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Analysis of PAPR and BER Reduction in MIMO-OFDM using Hybrid Moth Flame-Improved Firefly Algorithm

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Abstract: The hybrid innovation of Orthogonal Frequency Division Multiplexing (OFDM) through Multiple-Input Multiple-Output (MIMO) delivers a feasible substitute to increase the Quality of Service (QoS) to accomplish better data rate and spectral efficiency for the transmission network. An extraordinary Peak-to-Average Power Ratio (PAPR) and Bit Error Rate (BER) are the important parameters that can be considered in the analysis of the MIMO-OFDM network. Partition Transmit Sequences (PTSs) is one of the capable procedures and direct methods to attain a reasonable PAPR performance. However, it needs a serious restoration process to discover the vital features that produce a computational multi-layered design with sub-blocks. Here, a reduced computational complexity PTS scheme is proposed which is completely depends on the hybrid procedure named as Moth Flame Optimization with Improved Firefly Algorithm (MFO-IFFA). The simulation outcomes demonstrated the capability of the proposed MFO-IFFA approach decreases the PAPR reduction up to 3.6 dB. Similarly, the proposed MFO-IFFA overcomes the significant evolutionary procedures mentioned in the existing works such as Additive Signal Mixing (ASM), Adaptive Simplified Optimized Iterative Clipping and Filtering (ASOICF) and Hybrid Independent Component Analysis (HICA).

Keywords: Bit error rate, Improved firefly algorithm, Multiple-input multiple-output, Moth flame optimization, Orthogonal frequency division multiplexing, Peak-to-average power ratio, Partial transmit sequences.

1. Introduction

For the past few years, OFDM is a promising guideline/radio entrée plan for future distant correspondence systems because of its inborn protection from multipath deterrent on account of a low picture rate, the usage of a cyclic prefix and its tendency to different transmission approaches [1, 2]. One of the significant drawbacks of the OFDM signal considering multicarrier transmission is the PAPR of the transmission signal which reduces the magnitude of OFDM signal transmission [3]. OFDM signal requires a broad commitment setup which results in unproductive power change [4]. MIMO-OFDM is an appealing system for high data rate, yet it shows a significant reduction in PAPR because of the nonlinear region of the High Power Amplifier and degradation of Bit Error Rate (BER) [5]. To overcome this, a high power amplifier should be worked with broad power back-offs and efficient developments in transmitter power [6].

In the MIMO-OFDM network, Selective Mapping (SLM) and Partial Transmit succession (PTS) is considered as one of the generally utilized probabilistic strategies to solve the PAPR performances [7]. The standard of probabilistic methodology depends on diminishing the probability of high PAPR by making a couple of OFDM pictures passing on similar information and choosing the one having the most insignificant PAPR. However, the MIMO–OFDM [8, 9] offers countless benefits, yet the top signs move into the speaker submersion region with some errors. In [10, 11], different traditional crossover methods and hybrid strategies have been proposed for diminishing the PAPR of the MIMO–OFDM system. Each conventional plan has its specific advantages and drawbacks as out-of-band disorder and data rate error [12]. Nonetheless, the half breed procedure joins a few routine plans together and accumulates their pay and benefits in a combinational philosophy, yet the computational quality in the hybrid method is also a significant issue [13, 14]. Since the OFDM images experience the ill effects of exceptionally high upsides of its PAPR and BER; likewise, MIMO-OFDM images have a similar issue [15]. The main advantage of MFO-IFFA algorithm is that the search mechanism is simple and easy to realize. The learning strategy of proposed algorithm shows the historical searching information to be transmitted between moth's flame and fireflies. At the receiver end, proposed MFO-IFFA block is visually compromised with impedance through communication series to reduce the error. The significance of this work is

- MFO-IFFA is proposed to decrease PAPR and BER which are summed up to take care of this popular issue in MIMO-OFDM.
- Improved Firefly based-PTS calculation is proposed to achieve a comparative PAPR decrease with less computational complexity at a quicker convergence rate.
- To avoid different polar encodings with high complexity, an MFO-IFFA transmitter by developing the linear polar code is executed.

The organization of this research paper is given as follows: The survey of the recent techniques related to polar coding based MIMO-OFDM are described in Section 2. The problem statement of this research is given in Section 3. The preliminaries and their system model are explained in Section 4. The description of the proposed MFO-IFFA with block diagram is specified in Section 5. The simulation results and its comparative analysis of MFO-IFFA are declared in Section 6. The conclusion of this research work is given in Section 7.

2. Literature review

Bhandari [16] exhibited another channel gauge procedure since the predominant channel gauge techniques were not adequate to determine the ISI issue. The projected assessment was joined with Independent Component Analysis (ICA) consequently this technique is called Hybrid ICA (HICA) to limit the ISI impact. The broad reproduction investigation of the proposed HICA needed to guarantee the adaptability just as unwavering quality. Even though the PAPR execution has not been diminished in both ICA and HICA procedures, still there is excessive energy consumption while transmitting the data.

Stephen Kiambi, Elijah Mwangi, and George Kamucha [17] demonstrated a low-complexity Additive Signal Mixing (ASM) approach for decreasing PAPR in space-time-coded MIMO-OFDM. The key concept is to provide a peak-cancelling signal for every MIMO-OFDM branch depending on a system-specific clipping threshold. The peak-cancelling signals are introduced to the branched signals to lower PAPR. Just the nonzero samples of the peak-cancelling signals are provided simultaneously with the PAPR-reduced signals for use in reconstructing clipped amplitudes to minimize data rate loss and total energy. Clipping, on the other hand, can result in severe BER degradation and strong out-of-band radiations.

Prasad [18] developed a Scaled Particle Swarm Optimization (SPSO) technique to fractional communicate grouping method to find the ideal stage highlights for dropping the pinnacle normal proportion at a speedier combination rate and lesser calculation unpredictability. PTS strategy has specific issues like exorbitant calculation convolution in light of its complete inspecting of ideal stage highlights. This work additionally proposes a versatile preliminary based visually impaired collector to recognize the chosen signal (or frozen information block) without excess data transmission to settling this issue. On the other hand, this method fails in modifying the size of velocity step to carry on the optimal point exploration.

Vijaya Kumar Padarti and Venkateswara Rao Nandhanavanam [19] propose an improved Adaptive Simplified Optimized Iterative Clipping and Filtering (ASOICF) technique to minimize PAPR in OFDM systems. This research also uses Lagrange Multiplier Optimization (LMO), which has the advantage of reducing the number of iterations in a customizable way. This adaptive approach greatly minimises the PAPR in OFDM signals, according to our findings. However, this method requires a greater number of repetitions to reach the desired result.

Seung-Chan Lim, Namshik Kim, and Hyuncheol Park [20] proposed a polar coding-dependent SLM technique for PAPR decrease deprived of communicating controller moments. The proposed SLM verifiably takes advantage of free and consistently appropriated frozen information squares to specifically send the OFDM signal with the most minimal PAPR. And the visually impaired beneficiary recuperates the sent thawed information with high exactness. But, SLM computational intricacy increments straight as the number of stage arrangements builds which compares to the quantity of IFFT block.

M. Vijayalakshmi and K. Ramalinga Reddy [21] have developed a novel approach for reducing PAPR by merging PTS and Gaussian pulse-based TR approaches. The TR technique's core idea is to create an additive time-domain signal that reduces the PAPR of the actual transmit signal while increasing the average power, reducing the OFDM system's power efficiency. To minimise the average power, the method employs an adaptive optimization strategy known as GWO-ABC (incorporation of grey wolf optimization and artificial bee colony). However, this method was not suitable for a large number of sub-carriers.

3. Problem statement

- Due to the recognizing features, higher PAPR can be considered as a significant disadvantage of MIMO-OFDM.
- Besides these valuable benefits, it experiences the extraordinary covering changes of the communicated signal named PAPR, which reduces the effectiveness of a high power amplifier.
- Due to the decrease in BER, the complexity of nonlinear elements and out-of-band emission gets increases.

4. Preliminaries

On the other hand, there have been not many explores interested in the process of polar coding-dependent methods to determine the PAPR in MIMO-OFDM frameworks.

4.1 PTS

PTS method divides the data of input block $X = [X_1 X_2 X_3 \ldots\ldots X_M]$ into V split sub-blocks that given Eq. (1)

$$X_v = \left[X_{v,1} X_{v,2} X_{v,3} \ldots . X_{v,M}\right] 1 \leq v \leq V \quad (1)$$

where the sub-impedes (X_v) that are found successively, equivalent magnitude and symmetrical and error of every square are expressed in Eqs. (2) and (3).

$$X = \sum_{v=1}^{V} X_v \quad (2)$$

$$\acute{X} = \sum_{v=1}^{V} b_v X_v \qquad v = 1,2,..V \quad (3)$$

Where $b_v = e^{j\emptyset_v}$. The procedure of stage factors b_v should be selected to some degree of PAPR, which is stated as Eqs. (4) and (5).

$$x = IFFT\{\sum_{v=1}^{V} b_v X_v \ \} = \sum_{v=1}^{V} b_v IFFT\{X_v\} \quad (4)$$

$$x = \sum_{v=1}^{V} b_v X_v \quad (5)$$

Where, $\{x_v\}$ denotes the obtained PTSs.

Here, the phase value deliberated in the respective set is specified in Eq. (6).

$$\varphi_k^m = \frac{2\pi i}{W} \ \ i = 1,2,..W-1 \quad (6)$$

Where a quantity of foreordained discrete stage is represented as W . The subcarrier direction is specified through Eq. (7).

$$y_k = \sum_{m=1}^{M} b_k^m . X_k^m \quad (7)$$

Where weighting factors are specified as b_k^m, which are needed to illuminate the collector as the side data which is written in Eq. (8).

$$y_k = \sum_{m=1}^{M} b_k^m . x_k^m \quad (8)$$

Eqs. (7) and (8) shows that the weighting variable can be increased whichever in the recurrence or interval areas and enhanced PAPR execution is as similar as assumed through Eq. (9).

$$\breve{M} = arg \min_{0 \leq w \leq W} \max_{0 \leq n \leq L-1} \left|\sum_{m=1}^{M} b_k^m x_n^M\right| \quad (9)$$

Where adjusted variable ($\breve{M}$) is used to bring the lowermost PAPR value.

5. Proposed method

PTS is one of the viable procedures for lessening the PAPR in MIMO-OFDM frameworks. PTS strategy has a few issues, for example, higher computational intricacy because of its comprehensive ideal stage factors. To overcome this disadvantage, MFO-IFFA is exploited to give quicker intermingling to the ideal worth just as lessening PAPR adequately. The results show that the proposed MFO-IFFA-PTS method decreases PAPR/BER successfully and is generally reasonable for applications with the 64-QAM balance plot.

5.1 System model

Fig. 1 shows the total MIMO-OFDM transmitter and collector framework utilizing the Improved

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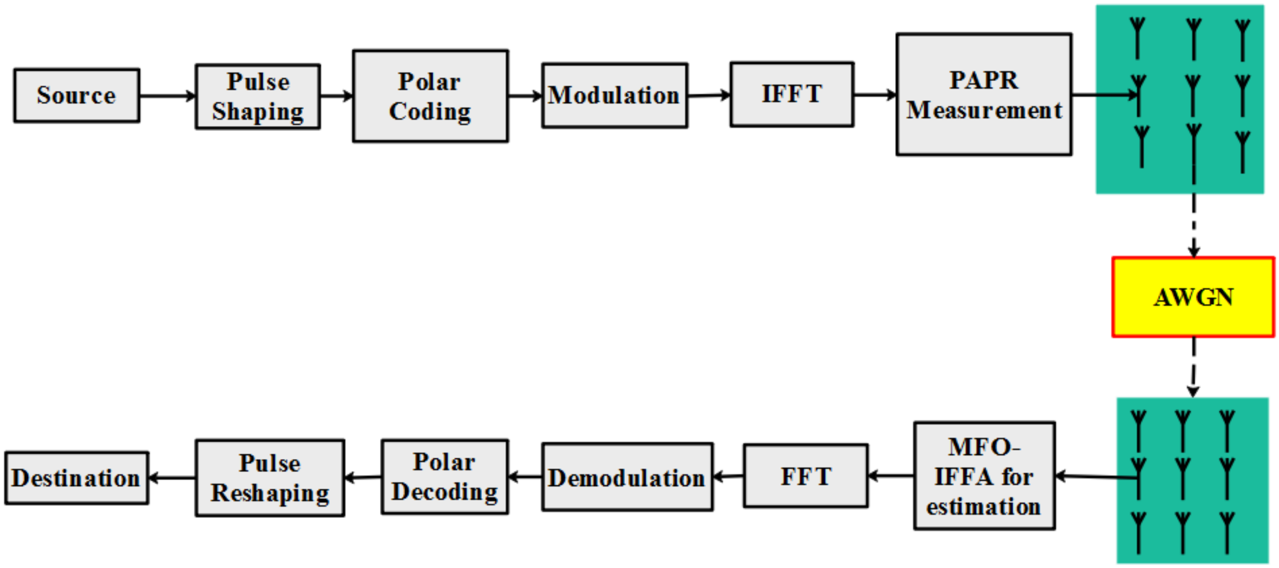

Figure. 1 Proposed MIMO-OFDM system model

Firefly strategy. In the projected framework model, transmitter information from clients is arbitrarily produced and afterwards sent to adjustment progression on every stage. The weakening variable is a perplexing number. At end of the collector, proposed MFO-IFFA block-based visually impaired impedance with communication cycle while crossing the approach. Whenever information is sent from transmitter radio wires through AWGN (Additive White Gaussian Noise) channel, then exploit the second calculation to evaluate the signals. After that received signals are processed for demodulation process. Once the demodulation is done, polar decoding will occur, those demodulated signals are received at the receiver side.

5.2 Moth flame optimization

Moths strive to form stable points with neighbouring light sources, such as fire, by coming closer to them in a meandering path close to the source. The MFO computation is based on fly assets that are similar. This position update is utilised to acquire the flame's optimal location, and the MFO is updated with a new best individual location. The MFO performs the same procedures as the moth's location update and new location generation. Every moth's fitness function is recorded in an array that is arranged in matrix form and intended for storing analogous criteria that are similarly described by an array. Formerly moth position is designed using a subsequent function Eq. (10).

$$M_i = S(M_i, F_j) \tag{10}$$

If M_i characterizes the ith Moth, jth a flame is designated by F_j and function of a spiral path is stated as S. Deliberating the aforementioned state, the moth route is described as subsequent Eq. (11),

$$S(M_i, F_j) = D_i . e^{bt} . \cos(2\pi t) + F_j \tag{11}$$

where distance amongst the ith moth and jth flame of problematics are signified as D_i. Constant values are stated as b that support the outline of the curved route and t diverge in the range of -1 and 1 indiscriminately. Supplementary D_i is designed as in Eq. (12),

$$D_i = |F_j - M_i| \tag{12}$$

In Eq. (3), M_i represents ith Moth, F_j represents jth flame and D_i signifies distance amongst the nodes. Through the usage aforementioned equivalence, the moth location is restructured all over the flame. Using flame, the population gets diminished through the repetition count. Those formulations are mentioned in Eq. (13),

$$Flame\ no = round\left(N - 1 \times \frac{N-1}{T}\right) \tag{13}$$

where N denotes the maximum flame count and T represents the maximum iterations count.

5.3 Normal firefly algorithm

The FA is an arbitrary inquiry calculation dependent on swarm aptitude which pretends the fascination instrument amongst distinct fireflies in

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the environment. Towards, admire specific attributes of fireflies while developing numerical models of FA, the accompanying glorification standards are utilized:

- All the fireflies are fascinated merely through the light strength amongst clusters irrespective of femininity;
- The fascination of fireflies to one another is corresponding to light splendour;
- The splendour of fireflies is identified with the fixed capacity values.

Because of the deficiencies of the normal FA, Yang advanced a test work through FA individualities to accomplish improved enhancement execution. The FA outcomes display viably address the sort of worldwide streamlining issue, FA was effectively employed to worldwide advancement issue of tension funnelling plan. In any case, the boundaries in normal FA are fixed ahead of time, which stimulates premature convergence which can't combine inappropriate boundary settings. Henceforth, the standard FA should be improved to accomplish better advancement execution.

5.4 Improved firefly algorithm

By investigating the boundaries of the FA, light retention coefficient γ is excessively enormous and works as decent worth. Every firefly contains bright influence $I\ (r)$ which is written in Eq. (14).

$$I\ (r) = I_0 e^{-\gamma r^m}\ m \geq 1 \quad (14)$$

So, firefly attraction β can diverge conferring to the calculation assumed through Eq. (15),

$$\beta(r) = \beta_0 e^{-\gamma r^m}\ m \geq 1 \quad (15)$$

where β_0 signifies the maximum attractive quality (at $r\ =\ 0$) and γ is the light assimilation constant, which regulates the diminishing of the light power. The expanse amongst dual fireflies i and j at p_i and p_j locations are considered as Eq. (16).

$$r_{ij} = |p_i - p_j| = \sqrt{\sum_{k=1}^{l} p_{i,k} - p_{j,k}{}^2} \quad (16)$$

Where $p_{i,k}$ is three-dimensional harmonize p_i. The effort is defined by Eq. (17).

$$p_i = p_i + \beta_0 e^{-\gamma_{ij}^2}(p_i - p_j) + \alpha(rand - \tfrac{1}{2}) \quad (17)$$

Table 1. Simulation specifications

Parameters	Values
Acceleration Constant	2
FFT Size	256
Firefly Size (S)	30
Generation (G)	10
Inertia weight	0.9
Iteration Count	3000
Modulation scheme	QPSK, 64-QAM, 128-QAM
Over Sampling Factor (L)	3
Phase Weighting Factor (W)	3
Scaling Factor	2
Sub-block Number (V)	3

Where the initial term is the current situation of a firefly I (p_i is the arrangement of a firefly). At every iterative advance, the splendour and the engaging quality of every firefly are registered. The brilliance of every firefly is contrasted and any remaining fireflies and the places of the fireflies are refreshed utilizing condition Eq. (17).

6. Result and discussion

To outline the presentation of the proposed calculation, IEEE 802.16d particulars and its models have completed utilizing MATLAB R2018a programming. Fig. 1 shows the midpoint of PAPR execution both for the conventional PTS strategy (CPTS) and the proposed MFO-IFFA-PTS technique while changing the number of cycles.

Table 1 displays of simulation specifications of the proposed system. At this point, once the latency weight ω was shifted from 0.4 to 0.9, the worth $\varpi\ =\ 0.4$ aided in the nearby pursuit, though the worth $\varpi\ =\ 0.9$ aided in the worldwide search. Consequently, the latency weight is viewed as 0.9 and the acceleration constant is used as 2 to improve the worldwide search. To confirm the exhibition of the suggested method, a square length of 1024 is planned by the thickness advancement.

6.1 Performance of PAPR

To assess the PAPR execution, deliberate the Complementary Cumulative Distribution Function (CCDF) of PAPR, which means the likelihood of PAPR proceeds a worth bigger over a limit γ. For a specific steady α, the mathematical CCDF for PAPR has been dissected. Fig. 2 represents the exhibition of PAPR at 64-QAM.

Fig. 2, clearly shows that the proposed MFO-IFFA outperforms the existing algorithms such as Selective Mapping (SLM), Partial Transmit Sequence (PTS) and ordinary OFDM.

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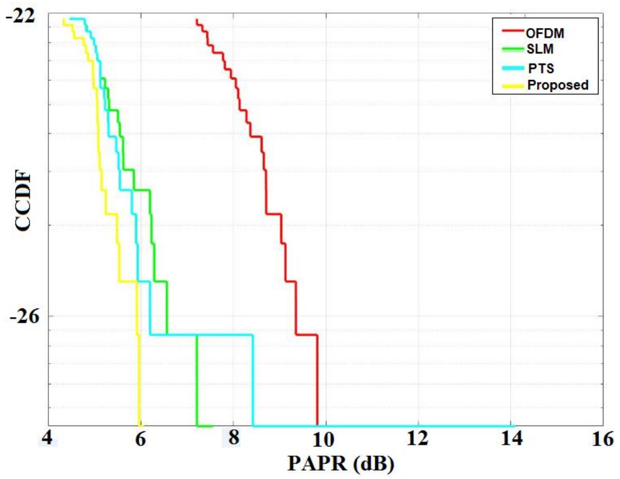

Figure. 2 Performance of PAPR at 64-QAM

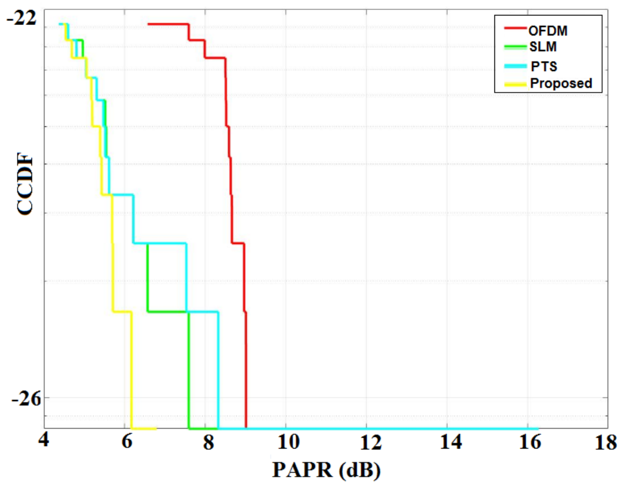

Figure. 3 Performance of PAPR at 128-QAM

Fig. 3 shows the performance of PAPR at 128-QAM. From Fig. 2 and 3, it is seen that the PAPR execution of the proposed MFO-IFFA techniques is practically comparable with conventional techniques while analysing under 128-QAM. From this reality, the PAPR execution of the MIMO-OFDM sign would not rely upon the tweak technique as old as the regular OFDM framework. The PAPR execution of the proposed MFO-IFFA accomplished preferable PAPR execution over Conventional PTS strategy. The PAPR execution of the proposed strategy can be united right off the bat as contrasted and the PTS technique. The MIMO-OFDM framework execution was considered by estimating the BER and PAPR over various channel regulations.

6.2 Performance of BER

The plan of different radio wires at the transmitter and beneficiary end builds variety gain and multiplexing gain. Variety gain alludes to acquiring a further developed Bit Error Rate (BER) execution by giving the beneficiary different duplicates of the

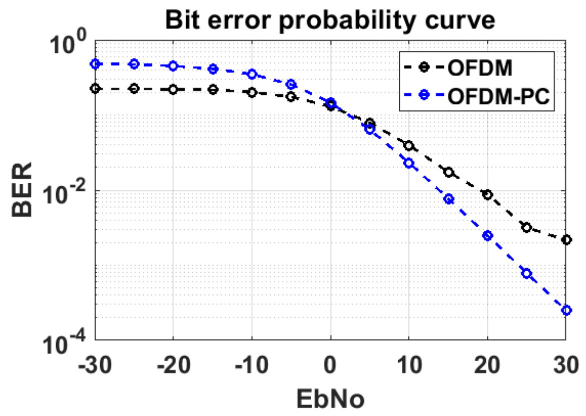

Figure. 4 Performance of BER at QPSK modulation

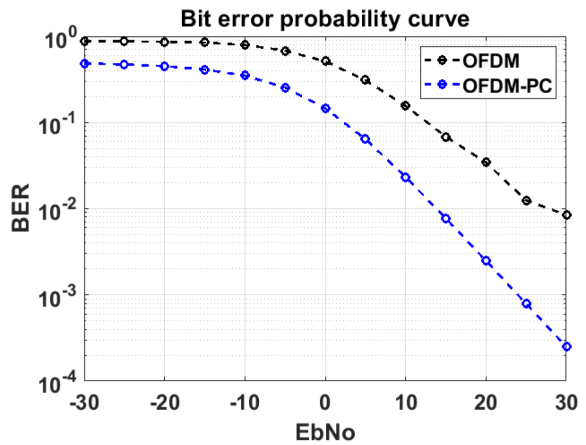

Figure. 5 Performance of BER at QAM modulation

communicated signal. Spatial multiplexing one of the MIMO innovations builds information rate by communicating various information streams over numerous send and get antennae, while utilizing the same data transfer capacity and with no extra power use.

Fig. 4 and 5 shows that BER diminishes monotonically to 30 at SNR of about - 24 dB at ordinary MIMO-OFDM, about - 27 dB utilizing Polar coding, which implies that best execution is accomplished while employing Polar Coding. Thereafter, analyse the frameworks without OFDM and with OFDM those results are updated in the above Fig. 4 and 5. Fig. 4 and 5, shows that the exhibition of BER at QAM balance accomplishes less BER when contrasted and QPSK modulation.

6.3 Comparative analysis

The comparative analysis of proposed MFO-IFFA and SPSO-PTS method in terms of PAPR are tabulated in below Table 2. From Table 2, indicates that the proposed MFO-IFFA method produces less PAPR value (7.1 dB) when compared with existing ASM [17] and SPSO-PTS [18] which accomplishes a

Table 2. Comparative analysis of PAPR

Existing Methods	PAPR, dB
ASM [17]	7.3
SPSO-PTS [18]	7.4
Proposed MFO-IFFA	7.1

PAPR of around 7.3 & 7.4 dB respectively. From the outcomes, it shows that the proposed MFO-IFFA method incorporates at a quicker amount once contrasted with the supplementary PTS strategies.

By modifying a slight expansion in the firefly power, MFO-IFFA has been proposed which brought the reduction in PAPR at the range of 0.2–0.4 dB when contrasted with conventional strategies.

Fig. 6 and 7 shows the comparative analysis of PAPR and BER reduction, where Table 3 shows the analysis of conventional HICA method [16] under the QAM regulation ([2x2], [4x4]). Additionally, QAM 64 regulation procedure utilizing HICA and proposed MFO-IFFA channel assessment techniques have been simulated. Table 3 are displaying the normal exhibitions for PAPR and BER individually. The comparable importance is commencing over the QAM regulation dependent outcomes. In the process of QPSK and QAM, BER execution of QAM is superior. Consequently, QAM-64 is predominant than utilizing QPSK adjustment.

Table 3. Comparative analysis of PAPR and BER performance

QAM Modulation	PAPR (dB)		BER	
	HICA [16]	Proposed MFO-IFFA	HICA [16]	Proposed MFO-IFFA
2 x 2	6.86	6.81	0.0042	0.0031
4 x 4	6.78	6.74	0.0055	0.0025

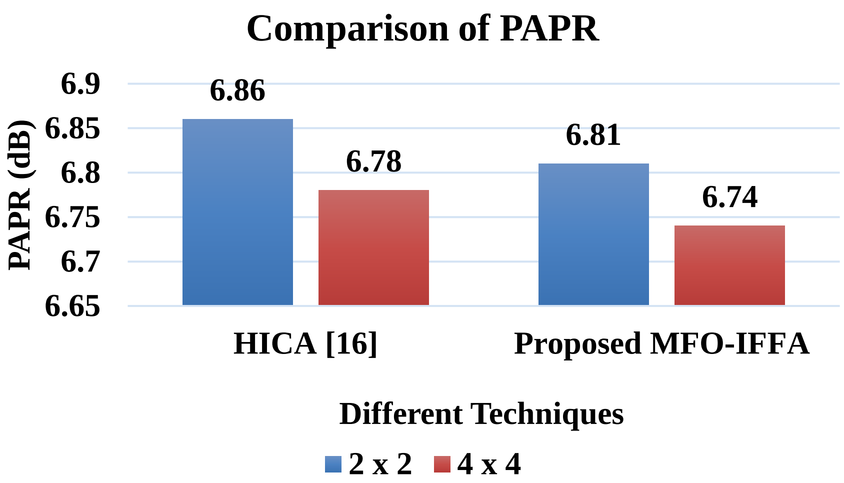

Figure. 6 Performance of PAPR reduction

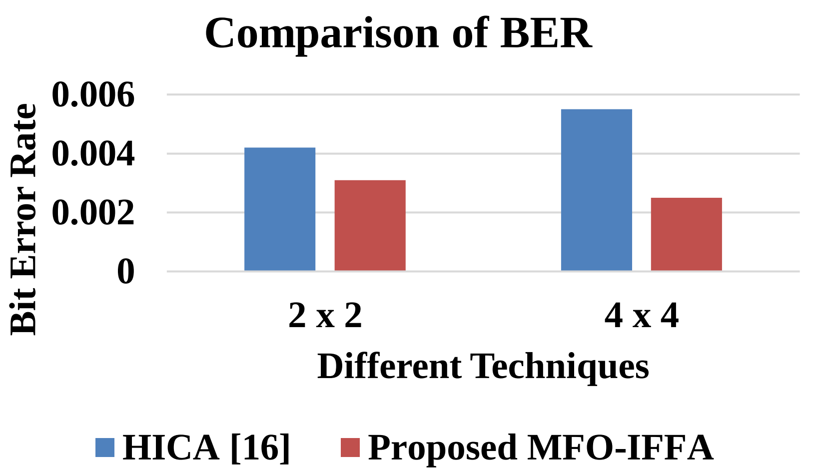

Figure. 7 Performance of BER reduction

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Table 4. PAPR comparison

QPSK Modulation	Existing Methods	PAPR (dB)
	ASOICF [19]	4
	Proposed MFO-IFFA	3.6

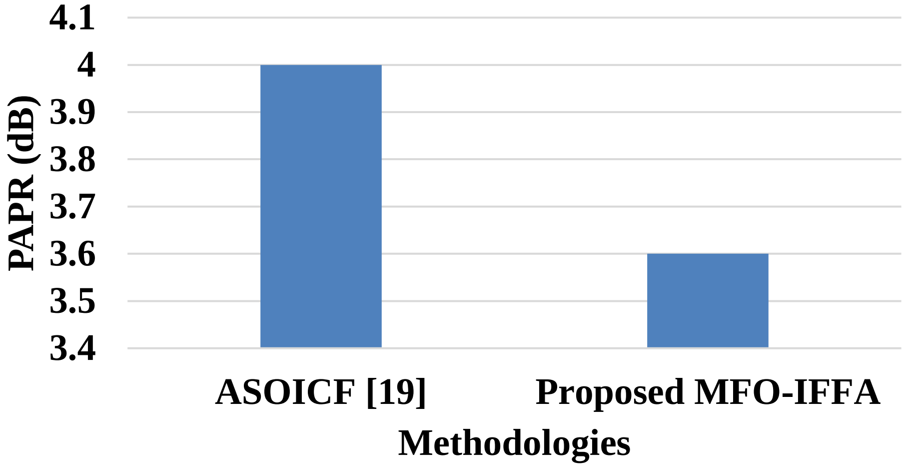

Figure. 8 Comparative analysis of PAPR

Table 4 shows the comparative analysis of PAPR with existing ASOICF [19] techniques. A performance of PAPR is designed for proposed and existing technique is appeared in figure 8. This figure is plotted at a condition when over sampling factor of QPSK modulation at 4, the PAPR determined using ASOICF is 4 dB. Subsequently, the proposed MFO-IFFA achieves the PAPR of 3.6 dB which is better than existing ASOICF [19]; and also reduces the randomness of OFDM signal effectively.

7. Conclusion

In this research, the polar coding of PTS is planned on MIMO-OFDM and MFO-IFFA is proposed for PAPR and BER while transmitting the data. In this paper, MFO-IFFA calculation is employed to PTS strategy for the determination of ideal stage features to decrease PAPR at a quicker rate. The simulation outcomes display that the proposed MFO-IFFA calculation provides better results through a PAPR decrement at the range of 7.1 dB when compared with conventional OFDM methods. The proposed research is a compelling technique as it gives a decent compromise between PAPR decrease and computational intricacy. The simulation outcomes display that projected MFO-IFFA outperforms the conventional SPSO-PTS, ASOICF and ASM based estimation that was unsuccessful while attaining the trade-off amongst PAPR performances. The results, indicates that the proposed MFO-IFFA achieves the PAPR reduction up to 3.6 dB. Additionally, the BER of the proposed MFO-IFFA for 4×4 is 0.0025, which is less when compared to HICA. In future, this research can be further prolonged by using recent optimization technique under various modulation.

Conflicts of Interest

The authors declare no conflict of interest.

Author Contributions

The paper conceptualization, methodology, software, validation, formal analysis, investigation, resources, data curation, writing—original draft preparation, writing—review and editing, visualization, have been done by 1st author. The supervision and project administration, have been done by 2nd author.

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