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Logarithmic Companding using Firefly Algorithm for PAPR Reduction in OFDM System

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Abstract

Orthogonal frequency division multiplexing (OFDM) is a digital transmission method developed to meet the increasing demand for higher data rates in communications which can be used in both wired and wireless environments. However OFDM is handicapped with a major problem of high peak-to-average power ratio (PAPR), which gives rise to non-linear distortion, inter-symbol interference and out-of-band radiation. Several PAPR reduction techniques have been devised over the last few decades in order to surpass this problem of PAPR. In this paper we have analysed the effectiveness of logarithmic companding technique which is optimized using firefly algorithm for PAPR reduction and the simulation results are compared with other techniques proposed in literature.

Keywords: *A-law, CCDF, companding, firefly algorithm, OFDM, PAPR, SLM*

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INTRODUCTION

In recent times, the mandate for multimedia data services has grown drastically which motivated us in the phase of 4th generation wireless communication system. This obligation of multimedia data service where users are in huge numbers and under bounded spectrum, latest digital wireless communication system adopted technologies which are bandwidth proficient and stout to multipath channel environment known as multi-carrier communication system.

In multi-carrier modulation, the utmost frequently used technique is orthogonal frequency division multiplexing (OFDM). OFDM forms root for all 4G wireless communication systems due to its giant size in relations of number of subcarriers, high data rate in excess of 100 Mbps and omnipresent coverage with great mobility.

Regardless of the many benefits of OFDM it still undergoes from some constraints such as sensitivity to carrier frequency offset and a large peak to average power ratio (PAPR) [1]. The great PAPR is due to the superposition of N liberated likewise spaced subcarriers at the output of the inverse fast fourier transform (IFFT) in the transmitter. A great PAPR is a problem as it needs amplified intricacy in the word length at the output of the IFFT and the digital to analog converter (DAC).

Perchance the supreme thoughtful problem is the abridged efficacy of the high power amplifier (HPA) which must supply for this low probability large peaks. So, it is extremely important to decrease PAPR. Some schemes have been proposed to reduce the PAPR. These techniques can be divided into two main categories:

- Signal Scrambling
- Signal Distortion

Scrambling category entails different variations of codes used for scrambling to accomplish PAPR diminution. Midst coding techniques Barker codes, M sequences, Golay complementary and Shapiro-Rudin sequences have been utilized for lessening of PAPR. The key downside is that as number of carriers upsurges the related overhead with pursuit for best code growths exponentially. Midst this group better techniques are selective mapping, partial transmit sequences and block coding [2–5].

The distortion category attempts to reduce PAPR by manipulation of signal before amplification. Clipping of signal prior to amplification is a simplest method but it causes increase in both out-of-bands (OOB) as well as in-band interference thus compromises upon performance of system. Amongst this category better techniques include companding, peak windowing, peak power suppression, peak cancellation, weighted multicarrier transmission etc. [6–7].

In companding technique the OFDM signal is first compressed at the transmitter and then it is expanded at the receiver. Compression can be performed according to A-Law [7–9]. PAPR can be highly reduced if the appropriate value of A is selected for companding. In this paper, we have proposed Firefly algorithm for optimizing the value of A for reduction of PAPR and the simulation results are compared with conventional techniques [10–12].

The remaining of this paper describes PAPR and the complementary cumulative distribution function (CCDF), the norm of companding technique and proposed firefly algorithm, and later the simulation results for proposed technique are presented and compared with conventional techniques followed by conclusions.

PAPR IN OFDM SYSTEM

In an OFDM system, the serial data stream which is to be transmitted is alienated into parallel data stream establishing series of frames. All bits/symbols in a frame is modulated by N subcarriers, $= [X(0), X(1), \dots\dots, X(N-1)]^T$, which are orthogonal. This is achieved by as, $\Delta f = \frac{1}{NT}$ where T denotes the duration of OFDM symbol, Δf is the subcarrier spacing and N is number of subcarriers. After modulation, the frequency domain symbol is converted to time domain symbol with an N-point IFFT operation. The transmitted symbol is given by,

$$x(t) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X(k) e^{j2\pi t \Delta f k} , \qquad 0 \le t \le NT \tag{1}$$

Where. NT is the data block period.

PAPR is an important factor to be measured about OFDM, as high values of PAPR has some shortcomings. It is defined as the ratio of the maximum power to the average power for the given signal. For this signal, the PAPR can be defined as follows:

$$PAPR = \frac{\max_{0 \le t \le NT} |x(t)|^2}{\frac{1}{NT} \int_0^{NT} |x(t)|^2 dt} \tag{2}$$

The utmost common and recurrently used performance measure for PAPR reduction techniques is termed as complementary cumulative distribution function (CCDF). Th probability that the PAPR of a data-block outstrips a given threshold $PAPR_0$.is given by CCDF. If the CCDF graph is plotted against the threshold values, the more vertical the graph is, the better is the PAPR reduction performance. It is denoted by,

$$CCDF = P_r(PAPR > PAPR_0) \tag{3}$$

COMPANDING TECHNIQUE AND PROPOSED FIREFLY ALGORITHM

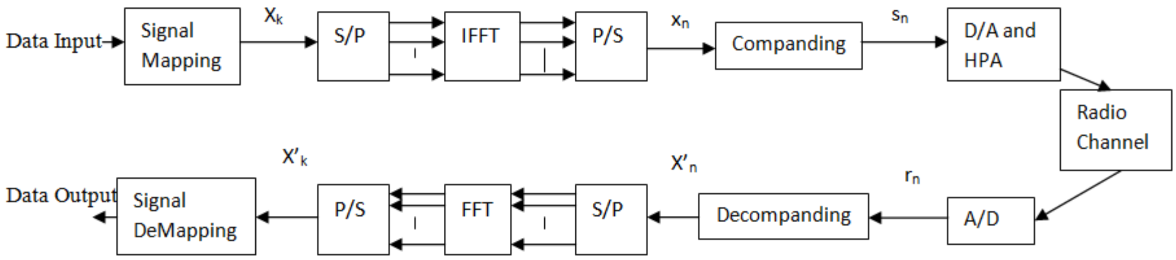

Fig. 1: *Block Diagram of OFDM System with Companding Technique.*

A-Law is a simple but effective companding technique to reduce the peak-to-average power ratio of OFDM signal. The inkling emanates from the use of companding in speech processing. Meanwhile OFDM signal is like speech signal in the logic that large signals only occur very rarely, the similar companding technique might be used to mend OFDM transmission performance. A QAM-OFDM system diagram is shown in Figure 1. The entering bit stream is packed into *x* bits per symbol to form a complex number where *x* is determined by the QAM signal constellation. Ouput to the IFFT is given as follows:

$$x(n) = \frac{1}{\sqrt{N}} \sum_{k=1}^{\frac{N}{2}-1} (a_k cos \frac{2\pi kn}{N} + b_k sin \frac{2\pi kn}{N}) \ \ ,n = 0,1,2 \ldots..N-1 \tag{4}$$

The 'A' law companding technique can be then presented. The samples of OFDM signal x(t) are companded before it is converted into analog waveform. The signal after companding is given by:

$$s(n) = \begin{cases} \dfrac{A|x(n)|}{1 + log\, A} sgn(x(n)), & for\ 0 \leq |x(n)| \leq \dfrac{V}{A} \\ \dfrac{V(1 + log(A|x(n)|/V))}{1 + log\, A} sgn(x(n)), & for\ \dfrac{V}{A} \leq |x(n)| \leq V \end{cases} \tag{5}$$

V is normalization constant.
The value of A is optimized using firefly algorithm[8-12].

The objective function of a given optimization problem is centered on differences in light intensity in the firefly algorithm. It aids the fireflies to travel in the direction of brighter and more striking locations in order to obtain optimal solutions. All fireflies are considered by their light intensity related with the objective function. Each firefly is altering its position iteratively. The firefly algorithm has three rules:

- Every fireflies are unisex, and they will travel in the direction of extra eye-catching and brighter ones.
- The attractiveness of a firefly declines as the distance from the other firefly rises and is proportional to its brightness. If there is not an extra attractive firefly than a particular one, it will move randomly.

- The brightness of a firefly is dogged by the value of the objective function. For maximization problems, the brightness depends propotionally on the value of the objective function.

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

$$\beta(r) = \beta_o e^{-\gamma r^m}, m \geq 1 \tag{6}$$

Where β_o denotes the maximum attractiveness (at *r*=0) and γ is the light absorption coefficient, which controls rate at which the light intensity is decreasing. The distance between two fireflies *i* and *j* at positions x_i and x_j can be defined as follows:

$$r_{ij} = \sqrt{\sum_{K=1}^{d} \left(x_{i,k} - x_{j,k}\right)^2} \tag{7}$$

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

$$x_i = x_i + \beta_o e^{-\gamma r_{ij}^2}\left(x_i - x_j\right) + \alpha(rand - 0.5) \tag{8}$$

Where the current position of a firefly is the first term *i*, the firefly's attractiveness is denoted by second term and the last term is the random movement. If there are no brighter firefly (rand is a random number generator uniformly distributed in the range <0, 1>). γ defines the variation of the attractiveness and its value is responsible for the speed of FA convergence.

In this paper, objective function gives the PAPR value of the normal μ law companding technique. Initial fireflies position is determined using the upper and lower bounds and the number of fireflies considered. Now these fireflies positions are passed as input in the objective function which takes it as value of μ and calculates the PAPR at different values. These values determine the light intensity of fireflies and then the firefly with higher value of PAPR is moved towards the firefly having less value of PAPR. Finally they are ranked in descending order according to their PAPR value and the firefly position at which minimum PAPR is obtained is returned as the value of optimized value of μ.

The pseudo-code form is used for presentation of firefly algorithm:

1**.** Initialize algorithm's parameters:
- Number of fireflies *(n)*,
- β_0, γ, α
- Maximum number of generations (iterations, Max-Gen).

2. Define the objective function *f(x)*, $x=(x_1, \ldots, x_d)T$.
3. Generate initial population of fireflies x_i(i=1, 2. . .,*n*). Light intensity of firefly I_i at x_i is determined by value of objective function.
4. While iter <= MaxGen
5. For *i*=1:*n*
6. For *j*=1:*n*
7. If (*Ij*>*Ii*) move firefly *i* towards firefly *j* in *d*-dimension according to Eq. (8); End if.
8. Obtain attractiveness, which varies with distance *r* according to Eq. (6).
9. Find new solutions and update light intensity
10. End for *j*.
11. End for *i*.
12. Rank the fireflies and find the current best
13. End while
14. Find the firefly with the highest light intensity.

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

$$xi = LB + rand \cdot (UB - LB) \quad (9)$$

Where the lower and the upper bounds are indicated by LB and UB s of *i*-th firefly. After the assessment of the initial population the firefly algorithm arrives its main loop, which symbolizes the maximum number of generations of the fireflies(iterations). For every generation the firefly with the maximum light intensity (the solution with the best value of objective function) is selected as the potential optimal solution. The firefly algorithm simulates parallel run strategy. The *n* solutions are population generateg for *n* fireflies.

SIMULATION RESULTS

Table 1 illustrates the parameter name and value used for MATLAB simulation of the system model. Parameter description is given along with.

Table 1: *For Simulation Parameter Settings.*

Parameter	Description	Value
N	No. of Subcarriers	64, 128, 256, 512
M	Constellation Size	16(QAM)
numFireflies	number of fireflies in group	30
maxGen	maximum nuber of allowed iteration	5
Alpha	randomness	17
Beta	attractiveness	1
Gamma	Absorption Coefficient	0.2
Delta	Randomness reduction	0.99

The CCDF vs. PAPR performance of the system is described in Figure 2 to 5. The Table 1 shows parameter settings for the system model and the firefly algorithm.
The only difference being in the number of subcarriers *N* (64, 128, 256, and 512) used and the underlying modulation used (16-QAM). In each simulation the optimized value of μ are obtained using firefly algorithm.

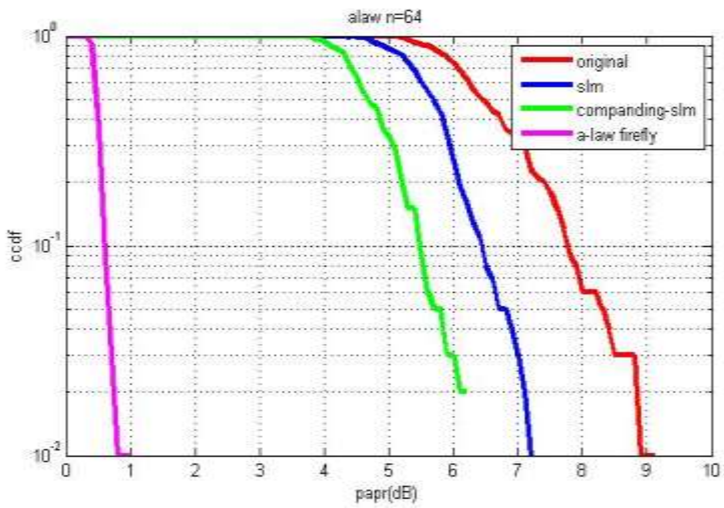

Fig. 2: *System Performance for N=64 and 16-Qam.*

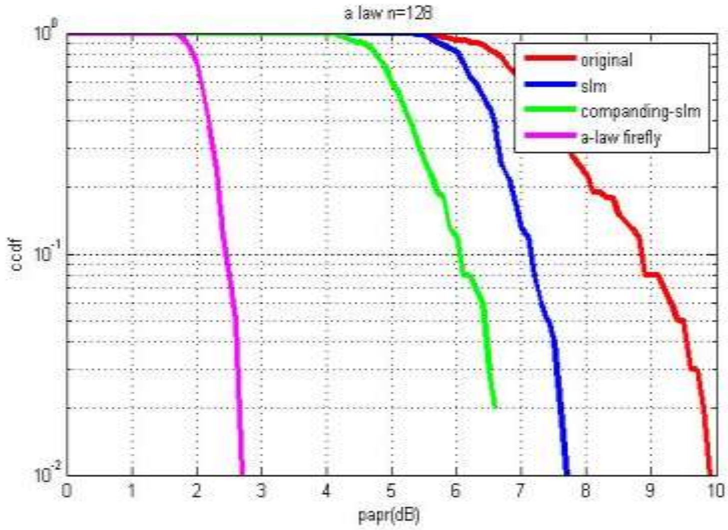

Fig. 3: *System Performance for N=128 and 16-Qam.*

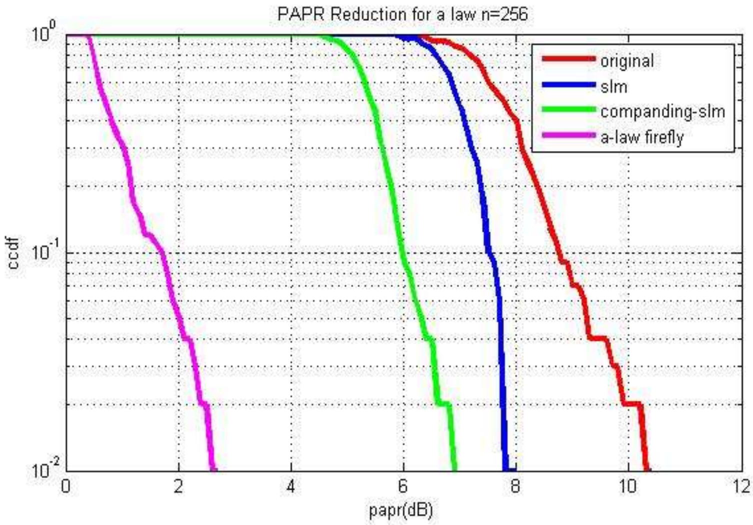

Fig. 4: *System Performance for N=256 and 16-Qam.*

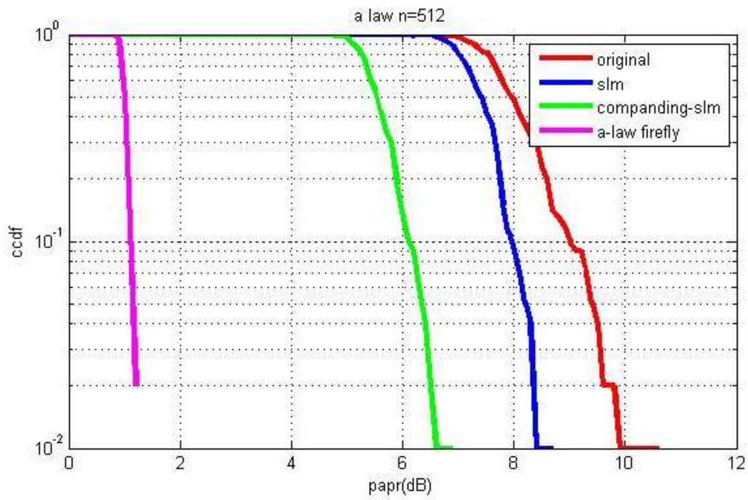

Fig. 5:*SystemPerformance for N=512 and 16-Qam.*

The curves of the CCDF for random original OFDM symbols generated and the PAPR reduction scheme are shown in the above results. It is very clear that the firefly optimized companding scheme reduces the PAPR significantly in OFDM system. When, the CCDF is 10^{-2}, the PAPRs are 1, 6, 7 and 8.8 dB for the firefly optimized A-law companding, slm-companding, conventional SLM and original OFDM signals respectively at number of subcarriers, N=64 in Figure 2. Maximum PAPR reduction is obtained in case of N=64. However, if the CCDF graph is plotted against the threshold values, the more vertical the graph is, the better is the PAPR reduction performance and a more vertical graph is obtained in case when N=512 in Figure 5 where PAPR is 1.2 dB for firefly companding at CCDF of 10^{-2}.

CONCLUSIONS

Companding techniques can resolve the high PAPR problem for OFDM systems. In this paper, performance of companding technique with value of A is optimized using firefly algorithm. It is then evaluated for PAPR reduction in OFDM system and the results are compared with the previously proposed techniques in literature. The simulation results disclose that proposed technique offers effectual PAPR reduction than the other conventional techniques. Furthermore, firefly algorithm has only three control parameters, so it is easy to be adjusted.

REFRENCES

1. Tao Jiang, Cai Li, Chunxing Ni. Effect of PAPR Reduction on Spectrum and Energy Efficiencies in OFDM Systems With Class-A HPA Over AWGN Channel. *IEEE Trans. Broadcast.* Apr 2013; 59(3): 513–519p.
2. Zhongpeng Wang. Reduction PAPR of OFDM Signals by Combining SLM with DCT Transform. *Int. J. Communications, Network and System Sciences.* 2010; 888–892p.
3. Li CP, Wang SH, Wang CL. Novel Low-Complexity SLM Schemes for PAPR Reduction in OFDM Systems. *IEEE Trans. Signal Process.* May 2010; 58(5): 2916–2921p.
4. Jiang T, Xiang W, Richardson PC, *et al.* PAPR Reduction of OFDM Signals Using Partial Transmit Sequences with Low Computational Complexity. *IEEE Trans. Broadcast.* Sep 2007; 53(3): 719–724p.
5. Jenn-Kaie Lain, Shi-Yi Wu, Po-Hui Yang. PAPR Reduction of OFDM Signals Using PTS: A Real-Valued Genetic Approach. *EURASIP Journal on Wireless Communications and Networking.* 2011.
6. Wang Y, Luo Z. Optimized Iterative Clipping and Filtering for PAPR Reduction of OFDM Signals. *IEEE Trans. Communication.* Nov 2010; 59(1): 33–37p.
7. Hou J, Ge J, Zhai D, *et al.* Combined SLM and Companding for PAPR Reduction in OFDM. *Proceedings of International Conference, ICERECT 2012.* 579–585p.
8. Hou J, Ge J, Zhai D, *et al.* Peak-to-Average Power Ratio Reduction of OFDM Signals with Nonlinear Companding Scheme. *IEEE Trans. Broadcast.* Jun 2010; 56(2): 258–262p.
9. Wang XB, Tjhung TT, Ng CS. Reduction of Peak-to-Average Power Ratio of OFDM System using a Companding Technique. *IEEE Trans. Broadcast.* Sep 1999; 45(3): 303–307p.
10. Tao Zhang, Shuai Li, Xiangu Yu. Performance Global Optimal Firefly Algorithm in Peak-to-Average Power Ratio Reduction of Orthogonal Frequency Division Multiplexing Systems. *Research Gate*. 2014.
11. Hung H-L, Huang Y-F, Yeh C-M, *et al.* Performance of Paticle Swarm Optimization techniques on PAPR

Reduction for OFDM Systems. In *Proc. IEEE International Conf. Systems, Man Cybernetics (SMC)*. Oct 2008; 2390–2395p.

12. Zhang Y, Ni Q, Chen H-H, *et al.* An Intelligent Genetic Algorithm for PAPR Reduction in a Multi-Carrier CDMA Wireless System. In *Proc. IEEE International Conf. Wireless Commun. Mobile Computing (IWCMC)*. Aug 2008; 1052–1057p.

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