Hybrid PAPR reduction technique in OFDM system based on Exponential Companding

[1] A. Lakshmi Narayana, [2] V.B.S. Srilatha Indira Dutt, [3] G. Sasibhushana Rao, [4] A.Abhishiktha
[1]Assistant Professor, [2]Associate Professor, [3]Professor, [4]Junior Research Fellow
[1] Department of Electronics and Communication Engineering,
[1]ANITS, Visakhapatnam, INDIA

Abstract: Orthogonal frequency division multiplexing is multicarrier wireless communication modulation scheme, which is a fascinating approach for wireless communication applications to achieve very high data rates. However, its key limitation is its large peak to average power ratio (PAPR), which results in significant distortion while passing through a nonlinear device, such as a transmitter high power amplifier (HPA). In this paper combination of Exponential companding (EC) with Discrete Hartley Transform (DHT) is proposed to reduce the PAPR in great extent when compared to EC with Walsh–Hadamard transform (WHT). Simulation results show that DHT with EC will obtain effective reduction of PAPR over WHT with EC.

***IndexTerms* – OFDM, PAPR, Discrete Hartley Transform; Walsh–Hadamard transform, Exponential companding.**

I. INTRODUCTION TO OFDM

Orthogonal frequency division multiplexing (OFDM) is a robust and spectral efficient wireless communication technique which allows achieving very high data rates for the wireless communication applications. However, despite of its advantages, its key limitation is its large peak to average power ratio (PAPR), which leads to seviour performance degradation with nonlinear high power amplifier (HPA) at the transmitter.

PAPR is mostly used characteristic for envelop fluctuations of OFDM by relating peak power and mean value power. Several techniques were proposed to reduce PAPR [1,2]. Selective level mapping (SLM), partial transmit sequence (PTS), companding techniques [3-9], Discrete Hartley Transform [10-11] were proposed. In those techniques companding technique gains more attention due to its simplicity and flexibility. The companding concept was initially introduced in [5]. That uses the μ-law companding technique, which reduces PAPR by increasing the average power while maintain the peak power remains unchanged. Later, Exponential Companding (EC) was proposed in [6], which can improve reduction of PAPR of OFDM by changing the dispersion (distribution) of OFDM signals while maintain average power remains constant. Later on, a new nonlinear companding scheme is proposed [7] which alter the Gaussian distributed signal into distribution form by using a linear function format. This nonlinear companding technique reduces the OFDM signal's PAPR at cost of increasing computational complexity. Then Two Piecewise Companding (TPWC) technique was proposed in [8] which compresses large signal amplitudes and expands small signals by two different piecewise functions. All these companding techniques reduce the PAPR but producing companding distortion. Recently, a piecewise linear companding technique was investigated in [9] to decrease the distortion by scaling the signals linearly with amplitudes close to the given companded peak amplitude for increasing the average power and clipping the signals with amplitudes over a given companded amplitude for reducing the peak power. The DHT Precoded system [10, 11] shows better PAPR reduction than WHT precoded system and Selected Mapping OFDM system. This DHT precoded OFDM system has the advantage that it doesn't require any additional power requirement, Complex optimization and side information to be sent to Receiver.

In this paper a new effective PAPR reduction technique of OFDM using DHT precoding with exponental companding transform (EC) is proposed to reduce the PAPR of OFDM signal over WHT precoding with exponental companding transform (EC). The incoming input data stream is firstly transformed by DHT or WHT and then this transformed data stream is given as input to IFFT signal processing unit then piece wise linear companding transform is applied. The OFDM system with proposed technique is shown in Figure 2.

This paper starts with the introduction of the topic in section I. Section II presents a Typical OFDM system model with a conception of PAPR problem. Exponential Companding (EC) technique is introduced in section III. Section IV provides signal processing steps to implement a PAPR reduction technique by combining Exponential Companding transform and DHT. Simulation results are conferred in section V and finally the Conclusion is given in VI.

II. FORMULATION OF PAPR PROBLEM

Typically, independent data symbols are modulated by using baseband modulation schemes like phase-shift keying (PSK) as well as Quadrature Amplitude Modulation (QAM). OFDM signal is nothing but sum of those independent modulated data symbols. The oversampled time-domain OFDM symbols can be calculated as

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

Where $n = 0,1,...,LN-1$ time is index and is the oversampling factor. Usually, $L \ge 4$ is used to exactly characterize to PAPR of the continuous-time signal. To ensure the Nyquist criteria of OFDM signal is done by inserting $(L-1)N$ zeros in the middle of length vector, i.e.

$$X_e = \left[X_0, X_1, ..., X_{\frac{N}{2}-1}, \underbrace{0,....,0}_{N(L-1)}, X_{\frac{N}{2}}, ..., X_{N-1} \right]^T . \quad (2)$$

It is clear that x = $IFFT_{LN}\{X_e\}$. For a large N (e.g. $N \ge 64$), the real and imaginary parts of OFDM are approximated as independent and identically distributed Gaussian random variables with zero mean and a variance σ_x^2. Based on this criterion, the amplitude of OFDM signal $|x_n|$ follows a Rayleigh distribution with the probability density function (PDF) as

$$f_{|x_n|}(x) = \frac{2x}{\sigma_x^2} e^{-\frac{x^2}{\sigma_x^2}} \qquad x \ge 0. \qquad (3)$$

The cumulative density function (CDF) of $|x_n|$ is therefore

$$F_{|x_n|}(x) = \Pr ob\{|x_n| \le x\} = \int_0^x \frac{2y}{\sigma_x^2} e^{-\frac{y^2}{\sigma_x^2}} dy = 1 - e^{-\frac{x^2}{\sigma_x^2}}, \quad x \ge 0 \quad (4)$$

The PAPR of OFDM signal in a given frame is defined as

$$PAPR_X = \frac{\max_{n\in[0,LN-1]} \{|x_n|^2\}}{E\{|x_n|^2\}}. \qquad (5)$$

It is more favourable to consider the PAPR of OFDM as a random variable and employ a statistical description given by the complementary cumulative distribution function (CCDF), stated as the probability that the PAPR of signal (x) exceeds an assigned level $\gamma_0 > 0$, i.e.

$$CCDF_X(\gamma_0) = \Pr ob\{PAPR_X > \gamma_0\} = 1 - (1 - e^{-\gamma_0})^N \quad (6)$$

III. EXPONENTIAL COMPANDING TECHNIQUE

A lot of companding techniques are available in the literature while The exponential companding (EC) is most popular companding techniques. The companding function *h*(x) of EC transform is given as

$$h(x) = sgn(x)^d \sqrt{\alpha_{EC}[1-\exp(-x^2/\sigma^2_{EC})} \qquad (7)$$

where, sgn(x) is the signum function, ‘d’ is the degree of companding scheme and σ^2_{EC} is the variance of input signal applied for companding. The positive constant ‘α_{EC}’ determines the average power of output signal.

At the receiver side, the inverse function of *h*(x) is used in the de-companding operation which is defined as

$$h^{-1}(x) = sgn(x) \sqrt{-\sigma^2_{EC} \log_e (1-(x^d/\alpha_{EC}))} \qquad (8)$$

IV. PROPOSED TECHNIQUE

In this section, a hybrid companding transform (DHT Precoded OFDM with EC) to reduce the PAPR of OFDM signal is proposed. The incoming input data stream is firstly transformed by DHT or WHT, and then the transformed data stream is given as input to IFFT signal processing unit. The OFDM system with proposed technique is shown in Fig.1

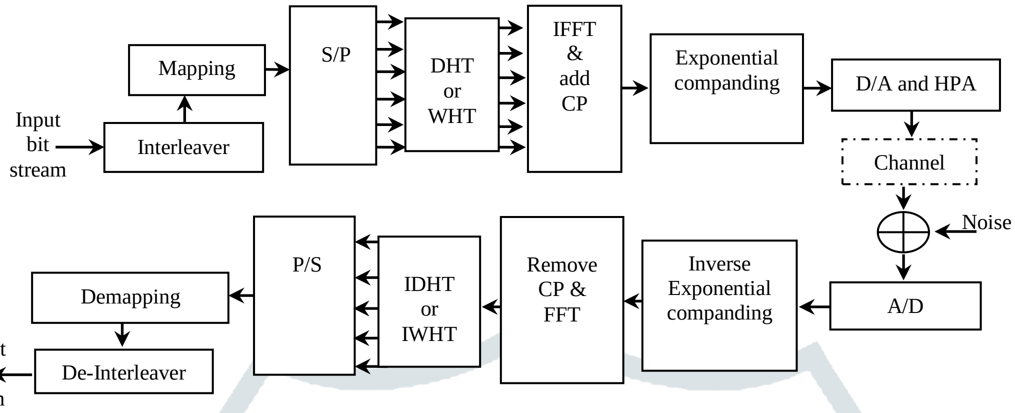

Fig.1 Block diagram of the Proposed Method (DHT Precoded OFDM with Exponential Companding).

Algorithm:

Step1: Firstly DHT transform is applied to the sequence X i.e. $Y = HX$ (9)

Where H is the Precoding matrix given as

$$P = \begin{bmatrix} p_{00} & \cdots & p_{0(N-1)} \\ \vdots & \ddots & \vdots \\ p_{(N-1)0} & \cdots & p_{(N-1)(N-1)} \end{bmatrix} \quad (10)$$

Step2: Apply IFFT to DHT transformed signal, $y = ifft(Y)$, where $Y = [Y(1)\ Y(2)\ ....\ Y(N)]^T$

$$y_n = \frac{1}{\sqrt{NL}} \sum_{k=0}^{N-1} Y_k . e^{j2\pi \frac{kn}{NL}}, \quad 0 \le n \le NL-1 \quad (11)$$

Step3: Apply Exponential Companding transform to y, i.e. $s(n) = C\{y(n)\}$

$$= h(x) = sgn(x)^d \sqrt{\ } \alpha_{EC}[1-exp(-x^2/\ \sigma^2_{EC}) \quad (12)$$

Step4: Apply Exponential Decompanding transform to the received signal r (n), i.e. .

$$= h^{-1}(x) = sgn(x) \sqrt{\ } - \sigma^2_{EC} \log_e (1-(x^d/\ \alpha_{EC})) \quad (13)$$

Step5: Apply FFT transform to the signal $\hat{y}(n)$, i.e. $\hat{Y} = fft(\hat{y})$, where $\hat{y} = [\hat{y}(1)\ \hat{y}(2)\ ....\ \hat{y}(N)]^T$

Step6: Apply inverse DHT transform to the signal $\hat{Y}$, i.e. $\hat{X} = H^{-1}\hat{Y}$.

Step7: Then the signal $\hat{x}$ is demapped to bit stream.

The DHT is also invertible transform which allow us to recover the xn from Hk and inverse can be obtained by simply multiplying DHT of H_k by (1/N).

V. SIMULATION RESULTS

Computer simulation results are conferred in this section using Matlab 2015a, as a tool to appraise the performance of the proposed technique i.e. hybrid companding transform with reference to the PAPR reduction. The number of subcarrier N = 256 and oversampling factor L is 4 considered as per IEEE 802.16 (WiMAX) standards. The baseband modulation techniques 8-QAM is considered as the mapping formats.

A.PERFORMANCE IN PAPR REDUCTION

The PAPR reduction of the proposed Hybrid Companding Transform is compared with that of Piecewise Linear Companding and Exponential Companding schemes. The Complementary Cumulative Distribution Function (CCDF) of PAPR is simulated and shown in the figures Figure. 2 to Figure 3 for the Proposed method and existing companding techniques PLC & EC. We can understand that this proposed technique can draw good PAPR reduction. CCDF plot of the OFDM signal processed by the Proposed Composite transform is compared with that of Precoding methods (WHT and DHT) and with EC and PLC schemes. The CCDF performance of the above methods for various values of M-QAM (M = 8) modulated OFDM signals is presented in figures Figure 2 & Figure 3.

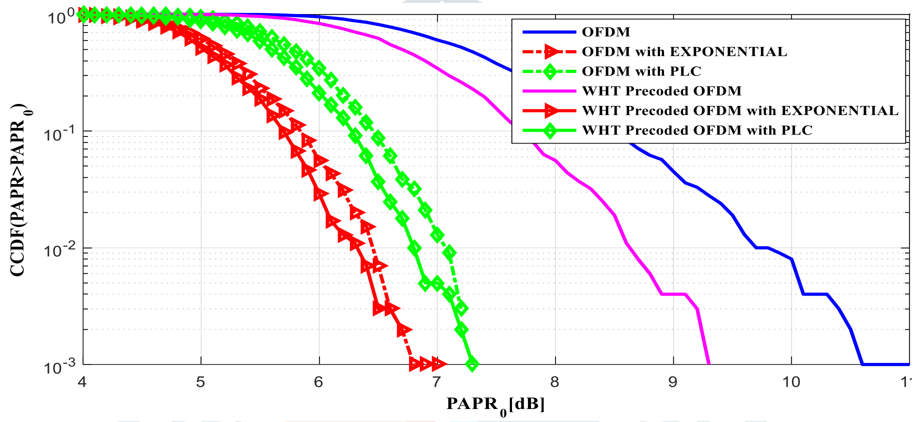

Fig.2. CCDF plot of the proposed method WHT with EC with 8-QAM modulation.

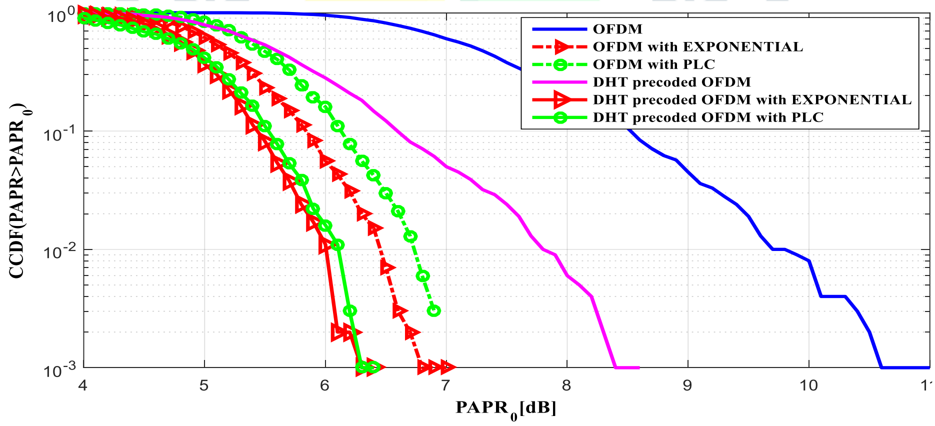

Fig.3. CCDF plot of the proposed method DHT with EC with 8-QAM modulation.

Table-1 indicates the PAPR values of this proposed method along with the existing method over 32-QAM as the mapping techniques.

Table-1 PAPR values	M=8
OFDM	9.7
OFDM WITH EXPONENTIAL	6.452
OFDM WITH PLC	6.905
WHT PRECODED OFDM	8.623
WHT PRECODED OFDM WITH EXPONENTIAL	6.306
WHT PRECODED OFDM WITH PLC	6.8
DHT PRECODED OFDM	7.795
DHT PRECODED OFDM WITH EXPONENTIAL	6.005
DHT PRECODED OFDM WITH PLC	6.106

From above table it is observed that the two proposed methods show significant PAPR Reduction capabilities compared with the existing Piecewise Linear Companding (PLC) and Exponential Transform.

Table 2 Improvement of two proposed techniques in PAPR at M = 32 QAM among various techniques.

	Improvement over OFDM in dB	Improvement over OFDM in %
OFDM WITH EXPONENTIAL	3.248	33.49 %
OFDM WITH PLC	2.795	28.82 %
WHT PRECODED OFDM	1.077	11.10 %
WHT PRECODED OFDM WITH EXPONENTIAL	3.394	34.99 %
WHT PRECODED OFDM WITH PLC	2.9	29.8 %
DHT PRECODED OFDM	1.905	19.64 %
DHT PRECODED OFDM WITH EXPONENTIAL	3.695	38.09 %
DHT PRECODED OFDM WITH PLC	3.594	37.05 %

The Proposed technique (WHT Precoded OFDM with EC) is having highest improvement of 3.394 dB when compared with the other techniques as observed from Figure 2. The Proposed technique (DHT Precoded OFDM with EC) is having highest improvement of 3.695 dB when compared with the other techniques as observed from Figure 3. Even if we increase the M-ary value also the proposed methods exhibits the similar performance. Among the two proposed methods, the DHT Precoded OFDM with Exponential Companding shows better PAPR reduction capabilities than WHT Precoded OFDM with Exponential Companding.

VI. CONCLUSION

In this paper, a composite companding transform method DHT Precoded OFDM with EC and WHT Precoded OFDM with EC are proposed for reduction of PAPR of OFDM signals and the Simulation results are compared with the existing Piecewise linear companding (PLC) technique and original OFDM. The PAPR is improved by 34.99 % when considering WHT with EC, where as the PAPR is improved by 37.05 % when considering DHT with EC. So, among the two proposed methods, the DHT Precoded OFDM with Exponential Companding shows better PAPR reduction capabilities than WHT Precoded OFDM with Exponential Companding.

REFERENCES

[1] T. Jiang and Y.Wu, "An overview: Peak-to-average power ratio reduction techniques for OFDM signals," IEEE Trans. Broadcast., vol. 54, no. 2,pp. 257–268, Jun. 2008.

[2] S. H. Han and J. H. Lee, "An overview of peak-to-average power ratio reduction techniques for multicarrier transmission," IEEE Trans.Wireless Commun., vol. 12, no. 2, pp. 56–65, Apr. 2005.

[3] R. W. Bäuml, R. F. H. Fischer, and J. B. Huber, "Reducing the peak- to average power ratio of multicarrier modulation by selected mapping," IEEE Electron. Lett., vol. 32, no. 22, pp. 2056–2057, Oct. 1996.

[4] S. H. Müller and J. B. Huber, "OFDM with reduced peak-to-average power ratio by optimum combination of partial transmit sequences" IEEE Electron. Lett., vol. 33, no. 5, pp. 368–369, Feb. 1997.

[5] X. Wang, T. T. Tjhung, and C. S. Ng, "Reduction of peak-to-average power ratio of OFDM system using a companding technique," IEEE Trans. Broadcast., vol. 45, no. 3, pp. 303–307, Sep. 1999.

[6] T. Jiang, Y. Yang, and Y.-H. Song, "Exponential companding technique for PAPR reduction in OFDM systems," IEEE Trans. Broadcast., vol. 51,no. 2, pp. 244–248, Jun. 2005.

[7] Y. Wang, J. Ge, L. Wang, J. Li, and B. Ai, "Nonlinear companding transform for reduction of peak-to-average power ratio in OFDM systems," IEEE Trans. Broadcast., vol. 59, no. 2, pp. 369–375, Jun. 2013.

[8] P.Yang and A. Hu, "Two-piecewise companding transform for PAPR reduction of OFDM signals," in Proc. Wireless Commun. Mobile Comput. Conf. (IWCMC), Istanbul, Turkey, Jul. 2011, pp. 619–623.

[9] Meixia Hu, Yongzhao Li,Wei Wang, and Hailin Zhang," A Piecewise Linear Companding Transform for PAPR Reduction of OFDM Signals With Companding Distortion Mitigation," IEEE transactions on broadcasting, vol. 60, no. 3, september 2014.

[10] Mohammed A.Aboul-Dahab, Esam A. A. A. Hagras, Ahmad A. Elhaseeb "PAPR Reduction Based on DFT Precoding for OFDM Signals ", International Journal of Future Computer and Communication, Vol. 2, No. 4, August 2013

[11] Imran Baig, Varun Jeoti,"PAPR analysis of DHT precoded OFDM system for M-QAM", International Conference on", Intelligent and Advanced Systems (ICIAS), 2010

[12] A Text Book on '"MIMO-OFDM Wireless Communications with MATLAB". By Yong Soo Cho, Won Young Yang.