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PIECEWISE LINEAR ITERATIVE COMPANDING TRANSFORM FOR PAPR REDUCTION IN MIMO OFDM SYSTEMS

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ABSTRACT

This paper presents a effective iterative piecewise linear companding transform for PAPR reduction. It also presents an efficient iterative procedure of companding. This procedure mainly aims to mitigate the companding distortion that occurs during the clipping operation. This analysis provides a trade off between the reduction in PAPR and BER performance. Simulation results shows that proposed iterative piecewise companding transform (IPCT) can effectively reduce the PAPR.

Keywords: OFDM, PAPR, companding transform, OBI, spectral re-growth.

1. INTRODUCTION

OFDM (Orthogonal frequency division multiplexing) has been widely adopted in various wideband wireless communication systems because of its high spectral efficiency and inherent error tolerance under different channelling conditions. However, this OFDM suffer from a criticaldrawback i.e. the approximated Gaussian-distributed output samples produce high Peak-to- Average Power Ratio (PAPR), leading to the inter-modulation among sub-carriers and undesired Out-of-Band Interference (OBI) [1]. In order to overcome this HPAs (High power amplifiers) with extremely wide range are required. [2]. Many research algorithms have been proposed so far to mitigate this effect like Clipping & Filtering [3], Selective mapping technique [4], Partial Transmit sequence [5], Tone reservation method [6] and companding transforms [7].

Digital clipping suffers from three problems: in-band distortion, which causes significant performance penalty [8]; out-of-band radiation, which reduces the spectral efficiency [9] and peak re-growth after digital to analog conversion [10]. In addition, it is more reasonable to treat clipping noise as a kind of impulsive noise rather than a continual additive Gaussian noise for most realistic case when clipping level is relatively high [11]. The best solution for these problems is to adapt companding transform (CT). So far many CTmethods are proposed in literature μ-law companding [12], Exponential companding (EC) [13]. However, it is noted that, similar to clipping, CT also has an extra pre-distortion processing applied to original symbol. For most existing CT methods, the signal's PAPR is reduced at the expense of limited BER degradation and significant out-of-band spectral re-growth.

To eliminate this spectral re-growth in CT, a specially designed frequency response filtering with a fixed rectangular-window was used [15]. Furthermore, to suppress the time-domain peaks regeneration caused by this frequency domain filtering, Iterative CF (ICF) technique was introduced [16]. However, ICF requires several iterations to approach a desired PAPR level. Recently, an optimized ICF method [14] based on convex optimization was proposed to dramatically decrease the number of required iterations. But unfortunately, its benefits come at the price of an increased complexity.

Motivated by this a iterative companding transform is proposed in this paper mitigating the trade off between the BER and PAPR. As of this paper, it presents the analysis of the approach with piece wise companding where the signals with amplitudes over a given companded peak amplitude are clipped for peak power reduction, and the signals with amplitudes close to the given companded peak amplitude are linearly scaled for power compensation.

This paper is organized as follows, section I briefly explains about the basics of OFDM and the research made by the earlier authors, section II depicts the formulation PAPR, section III explains about the companding transforms that were used in this research. Section IV briefly explains about the proposed methodology, and application of the companding transforms with the proposed approach ending with the experimental results and conclusions

2. PEAK TO AVERAGE POWER RATIO FORMULATION

Let $X = [x_0, x_1, \ldots \ldots x_{N-1}]$ represents the data sequence that is to be transmitted independently in OFDM system with N sub carriers. The signal is oversampled with a factor L (L=4) and the OFDM symbols can be represented as

$$x_n = \frac{1}{\sqrt{NL}} \sum_{k=0}^{NL-1} X_k e^{i2\pi \frac{kn}{NL}} \quad 0 \le n \le NL \tag{1}$$

Where $X = [x_0, x_1, \ldots \ldots x_{N/2-1}, 0,0 \ldots ..0, x_{N/2}, \ldots . x_N]$ is the input signal vector.The PAPR of this transmitted signal is given as

$$PAPR = 10log10(\frac{\max(|x_n|^2)}{E(|x_n|^2)} \tag{2}$$

Generally, the PAPR reduction capability is measured by the Complementary Cumulative Distribution

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Function (CCDF), which is defined as the probability that the signal's PAPR exceeds a specific threshold value $\gamma_0 > 0$

$$CCDF(\gamma_0) = Prob\{PAPR > \gamma_0\} = 1 - (1 - e^{-\gamma_0})^N \quad (3)$$

The principle of CT is described as follow. CT compresses the high peaks and enhances the low signals simultaneously, thus, decreasing the PAPR of the transmitted signal prior to the digital to analog convertor and HPA.

3. COMPANDING TRANSFORMS

This section presents different companding transforms that are used in this paper.

a) Linear Symmetrical Transform (LST)

This is the simplest of the CT whose companding function is given as

$$f(x) = (k.|x| + b).\operatorname{sgn}(x) \quad (4)$$

Where sgn(.) is the sign function. The two parameters 0<k<1 and b>0 are used to specify the companding profile in order to maintain an unchanged power after CT. The inverse companding is given as

$$f^{-1}(x) = \frac{|x|-b}{k}\operatorname{sgn}(x) \quad (5)$$

b) Two Piecewise Companding (TPWC)

This is a Linear Non symmetrical transform (LNST) which is the best in terms of PAPR reduction and also provides a solution for abrupt jump issue during companding [17]. Its function is given as

$$f(x)\begin{cases} u1|x|.\operatorname{sgn}(x), & |x| \le v \\ (u2|x| + s).\operatorname{sgn}(x) & |x| > v \end{cases} \quad (6)$$

Where u1>1, 0<u2<1 and s=(u1-u2)v>0 and 0≤v≤V is the cut off point with $v = \max\{|x_n|\}$. The de-companding function is given as

$$f^{-1}(x) = \begin{cases} \frac{1}{u}|x|.\operatorname{sgn}(x) & |x| \le u_1 v \\ \frac{1}{u_2}(|x| - s).\operatorname{sgn}(x) & |x| > u_1 v \end{cases} \quad (7)$$

The relation between three variables u1, u2, v is given with linear equation as
$u_1^2((1 - \exp(-\partial^2)) + u_2^2.\exp(-\partial^2)$=1
Please refer [18] for more info on this approach.

c) Piece wise Linear Companding (PLC)

When the original signal xn is companded with a given peak amplitude Ac, the companding function is given as

$$f(x) = \begin{cases} x & |x| \le A_i \\ kx + (1-k)A_c & (1-k)A_c < |x| \le A_c \\ \operatorname{sgn}(x)A_c & |x| > A_c \end{cases} \quad (8)$$

And its de-companding function is given as

$$f^{-1}(x) = \begin{cases} x & |x| \le A_i \\ (x - (1-k)A_c/k & (1-k)A_c < |x| \le A_c \\ \operatorname{sgn}(x)A_c & |x| > A_c \end{cases} \quad (9)$$

It is observed that the proposed companding transform is specified by parametersA_c, A_i, andk. As the average signal power is maintained constant, then according to the definition of PAPR in (2), the PAPR value of the proposed scheme that can be achieved theoretically is determined by Ac. [19].

4. PROPOSED ITERATIVE MECHANISM

The main objective of this approach is to obtain a significant PAPR reduction at the expense of a less amount of band distortion and spectral re growth. The block diagram of the proposed approach is shown below:

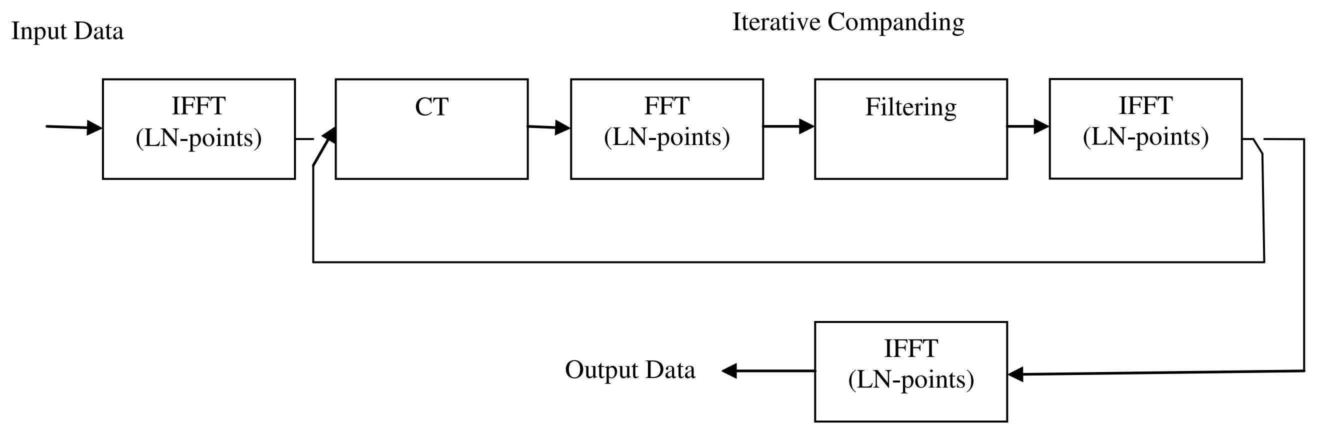

Figure-1. Block diagram of Iterative companding.

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The proposed approach is summarized as

a) Initialize the desired PAPRdes and the maximum number of iterations. Select companding parameters of the concerned companding transform.
b) Convert the frequency domain symbols X to over sampled time domain OFDM signal x using L oversampling factor.
c) At the first iteration m=1 & k1=1 a new symbol enters the iterative loop , set k1=k2=2;
d) At first iteration xout=x, other wise$x_{out}^{m} = x^{m-1}$
e) x^m is companded by the concerned CT to generate y^m
f) Convert y^m to frequency domain to generate c^m using NL-FFT points
g) Perform the frequency domain filtering by multiplying it with Hrect to get c^{mo}
h) Convert c^{mo} to time domain using NL-IFFT points.
i) Calculate PAPR denoted as $PAPR^m$, if $PAPR^m \leq PAPR_{des}$ or m>M iteration the set k2=1 and exit the loop if not return to step 3 .

The filtering response is given as

$$H_{rect} = \begin{cases} 1 & 1 < k \leq N-1 \\ 0 & N \leq k \leq LN-1 \end{cases} \qquad (10)$$

5. SIMULATION RESULTS

For the experimental analysis of the proposed iterative algorithm, four companding transform are used, LST, TPWC, PLC and EC.

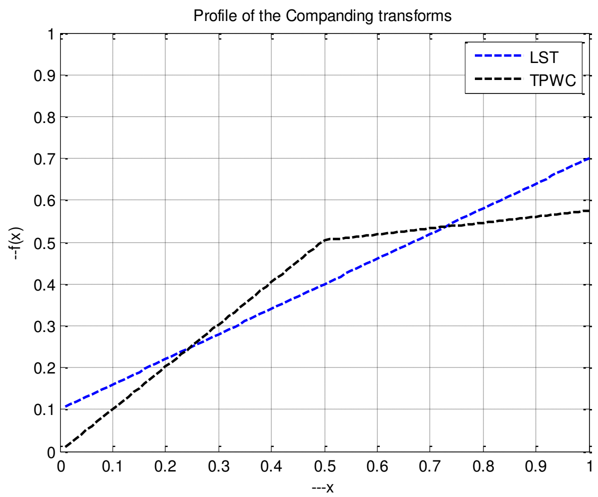

Figure-2. Profile of LST and TPWC companding transforms.

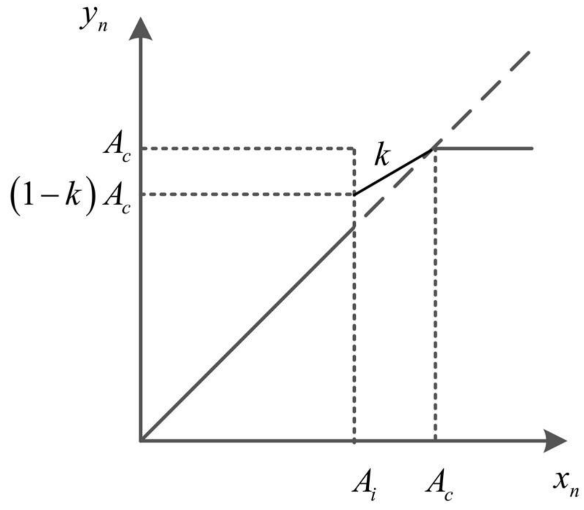

Figure-3. Profile of the piece wise linear companding transform.

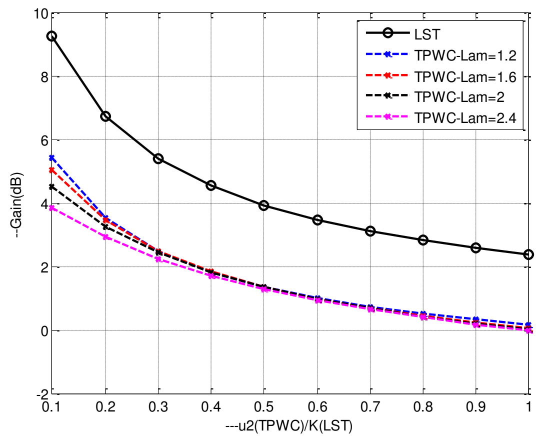

Figure-4. Gain of the LST and TPWC approaches.

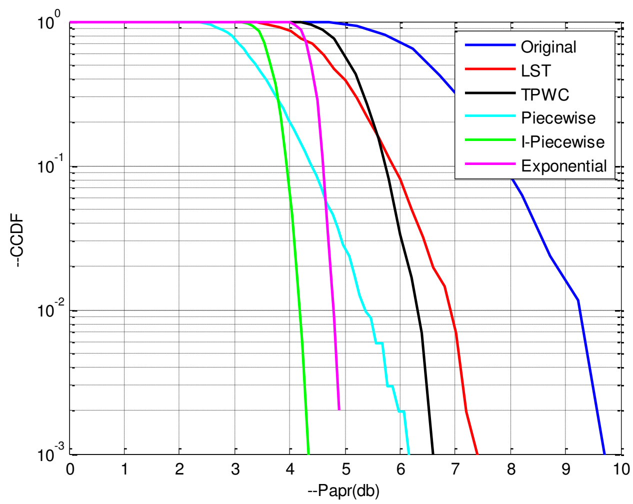

Figure-5. PAPR analysis with the proposed approach and comparison against others.

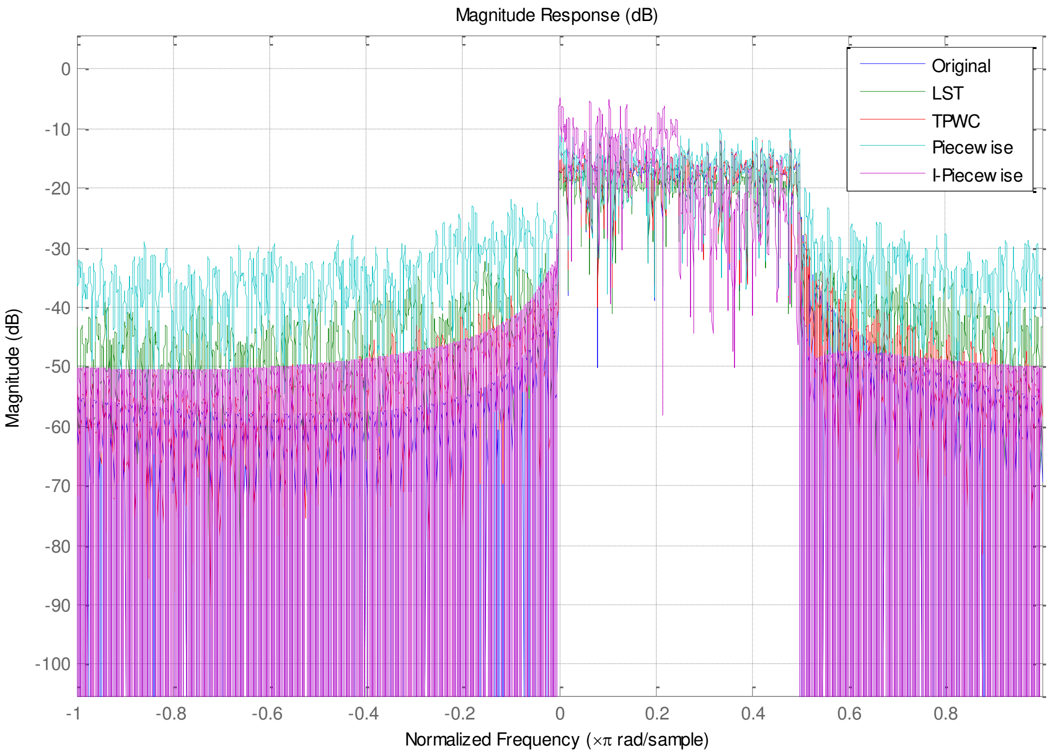

Figure-6. Power spectral density of companded signals showing decrease in distortion with proposed approach.

6. CONCLUSIONS

This paper presents an effective way of decreasing the non linear distortion and spectral re-growth with iterative based piecewise companding transform. The present approach decreases the PAPR about 0.8 to 1 dB with respect to earlier methods. This also provides an efficient decrease in spectral re-growth providing an efficiency of about 5-8 db when its spectral density is analysed. In future the approach will be examined under different channelling environments for the BER performance.

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