) \right|^2 \right\}} \tag{2}$$

The analysis of PAPR reduction approach is evaluated by CCDF metrics. It is the probability that the PAPR beyond a level of threshold $PAPR_0$.

$$CCDF = p(PAPR > PAPR_0) = 1 - \left(1 - e^{-PAPR_0}\right)^N \tag{3}$$

C. PAPR Reduction using Chaotic OFDM Encryption

Chaos-based encryption with PAPR reduction is the main task behind these tactics. Essentially there are two kinds of PAPR reduction namely [27]:

- Chaotic signal scrambling: Chaotic PTS
- Chaotic precoding: Discrete Fourier transform (DFT)

(i) Scrambling of Chaotic signal

In PAPR reduction, it is one of the traditional strategies, sequences may be activated to randomly scramble an entry data block of OFDM signs. Hence, for the final transmission, it will select the minimum PAPR scrambled OFDM signals. The physical-layer security is improved by the chaotic sequences in OFDM symbol scrambling. Meanwhile, for correct retrieval of the actual OFDM data, the initial keys are required. Simultaneously, the performance of the transmission is improved by the reason of effective reduction in PAPR through signal scrambling.

(ii) Chaotic Discrete Fourier Transform Encryption (Chaotic DFT)

According to fig 1, OFDM data encryption with chaotic DFT-PTS is treated. After the QAM subcarriers, a pseudo-random binary sequence (PRBS) is transmitted to the serial-to-parallel (S/P) conversion, next it transferred for encryption at the receiver side. There are three stages used for implementing chaotic encryption. First, for OFDM symbol synchronization insertion of the chaotic training sequence, next, chaotic random partition and finally, for PAPR optimization the chaotic phase weighing factors (PWF). The chaotic sequence for the encryption is,

$$\begin{aligned} \dot{l} &= f(-l+m) + mnk \\ \dot{m} &= g(l+m) - \ln k \\ \dot{n} &= hm - k + slmk \\ \dot{k} &= -tk + lmn \end{aligned} \tag{4}$$

where, f, g, h, s, and t are the constants. For OFDM signal encryption in order to create digitized chaotic sequences using Eqn. (5) [28]

$$D_{x,i} = \mathrm{mod}(extract(x_i, m, n, p), M) \tag{5}$$

where the integer output is expressed by $extract(x_i, m, n, p)$ is found by the p^{th}, m^{th}, and n^{th} digits in the decimal part of x_i, the remainder of fraction a by b is denoted by *mod(a, b)*, In the digital sequence the maximum digital value is denoted by M, which is 256 in all approaches. Likewise, the further sequences $\{u_i\}$, $\{z_i\}$, and $\{y_i\}$ can be digitalized into $\{D_{u,i}\}$, $\{D_{z,i}\}$, and $\{D_{y,i}\}$.

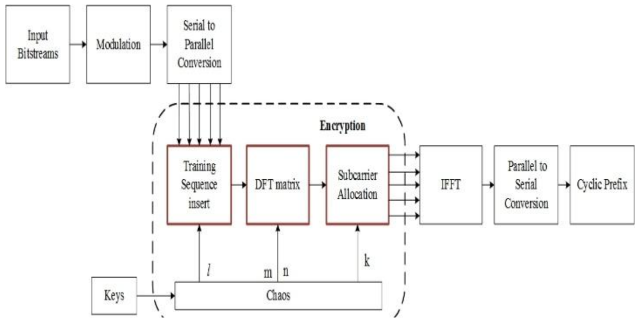

Fig 2: Diagram of Chaotic-DFT sequence

Chaotic-DFT data encryption is executed multi-fold, named chaotic subcarrier allocation, chaotic TS insertion and chaotic DFT matrix generation all are prearranged by digital chaotic sequences [29]. The typical M×M DFT matrix is assumed by F, then the matrix constraints are given by,

$$F_{\mu,v} = \frac{1}{\sqrt{M}} e^{\frac{-j2\pi(\mu-1)(v-1)}{M}} \qquad 0 \le \mu, v \le M-1 \tag{6}$$

where the indexes of row and column are denoted by μ, v individually. A reconfigurable matrix can be created by using the Eq. (6),

$$F'_{\mu,v} = \frac{1}{\sqrt{M}} e^{\frac{-j2\pi(\mu-m)(v-n)}{M}} \qquad 0 \le \mu, v \le M-1 \tag{7}$$

where the real constants are represented as m, n, which can be pre-set with chaotic sequences attained in Eq. (5) as

$$m_{y,i} = ...+10n_1 + n_2 + 0.1n_3 + 0.01n_4 + ... \tag{8}$$

where n_j^{th} term in the decimal portion of y is represented by n_j. Also, from $\{z_i\}$, $\{n_{z,i}\}$ can be made equally as $\{m_{y,i}\}$. For the reconfigurable DFT matrix F' the same original features in the basic ordinary F are retained. In addition, for the same column or row indexes all of the components in F' are in a geometric system using the similar mutual ratio of $e^{-j2\pi/M}$.

The chaotic sequence is used to produce the phase weighting factors $\{R_l\}$ in PTS and it will be optimized by optimization techniques.

$$R_l = e^{j\frac{2\pi D_{x,i}}{M}} \qquad i = 1, 2, ..., K \tag{9}$$

where the overall phase weighing factors is denoted by K.

The resultant time-domain vector after transforming from frequency to time-domain and the phase weighting factors multiplying is,

$$x = \sum_{l=1}^{L} R_l x^{(l)} \tag{10}$$

$$x_n^{(l)} = \frac{1}{\sqrt{N}} \sum_{S=0}^{N-1} X_s^{(l)} e^{j\frac{2\pi sn}{N}} \quad (11)$$

where the IFFT (inverse fast fourier transformation) of $X^{(l)}$ is denoted by $x^{(l)}$, the indices of OFDM symbol and subcarrier is expressed by *s* and *n* respectively.

Based on PAPR all of the arrangements of sub-blocks are searched by the phase weighing factors in PTS. Through the optimized grouping of the corresponding PWF and sub-blocks, the minimum PAPR is obtained [29].

$$PAPR_{PTS} = \min\left(PAPR\left(\sum_{l=1}^{L} R_l x^{(l)}\right)\right) \quad (12)$$

D. Proposed: Hybrid Whale Optimization and Moth Flame Optimization (HWOMFO) based Weighting factor Optimization

The hybrid optimization has been used for updating the weighting factor to the PTS to decrease the PAPR. PAPR reduction of all L sub-blocks is the main aim obtained by phase rotation and join the P/S conversion. Through the optimized combination of the sub-blocks and corresponding PWF, the minimum PAPR is obtained.

$$fitness\ \ function(x) = \frac{1}{PAPR(x)} \quad (13)$$

The behavior of humpback whales is mimicked by the Whale Optimizer Algorithm (WOA). The bubble-net hunting approach is used to simulate the algorithm.

Encircling prey: The small prey encircled by the whale and next to its position is modified on the way to a globally optimum solution.

$$\vec{d} = \left|\vec{c}.\vec{x}_t^{*} - \vec{x}_t\right| \quad (14)$$

$$\vec{x}_{t+1} = \vec{x}_p^{*} - \vec{a}.\vec{d} \quad (15)$$

The coefficients $\vec{a}$ and $\vec{c}$ are evaluated by,

$$\vec{a} = 2ar - a \quad (16)$$

$$\vec{c} = 2r$$

where current time is denoted by *t*, the coefficient vectors are represented by $\vec{a}$ and $\vec{c}$, the position vector of the better value is denoted by $\vec{x}^{*}$, next, the position vector is represented by $\vec{x}$, random vector in [0, 1] is represented by *r*, the absolute value is denoted by "| |".

Bubble-net attacking technique: Two separate models are as follows to reach a mathematical equation:

- ***Shrinking encircling system:*** By linearly reducing the value of $\vec{a}$ ~ [0, 2], this method is used. $\vec{a}$ ~ [−1, 1] is a random value for a vector.
- ***Updating position in Spiral:*** Between Small prey and whale the position update showed a Helix-shaped movement

$$M = \vec{d}' e^{bt} \cos(2\pi l) + \vec{x}_t^{*} \quad (17)$$

where the distance from ith whale to the prey is denoted by $\vec{d} = \left|\vec{x}^{*} - \vec{x}\right|$, a random number in [−1, 1] is represented by *l*. Furthermore, if the probability is 50% means, then its positions are evaluated by:

$$\vec{x}_{t+1} = \begin{cases} \vec{x}_p^{*} - \vec{a}.\vec{b} & if\ p < 0.5 \\ \vec{d}' e^{bt} \cos(2\pi l) + \vec{x}_t^{*} & if\ p \geq 0.5 \end{cases} \quad (18)$$

where the random number in [0, 1] is represented by *p*. The humpback whales randomly search for prey in addition to the bubble-net method.

Whales, search the prey randomly and change their position based on the search agent position. $\vec{a} > 1\ or\ \vec{a} < 1$ is used to force the whale to interchange away from the reference whale. It is arithmetically deliberated as monitors:

$$\vec{d} = \left|\vec{c}\,.\,\vec{x}_{rand} - \vec{x}_t\right| \quad (19)$$

$$\vec{x}_{t+1} = \vec{x}_{rand} - \vec{a}.\vec{d} \quad (20)$$

where $\vec{x}_{rand}$ is a random position vector.

A novel nature-inspired algorithm is named MFO algorithm. The navigating mechanism of moths in nature is simulated by this algorithm called transverse orientation. It has been used to reduce the PAPR in wireless communication. It is hybrid with whale optimization. The position to be updated by this optimization.

The position of i^{th} moth as regards j^{th} flame is updated by:

$$M_i = S(M_i, F_j) = D_{ij} e^{bt} \cos(2\pi t) + F_j \quad (21)$$

where the distance of the i^{th} moth for the j^{th} flame is denoted by D_{ij}, a constant for describing the logarithmic spiral shape is represented by *b*, and the random value in [-1,1] is denoted by *t*.

$$D_{ij} = \left|F_j - M_i\right| \quad (22)$$

where M_i specify the i^{th} moth, and F_j designates the j^{th} flame.

In search space due to moths updating the position based on N different location, the exploitation of the best result may degrade. An adaptive mechanism is proposed for reducing the problems by introducing the number of flames (F_{no}) by Eqn. (23).

$$F_{no} round\left(N - v \times \frac{N-1}{T}\right) \quad (23)$$

where the recent iterations are denoted as *v*, the highest number of flames is represented by *N*, and the maximum iterations are *T*. Fig 3 shows the flowchart for the proposed HWOMFO.

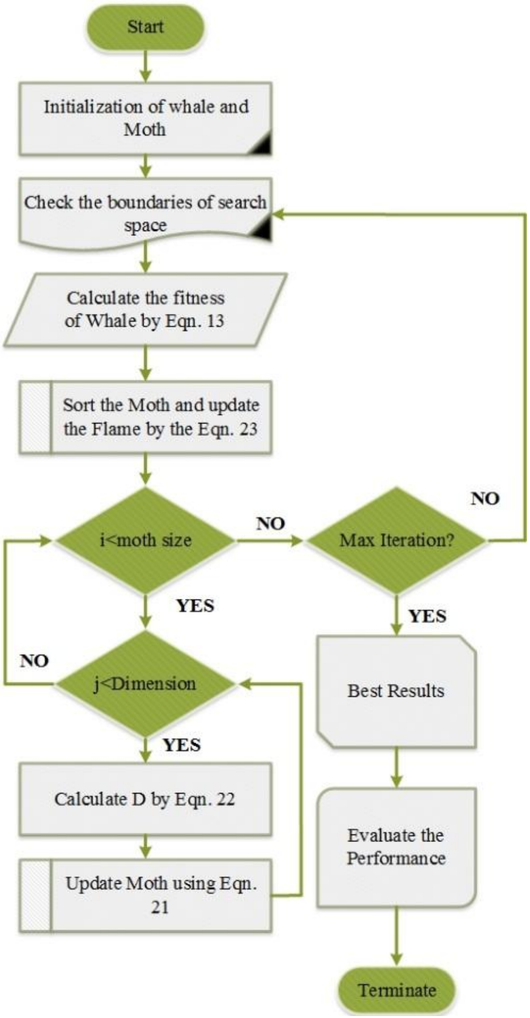

Fig 3: Flow-Chart for proposed HWOMFO

IV. EXPERIMENTAL RESULTS

Here, PAPR reduction results of the newly introduced organization equated with SLM approach and the various channel BER presentation are focused. The experiment is processed in MATLAB platform with PTS constraints to get desired results. BER and CCDF regard to SNR are the parameters utilized in the proposed approach. In addition, the final outcomes are compared on the basis of computation time. Several optimization approaches based comparison is performed here. The final outcomes of actual OFDM design besides its combinations such as PTS, PTS-GWO, and PS-GWO are related to designed approach PTS based HWOMFO.

Table 1 gives the CCDF of PAPR performance and the constraints of the designed scheme by 16 subcarriers OFDM- system.

Table 1: Parameters used in Proposed Implementation

Sl.No	***Parameter***	***Values***
1	Number of bits to be transmitted	1000
2	Modulation Approach	QAM
3	Modulation Range	16
4	FFT Size	64
5	Channel	4*100
6	Maximum Iterations	500
7	Oversampling Factor	4
8	Number of Sub Bands	64
9	Cyclic Prefix Size	64
10	Number of Subcarriers	64

Fig 4 shows the results of BER with respect to SNR for original OFDM and others. SNR and BER also use as a standard in communication protocols. Here, the proposed design achieved better outcomes in BER even if the SNR increased. 50% extra better performance achieved in the proposed design compared to actual OFDM. For the bit error rate performance, the newly introduced model compared with actual OFDM and other existing approaches such as PTS, PTS-GWO, and PS-GWO. The existing strategy PS-GWO obtained the second most better results in PAPR reduction.

The performance of BER for our proposed strategy is compared with existing approaches at SNR=5 is given in table 2.

Table 2: BER comparison at SNR=5

Sl.No	**Techniques**	**BER**
1	Original OFDM	10^{-2}
2	PTS	$10^{-2.2}$
3	PTS-GWO	$10^{-4.5}$
4	PS-GWO	$10^{-5.9}$
5	HWOMFO	10^{-7}

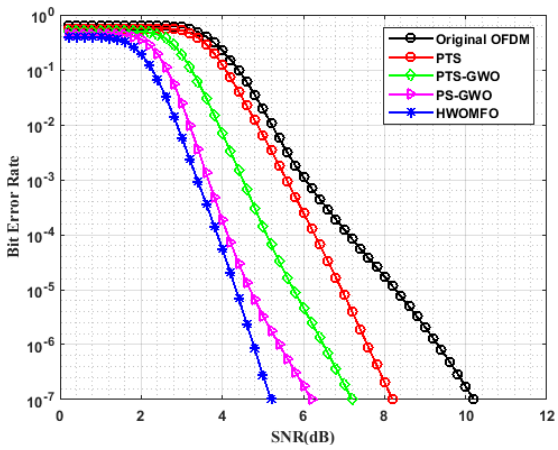

Fig 4: Performance of BER with respect to SNR

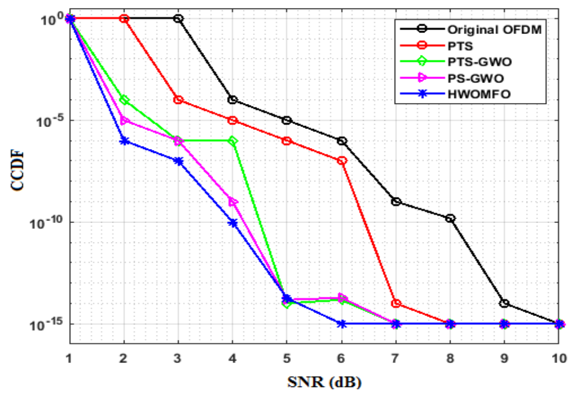

Fig 5: Performance CCDF of PAPR in terms of SNR

Figure 5 shows the relation among the CCDF regarding PAPR for all the designs. CDF is used to identify the probability of a variable taking a value ≤ x, CCDF is used to discover the probability of a variable taking a value > x. Compared to the existing approaches our proposed strategy achieves better distribution values. The CCDF distribution values are measured in terms of SNR value. Compared with original OFDM our proposed strategy gets 5 times better value. CCDF also compared with original OFDM, PTS, PTS-GWO, and PS-GWO.

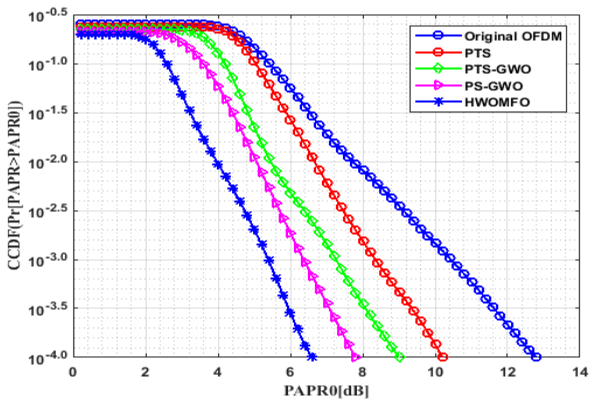

Fig 6: PAPR Reduction at Initial Condition

The PAPR performance via CCDF at initial conditions plots are illustrated in figure 6. In this graph, the comparison is done with original OFDM for PAPR reduction, PTS scheme, PTS-GWO, PS-GWO, and the proposed method HWOMFO. The figure clearly shows that the proposed design provides better outcomes than the other approaches. Our proposed approach gets 6.8dB at 10^{-4} CCDF. In addition, when the PAPR increases then the CCDF function decreased. However, the proposed approach obtains better results than others.

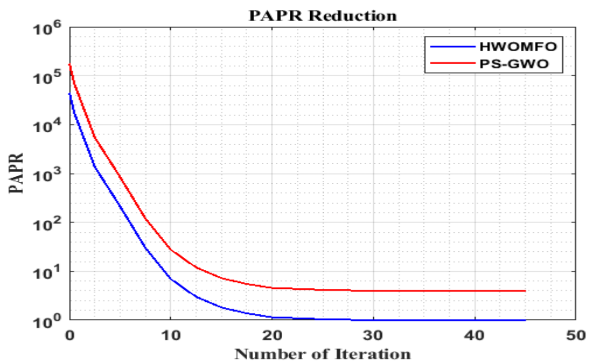

Fig 7: PAPR in a different iteration

The comparison of PAPR with respect to different iteration cycle shown in figure 7, compared with existing PSO-GWO model. When the iteration number increases the PAPR decreased in a better way. Our proposed strategy converges into less number of iteration and gives better PAPR reduction. Hence, our proposed approach reduces the PAPR in better than the existing.

Table 3 gives the performance values of computation time compared with existing approaches [30].

Table 3: Performance Values of Computation Time

Sl.No	Techniques	Computational Time (Sec)
1	Original OFDM	0.88
2	PTS	0.78452
3	PTS-GWO	0.483321
4	PS-GWO	0.453
5	HWOMFO	0.321

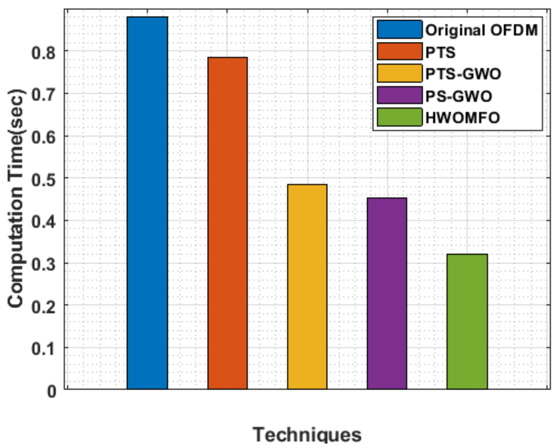

Fig 8: Comparison of Computation Time

Figure 8 describes the computation time regarding seconds for all the design utilized in the experiment. The designed approach obtained less than 35% computation time compared to actual OFDM. In addition, the existing PS-GWO and PTS-GWO take more than 45% of the time, PTS takes more than 75% of computation time and original OFDM takes more than 85% of computation time. According to the results, the computation time of the proposed strategy is less than the existing, hence the PAPR reduction gets better than the others.

V. CONCLUSION

Hybrid optimized PTS based chaotic-DFT PAPR reduction has been proposed in this paper. Encryption using chaotic sequences is used here is to reduce the PAPR in OFDM. The chaotic sequences are delivered for encryption according to the characteristics of the wireless channel. The system model is shortened and reduce the PAPR by the PTS based chaotic sequence. Here, a hybrid optimization is used for updating the weighting factor in PTS. It provides fast convergence quality and less complexity in the proposed strategy. This combination provides better than others. Furthermore, PTS-based hybrid optimization reduces PAPR problems and provides better throughput. In addition, the proposed approach realize the encryption in the chaos practice, the reliability and security of the scheme be enhanced. Experimental results give the enactment in terms of CCDF, BER, computation time and PAPR reduction. The computation time of the proposed approach is only less than 35%, compared to the existing proposed scheme proposed approach gets better computation time. BER in terms of SNR has very much low in designed scheme and the PAPR According to the results, the proposed PTS based Chaotic-DFT is robust with respect to PAPR reduction, CCDF, computation time and BER.

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