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RESEARCH ARTICLE

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COMPARATIVE PERFORMANCE ANALYSIS OF DIFFERENT MODULATION TECHNIQUES FOR BER AND PAPR REDUCTION USING FIREFLY ALGORITHM OF OFDM SIGNAL

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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 significantly affected by peak-to-average-power ratio (PAPR). This paper describes the issue of the PAPR in OFDM which is a major drawback, and presents firefly algorithm used for optimizing companding technique to reduce it. The effect on system performance in terms of the Bit Error Rate (BER) is simulated for an OFDM transceiver with a saturated High Power Amplifier and the simulation results are compared with other techniques proposed in literature.

Keywords: BER, CCDF, Companding, Firefly Algorithm, HPA, OFDM, PAPR.

1. Introduction

As an attractive technology for wireless communications, Orthogonal Frequency Division Multiplexing (OFDM), which is one of multi-carrier modulation (MCM) techniques, offers a considerable high spectral efficiency, multipath delay spread tolerance, immunity to the frequency selective fading channels and power efficiency. As a result, OFDM has been chosen for high data rate communications and has been widely deployed in many wireless communication standards such as Digital Video Broadcasting (DVB) and based mobile worldwide interoperability for microwave access (mobile WiMAX) based on OFDM access technology [1]. However, still some challenging issues remain unresolved in the design of the OFDM systems. One of the major problems is high Peak-to-Average Power Ratio (PAPR) of transmitted OFDM signals [2]-[3]. A large PAPR is a problem as it reduces the efficiency of the High Power Amplifier (HPA). If the high PAPR is allowed to saturate the HPA out of band radiation is produced affecting adjacent channels and degrading the Bit Error Rate (BER) at the receiver. As portable devices have a finite battery life it is important to find ways of reducing the PAPR allowing for a smaller more efficient HPA, which in turn will mean a longer lasting battery life. Therefore, it is important and necessary to research on the characteristics of the PAPR including its distribution and reduction in OFDM systems, in order to utilize the technical features of the OFDM.

This paper emphasis mainly on the PAPR reduction of OFDM system using μ law Companding technique which is optimized using Firefly algorithm for maximum reduction in PAPR. Several techniques have been proposed to reduce PAPR and these can be classified as: Signal Scrambling and Signal Distortion. Scrambling category consists of different variations of codes used for scrambling to achieve PAPR reduction. The main drawback is that as number of carriers increases the associated overhead with search for best code increases exponentially. Amongst this category better techniques are selective mapping, partial transmit sequences and block coding [4]-[6]. 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 [7], peak windowing, peak power suppression, peak cancellation, weighted multicarrier transmission etc. Signal companding methods have low-complexity, good distortion and spectral properties; however, they have limited PAPR reduction capabilities. So improved Companding technique is proposed in this paper and simulation results obtained using MATLAB for PAPR reduction are compared with previously discussed techniques in literature. Also system performance is evaluated as BER v/s SNR results are simulated and the results are compared with other techniques.

The remaining of this paper is organized as follows: In Section II, PAPR and the complementary cumulative distribution function (CCDF) are introduced. The principle of companding technique and proposed firefly algorithm are described in Section III. In Section IV, the simulation results for proposed technique are presented and compared with conventional techniques. Conclusions are made in Section V.

2. Motivation for PAPR Reduction

A. Definition of PAPR and CCDF

An OFDM signal consists of a number of independently modulated SCs, which can give a large peak-to-average power ratio (PAPR) when added up coherently. When N signals are added with the same phase, they produce a peak power that is N times the average power. The PAPR of OFDM signals is defined as the ratio between the maximum instantaneous power and its average power:

$$PAPR = \frac{\max_{0 \leq t \leq NT} |x(}{\frac{1}{NT}\int_0^{NT} |x(t)|^2} \qquad (1)$$

The most common and frequently used performance measure for PAPR reduction techniques is termed as Complementary Cumulative Distribution Function (CCDF). The probability that the PAPR of a data-block exceeds 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,

$$CCDF = P_r(PAPR > PAPR \qquad (2)$$

B. Nonlinear characteristics of HPA

Non linearities provide the greatest obstacle to OFDM as a practical system due to their distorting effect on the quality of the system. The RF amplifier must be driven as close as possible to the maximum signal in the linear region to make it efficient, however when operating near the saturation point it exhibits non linear behavior distorting the transmitted signal. This distortion causes spectral regrowth in the transmitter which can adversely affect adjacent frequency bands, and an increased BER at the receiver. A balance must be met between allowable distortion and the linear region of an amplifier. It is therefore important to aim at a power efficient operation of the non-linear HPA with low back-off values and try to provide possible solutions to the interference problem brought about. Hence, a better solution is to try to prevent the occurrence of such interference by reducing the PAPR of the transmitted signal with some manipulations of the OFDM signal itself.

$$\eta = \frac{0.}{PAI} \qquad (3)$$

Where η is the HPA efficiency.

That means the efficiency of HPA is inversely proportional to the PAPR. Therefore, in order to have high efficiency, it is extremely important to employ some scheme to reduce PAPR.

3. System Model

Companding technique using Firefly Algorithm

Companding techniques are used to decrease dynamic range of the signal in order to prevent it from distortions caused by channel with limited range. The bottleneck of the OFDM system in terms of high PAPR is power amplifiers and AD/DA converters. High peaks of the OFDM signal usually exceed the maximum amplification level, which result in clipping of high peaks by the amplifier. Clipping distorts the signal by increasing the BER and widen its spectrum. The second bottleneck comes from the limited number of quantization levels in AD/DA converters. High rare peaks will waste quantization resolution by reducing the range of mapping for the main signal. Thus the quantization error will be increased. This becomes especially critical when we have a system with small quantization resolution.

The companding technique compresses the signal, making its distribution quasi-uniform, such that signal's maximum amplitude does not exceed system's limitations. Thereby, no distortions will occur at the bottlenecks. At the receiver site the original signal is obtained by reverse operation of expanding.

A QAM-OFDM system diagram is shown in Figure .1. The incoming bit stream is packed into *x* bits per symbol to form a complex number where *x* is determined by the QAM signal constellation. Output to the IFFT is given as follows

$$x(n) = \frac{1}{\sqrt{N}} \sum_{k=1}^{\frac{N}{2}-1} \left(a_k cos\frac{2\pi kn}{N} + b_k sin\frac{2\pi kn}{N} \right)$$

$$, n = 0,1,2 \ldots\ldots N-1. \qquad (4)$$

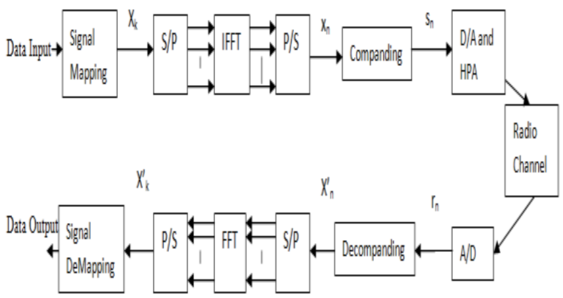

Figure 1: Block Diagram of OFDM System with Companding Technique

The µ law companding technique can be then introduced. μ Law is a simple but effective companding technique to reduce the peak-to-average power ratio of OFDM signal. In the µ law companding, compressor squeezes the signal at the transmitter site according to the following formula:

$$s(n) = \frac{V sgn\,(x(n)) \ln \left[1+\mu\left|\frac{x(n)}{V}\right|\right]}{\ln\,(1+\mu)} \qquad (5)$$

Where µ is the µ -law compression parameter and V is normalization constant.

And at the receiver side µ law expander restores original signal by:

$$x(n) = \frac{V}{\mu}\left(e^{\frac{|s'_n|\ln(1+\mu)}{V}} - 1\right) sgn(s(n) \qquad (6)$$

The value of µ is optimized using **firefly algorithm** [8]-[10].

We can idealize the flashing characteristics of fireflies so as to develop firefly-inspired algorithms. Firefly Algorithm (FA or FFA) developed by Xin-She Yang at Cambridge University in 2007, use the following three idealized rules:

- All the fireflies are unisex so it means that one firefly is attracted to other fireflies irrespective of their sex.
- Attractiveness and brightness are proportional to each other, so for any two flashing fireflies, the less bright one will move towards the one which is brighter. Attractiveness and brightness both decrease as their distance increases. If there is no one brighter than other firefly, it will move randomly.
- The brightness of a firefly is determined by the view of the objective function.

For maximum optimization problems, the brightness I of a firefly for a particular location x could be chosen as I(x) f(x). Even so, the attractiveness β is relative, it should be judged by the other fireflies. Thus, it will differ with the distance r_{ij} between firefly i and firefly j. In addition, light intensity decreases with the distance from its source, and light is also absorbed by the media, so we should allow the attractiveness to vary with the varying degree of absorption.

FFA Meta-heuristic()

Begin;

Initialize algorithm parameters:

MaxGen: the maximal number of generations

γ: the light absorption coefficient

r: the particular distance from the light source

Define the objective function of f(x), where x=(x1,........,xd)T

Generate the initial population of fireflies or xi (i=1, 2 ,..., n)

Determine the light intensity of Ii at xi via f(xi)

While (t<MaxGen)

    For i = 1 to n (all n fireflies);

        For j=1 to n (n fireflies)

            If (Ij> Ii),

                move firefly i towards j by using

$$x_i = x_i + \beta_o e^{-\gamma r_{ij}^2}\left(x_i - x_j\right) + \alpha(rand - 0.$$

Where $r_{ij} = \sqrt{\sum_{K=1}^{d}(x_{i,k} - x_{j,k}}$

end if

Attractiveness varies with distance r via Exp [-γr^2];

Evaluate new solutions and update light intensity;

End for j;

End for i;

Rank the fireflies and find the current best;

End while;

Post process results and visualization;

End procedure

In this paper, Objective function gives the papr value of the normal law companding technique. Initial Fireflies position is determined using the upper and lower bounds and the number of fireflies considered. Now these fireflies position are passed as input in the objective function which takes it as value of 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 .

4. SIMULATION RESULTS

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

TABLE I: PARAMETER SETTINGS FOR SIMULATION.

Parameter	Description	Value
N	No. of Subcarriers	64
Numfireflies	No. of fireflies in group	30
maxGen	Maximum no. of iterations	5
Alpha	Randomness	17
Beta	**Attractiveness**	**1**
Gamma	**Absorption coefficient**	**0.2**
delta	**Randomness reduction**	**0.99**

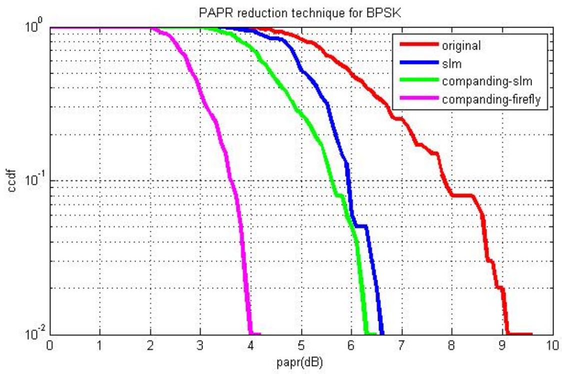

Figure 2. Distribution of PAPR for different PAPR reduction schemes for BPSK

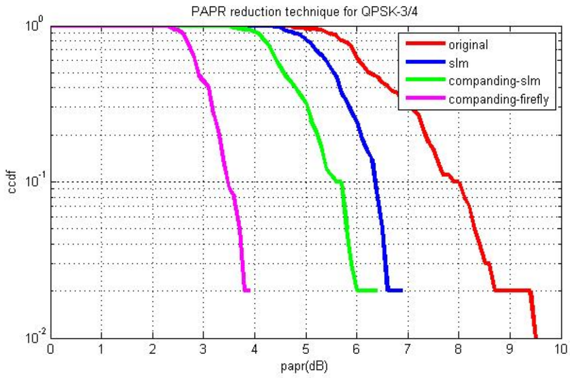

Figure 3. Distribution of PAPR for different PAPR reduction schemes for QPSK

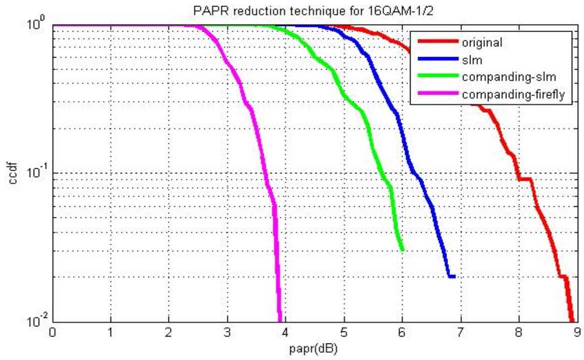

Figure 4. Distribution of PAPR for different PAPR reduction schemes for 16QAM

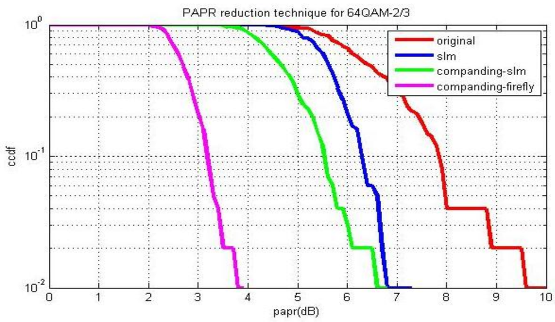

Figure 5. Distribution of PAPR for different PAPR reduction schemes for 64 QAM

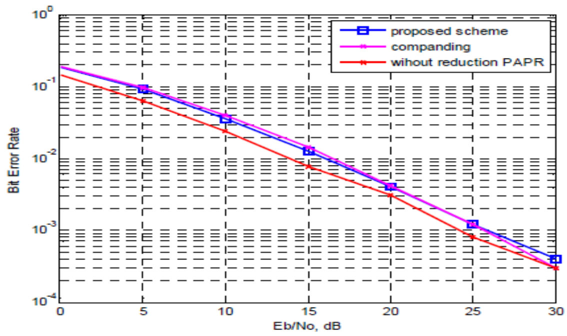

Figure 6. BER v/s SNR for different PAPR reduction techniques

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 reduce the PAPR significantly in OFDM system.

Figure.2-5 shows the CCDF performance of proposed scheme for the PAPR reduction for different modulation techniques. When, the CCDF is 10^{-2}, the PAPRs are 3.7 dB, 6.5 dB, 7 dB and 9.8 dB for the Firefly optimized companding, slm-companding, conventional SLM and original OFDM signals respectively for 64QAM modulation technique. Maximum PAPR reduction is obtained in this case.

Figure 6 shows the BER performances of OFDM system with proposed PAPR reduction scheme. As the value of is increased the BER of the system degrades. Here BER is only degraded by approximately 1 dB for firefly optimized system where as for companding technique using high values for reducing PAPR would degrade the system performance highly.

5. Conclusions

Companding techniques can solve the high PAPR problem for OFDM systems. In this paper, performance of companding technique with value of μ optimized using Firefly algorithm is evaluated for PAPR reduction in OFDM system and the results are compared with the previously proposed techniques in literature. The simulation results reveal that proposed technique offers efficient PAPR reduction than the other conventional techniques. The performance of BER degrades as the value of μ is increased and thus firefly algorithm searches for optimized value of μ that not only reduces the papr but also maintains the BER performance of system. Moreover Firefly algorithm has only three control parameters, so it is easy to be adjusted.

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