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A SUB-OPTIMAL PTS ALGORITHM BASED ON BACTERIAL FORAGING OPTIMIZATION TECHNIQUE FOR PAPR REDUCTION IN MIMO-OFDM SYSTEM

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ABSTRACT

A suboptimal partial transmit sequence (PTS) based on bacterial foraging optimization (BFO) algorithm is presented for the low computation complexity and the reduction of the peak-to-average power ratio (PAPR) of a multiple input multiple output orthogonal frequency division multiplexing (MIMO-OFDM) system. In general, PTS technique can improve the PAPR statistics of a MIMO- OFDM system. However, it will come with an exhaustive search over all combinations of allowed phase weighting factors and the search complexity increasing exponentially with the number of subblocks. In this paper, we work around potentially computational intractability; the proposed bacterial foraging optimization (BFO) scheme exploits heuristics to search the optimal combination of phase factors with low complexity. Simulation results show that the BFO technique can effectively reduce the computation complexity, PAPR reduction and BER performance of MIMO - OFDM system.

Keywords: *MIMO-OFDM, Partial Transmit Sequence, Peak-To-Average Power Ratio, Bacterial Foraging Optimization, Bit Error Rate.*

1. INTRODUCTION

The multiple-input multiple-output (MIMO) united with space time coded orthogonal frequency division multiplexing (OFDM) is one of the most hopeful systems providing large system capacity without additional bandwidth consumption for high speed wireless communication systems. To get better reliability through diversity gain, MIMO-OFDM [1-8] presents spatial diversity and enhances the system's capability on time variant and frequency selective channels. Time-domain broadcasted signal with an elevated PAPR (peak-to-average power ratio) particularly for a large number of subcarriers is the vital problem for MIMO-OFDM applied systems. Numerous methods for reduction of PAPR have been introduced. Clipping, coding, adaptive pre-distortion, DFT-spreading and probabilistic (scrambling) technique are the PAPR reduction methods [3].

The probabilistic (scrambling) technique comprises of SLM (Selective Mapping), PTS (Partial Transmit Sequence), TR (Tone Reservation) and TI (Tone Injection) techniques. Clipping and filtering have been proposed in [11] to reduce the PAPR of MIMO-OFDM. Even though Clipping is the simplest technique; it causes in-band signal distortion and out-of-band radiation. The authors in [12] have proposed classic SLM technique to reduce the PAPR of OFDM signals which doesn't require transmitting the extra SI index. Normally the PTS method is used among these techniques for PAPR reduction since it gets enough PAPR reduction and also because it is a distortion-less technique. One of the most generally used method for PAPR, PICR and PAR reduction by disjoint original data into sub-blocks is PTS. This technique splits original data into sub-blocks which are phase-shifted by constant phase factors [2]. The author in [9] projected PTS method, which has enhanced the PAPR performance evaluated to C-PTS while the complexity is even improved. Primarily, a new phase sequence was produced and approved out by primary producing the matrix of phase sequence. Based on the necessity for PAPR reduction and difficulty it is partitioned. With this new phase sequence, the difficulty of PTS decreases significantly as it decreases the number of IFFT at the expenditure of a small PAPR degradation. However, the complete search difficulty of the normal PTS method is boosted exponentially with the number of sub blocks, so it is practically not achievable for a large number of sub blocks. One of the most composite and difficult problems is to find out the best weighting factor [4]. For achieving the

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rotation phase vector for the PTS method, the RVGA (Real Valued Genetic Approach) method was presented by the authors in [6] to diminish the PAPR of OFDM signals.

In paper [4], the author works around potentially computational intractability; the projected PSO system exploits heuristics to look for the most advantageous combination of phase factors with small complexity. Based on the ABC (Artificial Bee Colony) algorithm, the authors in [2-5] presented the PAPR reduction method in OFDM. Their proposed scheme [2] can look for the enhanced mixture of the primary phase factors. To reduce the computational difficulty of the PTS in the OFDM system, they propose a PTS based on an artificial bee colony (ABC) algorithm (ABC-PTS) in this article. By a random search strategy (RS-PTS) and optimum PTS the ABC-PTS [5] was evaluated to conventional PTS. To diminish peak to average power ratio, the Co-PTS technique was proposed [7] with the SFBC MIMO-OFDM signal, which makes use of exchange optimization. At the same time, the number of candidate sequences is enlarged by employing spatial sub block circular permutation, which advances PAPR reduction presentation regularly. Due to this elevated PAPR there is a strict degradation of bit error rate (BER) presentations and in-band and out-of-band distortion arises in the non-linear amplifier and guides it to power inefficiency in the RF section of the transmitter.

In this paper, PAPR of MIMO - OFDM is considered as the problem space because computation complexity and number of searches to optimize the best phase factor is high. Therefore, this paper proposes the Partial Transmit Sequence based Bacterial Foraging Optimization Algorithm (BFOA-PTS) to reduce PAPR compared with existing approaches [2-4-5]. Here the selected phase factors differ from the existing approaches which will be explained in the phase factor optimization section. Three control parameters named number of bacteria, number of chemotaxis and number of swim are concentrated for performance evolution of the proposed method.

This paper is organized as follows: In section II PAPR reduction in MIMO-OFDM is introduced and CCDF is also described. Section III depicts the block diagram of BFOA-PTS of MIMO-OFDM in detail. Section IV describes the allowed phase factor and essential of optimization. Sections V and VI briefly explain the concept of the Bacterial Foraging Algorithm and optimization of the best phase factor combination. In section VII various simulation results are presented with comparison graphs and tables. Finally this paper is concluded in section VIII.

2. MIMO-OFDM and PAPR

In a MIMO-OFDM system with N subcarriers, the continuous time complex baseband is defined as

$$x(t)=\frac{1}{\sqrt{N}} * \sum_{n=0}^{N-1} Xn^{j2\pi(n/N)t} \qquad (1).,$$

$$0 \leq t \leq N-1$$

The high rate input data X is split into N. Low rate data X_0, X_1, …., X_{N-1} are transmitted through N subcarriers and M transmitters and receiver antennas. Here N frequencies or subcarriers are orthogonal to each other i.e.,^f=1/NT and T is the time period. The N subcarriers are independently modulated by a 16 QAM Modulator and N points IFFT (Inverse Fast Fourier Transform) generate the ready-to-transmit signal. The MIMO-OFDM transmits this signal through M transmitter antennas simultaneously. The N points FFT (Fast Fourier Transform) and the 16 QAM Demodulator broadcast the complex signal x(t) through N receiver antennas where M≥N. PAPR is defined as the ratio between the maximum and the average power of complex baseband signal x(t) which is given as,

$$PAPR[x(t)]=\max\{|x(t)^2/E\{|x(t)|^2\} \qquad (2)$$

E{.} denotes the expected value of the MIMO-OFDM system. The complementary cumulative distribution function (CCDF) is the commonly used performance measures for PAPR reduction, which is denoted as $CCDF=(PAPR > PAPR_0)$. CCDF of MIMO-OFDM is the probability that the PAPR of an MIMO-OFDM symbol exceeds the given threshold $PAPR_0$. The MIMO-OFDM transmits independent data (say $\mathbf{X}^{t1}$, $\mathbf{X}^{t\ 2}$… $\mathbf{X}^{tN}$) on M transmitter antennas simultaneously and in the same frequency band. At the receiver, N receiver antennas receive the signal rj. Thus we have the following received signals in each receiver antenn

$$r1=h_{11}X_{t1}+h_{12}X_{t2}+\ldots\ldots.+h_{1N}X_{tN}$$
$$r2=h_{21}X_{t1}+h_{22}X_{t2}+\ldots\ldots.+h_{2N}X_{tN}$$

.

.

$$rN=h_{N1}X_{t1}+h_{N2}X_{t2}+\ldots\ldots.+h_{nN}X_{tN}$$

3. PTS TECHNIQUES

Figure 1 show the block diagram of BFO-PTS based MIMO-OFDM system In the PTS technique, an input data block of N symbols is partitioned into disjoint subblocks. The subcarriers in each

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subblock are weighted by a phase factor for that subblock. The phase factors are selected such that the PAPR of the combined signal is minimized.

In the conventional PTS technique [8, 9] input data block X is partitioned into M disjoint subblocks $X_m = [X_{m,0}, X_{m,1}, \ldots, X_{m,N-1}]^T$, $m = 1, 2, \ldots, M$, and the subblocks are combined to minimize the PAPR in the time domain. The L-times oversampled time domain signal of X_m, $m = 1, 2, \ldots, M$, is denoted $\mathbf{x}_m = [x_{m,0}, x_{m,1}, \ldots, x_{m,NL-1}]^T$. set of $\mathbf{x}_m$, m = 1, 2, …, M, is obtained by taking an IFFT of length NL on X_m concatenated with $(L-1)N$ zeros. These are called the partial transmit sequences. Complex phase factors, $b_m = e^{j\varphi m}$, m = 1, 2… M, are introduced to combine the PTSs. The phase factors is denoted as a vector $W = [w_1, w_2 \ldots w_m]^T$.

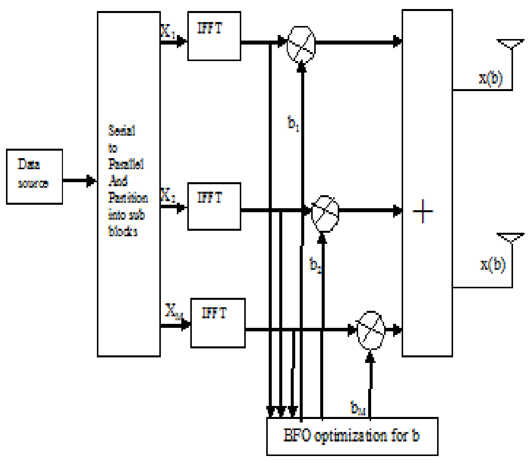

Figure 1. Block diagram of BFO-PTS method

The time domain signal after combining is given by

$$x(b) = \sum_{m=1}^{M} b_m \cdot x_m \qquad (3)$$

where $x(b) = [x_0(b), x_1(b), \ldots\ldots\ldots\ldots x_{NL-1}(b)]^T$

In the proposed method two transmitting and receiving antennas are considered for simulation.

4. PHASE FACTOR OPTIMIZATION

In general, the selection of the phase factor is limited to a set with finite number of elements to reduce the search complexity. The set of allowed phase factors is

$\mathbf{P} = \{e^{j2\pi l/w}, l=0,1 \text{---} W-1\}$ (4)

where W is the number of allowed phase factors. We can fix a phase factor without any performance loss. There are only M−1 free variables to be optimized and hence W^{M-1} different phase vectors are searched to find the global optimal phase factor. The search complexity increases exponentially with M, the number of sub-blocks.

The selection of the phase factor is restricted to a set with finite number of elements to reduce the search complexity or number of searches. Existing approaches have taken the allowed phase factor W=2,b={+1,-1}or W=4,b={+1,-1,+j,-j}. Here in the proposed method the set of allowed phase factors W is chosen equal to the number of sub-blocks M i.e., $W \propto M$. By incrementing the size of the allowed phase factor, PAPR of an MIMO-OFDM system can get reduced. The set of allowed phase factor P can be obtained from equation (4) .The phase factor possibilities are given by $b^i = e^{j\phi M}$ where $\phi \in [0, 2\pi]$. For example if we consider M=8 we choose W=8, b= {1, 0.7071 + 0.7071j, j, -0.7071 + 0.7071j, -1, -1, -0.7071 - 0.7071j, -j, 0.7071 - 0.7071j}.

So, the main goal of the PTS technique is to optimize the best phase factor b^i from the phase vector b. The search complexity also increases exponentially with W, number of phase factor since in the proposed method, the allowed phase factors W are directly proportional to the number of subblocks M.

5. BACTERIAL FORAGING OPTIMIZATION:

In recent years E.coli introduced the Bacterial Foraging Optimization Algorithm (BFO) for numerical optimization problems [10]. In BFO, a bacterium keeps foraging on food population by two basic steps, tumble and swim. The main goal of a bacterium is to optimize the best food position within the pre-defined iterations. Chemotaxis is the initial step for a bacterium in which N_s numbers of swim steps are to be followed. When a bacterium completes each swim it calculates the fitness of current food position and compares it with the previous position. Once the fitness of the current food decreases, then the previous position of the bacterium gets changed in the moving direction which is known as tumble. Tumble is a unit walk in any random direction on food sources. In case a bacterium optimizes best fitness in the next swim steps, it keeps moving in the same direction up to N_s swim steps. Alternation between the swim and tumble steps involves in one chemotaxis iteration.

After completion of N_c chemotaxis steps, a bacterium finds M best food positions, therefore N number of bacteria optimize $S = N_c * N$ number of food positions. Reproduction and Elimination-dispersal are the augment steps in BFOA. In the reproduction step, bacteria in the S food positions are arranged in descending order and split into two i.e, $S_r = S/2$. Now the 2nd half of S bacteria are killed as their fitness is low. The healthiest bacteria split into two and are placed in the same food

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position for the next iteration. After N_r reproduction steps are completed the elimination-dispersal step is placed based on the elimination probability E_{pr}. In elimination-dispersal few bacteria are removed from the food position randomly based on E_{pr}. Then some of the bacteria are placed in random food positions for the next iteration. After N_{ed} elimination-dispersal steps the best food position is optimized by the healthiest bacteria.

6. BFO- PTS FOR PAPR REDUCTION:

In this paper, BFO algorithm is proposed to optimize the best phase factor from W^{M-1} combinations where M is the number of sub-blocks and W is the allowed phase factor. In the PAPR reduction, the food source is equivalent to phase vector $b = \{b_{i1}, b_{i2}, b_{i3, \ldots}, b_{i\ WM-1}\}$, $i = 1,.. W^{M-1}$. In BFO-PTS the objective is to find the minimum of fitness P (b_i) i.e., the best phase factor combination for which the PAPR value is minimum.

The table 1 shows the parameters involved in BFO algorithm

Table 1. Parameters used in BFO

No. of Bacteria	$N = [B_{i1}, B_{i2},..B_n]$
No. of Chemotaxis	N_c
No. of Swim	N_s
No. of Reproduction	N_r
No. of Elimination-dispersal	N_{ed}
Elimination probability	E_{pr}

Step 1. Initially N bacteria are randomly placed into the population

Step 2. Each bacterium B_i calculates P (b_i) where

$$P(b_i) = \max [|x^t(b_i)|^2] / E [|x^t(b_i)|^2]$$

Step 3. Calculate fitness of B_i at i^{th} swim, $P^{new}(b_i)$

3.1. Check $\{P^{new}(b_i) < P(b_i)\}$

3.2. Then if $P(b_i)=P^{new}(b_i)$ continue with next swim step up to N_s

3.3. If $\{P^{new}(b_i) > P(b_i)\}$ then take the tumble step. Here tumble denotes 1 unit walk in a random direction.

Step 4. Continue step 3 up to N_c chemotaxis steps

Bacteria B_i optimize $\{N_{c*}\ P^{new}(b_i)\}$ So N bacteria optimize $S = (N_c *N)$ best food positions (phase factors).

Step 5. Reproduction.

5.1. Arrange S in ascending fitness P (b_i).

5.2. The S_r = S/2 bacteria with the highest P (b_i) fitness die and other S_r bacteria with the best fitness split into two bacteria which are then placed into the same location.

Step 6. Continue step 3 to step5 up to N_r reproduction steps

Step 7. Elimination-Dispersal

7.1. Initialize Elimination probability E_{pr}

7.2. An individual bacterium is selected stochastically according to E_{pr} to be removed from the population.

7.3. The removed bacteria are replaced by the new bacteria which are randomly placed in the population.

Step 8. After N_{ed} processes are completed, the bacterium with minimum P (b_i) is selected.

7. SIMULATION RESULTS:

In this section, we show that the BFO-PTS performance in terms of PAPR reduction with reduced computational complexity of searching the phase factors when compared with ABC-PTS [2-5] and PSO-PTS [4]. Several simulations have been conducted to evaluate and compare our proposed BFO-PTS method with existing methods. The analysis of the proposed BFO-PTS system using two transmitting and receiving antennas has been carried out using MATLAB 12.0. The simulation parameters considered for this analysis is summarized in Table 2.

Table 2. Simulation Parameters

Simulation parameters	Type/value
Number of subcarriers	256
Number of subblocks(M)	4,8,16,32
Oversampling factor(L)	4
Number of antennas(T_x)	2×2
Modulation Scheme	QAM
Phase Factor(W)	2,4,8,16,32

Existing approaches chose among the allowed phase factors W = 2 or W = 4. When a larger value of phase factor (W) is chosen, better PAPR reduction is obtained than the existing approaches. Here, W is changed iteratively in $[0,2\pi]$. Computation time and memory required to simulate higher subblocks with more phase factor combination is high. So we limit the simulation to the following simulated results.

In the BFO-PTS method, there are three control parameters: number of bacteria N, number of chemotaxis steps N_c and number of swim steps N_s. Other parameters used in the BFO-PTS do not change the population size. Number of searches is calculated by ($N^* N_c^* N_s$).

Figure 2 shows the BFO-PTS PAPR reduction for M = 2, 4, 8, 16 and 32 sub-blocks with phase factor, W= 2 respectively with the original MIMO-OFDM PAPR. In each combination, the BFO - PTS can obtain best phase factor combination with minimum number of searches.

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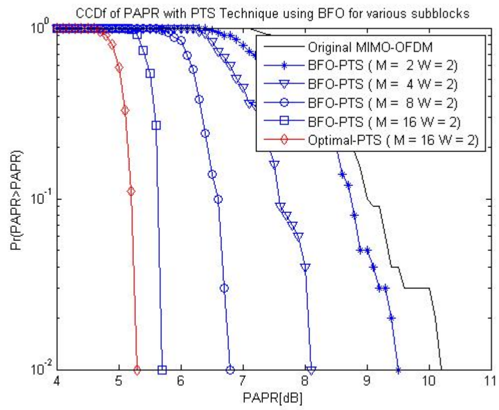

Figure 2. CCDF Of PAPR With PTS Technique Using BFO-PTS For Various Sub-Blocks M=2, 4, 8, 16 & 32 For Phase Factor W=2 And Original MIMO-OFDM

Figure 3.1 and Figure 3.2 shows the PAPR values for different phase factor combinations W= 2, 4, 8, 16, 32 with M= 2 and 4 sub-blocks. BFO-PTS reduces the PAPR with minimum number of searches of finding the optimum phase factor combination.

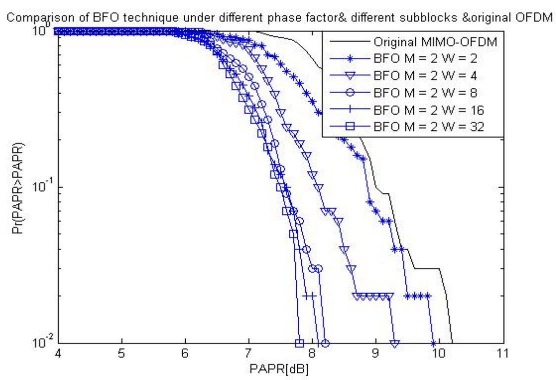

Figure 3.1 BFO-PTS With M=2 For Phase Factor W=2, 4, 8, 16, 32

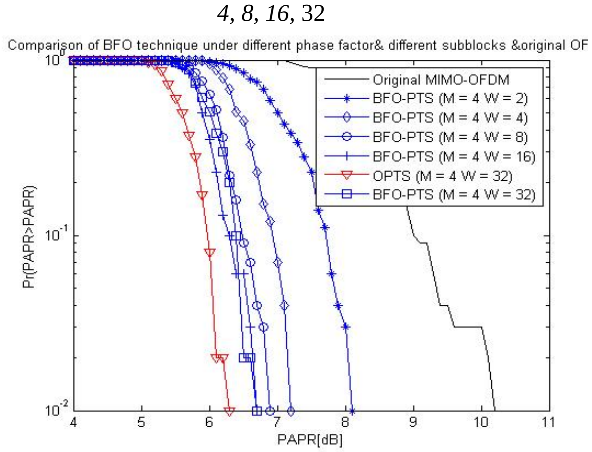

Figure 3.2. BFO-PTS With M=4 For Phase Factor W=2, 4, 8, 16, 32

Figure 3.3 shows the PAPR values of BFO-PTS for M = 8 sub-blocks W= 2 and 4 phase factor combination.To evaluate the optimum phase factor combination using BFO-PTS for M=8 and W=2 combination, we have assigned the B = 5 bacteria, N_c = 4 chemotaxis steps, N_s = 3 swim steps, N_r = 3 reproduction steps, N_{ed} = 2 Elimination-dispersal steps and $E_{pr\,=}$ 0.2 elimination probability. On the first chemotaxis iteration, each bacterium takes three swim steps and optimizes one best PAPR value at the last swim step. Accordingly, five bacteria optimizes B * N_c = 5 * 4 = 20 best PAPR values at the completion of N_c chemotaxis steps. As the next step of BFO-PTS is reproduction, the optimized values S are sorted and divided into S_r = S/2 values. Therefore the best 10 values moves into next generation and it reproduces the same values at the same positions. Hence S = 20 bacteria swim in the direction of searching best food and optimizes the S * N_c number of values. Once N_r reproduction steps are completed, the first of N_{ed} elimination-dispersal step are taken with the elimination probability of $E_{pr\,=}$ 0.2. But, elimination steps involved in BFO-PTS selects and replaces the values on random search. Finally, the best PAPR 6.90 dB is chosen from the optimized PAPR values.

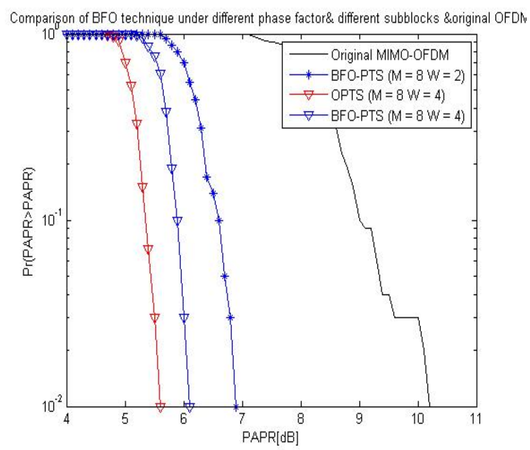

Figure 3.3 BFO-PTS With M=8 For Phase Factor W=2&4

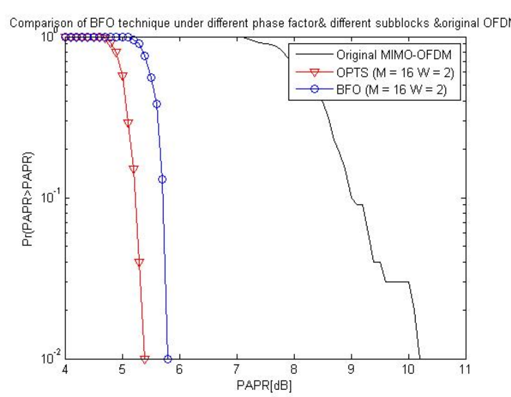

Figure 3.4. BFO-PTS With M=16 For Phase Factor W=2

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Figure 3.4 shows the PAPR values of M = 16 sub-blocks and W = 2 phase factor combination with optimum PTS. The number of possible phase factor combination increases with the increase in phase factors for M=16 subblocks. As the number of subblocks and the set of phase weighting factor are increased, the performance of the PAPR reduction becomes better. However, the processing time gets longer because of much iteration. For example M=16 &W=4 has 4^{16-1}=huge no of combinations for which simulation is time consuming. So we limit our simulation for this combination (M=16 & W=2) in which BFO –PTS produces best PAPR in only 900 searches out of 32,768 combination.

In Figure 4 we have compared the PAPR values of MIMO-OFDM using BFO-PTS and PSO-PTS for M = 8 sub-blocks and W = 2 phase factors cobination. The BFO-PTS method has reduced the PAPR up to 6 .9 dB in 60 searches when compared to the PAPR value of PSO-PTS of 8.0 dB in 88 searches.

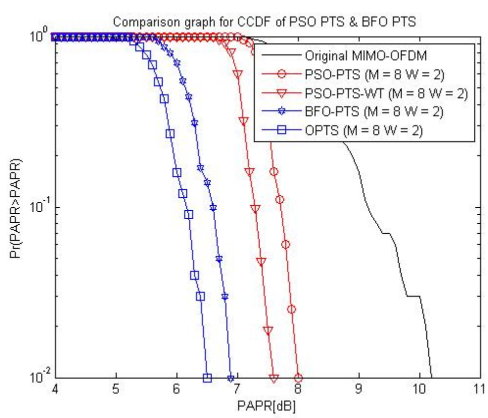

Figure 4.CCDF Comparison graph of PSO PTS & BFO PTS (M=8 & W=2)

Table 3. Computational Complexity of OPTS, BFO-PTS and PSO PTS W=2 & M=8

Method	Computation complexity	PAPR
OPTS	$W^{M-1}=2^{8-1}=128$	6.5 dB
PSO-PTS	$V\times O(W^3)=(1+Gn)\times O(W^3)$ $=(1+10)\times(2^3)=11\times8=88$	8.0 dB
PSO-PTS with threshold	23	7.6 dB
BFO-PTS	$N^* N_c{}^* N_s = 5{*}4{*}3 = 60$	6.9 dB

Table 3 illustrates the computational complexity of searching the best phase factor combination for M=8 subblocks and W=2 phase factor combination.BFO -PTS outperforms the existing PSO PTS method as it requires only 60 searches to obtain a PAPR of 6.9 db which is close to the optimum value of 6.5 db where PSO PTS requires 88 searches .

Figure 5 compares the PAPR values of MIMO-OFDM using BFO-PTS and ABC-PTS for M = 16 sub-blocks and W = 2 phase factor combination.

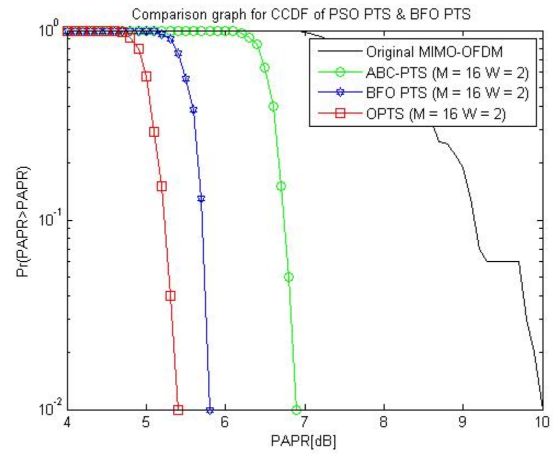

Figure 5. CCDF Comparison graph of ABC PTS & BFO PTS(M=16 & W=2)

Table 4. Computational Complexity of OPTS, BFO-PTS and ABC PTS (W=2 & M=16)

Method	Computational complexity	PAPR
OPTS	$W^{M-1}= 2^{16-1}=2^{15}=32768$	5.40 dB
ABC PTS	MCN∗SN= 256∗4 = 1024	6.91 dB
BFO-PTS	$N^* N_c{}^* N_s = 30{*}10{*}3 = 900$	5.80dB

Table 4 illustrates the computational complexity for M=16 subblock & W=2 phase factor. Here BFO PTS requires 900 searches to obtain the PAPR value of 5.80 db close to the optimum value of 5.40 db whereas ABS-PTS requires 1024 searches. In table 4, MCN*SN is the scale to measure the number of searches taken in the ABC-PTS method [5].

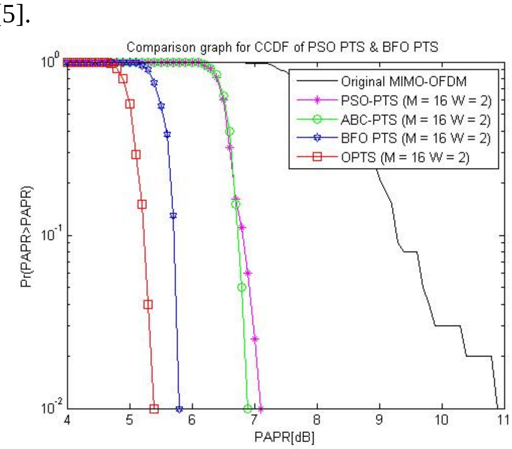

Figure 6. CCDF Comparison graph of ABC PTS, BFO PTS and PSO PTS(M=16 & W=2) for 900 searches

In Figure 6, comparison between the BFO-PTS, PSO-PTS and ABC-PTS methods is shown for 900 searches for W = 2 phase factor and M = 16 sub-

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blocks combination. The comparison shows that BFO PTS gives better PAPR reduction compared with PSO PTS & ABC PTS.

Table 5. Computational Complexity of OPTS, BFO-PTS,PSO-PTS and ABC PTS (W=2 & M=16) for 900 searches

Methods	Computational complexity	PAPR
OPTS	$W^{M-1} = 2^{16-1} = 2^{15} = 32768$	5.40 dB
PSO-PTS	$PS = 30*30 = 900$	7.10 dB
ABC-PTS	$GK = 30*30 = 900$	6.90 dB
BFO-PTS	$N* N_c * N_s = 30*10*3 = 900$	5.80 dB

In table 5, we have tabulated the PAPR values of various PTS methods such as ABC-PTS, PSO-PTS and BFO-PTS for 900 searches and the optimum PTS for 32,768 searches. Here P = S = 30 represents the population and G = K = 30 represents the maximal generations / iterations used in PSO-PTS and ABC-PTS. For 900 searches the table shows BFO PTS gives better PAPR reduction when compared with the other two methods. The proposed BFO-PTS scheme along with the increased phase factors election gives better PAPR reduction with minimum number of searches.

Figure 7 shows the performance of Bit Error Rate vs Signal-to-Noise Ratio comparison between the original MIMO-OFDM and the BFOA-PTS method when transmitting the input signal by 16 sub-blocks and 2 phase factors. It shows that our BFO-PTS method gives better BER performance than the original MIMO-OFDM.

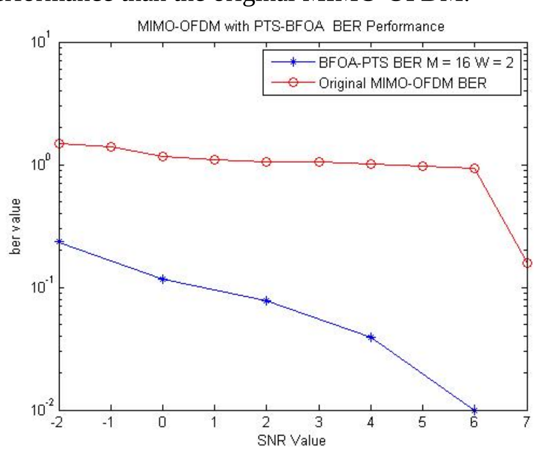

Figure 7. Performance graph BER vs SNR for the original MIMO-OFDM and BFO PTS MIMO-OFDM (M = 16 and W = 2)

7. CONCLUSION:

In this paper, we propose a BFO based PTS algorithm (BFO-PTS) to search better combination of phase factors for MIMO-OFDM signals. Compared to the existing PAPR reduction methods, the BFO-PTS algorithm can get better PAPR reduction and significantly reduce the computational complexity for larger PTS subblocks at the same time. Moreover, because the BFO-PTS algorithm only has three control parameters, so it is easy to be adjusted. Simulation results show that the BFO-PTS algorithm is an efficient method which can provide a better PAPR performance.

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