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An Innovative Piecewise Linear Companding Method for PAPR Reduction and Companding Distortion in OFDM System

[1]*Sangam Sai Krishna Kumar*, [2]*Mahender Veshala*

[1]M.Tech Digital Communications and [2]Assistant Professor, E.C.E. Department

[1,2] KU College of Engineering Technology, Kakatiya University, Warangal.

[1]saikrishna1991@gmail.com and [2]mahi415@gmail.com

Abstract- Orthogonal frequency division multiplexing (OFDM) is a popular modulation/multiplexing scheme offers high dataratesIt is considered as multicarrier transmission scheme supports future generation wireless as well as wireline communication systems.OFDM frequently suffers from high Peak to Average Power Ratio (PAPR) which eventually increases the Analogue to Digital and Digital to Analogue converters complexity levels and reduces HPA (RF) efficiency. Various Peak to average power ratio (PAPR) reduction schemes have been proposed in the past and companding is the popular PAPR reduction which is inserted after modulation in the OFDM system. Although companding scheme provides better results but simultaneously its presence as extra operation increases the bit error rate. In this paper, a novel piecewise linear companding scheme is implemented to reduce the PAPR impact and control the commanding distortion in the OFDM system. The piecewise linear companding scheme reduces the peak to average power ratio by clipping the amplitudes over the compounded peak amplitude. Finally, the simulation result yields the better spectral efficiency and batters BER performance while mitigating the companding distortion better way the PAPR is reduced in an accurate way.

Keywords: OFDM, PAPR, BER, HPA

I.INTRODUCTION

The 21st-century generation is dominated by the multimedia communications but spectral utilization plays an important role to meet the demand and provide the good services [1]. OFDM utilizes available spectrum in an effective way and provides a wide range of multimedia communications. It is accepted as a future generation communication system to support a wide range of application ranging from daily needs to high-level applications [2].

Communication through delay dispersive environments is a challenging task in high-speed digital communications and OFDM, which is also known as multiple frequency-shift keying (MFSK)[3]is consider has the relevant technique to communicate even in the delay dispersive environments with reliability and better accuracy[4]. Orthogonal frequency division multiplexing (OFDM) is basically a multi-carrier modulation scheme which supports a wide range of applications both in the indoor and outdoor environment.

The information sending over multiple carriers is an idea proposed by Chang in 1966 and the messages should be sent in a linear band limited channel without interferences both in terms of symbols and carriers [5]. The principle of transmitting information through linear channel [6] came into reality in 1971 and this initial implementation of OFDM consists of demodulators (which are coherent in nature) and oscillators in large numbers. In the late 1971 two noted researchers Weinstein and Ebert develop the OFDM mechanism with modulators and demodulators along with the DFT and after this work, a drawback is observed namely interferences [7]. Interferences are successfully resolved to some extent after inserting the cyclic prefix guard interval in order to maintain the orthogonally by Peled&Ruiz[8] in the year 1980.

II.LITERATURE SURVEY

A.PAPR Reduction Techniques

The mainly two modes are available to reduce the PAPR in OFDM are

1. **Partial Transmit Sequence**

Diminishing the PAPR to improve the efficiency at the transmitter end has been considered as the concerned area from two decades. Partial transmit sequence (PTS) is a popular and most efficient PAPR reduction scheme which is designed to diminish the PAPR impact from OFDM system.

The design behind the partial transmits scheme is based how efficiently the sub-block division is performed from the original OFDM signal. Another new thing implemented in this approach is phase rotation which helps the candidate to choose the signal with the lowest PAPR[13]. Original OFDM sequences are divided into disjoint symbol subsequence by using the partition process and in the latter step, each subsequent subcarrier is applied by IFFT and another process named distinct rotating vectors is used to make the sum of all blocks after multiplied by using the rotating vectors in an efficient way.

2. **Tone Reservation Approach**

PAPR reduction approaches have been proposed in the literature but the majority of the schemes are approximate while tone reservation approach is an accurate scheme proposed to reduce PAPR in an effective manner [14]. The theme behind the tone reservation approach is to design a reliable system to control the PAPR impact on the OFDM transmitter side.

The important factors used to mitigate PAPR impact in OFDM modulation scheme are reserved tones locations, complexity levels, reserved tones power and number of reserved tones. The beauty of the tone reservation approach is controlling the large amount of PAPR using small stones which decrease runtime complexity and increases performance drastically [15]. In traditional schemes, additional operations and information need to include at the receiver end while in the tone reservation approach no side information and no additional operation are required at the receiver end. The design of tone reservation approach is based on the data block summation and signal in terms of time domain [16]. The data block helps in minimizing high PAPR based on an original multi-carrier signal and note that data block which is used in this approach are termed as the depended block signal.

III. PROPOSED METHOD

Orthogonal frequency division multiplexing (OFDM) is a modulation scheme specially designed to offer high-speed wireless communications for supporting a wide range of applications ranging from ultra-short range to ultra-high range. Wireless communications are changing with great pace with technological advancements and OFDM to suffer from drawbacks like Peak to average power ratio (PAPR), Delay, Interferences and fading effect.

The PAPR reduction is a concerned area in OFDM modulation scheme and various PAPR reduction algorithms have reported in the literature but the majority of the algorithms focus on the PAPR reduction only a few works focus on the PAPR reduction with distortion but none can meet the desired results. PAPR reduction by companding technique is most successful and in the proposed method a new piecewise linear companding scheme is presented which deals with the companding distortion mitigation along with the PAPR reduction.

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The companding distortion mitigation is the primary aim of piecewise linear companding. Initially investigation of companding distortion effects is characterized in a theoretical way based on the bit error rate (BER) analysis. Bit error rate (BER) performance is improved gradually by reducing the companding distortion based on the commanding expressions and the main motto of the companding technique is to avoid the unnecessary compressions in peak power reduction and control the large signals expansion with respect to the small amplitude increments. The proposed piecewise linear companding transform is initialized to clip peak amplitudes of companding signal to reduce the impact of the companding distortion in an effective way.

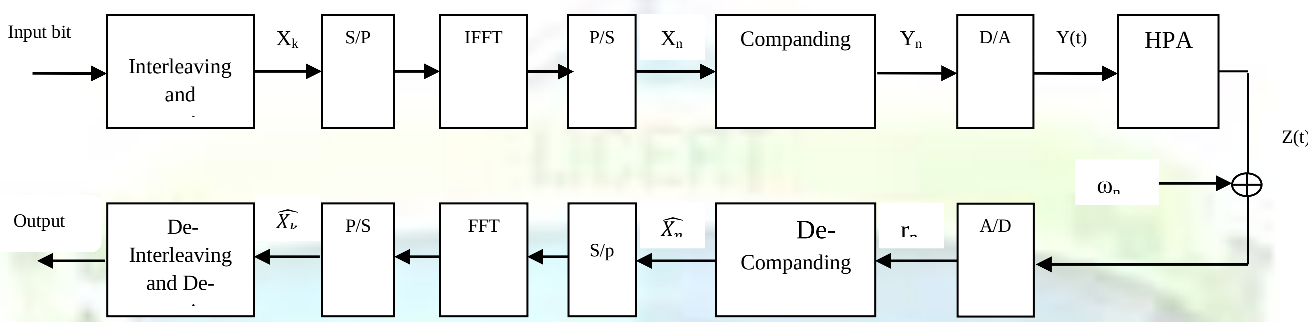

Figure 3.1 OFDM Modulation Scheme with Companding Transform

The amplitudes of the OFDM signal plays an important role in assessing the signal quality if the amplitudes of the signal increases beyond the threshold limit then it results in peak to average power ratio (PAPR). The proposed piecewise linear commanding design implementation depends on the two important factors (1) linear transform scaling design and (2) commanding peak amplitude design. Finally, experimental results examined that piecewise linear companding achieves better bit error rate (BER) than conventional companding schemes and enhanced power spectral density (PSD) in the process of reducing the PAPR.

A. SYSTEM MODEL

The above-demonstrated block diagram of OFDM-Companding transform shows the inclusion of companding transform as an additional block of the original default OFDM block diagram. The basic OFDM transmitted signal in terms of discrete time is illustrated as follow equation

$$x_n = \frac{1}{\sqrt{NL}} \sum_{k=0}^{NL-1} X_k e^{j2\pi\frac{kn}{NL}},\ 0 \le n \le NL, \quad (1)$$

In the above equation, different factors are taken into consideration as follows

Th term X represents X=$\left[X_0, X_{1,\ldots\ldots,} X_{\frac{N}{2}-1},\ 0, \ldots .,0, X_{\frac{N}{2}}, \ldots, X_N\right]$ represents OFDM input signal vector and the symbols which are going to insert in the input signal vector needs modulated in a linear way. The modulation process makes the carriers to accept the symbols in reliable way. Here each individual symbol are modulated by QAM or QPSK modulation schemes.

Here two important aspects are important namely sampling factor L and the number of subcarriers N. Author have inspired from central limit theory where the complex Gaussian process of $x_n$is estimated in approximated way and the statistics are revealed once the N is large enough. Subsequently the probability density function (PDF) is used to know the x_n amplitudes and x_n has Rayleigh distribution as follows

$$.\ \ f|x_n|(x) = \frac{2x}{\sigma_x^2} e^{\frac{-x^2}{\sigma_x^2}}\ x \ge 0, \quad (2)$$

Generally the term σ is defined as standard deviation of variation factor and in above notation the term σ_x^2 is used to represent the variance ofx_n.

Where σ_x^2=$E[X_k]^2$ denotes the two factors as follows

$E[.]$ =represents mathematical function

$|.|$= represents the modulus

The PAPR of OFDM signal represented in (1) is given by:

PAPR=$\frac{\text{Peak power}}{\text{Average Power}} = \frac{max|x(t)|^2}{E[|x(t)|^2]}$ (3)

B. COMPANDING TRANSFORM DESIGN CRITERIA

Orthogonal frequency division multiplexing (OFDM) scheme has standard block diagram with composed of parameters in the transmission end as Analog to digital conversion (A/D), Serial to parallel (S/P), modulation scheme (QPSK, BPSK or QAM) and then IFFT followed by channel and receiver section. But in proposed work along with all parameters an extra operation called companding operation is added after OFDM modulation process to reduce PAPR impact on the OFDM signal. Although companding transform has the ability to reduce to reduce the PAPR impact on the OFDM signal but subsequently the extra operation is a third party approach which results in the companding distortion. The companding operation design criterion is based on BER performance and BER is the key factor in analyzing the companding distortion in a reliable way. Both theoretical and practical approaches used by the companding transform to analyze the PAPR impact but initially PAPR impact is analyzed by theoretical in approximately.

The companding transform design depends on how efficiently commanding distortion can be mitigated and reduced. The theoretical analysis to reduce the companding distortion based on the BER is the key factor in designing the companding transform. The design of the companding transform require the following factors as follows

y_n= represents the companded signal,

x_n= represents the original OFDM modulation scheme,

c_n= represents the companding distortion.

The companding signal y_n can be expressed as

$$y_n = x_n + c_n \tag{4}$$

Note that companding distortion c_n has the same phase as original OFDM signalx_n.

C. NOVEL LINEAR COMPANDING APPROACH

A novel piecewise linear commanding approach has been proposed in this section and the design of the new piecewise linear companding scheme is designed in an effective way based on transform parameters in a theoretical analysis.

The proposed prices linear companding scheme is implemented on OFDM signal to mitigate the companding distortion and reducing the PAPR impact on the signal. The reduction of the peak power is followed by companding the original signal in with respect to the peak amplitude Ac

The following figures show the respective signal clips over peak amplitude Ac for peak power reduction and then power compensation process is carried on by a linear transformation of the signals which are close to the Ac. The proposed companding function representation is represented as follows

$$h(x) = \begin{cases} x & |x| \le A_i \\ kx + (1-k)A_c A_i < |x| \le A_c, \\ \quad sgn(x)A_c|x| > A_c \end{cases} \quad (5)$$

The proposed companding function is represented as above and $sgn(x)$ represents sign function and subsequently the respective de companding function at the receiver section is as follows

$$h^{-1}(x) = \begin{cases} x & |x| \leq A_i \\ kx + (1-k)A_c A_i < |x| \leq A_c\,, \\ sgn(x)A_c |x| > A_c \end{cases} \quad (6)$$

[**NOTE:**$h(x)$ is a Hermitian matrix represents the companding operation while $h^{-1}(x)$ represents decompanding operation respectively. Both perform compression and enhancing operations respectively to reduce PAPR and mitigate distortion in effective way]

The proposed linear companding scheme is different from traditional PAPR reduction schemes and the design of linear companding scheme is based on the peak amplitude companding signal parameters asA_c,A_i and k. The reduction of the PAPR in the OFDM modulation scheme is done when the power allocated to the carriers is goes beyond the average power limit and according to the definition of PAPR the peak power can be reduced can be achieved by peak amplitude A_c in theoretical PAPR value. The preset PAPR reduction is determined as A_c=$\sigma_x 10^{PAPR}\, preset/20$. Based on the above parameters the PAPR reduction can be solved as follows

$$\int_{A_i}^{A_c} kx + (1-k){A_c}^2 f_{|x_n|}(x)dx + \int_{A_c}^{\infty} A_c^2 f(x)dx = dx = X^2 f_{|x_n|}(x)dx. \, (7)$$

The above equation modified into the quadratic equation about k. The motto behind the implementation of the above equation is to keep the average signal power in constant mode. The constant K needs to be smaller than value 1 and constant K is taken in the interval [0, 1]. To keep the expanded signal peak amplitude not larger than Ac and in order to keep the limit constant K should not be a real number.

D. SELECTION OF THE COMPANDING TRANSFORM CRITERION

The companding distortion selection is aimed to minimize the companding distortion is derived in the sequel section. The calculation of the companding distortion according to [13] is

$$\sigma_c^2 = \int_0^{+\infty} |y_n - x_n|^2 f_{|x_n|}(x)dx = \left((A_c - A_i)^2 e^{-\frac{A_i^2}{\sigma_x^2}} - \sqrt{\pi}\sigma_x A_c \left(erf\left(\frac{A_c}{\sigma_x}\right) erf\left(\frac{A_i}{\sigma_x}\right)\right) + \sigma_x^2 \left(e^{-\frac{A_i^2}{\sigma_x^2}} - e^{-\frac{A_c^2}{\sigma_x^2}} \right)\right) - \sqrt{\pi}\sigma_x A_c erf\left(\frac{A_c}{\sigma_x}\right) + \sigma_x^2 e^{-\frac{A_c^2}{\sigma_x^2}} (8)$$

Here we observe the cost function in the form of convex which plots the contour plot in the first constraint of the above equation and consequently usage of the optimal parameter k is witnessed in the above equation which results in the companding distortion in the form of mini approach. Finally, this mini commanding approach is used for the determination of the A_c

IV.SIMULATION RESULTS

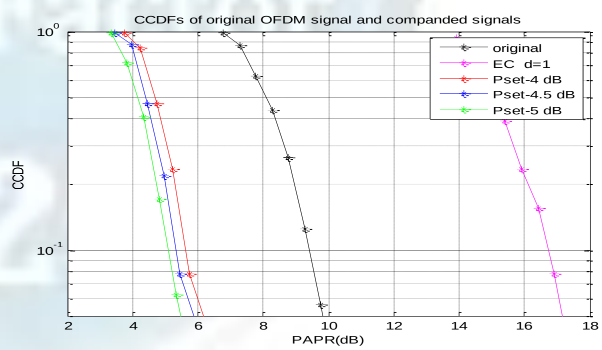

Figure 4.1 CCDF of original OFDM Signal and Companded Signals.

Analysis

Comparative analysis has performed between the proposed method and traditional algorithms with reference to the original signal. The analysis is carried out between PAPR and CCDF in x and y-axis respectively. The proposed method (green color) yields better results in terms of performance over Exponential companding.

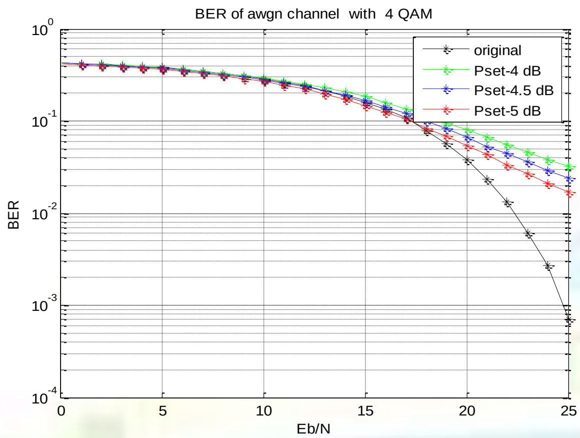

Figure 4 .2 BER of AWGN channel with 4 QAM

Analysis

Although lot of progress has been made in the literature to design the distortion less high data rate communication by removing the commonly erupting drawbacks but still the BER analysis in different transform based OFDM system and the performance analysis of the by using Matlab as source of medium in applications like LTE in the Exponential companding based OFDM and Piecewise linear companding based OFDM system model is still considered as concerned area in the field of high-speed communications. 4-QAM based BER analysis is performed with reference to original signal with different Preset values.

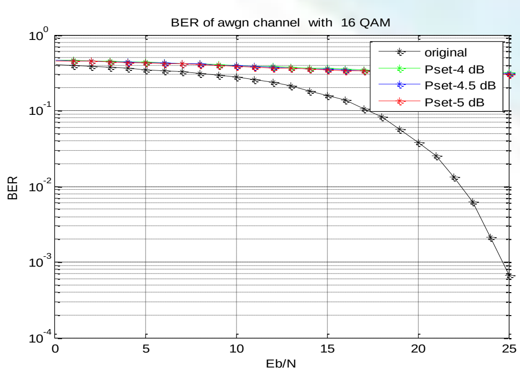

Figure 4.3 BER of AWGN channel with 16 QAM

Analysis

BER performance can be effectively improved by reducing the companding distortion. The 16-qam modulation scheme is implemented for acquiring effective BER analysis.

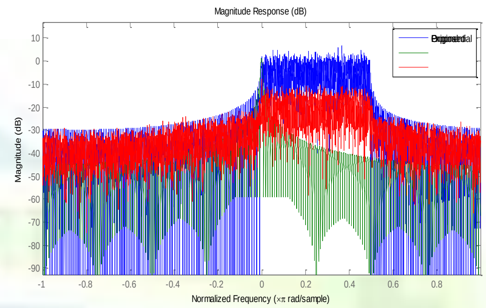

Figure 4.4 Magnitude Response

Analysis

The magnitude response figure shows spectral re-growth and performs the comparison among different companding schemes. To have a clear PSD comparison among these transforms, the PSDs are computed by means of period gram. As observed, the proposed scheme with PAPR preset = 4.5dB can achieve about 4.3dB, 1.85dB, and 1.8dB out-of-band interference EC schemes at the normalized frequency of 0.5, respectively.

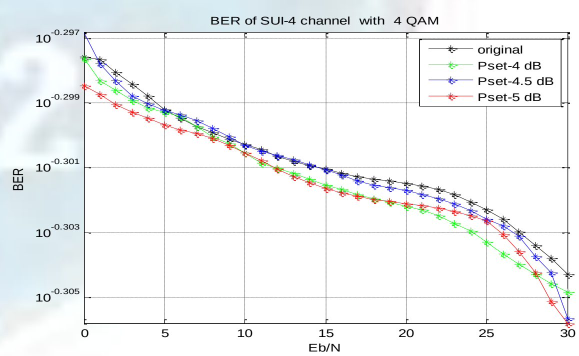

Figure 4.5 BER of SUI-4 channel with 4QAM

Analysis

BER analysis for the out-of-band channels (SUI) for 4-QAM is analyzed with different Present set values.

V.CONCLUSION

A new piecewise companding scheme proposed for improving the BER performance by mitigating the companding distortion in optimum level. The companding scheme aims to reduce the impact of the PAPR but results in the companding distortion which dramatically decreases the bit error performance and increases the complexity levels. A new Piecewise linear companding scheme is designed to reduce PAPR and commanding distortion mitigation in OFDM system by avoiding the unnecessary compression and expand larger signals with smaller amplitude increments. The experimental results show better BER performance, enhanced power spectral density and better spectral efficiency.

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