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Comparative Analysis of PAPR Reduction in PTS-OFDM Using Different Optimization Techniques

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ABSTRACT: One of the most compelling modulation technique in 4G communication is the orthogonal frequency division multiplexing. The OFDM (Orthogonal Frequency Division Multiplexing) system is having a high PAPR (Peak to Average Power Ratio) and poor spectral efficiency. Signal scrambling technique like Partial Transmit Sequence (PTS) is adopted to minimize the PAPR. In PTS technique search complexity is very high for optimal phase vectors. In this paper various optimization techniques are adopted to minimize the PAPR and computational complexity. A comparison between Shuffled frog leap algorithms, Particle swam optimization, Anti bee colony and Firefly algorithm is performed and it is observed that shuffled frog leap algorithm produces the finest results in terms of PAPR and minimizes the computational complexity. A LTE Uses OFDM for download and SC-OFDM for uplink. Since OFDM suffers with High PAPR it cannot be used for uplink because of battery life of mobile.

Keywords: PAPR, OFDM, PTS, Shuffled frog leap, firefly, ABC.

Abbreviations: PAPR, Peak to Average Power Ratio; OFDM, Orthogonal Frequency Division Multiplexing; PTS, Partial Transmit Sequence.

I. INTRODUCTION

Wireless Communication networks have accomplished a phenomenal development. The mobile wireless Generation (G) goes to a shift in the system's nature, speed, technology, frequency, data capacity, latency, etc. [1]. OFDM (Orthogonal Frequency Division Multiplex): OFDM is considered as a modulation technique in LTE because of its high data bandwidths while maintaining a significant degree of resilience to reflections and interference [2]. As data was carried on many carriers, if some were missing as a result of interference from reflections, etc. the system was yet capable. In uplink OFDMA is used and in case of downlink SC-FDMA (Single Carrier - Frequency Division Multiple Access) is adopted [3]. In literature many PAPR reduction techniques are used among that one of the best PAPR reduction technique is PTS [4]. In this PTS technique, identifying the best phase factors is a difficult task. To reduce the search complexity, different optimization techniques are used.

II. OFDM USING PARTIAL TRANSMIT SEQUENCE

In Partial Transmit Sequence technique the bit stream is transformed to a corresponding block of data, as needed in traditional OFDM transmission. It divides incoming data into a parallel block and divide into smaller sub-blocks. Sub blocks should have the same length as the original parallel block of data.

A. Mathematical Analysis
The input data is represented as:

$$X = [X1, X2 \ldots\ldots XN] \quad (1)$$

where X is the incoming serial data and N is the number of sub-carriers.

$$X_m = \mathrm{IFFT}(X) \quad (2)$$

The IFFT output is now multiplied with a pre-defined phase factor which can be represented as

$$b_w = e_w^{j\theta} \quad (3)$$

The modified OFDM symbol is represented as

$$x' = \sum_{m=0}^{M-1} b_w x_m \quad (4)$$

The OFDM symbol with less PAPR is transmitted.

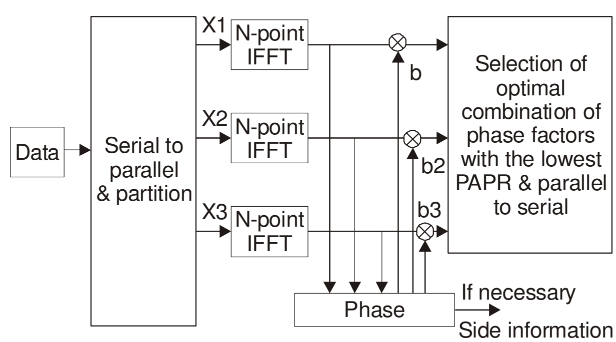

Fig. 1. Represents PTS OFDM.

III. PEAK TO AVERAGE POWER RATIO (PAPR)

In OFDM transmitted signal combines many sub carrier which leads to significant peak values in the time domain. PAPR is described as a ratio of peak power to an average power of transmitting signal [5]. The mathematical valuation of PAPR is defined in Eqn. (5).

$$PAPR = \frac{\text{Peak Power}}{\text{Average Power}} = \frac{|X[k^*]|^2}{E[X]} \quad (5)$$

The transmitted samples are IFFT samples of information symbols so the *k*th sample of IFFT symbol can be described as below

$$x(k) = \frac{1}{N}\sum_{i=0}^{N-1} X(i)\, e^{\frac{j2\pi ki}{N}} \tag{6}$$

IV. OPTIMIZATION

The objective function for optimization is PAPR of time domain transmitting signal as shown in Eqn. (5). Time domain signal is modified by multiplying phase factors so the modified OFDM signal will be 'X' as described in Eqn. (6) [6].

$$X(t) = ((X_1 * p_1) + (X_2 * p_2) + (X_3 * p_3) + \ldots + (X_B * p_B)) \tag{7}$$

Here Cost function is PAPR of UFMC with respect to phase vector so the cost function has a dependency on variable 'p'. So Cost Function can be defined as below Eqn. (8) [7].

$$F(p) = \frac{\max\{|x'(p)|^2\}}{\text{avg}\{|x'(p)|^2\}} \tag{8}$$

The optimizer have to find the 'P' that will bring PAPR of OFDM to low. In this we used five different optimizers like Artificial bee colony algorithm

– Particle swarm algorithm
– Shuffled frog leap algorithm
– Fireflies algorithm.

A. Artificial Bee Colony Algorithm

Employed bee to search the food source which is equal to randomly generated phase factor vector. Scouts search for new sources (phase vectors) if they are not observed by a random generation. Onlookers will select the best among them. ABC optimization approach is given as follows [8]

1. Phase initialization
2. Repetition of phase of employed bees, onlooker bees and scout bees
3. Memorize the best solution achieved so far

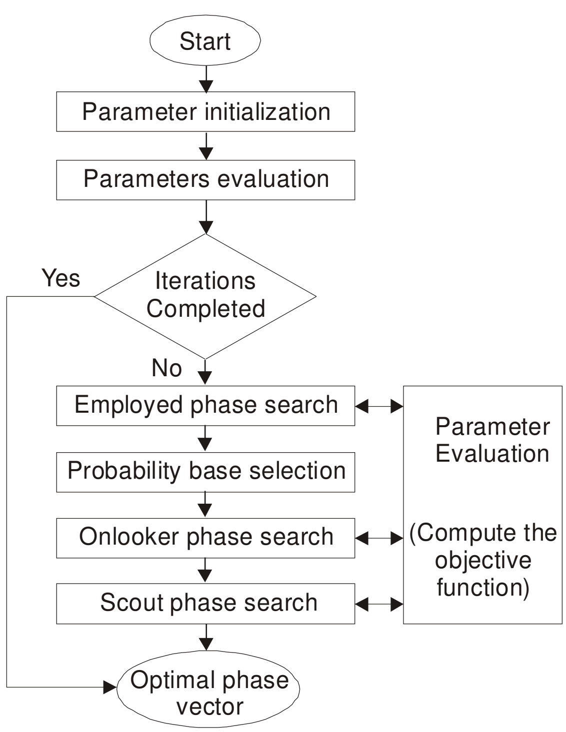

Fig. 2. Flowchart for Artificial Bee Colony Algorithm.

B. Particle Swarm Optimization Algorithm

The optimization work flow as follows randomly generate the phase vectors i.e. birds or particles, Calculate fitness function, Check the best among group called local best, Calculate velocity which direct the bird towards the local optima Velocity α (difference between current position and local optima). The next position of birds are calculated with respect to the previous position an velocity as follows [9].

Next position = present position + present velocity

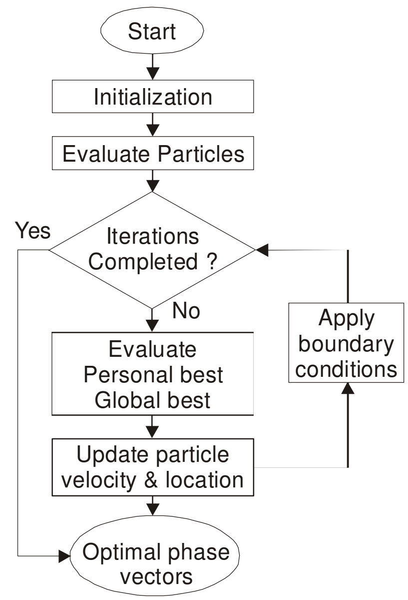

Fig. 3. Flow chart of Particle Swarm Algorithm.

C. Firefly algorithm

Firefly algorithm depended on the glimmering examples and conduct of fireflies. In essence, Firefly algorithm three idealized rules that Fireflies are unisex, engaging quality is relative to the brightness so they both abatement as their separation increments and the firefly brightness is obtained by the landscape of the objective function [10-11].

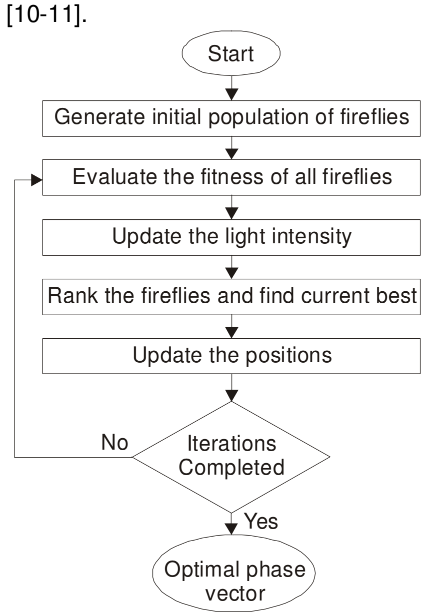

Fig. 4. Flow chart of Fire-Flies Algorithm.

D. Shuffled Frog Leap Algorithm (SFLA)

SFLA is meta-heuristic search algorithm for optimization. The SFLA is cooperative base search algorithm, inspired by natural memetics [12-13]. SFLA is inspired by the memetic nature of group of frogs while searching for the food resources. SFLA adopt the both deterministic and random approaches, deterministic nature help as cooperative nature to improve the chance of acquiring optimality by sharing information with other in population. The random help to explore the search space and to find new dimensions in search space. In SFLA the information transfer by observing actions of frog whereas in other natural inspired algorithms the information is transfer in crossover which need two parents, so degree of freedom for information transfer is more in SFLA. [14-15]

Overview of SFLA

Initialization: First generate F frogs randomly pop(i)=1,2…,F.

Global exploration

Step 1: If total number of memeplexes are K then each memeplex contains N frogs. So F=MN. Record local best from each memeplex L_M^{best} and global best among all memeplexes are G_{best} .

Step 2: Memetic evaluation will be performed within each memeplex to attain local best outlined below.

Step 3: After completing local memtic evolution the memeplexes will be shuffled to form new memeplexes. Check stopping criteria if satisfies end the process and record G_{best} as solution. Otherwise go to the Step 1.

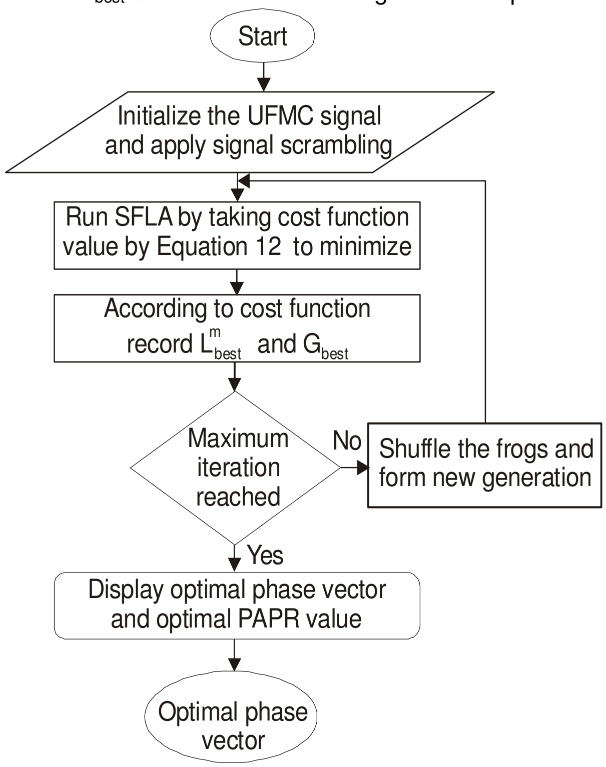

Fig. 5. Flow chart for SFLA to optimize PAPR.

Local exploration

Step 1: The maximum iterations "I_{sub}" for local exploration and number of frogs "N_{sub}" in sub-memeplex is initialized.

Step 2: Sub-memeplex is formed by the fitness of each frogs, if fitness is more it will place in sub-memeplex. Rank the frogs in sub-memeplex with their fitness as S_{best} to S_{worst}. Update the worst frogs with following equations.

$$f_{worst}(\text{new}) = f_{worst}(\text{old}) + D \quad (9)$$

$$D = rand * (S_{best} - f_{worst}(\text{old})) \quad (10)$$

Here D is step size. Validate the new values (D_{min}<D<D_{max}). If valid, update the f_{worst}, go the step 5. If not go to the step 3.

Step 3: Update the f_{worst} with Eqn. (13) but, step size D as in Eqn. (11). Validate new value. If valid update the f_{worst}, go to the step 5. If not go to the step 4.

$$D = rand * \left(G_{best} - f_{worst}(old)\right) \quad (11)$$

Step 4: Generate a random and valid frog position f_{new} and replace with the f_{worst} (old). Go to the step 5.

Step 5: Check if maximum iterations completed if true terminate the process record best values in memeplex. If not go to the step 2.

V. RESULTS

The below results is obtained by varying the iteration from 10 to 100 and by various optimization. Fig. 6 shows the CCDF plot for 10 iterations and the PAPR value for OFDM is 8.0978, the PAPR for PTS OFDM is 7.2751, the PAPR for PSO-PTS-OFDM is 7.0384,the PAPR for AC-PTS-OFDM is 6.691, the PAPR for FF-PTS-OFDM is 6.59 and the PAPR of SFL-PTS-OFDM is 6.56.

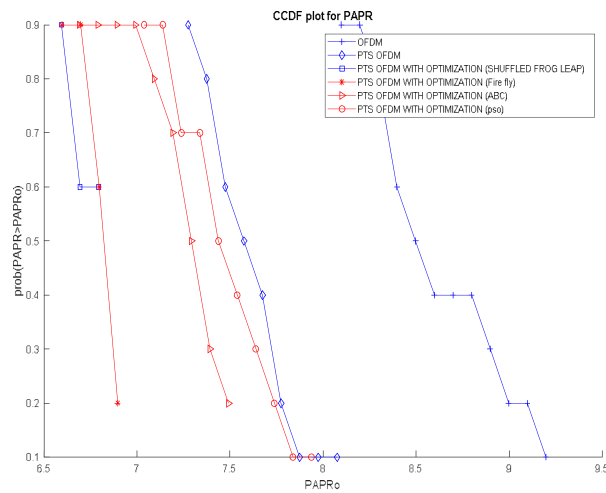

Fig. 6. CCDF PLOT for 10 iterations.

Fig. 6 shows the CCDF plot for 20 iterations and the PAPR value for OFDM is 7.456, the PAPR for PTS OFDM is 7.044, the PAPR for PSO-PTS-OFDM is 7.062, the PAPR for ABC-PTS-OFDM is 6.710, the PAPR for FF-PTS-OFDM is 6.492 and the PAPR of SFL-PTS-OFDM is 6.462.

Fig. 7 shows the CCDF plot for 50 iterations and the PAPR value for OFDM is 7.339, the PAPR for PTS OFDM is 7.0144, the PAPR for PSO-PTS-OFDM is 7.040, the PAPR for ABC-PTS-OFDM is 6.628, the PAPR for FF-PTS-OFDM is 6.36 and the PAPR of SFL-PTS-OFDM is 6.265.

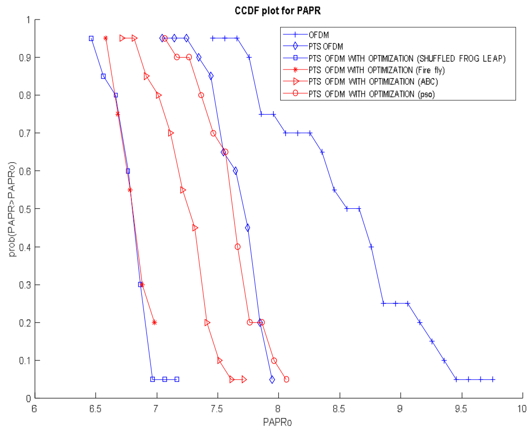

Fig. 7. CCDF PLOT for 20 iterations.

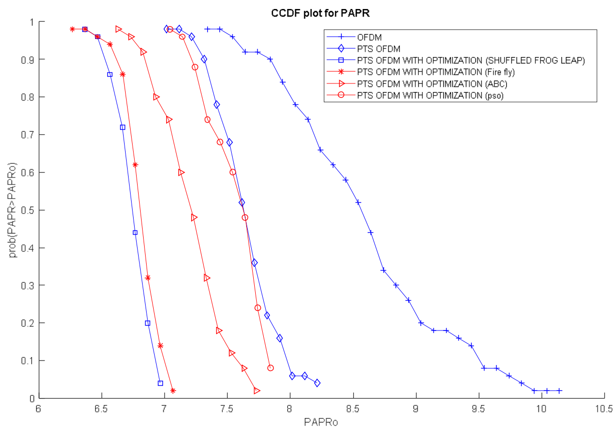

Fig. 8. CCDF PLOT for 50 iterations.

Fig. 8 shows the CCDF plot for 100 iterations and the PAPR value for OFDM is 7.239, the PAPR for PTS OFDM is 6.687, the PAPR for PSO-PTS-OFDM is 6.933, the PAPR for ABC-PTS-OFDM is 6.649, the PAPR for FF-PTS-OFDM is 6.3082 and the PAPR of SFL-PTS-OFDM is 6.265.

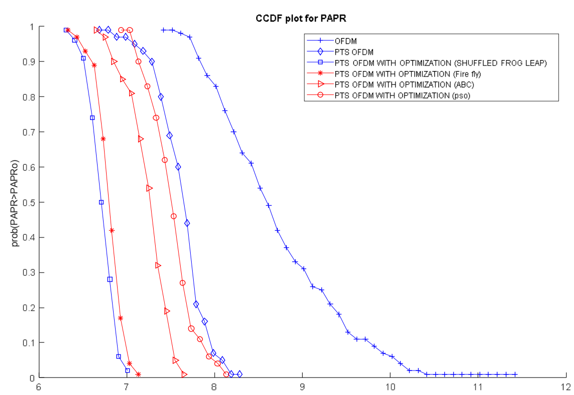

Fig. 9. CCDF PLOT for 100 iterations.

Fig. 9 and 10 shows the CCDF plot for 50 iterations and the PAPR value for OFDM is 7.213, the PAPR for PTS OFDM is 6.997, the PAPR for PSO-PTS-OFDM is 6.833, the PAPR for ABC-PTS-OFDM is 6.649, the PAPR for FF-PTS-OFDM is 6.3082 and the PAPR of SFL-PTS-OFDM is 6.265.

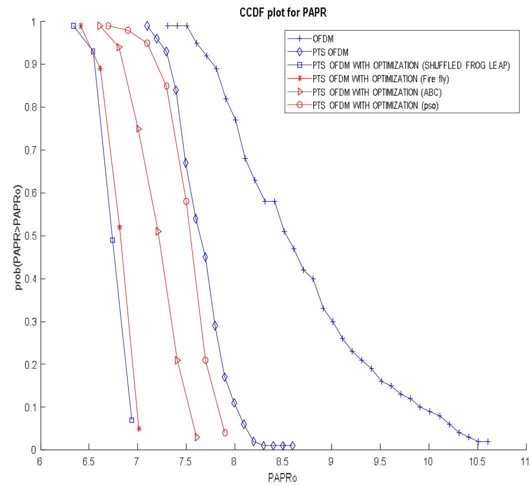

Fig. 10. CCDF PLOT for 100 iterations.

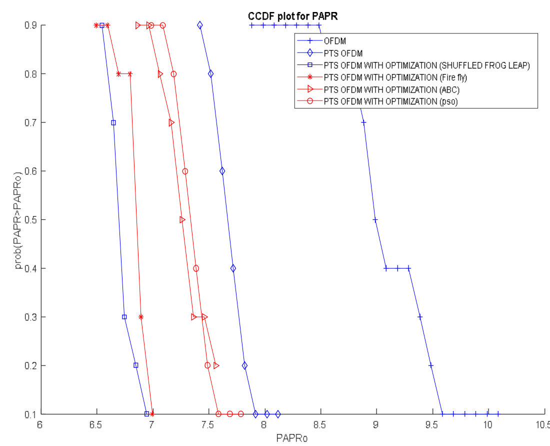

Fig. 11. CCDF PLOT for 100 iterations.

VI. CONCLUSION

From the above results it is observed that PTS-OFDM with shuffled frog leap algorithm produces best results when compare to OFDM and PTS-OFDM and other optimization techniques as iterations increases the PAPR value decreases and it is almost equal 6.23 dB. As the functional parameters of optimization techniques varies the PAPR value is obtained for less number of iterations. It is also observed that the Computational complexity is very less for SFL when compared to other optimization techniques.

Conflict of Interest. There is no conflict of interest.

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