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Performance Analysis of PAPR Reduction of OFDM Signal in Different Channels by Using Piecewise Linear Companding

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Abstract: ***In the OFDM communication system the main disadvantage factor is Peak Average to Power Ratio (PAPR) which limits the performance of the overall system. To limit this factor in the OFDM system there are so many techniques are there, depends on the nature of the system like clipping, Partial transmission, Selective mapping, Companding transform etc, in these technique companding technique is the a simple methodology to compress or compand the input signal based on the inflection points to reduce the PAPR in the system, while decompander is the technique in the receiver to expand the companded signal from the transmitter section in the OFDM. The piecewise linear companding is based on the linear equations to compress the OFDM sequence where the companding distortion should be considered, in this model we present a performance analysis of the PAPR reduction in different channels with proficient companding based on the piecewise linear equations. The whole system considered under Rician fading channel model gives the reduced PAPR and optimal BER rate of the OFDM system with less companding distortion.***

Keywords: OFDM, PAPR, piecewise linear function, Companding, Companding distortion

1. Introduction

Recently OFDM (Orthogonal Frequency Division Multiplexing) becomes a very popular technique for wireless communication. OFDM has been used in different types of communication systems such as Wireless LAN network, HDTV, Wireless ATM transmission system and the popular trend LTE and LTE advanced 4G mobile standards. And the OFDM have so many advantages such as makes efficient use of the spectrum by allowing overlap, Eliminates ISI and IFI through use of a cyclic prefix, It is possible to use maximum likelihood decoding with reasonable complexity. But unfortunately OFDM signals has a large envelope fluctuations , these envelope fluctuations are related to the peak power of the OFDM signal, but OFDM has high peak to average power ratio(PAPR) by reducing these high PAPR we reduced the envelope fluctuations of the OFDM signal.

Due to high PAPR of the OFDM signals there were so many effects in the OFDM signals. Due to high PAPR at the source the signal which causes the in band distortion and out of band radiation, and the performance evolution of non linear devices such as Analog to Digital converters (ADC), Digital to Analog convertors (DAC) will be decreased and the complexity will be increased, due to this high PAPR at the receiver the non linear high power amplifiers (HPA) will get into saturation region, finally the bit error rate (BER) of the system was degraded. That's why the reduction of PAPR becomes one of the most popular research areas in the OFDM system in now a day.

There are so many PAPR reduction schemes are exist. CCDF is the measure of the PAPR and it describes the distribution of PAPR in OFDM system. These PAPR reduction schemes classified based on the criteria distortion such as distortion schemes as clipping and companding. Clipping is very simplest technique but it may cause in-band and out-band interference while destroying the orthogonalty between subcarriers. The second one is distortion less techniques such as Selective Mapping (SLM) , Partial Transmit Sequence (PTS) in this the spectral efficiency decreases and the complexity was increased with number of sub carriers.

The second classification of PAPR reductions is based on the whether they are probabilistic or not such as Tone Reservation (TR), Tone Injection (TI), Active Constellation Extension (ACE), Error Insertion (EI). Companding is the one of the best technique for reducing PAPR but it increases the bit error rate of the system. This paper discusses one of the alternative techniques for reducing PAPR with optimizing companding distortion and bit error rate (BER). The technique is piece wise linear companding transform. The paper describes the how the PAPR reduction takes place in different channels such as AWGN, SUI and Racian fading channel and how the performance can be evaluated. And the objective of the this paper is performance evolution of PAPR reduction with low BER and companding distortion.

2. Piece Wise Linear Companding Scheme

Based on the on top of design criteria for companding transform, a brand new piecewise linear companding theme is planned in this section. Then, with a theoretical analysis given, transform parameters are rigorously designed.

When the initial signal x_n is applied as input to the companding transform with a given peak amplitude Ac, the companding scheme cuts the signals with amplitudes over Ac for peak power reduction, and linearly transforms the signals with amplitudes close to Ac for power compensation. Then, the companding transform of the companding scheme is

$$h(x) = \begin{cases} x & |x| \le A_i \\ kx + (1-k)A_c & A_i < |x| \le A_c \\ sgn(x)A_c & |x| > A_c \end{cases} \quad (1)$$

Here the sgn(x) is the sign function.

Consequently, the decompounding transform at the other side is

$$h^{-1}(x) = \begin{cases} x & |x| \le A_i \\ \frac{x-(1-k)A_c}{k} & (1-k)A_c < |x| \le A_c \\ sgn(x)A_c & |x| > A_c \end{cases} \quad (2)$$

It is obvious that the proposed companding transform is specified by parameters A_c, A_i and k. Ac is the peak amplitude of the companded signals. As the average signal power is observed invariable, then according to the meaning of PAPR, the PAPR value of the proposed scheme that can be achieved notionally is determined by A_c. With a preset theoretical PAPR value, A_c can be determined as $A_c = \sigma_x 10^{PAPR_{preset}/20}$. With determined A_c, parameters A_i and k can be obtained by solving.

With the premise of keeping the typical signal power constant, k has to be a positive real number smaller than one. Besides, to limit the peak amplitude of the distended signals not larger than A_c, k should not be a negative real number. Therefore, k is confined to the interval (0, 1).

2.1 Companding Transform Parameter Selection Criterion

Aiming at minimizing Companding distortion, the selection criterion for the parameters of the companding transform is derived in the sequel. The companding distortion of the companding transform can be calculated as

$$\sigma_c^2 = \int_0^{+\infty} |y_n - x_n|^2 f_{|x_n|}(x)dx = \left((A_c - A_i)^2 e^{-\frac{A_i^2}{\sigma_x^2}} - \sqrt{\pi}\sigma_x A_c \left(erf\left(\frac{A_c}{\sigma_x}\right) erf\left(\frac{A_i}{\sigma_x}\right) \right) + \sigma_x^2 \left(e^{-\frac{A_i^2}{\sigma_x^2}} - e^{-\frac{A_c^2}{\sigma_x^2}} \right) \right) - \sqrt{\pi}\sigma_x A_c erf\left(\frac{A_c}{\sigma_x}\right) + \sigma_x^2 e^{-\frac{A_c^2}{\sigma_x^2}} \quad (3)$$

It can be seen from (3) that with a determined A_c, varies with k. Therefore, for each determined A_c, we prepare the problem of solving k as an optimization problem to mitigate companding distortion.

$$arg\ min_{k \in R}\ \sigma_c^2$$
$$\text{subjected to: } a_2 k^2 + a_1 k + a_0 = 0, k \in [0,1), \quad (4)$$

and $A_c = \sigma_x e^{PAPR_{preset}/20}$ As observed, the cost function is convex. Consequent we can find the optimal k which leads to the mini companding distortion for each determined A_c.

3. Rician Fading Channel Model

Rician fading channel can be explained by two key parameters: k and Ω. k is the ratio between the power in the direct path and the power in a Rician fading channel can be described by the other scattered paths. Ω is the total power from the paths together ($\Omega = v^2 + 2\sigma^2$) and acts as a scaling factor to the distribution. The received signal magnitude R is then Rice distributed with parameters $v^2 = \frac{k}{1+k}\Omega$ and $\sigma^2 = \frac{\Omega}{2(1+k)}$ and the resulting PDF is:

$$f(x) = \frac{2(1+k)x}{\Omega} \exp\left(-k - \frac{(1+k)x^2}{\Omega}\right) I_0\left(2\sqrt{\frac{k(1+k)}{\Omega}}x\right) \quad (5)$$

Here $I_0(\cdot)$ is the 0th order modified Bessel function of the first kind. From the below results the system under rician fading channel gives the superior PAPR reduction and BER performance than the system under AWGN and SUI channel.

4. Results and Analysis

The figure1 and figure2 shows the CCDF of original OFDM signal and companded signals of system under AWGN channel and Rician fading channel. The figure 2 shows the better reduction of peak to average power ratio (PAPR) than figure 1 that is racian fading channel gives better reduction of PAPR.

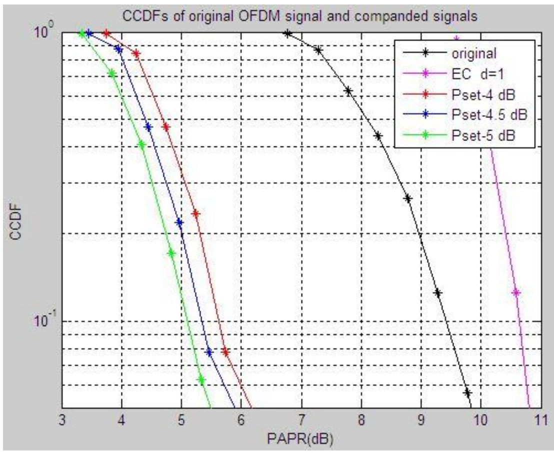

Figure1: CCDF of original OFDM signal and comapanded signals

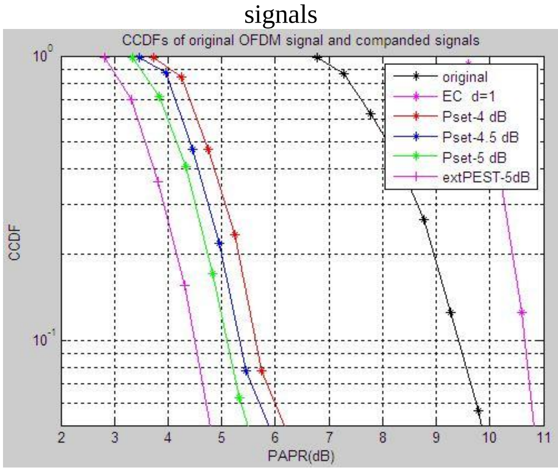

Figure 2: CCDF of original OFDM signal and comapanded signals over rician fading channel

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The figure 3,figure 4 and figure 5 shows the BER performance OFDM signal over AWGN , SUI and Rician fading channel with 4 QAM. From the following figures Rician fading channel gives better reduction bit error rate (BER) compare to other channels AWGN and SUI.

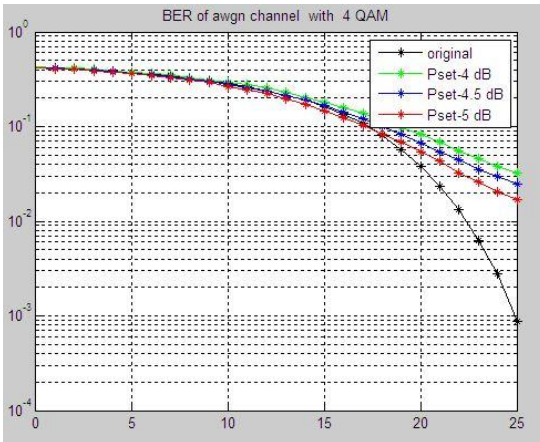

Figure 3: BER of AWGN channel with 4 QAM

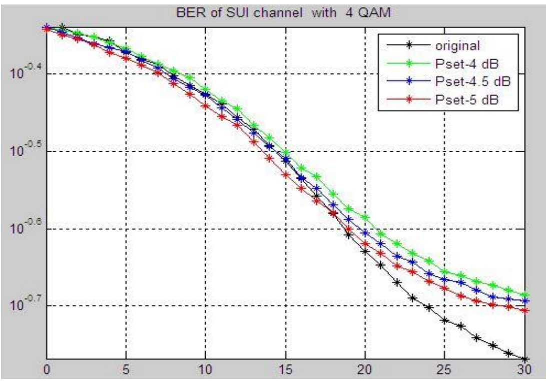

Figure 4: BER of SUI-4 channel with 4 QAM

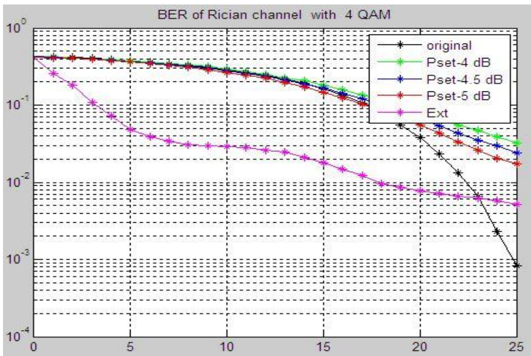

Figure 5: BER of AWGN channel with 4 QAM

The figure 6 shows the power spectral density of original OFDM signal and companded signals. It will reduce the spectral regrowth problem

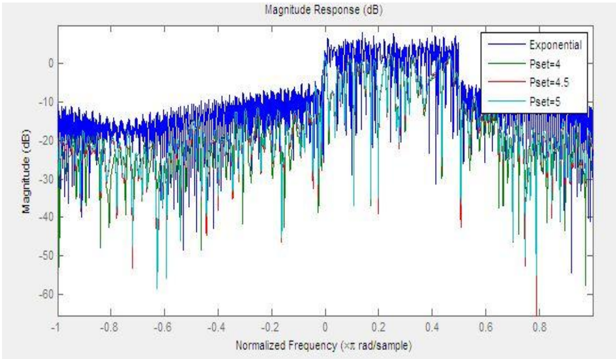

Figure 6: magnitude response

5. Conclusions

In our methodology the reduction of PAPR based on the companding transform with piecewise linear equations, the basic companding scheme introduces the distortion in the system which leads the system degraded results in the form of poor BER performance, PAPR as well. By our method we could make the system based on the optimal values of the different amplitude values called as inflection values. The proposed method with AWGN, SUI, Rician fading channel implementation , the racian fading channel give the enhanced performance of the less PAPR and BER with mitigation of the companding distortion.

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