

PAPR REDUCTION IN OFDM SYSTEM USING NON LINEAR COMPANDING ALGORITHM

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ABSTRACT

Orthogonal Frequency Division Multiplexing (OFDM) has become the most widely adopted technology for various high data rate wireless communication systems due to the spectral bandwidth efficiency and robustness to frequency selective fading channels. Although, implementation of the OFDM system entails several difficulties. One of the major drawbacks in OFDM is the high peak-to-average power ratio (PAPR), nonlinearity of the high power amplifier causes to high out-of-band radiation, inter carrier interference, and bit error rate performance degradation. In this we introduce a new nonlinear companding algorithm that transforms the OFDM signals into the desirable statistics form defined by a linear piecewise function., more flexibility in the companding form and an effective trade-off between the PAPR and bit error rate performances can be achieved by introducing the variable slopes and an just inflexion point in the target probability density function. For this algorithm a theoretical performance study is presented and closed-form expressions regarding the achievable transform gain and signal attenuation factor are provided. We also verifying the selection criteria of transform parameters focusing on its robustness and overall performance aspects. The theoretical analyses of new algorithm are well verified via computer simulations.

INTRODUCTION

ORTHOGONAL frequency division multiplexing (OFDM) systems have been extensively applied in wireless communication systems, e.g. Worldwide Interoperability for Microwave Access (Wi MAX). It is widely known that OFDM is an attractive technique for achieving high data transmission rate in wireless communication systems and it is robust to the frequency selective fading channels [1]

OFDM systems have one major disadvantage, i.e. a very high Peak-to-Average Power Ratio (PAPR) at the transmitter [2] which causes signal distortion such as in-band distortion and out-of band radiation due to the nonlinearity of the high power amplifier (HPA) and a worse bit error rate (BER) [3]. To reduce the distortions caused by the nonlinearity of HPA it requires a large backoff from the peak power which is a significant burden, especially in mobile terminals The large PAPR increases the complexity of analog-to-digital converter (ADC) and digital-to-analog converter (DAC). Thus, PAPR reduction is one of the major problem in OFDM systems. PAPR reduction schemes can be classified according to several criteria. First, with respect to the computational operation in the frequency domain the PAPR schemes can be categorized as multiplicative and additive schemes tone reservation (TR) [5], peak canceling, and clipping [6] are additive schemes, because peak reduction vectors are added to the input symbol vector. On the other hand, Selected mapping (SLM) and partial transmit sequences (PTS) are examples of the multiplicative scheme because the phase sequences are multiplied by the input symbol vectors in the frequency domain [4]. Second, the PAPR reduction schemes can be also categorized based on whether they are deterministic or probabilistic. Deterministic schemes, such as peak canceling, clipping Probabilistic schemes, however, statistically improve the characteristics of the PAPR distribution of the OFDM signals avoiding signal distortion. SLM and PTS are examples of the probabilistic scheme because several candidate signals are generated and that which has the minimum PAPR is selected for transmission.

In this paper, we propose a new NCT algorithm which transforms the Gaussian distributed signal into a desirable distribution form defined by a linear piecewise function with an inflexion point. Compared to the previous methods, this algorithm will choose the proper transform parameters to reduce the impact of companding distortion on the BER performance.

In addition, it also allows more flexibility and freedom in the companding form to satisfy various design



requirements. The results regarding the achievable reduction in PAPR, signal attenuation factor, and the selection criteria of transform parameters are derived and verified through computer simulations.

II. CHARACTERIZATION OF OFDM SIGNAL

OFDM System Model

Let \mathbf{x} denote an input symbol vector in the frequency domain, where x_k represents the complex data of the k th subcarrier and N represents the number of subcarriers are represented by the N . The input symbol vector is also called the input symbol sequence. Generally, an OFDM signal is the sum of independent data symbols modulated by phase-shift keying (PSK) or quadrature amplitude modulation (QAM) each of which is separated by $1/N$ in the frequency domain, where T is the sampling period. Then, a continuous time baseband OFDM signal is defined as

$$s(t) = \sum_{k=0}^{N-1} x_k e^{j2\pi f_k t}$$

The discrete time base band OFDM signal sampled at the nyquist rate $t=nT$ can be given as

$$s[n] = \sum_{k=0}^{N-1} x_k e^{j2\pi f_k nT}$$

A discrete time OFDM signal vector denoted by \mathbf{a} . Then, \mathbf{a} corresponds to the inverse fast Fourier transform (IFFT) of \mathbf{X} , that is, $\mathbf{a} = \mathbf{Q}\mathbf{X}$, where \mathbf{Q} is the IFFT matrix. An oversampled discrete time OFDM signal vector can be denoted by \mathbf{a}_o , where \mathbf{a}_o is the oversampled discrete time OFDM signal sampled at $t = nT/N$ written as

$$s_o[n] = \sum_{k=0}^{N-1} x_k e^{j2\pi f_k nT/N}$$

Where i.e \mathbf{a}_o is $\mathbf{a}_o = \mathbf{Q}_o \mathbf{X}$

Continuous time baseband OFDM signals can be approximately represented by l times oversampled discrete time baseband OFDM signals. It is shown in [10] that choosing $l = 4$ is sufficient to approximate the peak value of the continuous time OFDM signals.

III .PROPOSED ALGORITHM

The main aim of the proposed algorithm is to transform the statistics of the amplitude into the desirable PDF defined by a piecewise function, which consists of two linear functions with an inflexion point. Assume the inflexion point and cutoff point of the PDF of a are $aB(0 < a < 1)$ and $B(B > 0)$, respectively. Thus, the desirable target PDF can be expressed as

where two slopes α and β are variable parameters that determine the desired companding form i.e. the ultimate

$$(10)$$

$$(11)$$

Clearly, CDF is a strictly monotonic increasing function and has the corresponding inverse function as follows.

shown at the bottom of the page. Where

– Additionally, in order to keep the input and output signal with a constant average power level, namely P_{avg} we can obtain

2). The transfer curves of this algorithm with various parameters are plotted in Fig. 1, from that we can see that the transform can achieve more reduction in the PAPR with α or increasing. Especially, it is noteworthy that the EC [9] and TC [13] are two special cases of the proposed algorithm. More specifics about the selection criteria of parameters are shown in Section IV.

At the receiver side, the companded signal can be recovered by the corresponding de-companding function as seen in (15), shown at the bottom of the page. In practice, since actual signal processed at the transmitter and receiver are the quantized signal with finite set of values, the functions in (13) and (15) can be numerically pre-computed and performed via the look-up tables [14]. Thus, its implementation complexity can be, therefore, significantly reduced.

IV. PERFORMANCE STUDY

The theoretical performance of the proposed algorithm is characterized in this section by using the two main evaluation criteria: the achievable reduction in PAPR and the impact of companding distortion on the BER performance at the receiver.

A. Desired Reduction in PAPR

By making appropriate substitution in (6), with the new

algorithm the ultimate PAPR of the companded signal is given by

$$P_{PAPR} = \frac{P_{max}}{P_{avg}} \tag{16}$$

Furthermore, a transform gain G is defined as the ratio of the PAPR of original signal to that of the companded signal [8], i.e.

$$G(dB) = 10 \log_{10} \left(\frac{P_{PAPR}}{P_{PAPR_c}} \right) \tag{17}$$

Where

The theoretical results of α and G are depicted in Fig. 2(a) and (b), respectively.

As can be seen, by adjusting the values of α and β this algorithm offers an adequate flexibility in the PAPR reduction. Consequently, the ultimate PAPR of the companded signal can be effectively confined in the interval [4.1 dB, 5.7 dB], or in other words, the achievable transform gain G in the PAPR is from 6 dB to 7.7 dB. Moreover, substituting (16) into (7), the CCDF of the PAPR with the proposed algorithm can be written as follows.

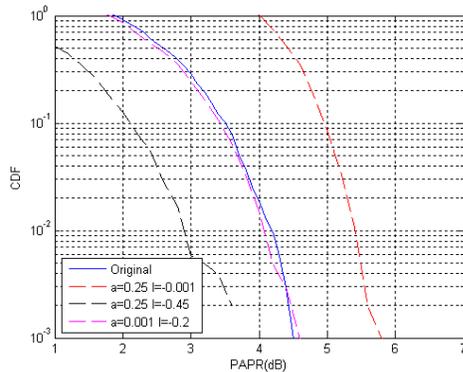


Fig. 4. PAPR reduction performance of different transforms for, OFDM system With $N=1024$, QPSK modulation, and oversampling ratio $J=4$.

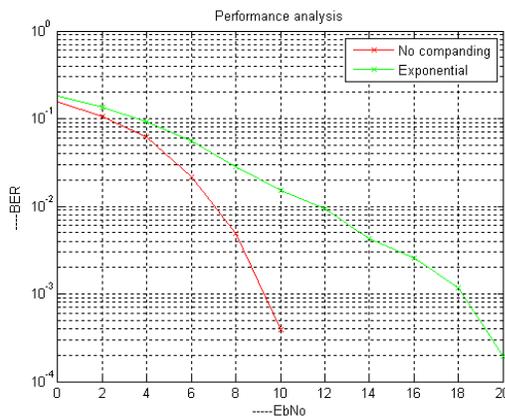


Fig.5. BER performance of different transforms under an AWGN channel for the OFDM system with $N=1024$ and 16QAM modulation

REFERENCE

- [1] W. Y. Zou and Y. Wu, "COFDM: An overview," IEEE Trans. Broadcast., vol. 41, no. 1, pp. 1–8, Mar. 1995.
- [2] J. Tellado, "Multicarrier transmission with low PAR," Ph.D. dissertation, Stanford Univ., Stanford, CA, 1998.
- [3] E. Costa, M. Midro, and S. Pupolin, "Impact of amplifier nonlinearities on OFDM transmission system performance," IEEE Commun. Lett., vol. 3, pp. 37–39, Feb. 1999
- [4] S. H. Müller, R. W. Bäuml, R. F. H. Fischer, and J. B. Huber, "OFDM with reduced peak to average power ratio by multiple signal representation," Ann. Telecommun., vol. 52, no. 1–2, pp. 58–67, Feb. 1997.
- [5] J. Tellado and J. M. Cioffi, "PAR reduction in multicarrier transmission systems," ANSI Document, T1E1.4 1.2, no. 2, pp. 284–293, Mar.

V. CONCLUSION

In OFDM systems the high PAPR is considered to be one of the major drawback because the large signal fluctuation gives rise to the low power efficiency, NCT is an out-of-band interference under the multipath fading channel or with the HPA. attractive solution to reduce the PAPR of OFDM signal due to its simplicity and effectiveness, In this paper we investigate a new NCT algorithm which changes the statistics of original signal from the complex Gaussian to a desirable PDF defined as a linear piecewise function. Thus, an effective and flexible trade-off between the PAPR and BER performance can be achieved to satisfy various system

requirements. Theoretical performance of this algorithm is characterized by means of the achievable reduction in PAPR and signal attenuation factor. Compared to the original signal the proposed algorithm can offer the transform gain in PAPR of 6.0 dB to 7.7 dB. In addition, the impact caused by companding distortion can be significantly reduced by choosing proper transform parameters; simulation results indicate that the new proposed algorithm substantially outperforms the existing NCT methods in the overall performance of OFDM system regarding the reduction in PAPR, BER and

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Technical Subcommittee, no. 97–367, pp. 1–14, Dec. 8, 1997.

[6] H. Ochiai and H. Imai, “Performance of the deliberate clipping with adaptive symbol selection for strictly band-limited OFDM systems,” *IEEE J. Sel. Areas Commun.*, vol. 18, no. 11, Nov. 2000.

[7] T. Jiang and Y. W. Wu, “An overview: Peak to average power ratio reduction techniques for OFDM signals,” *IEEE Trans. Broadcast.*, vol. 54, no. 2, pp. 257–268, June 2008

[8] X. Huang, J. Lu, J. Zheng, K. B. Letaief, and J. Gu, “Companding transform for reduction in peak-to-average power ratio of OFDM signals,” *IEEE Trans. Wireless Commun.*, vol. 3, no. 6, pp. 2030–2039, Nov. 2004.

[9] T. Jiang, Y. Yang, and Y. Song, “Exponential companding transform for PAPR reduction in OFDM systems,” *IEEE Trans. Broadcast.*, vol. 51, no. 2, pp. 244–248, June 2005.

[10] T. Jaing, W. Xiang, P. C. Richardson, D. Qu, and G. Zhu, “On the nonlinear companding transform for reduction in PAPR of MCM,” *IEEE Trans. Wireless Commun.*, vol. 6, no. 6, pp. 2017–2021, Jun. 2007.

[11] J. Hou, J. Ge, D. Zhai, and J. Li, “Peak-to-average power ratio reduction of OFDM signals with nonlinear companding scheme,” *IEEE Trans. Broadcast.*, vol. 56, no. 2, pp. 258–262, Jun. 2010.

[12] J. Hou, J. H. Ge, and J. Li, “Trapezoidal companding scheme for peak-to-average power ratio reduction of OFDM signals,” *Electron. Lett.*, vol. 45, no. 25, pp. 1349–1351, Dec. 2009

[13] S. S. Jeng and J. M. Chen, “Efficient PAPR reduction in OFDM systems based on a companding technique with trapezium distribution,” *IEEE Trans. Broadcast.*, vol. 57, no. 2, pp. 291–298, Jun. 2011

[14] Y. Jiang, “New companding transform for PAPR reduction in OFDM,” *IEEE Commun. Lett.*, vol. 14, no. 4, pp. 282–284, Apr. 2010

[15] D. Dardari, V. Tralli, and A. Vaccari, “A theoretical characterization of nonlinear distortion effects in OFDM systems,” *IEEE Trans. Commun.*, vol. 48, no. 10, pp. 1755–1764, Oct. 2000.

[16] P. Banelli, “Theoretical analysis and performance of OFDM signals in nonlinear fading channels,” *IEEE Trans. Wireless Commun.*, vo