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PAPR reduction of OFDM signals using PTS and Gaussian Firefly Algorithm

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Abstract-Orthogonal frequency division multiplexing (OFDM) method is a promising technique in this regard as it offers high data rate and reliable communications over several fading channels. But the main drawback of OFDM is the high peak to average power ratio (PAPR). In this thesis we present the technique to reduce the PAPR using Firefly algorithm in multicarrier modulation system. Simulation results show that the proposed scheme considerably outperforms the conventional system.

1.1 INTRODUCTION

In multi-carrier modulation, the most frequently used method is Orthogonal Frequency Division Multiplexing (OFDM); it has become very general in wireless communication. Unfortunately the main disadvantage of OFDM transmission is its large wrapping fluctuation which is quantified as Peak to Average Power Ratio (PAPR). Since power amplifier is used at the transmitter, so as to function in a perfectly linear area the working power must lies underneath the available power. For decrease of this PAPR lot of algorithms have been established. All of the methods have some sort of benefits and drawbacks. Clipping and Filtering is one of the simple method in which some part of transferred signal undergoes into distortion. Also the Coding arrangement decreases the data amount which is undesirable. If we deliberate Tone Reservation (TR) system it also allows the data rate loss with additional probable of increasing power. Again the methods like Tone Injection (TI) and the Active Constellation Extension (ACE) having criteria of increasing power will be unwanted in situation of power constraint environment. If we go for the Selected Mapping (SLM) and Partial Transmit Sequence (PTS) system, the PTS method has additional complexity than that of SLM method. This Selected Mapping is one of the promising methods due to its simplicity for implementation which familiarizes no distortion in the transmitted signal. It has been designated first in i.e. to be recognized as the traditional SLM method. This method has one of the disadvantages of sending the additional Side Information (SI) index along with the transmitted OFDM signal. This can be evaded using a special method described in.[1]

1.2 SWARM ALGORITHMS

PAPR reduction is a relatively new research topic and recently many new algorithms have been proposed. PAPR can be reduced using swarm algorithms to a great extent and fast too.[2]

1.2.1 Gaussian Firefly algorithm

In the firefly algorithm, the objective function of a given optimization problem is based on differences in light intensity. It helps the fireflies to move towards brighter and more attractive locations in order to obtain optimal solutions. All fireflies are characterized by their light intensity associated with the objective function. Each firefly is changing its position iteratively. The firefly algorithm has three rules:[3]

- All fireflies are unisex, and they will move towards more attractive and brighter ones.
- The attractiveness of a firefly is proportional to its brightness which decreases as the distance from the other firefly increases. If there is not a more attractive firefly than a particular one, it will move randomly.
- The brightness of a firefly is determined by the value of the objective function. For maximization problems, the brightness is proportional to the value of the objective function. [4]

Each firefly has its attractiveness β described by monotonically decreasing function of the distance r between two any fireflies:

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

Where β_0 denotes the maximum attractiveness (at $r = 0$) and is the light absorption coefficient, which controls the decrease of the light intensity. The distance between two fireflies i and j at positions x_i and x_j can be defined as follows: [5]

$$r_{ij} = \|x_i - x_j\| = \sqrt{\sum_{k=1}^{d} \left(x_{i,k} - x_{j,k}\right)^2} \tag{2}$$

Where $x_{i,k}$ is the k-th component of the spatial coordinate xi of ith firefly and d denotes the number of dimensions. The movement of a firefly is determined by the following form [1]:

$$x_i = x_i + \beta_0 e^{-\gamma r_{ij}^2}\left(x_j - x_i\right) + \alpha\left(rand - \frac{1}{2}\right) \tag{3}$$

Where the first term is the current position of a firefly i, the second term denotes a firefly's attractiveness and the last term is used for the random movement if there are not any brighter firefly (rand is a random number generator uniformly distributed in the range < 0, 1 >). For most cases $\alpha \in (0,\ 1)$, $\beta_0 = 1$. In practice the light absorption coefficient γ varies from 0.1 to 10. This parameter describes the variation of the attractiveness and its value is responsible for the speed of FA convergence.[4]

The initial population of fireflies is generated in the following form:

$$x_i = \text{LB} + rand \cdot (\text{UB} - \text{LB}) \qquad (4)$$

Where LB and UB denote [15] the lower and the upper bounds of i-th firefly. After the evaluation of the initial population the firefly algorithm enters its main loop, which represents the maximum number of generations of the fireflies (iterations). For each generation the firefly with the maximum light intensity (the solution with the best value of objective function) is chosen as the potential optimal solution). The firefly algorithm simulates parallel run strategy. The population of n fireflies generates n solutions. [6]

1.2.2 Firefly Algorithm Implementation

The individuals of the fireflies include the parameters of weights (ω), spread parameters (α), center vector (c) and the bias parameters (β). The mean vector $c_i$of the i-th neuron of hidden layers is defined by $c_i = (c_1^i, c_2^i \dots\ c_m^i)$, therefore, the parametric vector t_i of each of fireflies with $I_J + I\ +\ m_I\ +\ J$ parameters is expressed as:[7]

$$t_i = \begin{pmatrix} \omega_{11}^i, \omega_{12}^i, \dots, \omega_{IJ}^i, \alpha_1^i, \alpha_2^i, \dots, \alpha_I^i, c_{11}^i, c_{12}^i, \dots, c_{1m}^i, \dots \\ , c_{I1}^i, c_{I2}^i, \dots, c_{Im}^i, \beta_1^i, \beta_2^i, \dots, \beta_J^i \end{pmatrix}$$

The optimum vectors t_i of firefly of specific trained network can maximize the fitness function.

$$f(t_i) = \frac{1}{1 + MSE} = \frac{1}{1 + \frac{1}{N}\sum_{k=1}^{N} \| d(x_k - o(x_k) \|^2}$$

Where $d(x_i)$ and $o(x_i)$ are denoted to the desired output vector and actual output vector for training sample x_i of a network designed by parametric vectort_i . The N is the number of the training samples. The pseudo codes of this proposed algorithm and the steps of the proposed algorithm are detailed described as follows [7].[8]

Step 1. (Generate the initial solutions and given parameters)

In this step, the initial population of m solutions are generating with dimension [9]

$IJ + I + mI + J$, denoted by the matrix D.

$$D = [t_1, t_2, \dots, t_n]$$

$$t_i = \begin{pmatrix} \omega_{11}^i, \omega_{12}^i, \dots, \omega_{IJ}^i, \alpha_1^i, \alpha_2^i, \dots, \alpha_I^i, c_{11}^i, c_{12}^i, \dots, c_{1m}^i, \dots \\ , c_{I1}^i, c_{I2}^i, \dots, c_{Im}^i, \beta_1^i, \beta_2^i, \dots, \beta_J^i \end{pmatrix}$$

Where the values of weights (w) and centers (c) are assigned between -1 and 1, and the values of the spread and bias parameters α and β range from 0 to 1. Furthermore, the step will assign the parameters of firefly algorithm, that are,β_0 , the maximum cycle number (MCL) andγ. Let number of cycle l to be 0.[10]

Step 2. Firefly movement

In step 2, each solution t_i computes its fitness value $f(t_i)$ as the corresponding the brightness of firefly. For each solution t_i, this step randomly selects another one solution t_j with the brighter and then moves toward to t_j by using the following equations.

$$r_{i,j} = \|t_i - t_j\| = \sqrt{\sum_{k=1}^{IJ+I+mI+J} \left(t_{i,k} - t_{j.k}\right)^2}$$

$$\beta = \beta_0 e^{-\gamma r_{i,j}}$$

$$t_{i,k} = (1 - \beta)t_{i,k} + \beta t_{j,k} + u_{j,k}, k = 1,2, \dots, IJ + I + mI + J$$

Where $u_{j,k} \sim U(0,1)$a randomly number is ranged from 0 to 1 and thet_i, k is the k-th element of the solutiont_i.[11]

Step 3. (Select the current best solution)

The step 3 selects the best one from the all solutions and defines asx_i^{max}, that is,

$$i^{max} = arg \max_i f(t_1)$$

$$x_i^{max} = arg \max_{x_i} f(t_1)$$

Step 4. (Check the termination criterion)

If the cycle number l is equal to the MCL then the algorithm is finished and output the best solutionx_i^{max}. Otherwise, l increases by one and randomly walks the best solution x_i^{max}then go to Step 2. The best solution x_i^{max}will randomly walk its position based the following equation.[12]

$$t_{i^{max},k} \leftarrow t_{i^{max},k} + u_{i^{max},k}, k = 1,2, \dots, IJ + I + mI + J$$

1.3 RESULTS

1.3.1 Parameters Setting for MATLAB Simulations

The following Table 4.1 illustrates the parameter name and value used for MATLAB simulation of the system model described in previous chapters. Parameter description is given along with.

Table 4.1: Parameter Settings for Simulation.

Parameter	Description	Value
Sub Blocks	Sub-Block size	2, 4, 8, 16
OFDM Blocks	Input bits	Sub Blocks * 10^5
N	No. of subcarriers	128, 256, 512
L	Oversampling factor	4
M	Constellation Size	16 (QAM, PSK)
m	Bits/Symbol	$\log_2(M) = 4$
PAPR dB	PAPR in dB	4 to 11
Fitness Function	Fitness Function	@(x) max(abs(x(1)^2)) ./ mean(x(1))
Num Of Fireflies	Number of Fireflies	10
Max Iterations	Max Iterations	5

1.3.2 System performance (CCDF vs. PAPR)

Fig. 4.1 to 4.6 illustrates the CCDF vs. PAPR performance of the system described in previous chapter. The parameter settings for the system model and the Firefly algorithm are given in Table 4.1. The only difference being in the number of subcarriers N (128, 256, and 512) used and the underlying modulation used (16-QAM or 16-PSK). In each simulation the number of sub-blocks are varied from 2, 4, 8 and 16, whereas the number of possible phase shifts are varied from 0 to 2π. The phase shift values between 0 and 2π are obtained using Firefly algorithm.

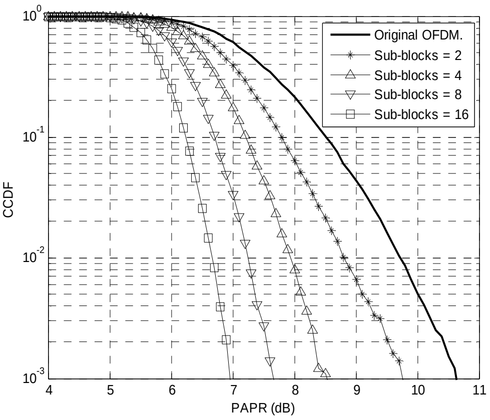

Fig. 4.1 System performance for *N*=128 and 16-QAM.

Fig. 4.1 illustrates the system performance (CCDF vs. PAPR) for underlying 16-QAM modulation and *N*=128 subcarriers. It can be seen that by increasing the number of sub-blocks PAPR reduces significantly. At CCDF of 10^{-2} PAPR is 8.8 dB for 2 sub-blocks, 7.9 dB for 4 sub-blocks, 7.3 dB for 8 sub-blocks and 6.7 dB for 16 sub-blocks. Moreover, a reduction of about 0.9 dB with respect to the original OFDM (without sub-blocks or rather 1 sub-block) is achieved if compared with PAPR of 2 sub-blocks. The results of the following figures are summarized in Table 4.2.

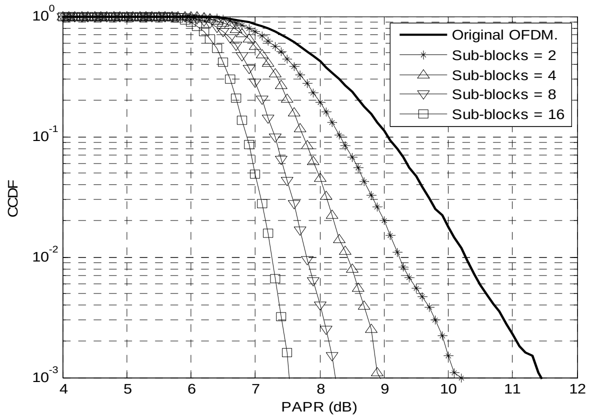

Fig. 4.2 System performance for *N*=256 and 16-QAM.

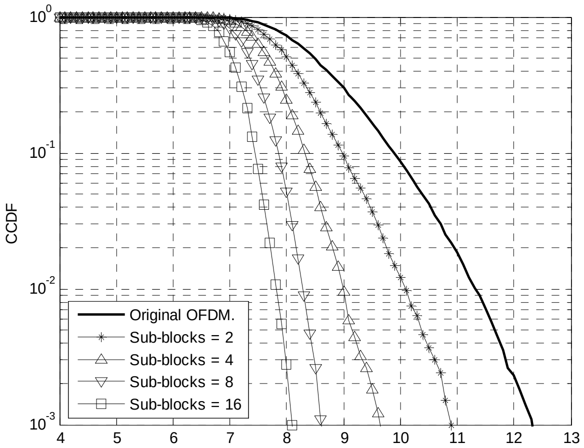

Fig. 4.3 System performance for *N*=512 and 16-QAM.

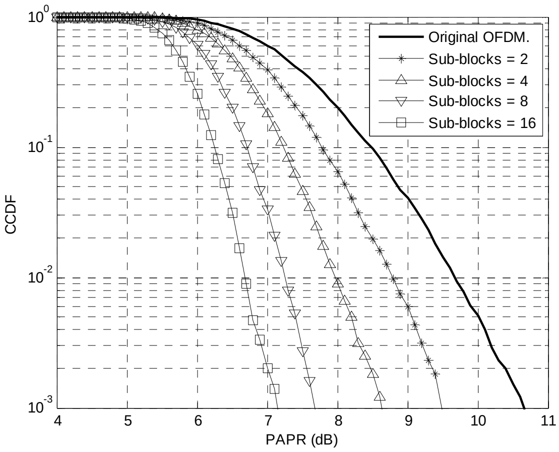

Fig. 4.4 System performance for *N*=128 and 16-PSK.

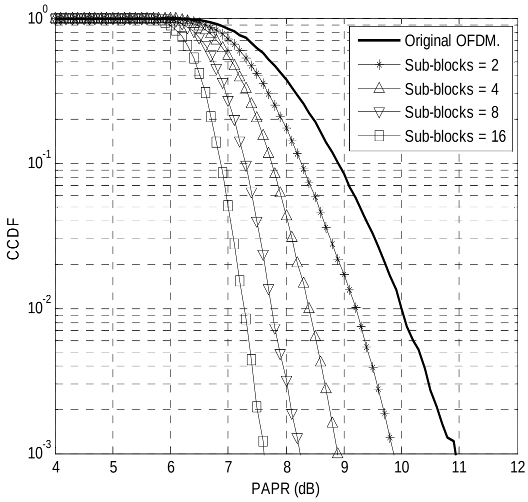

Fig. 4.5 System performance for *N*=256 and 16-PSK.

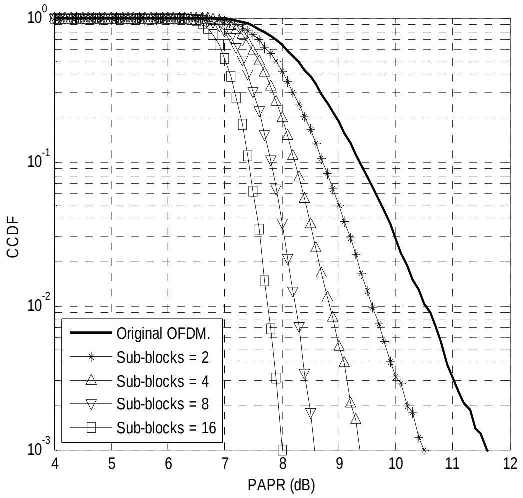

Fig. 4.6 System performance for *N*=512 and 16-PSK.

From the above figures it can be noted that there is significant improvement with increase in the number of sub-blocks and modulation. Table 4.2 summarizes the results obtained from Fig. 4.1 to Fig. 4.6. Note that sub-block value = 1, in the below table indicated original OFDM without sub-blocks or 1 block as a whole.

CONCLUSION

We presented the simulation results. As expected, simulations show that the performance of the proposed FF-PTS system provided almost the same PAPR statistics as that of the optimal exhaustive PTS, while maintaining a low computational load. Results show the effectiveness of the proposed method in reducing the computational complexity of the PTS algorithm.

The proposed FF-PTS technique provides a practical and economical approach toward solving the difficulty of high PAPR in OFDM systems

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