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Improved Companding Technique with Different Modulation Schemes for Better Papr in of DM Systems

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Article Info
Volume 82
Page Number: 2972 - 2977
Publication Issue:
January-February 2020

Article History
Article Received: *14 March 2019*
Revised: *27 May 2019*
Accepted: *16 October 2019*
Publication: *19 January 2020*

Abstract
Orthogonal Frequency Division Multiplexing (OFDM) is a digital multicarrier modulation using many closely spaced subcarriers. The problem in transmitted signal of OFDM scheme is high Peak-to-Average-Power Ratio (PAPR) andit leads the transmitter's high power amplifier into its non-linear region which cause high power consumption and degradation of BER performance. Among various techniques companding scheme appears attractive for its simplicity and effectiveness. The reduction in input sequence auto-correlation is done by Discrete Cosine Transform(DCT)prior to IFFT operation for PAPR reduction. In this paper, a combination of DCT and Improved two μ law companding with an offset, is proposed to achieve better PAPR reduction and efficient bandwidth utilization for lower and higher orders in PSK and QAM modulation. The main idea is to show the performance of ITM with DCT on the OFDM signal with reduced PAPR using simulation.

Keywords: *OFDM, PAPR , DCT, Improved two μ law companding.*

I. INTRODUCTION

Orthogonal Frequency Division Multiplexing is one of the digital multicarrier modulation schemes with high data rate communication in wireless system. It is extension of frequency division multiplexing with multicarrier that divides the available bandwidth into narrow band subcarriers and has effective parallel transmission of signals. The main advantage of a OFDM includes multipath fading, effective usage of bandwidth, high spectral efficiency and robustness to the transmitted signal.

Although it has these advantages, it also has some disadvantages such as Inter Symbol Interference (ISI) and PAPR. To eliminate the Inter Symbol Interference guard band intervals are introduced in between the subcarriers. Addition of the cyclic prefix technique resolves the ISI and Inter Carrier Interference.

The PAPR problem in OFDM system makes the high power amplifiers to operate in non-linear region. This creates the in-band growth, BER performance degradation and out of band radiations. Different techniques proposed to solve the PAPR problem in the OFDM system such as clipping, Selective Mapping(SLM), Tone Reservation (TR),Active constellation extension (ACE), and companding. Due to low complexity and easy implementation companding techniques have gained their attentions in PAPR teduction techniques.

Companding techniques are of two types namely linear and non-linear companding. Companding is the technique which compress the amplitude of large signals and expand the amplitude of small signal which reduces the PAPR. The addition of

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several sub carriers in the time domain of OFDM signal cause varying envelope on the signal and produces high PAPR. The µ law companding is introduced in speech signal processing and later in OFDM systems.

In the adaptive slope and threshold (ATS) companding transform scheme, expand signals only which are below a particular threshold amplitude and transmitting the rest of the signal without any change. To achieve the desired BER performance adaptively varying slope of expansion and threshold limiting the amplitude of input signals is required.

The unitary matrix transform proposed to decrease the PAPR in OFDM system. Inverse fourier transform matrix [8] Hadamard matrix transform [7] and Discrete cosine transform (DCT) [9] are combined with companding techniques results in further reduction of PAPR and also it affects the BER performance and spectral efficiency. Improved µ law companding technique is proposed to overcome the sharp step problem occurrence in choose of two different companding levels. The offset threshold is used to separate two µ values in the processed signal.

This paper presents the combination of ITM companding transform with DCT gives better PAPR reduction and power saving is achieved .

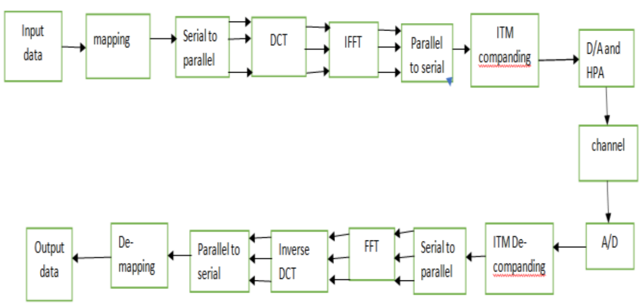

Figure 1 OFDM transceiver system

Section II explains the OFDM model. Section III explains the companding technique and chosen of µ values. The Discrete Cosine Transform is mentioned in Section IV. Section V has the evaluation of proposed scheme for different modulation technique. The Conclusion is provided in Section VI.

II. SYSTEM MODEL

In this section, basic blocks of OFDM transmitter and PAPR are discussed. Figure (1) shows OFDM model with DCT and compander. BPSK, QPSK and QAM are the different digital modulation schemes used in this paper. The modulated signal is subjected to IFFT to produce the OFDM signal. The input x(n) of the N point IFFT of the $X_k$gives the sampled OFDM signal and it is expressed as,

$$x(n) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X_k \exp\left(\frac{j2\pi kn}{N}\right) \qquad (1)$$

whereX_k represents the modulated signal on the k^{th} sub carrier. The approximation of PAPR in continuous OFDM signal is achieved by oversampling $X_k$by scaling factor L. Padding of the $X_k$symbols with (L-1)N zeros.

In general, PAPR is the ratio between the peak power to it's average power and is given by,

$$\text{PAPR} = 10\log_{10} \max\frac{[|x(n)|^2]}{E[|x(n)|]^2}\,\text{dB} \qquad (2)$$

The PAPR of this IFFT output is subjected to the companding technique and it is converted to analog by DAC, then it is transmitted through AWGN channel. The Cumulative Distributed Function (CDF) is used for the measuring efficiency of PAPR. If PAPR overshoots the given value then probability is measured by Complimentary Cumulative Distributed Function (CCDF) and is given by,

$$\text{CCDF} = P_r[\text{PAPR} > \text{PAPR0}] \qquad (3)$$

In the receiver signal is recovered back by the decompanding and FFT blocks and finally it is demodulated to obtain original input data stream. The additional block of DCT at transmitter and IDCT at receiver reduce the PAPR further in OFDM system.

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III.IMPROVED TWO μ LAW COMPANDING TRANSFORM

The μ law technique is a logarithmic non linear technique used in OFDM system for PAPR reduction. The effect this technique shows rapid decrease in PAPR when μ value increases.

In the two μs technique a threshold α is initiated where the signal below threshold is companded with μ_1 and rest of the signal μ_2 value is used. For optimum PAPR and BER performance the μ value and threshold α is varied based on the system requirements. The main drawback of this system is introduction of the steps between companding levels that would distort the signal producing noises.

To overcome the disadvantage of two μs companding another scheme improved two μ law companding is proposed. In this technique step is eliminated by using an offset result a smooth transition from μ_1 to μ_2. The addition of offset in two μs companding has reduced the PAPR with better BER performance.

The mathematical formula of transforms are $D_{ITM}(x,\mu_1,\mu_2)$and $D_{ITM}(r, \mu_1,\mu_2)$and they are expressed as,

$$D_1(x,\mu_1)=\frac{v}{\log(1+\mu_1)}\log\left(1+\frac{\mu_1|x|}{v}\right)\mathrm{sgn}(x), |x| \le \alpha \quad (4)$$

$$D_2(x, \mu_2) = \frac{v}{\log(1+\mu_2)}\log\left(1+\frac{\mu_2|x|}{v}\right)\mathrm{sgn}(x), |x| \ge \alpha \quad (5)$$

$$\Delta = \min(D_2(x, \mu_2)) - \max(D_1(x, \mu_1))$$

$$\therefore D_{ITM}(x,\mu_1,\mu_2) = k(\mu_1,\mu_2)D1(x,\mu_1)\ |x| \le \alpha \quad (6)$$

$$D_{ITM}(r,\mu_1,\mu_2) = \begin{cases} \frac{v}{K(\mu_1,\mu_2)}\left[e^{\frac{|r|\log(1+\mu_1)}{v}} - 1\right]\mathrm{sgn}(r), & |r| \le \beta \\ \frac{v}{K(\mu_1,\mu_2)\mu_2}\left[e^{\frac{|r|\log(1+\mu_2)}{v}|r-\Delta|} - 1\right]\mathrm{sgn}(r), & |r| \ge \beta \end{cases} \quad (7)$$

The power level of the signal can be increased by the companding technique. By using a normalization factor $k(\mu_1,\mu_2)$ average power of the signals are kept constant. The square root of two signal powers gives the $K(\mu_1,\mu_2)$ value

For the efficient work of ITM μ_1 should be smaller than μ_2 so that step can be removed at the peaks in the companded signal. Consider the threshold α is 0.3 that splits the signal into two parts. Signals around the average are subjected with μ_1 and the second part with peaks are slightly expanded or compressed by μ_2. When μ_1 and μ_2 increases, PAPR decreases and μ_1 has more effect on PAPR than μ_2. N two μs companding μ_1 expands the signal to average and μ_2 expand or compress the peaks when $\mu_1 < \mu_2$. But μ_2 has bigger effect on BER performance. To keep BER constant μ_1 is selected as lower than μ_2.

IV. DISCRETE COSINE TRANSFORM

DCT is somewhat similar to Discrete Fourier Transform (DFT), but operates only on real numbers and twice the length of DCT.

The reduction in input sequence auto-correlation is done by Discrete Cosine Transform(DCT) prior to IFFT operation for PAPR reduction and is defined by,

$$X_c(K) = \alpha(k)\sum_{n=0}^{N-1} x(n)\cos\left(\frac{\pi(2n+1)}{2N}\right) \quad (8)$$

where k=0,1,2,…,N-1.

The inverse DCT is given by

$$x(n) = \sum_{k=0}^{N-1} \alpha(k)X_c(k)\cos\left[\frac{\pi(2n+1)k}{2N}\right] \quad (9)$$

where n = 0,1,2,…,N-1

For both (9) and (10) α(k) is defined as

$$\alpha(k) = \begin{cases} \frac{1}{\sqrt{N}} k = 0 \\ \frac{2}{\sqrt{N}} k \neq 0 \end{cases} \quad (10)$$

Equation (9) can be expressed in matrix form as

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$$X_c = C_N x \qquad (11)$$

where X_c and x are vectors with dimension N×1, and C_N is a DCT matrix of dimension N×N, and C_N are orthogonal matrix vectors. This property of C_N reduce the peak powder of OFDM signal. Bu combining the DCT with companding technique further reduction of PAPR can be achieved.

V. PERFORMANCE EVALUATION

The overall performance comparison is made for the proposed technique with classic ITM schemes.Simulations are carried out for an uncoded OFDM based on DVB-T2. For the accurate estimation of PAPRthe number of sub carriers be chosen with J=4 as computation ratio and 10^4 frames are generated.A cyclic prefix with the length ¼ symbol is inserted to mitigate the ISI problem. In the simulation, we consider µ1=2 and µ2=7 for both proposed and ITM scheme.

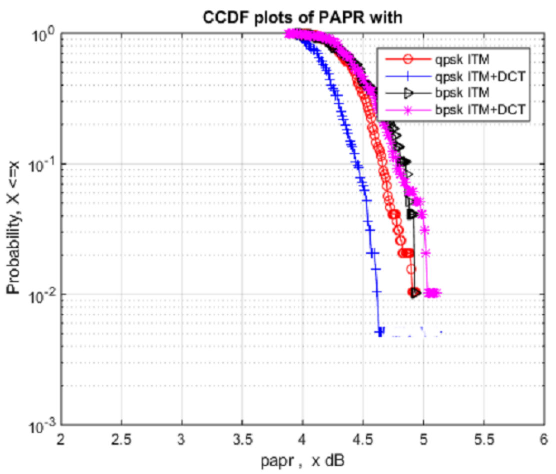

Figure 2 CDF plots of the PAPR comparison of ITM and DCT combined ITM for BPSK and QPSK modulation

Figure 2 shows the CCDFs of the PAPR for ITM processed signal and DCT combined ITM processed signal where the proposed technique for QPSK shows better PAPR reduction of 4.7 dB at CCDF = 10^{-2} than BPSK with ITM technique.

As shown in Figure. 2, QPSK with ITM with DCT produces lower PAPR compared to the BPSK with ITM scheme.The main reason for this is introduction of an offset resulting in a smooth transition from µ1to µ2.Thus low PAPR is achieved by Two µ-OFDM.

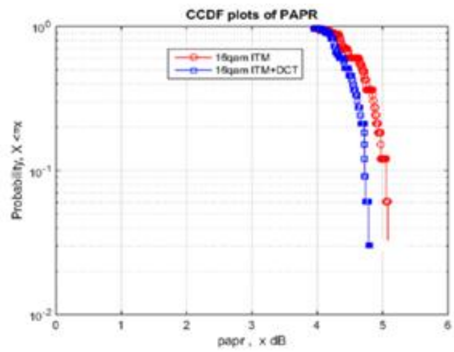

Figure 3 PAPR comparison of ITM and DCT combined ITM for 64 QAM

ITM for 16 QAM

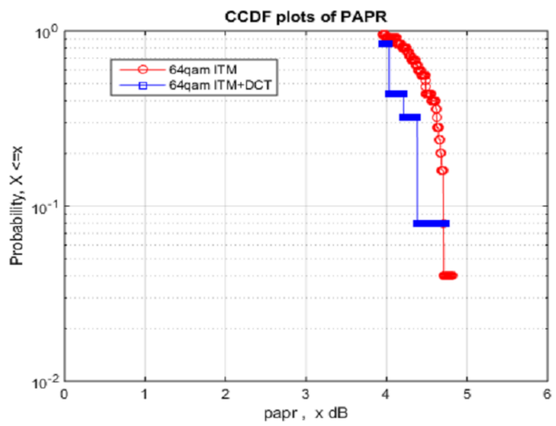

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Figure4 PAPR comparison of ITM and DCT combined

Figure 3, 4 and 5 shows the PAPR reduction schemes for different QAM orders. Comparing the figures 3, 4 and 5 higher order of 256 QAM shows better PAPRreduction of 3.1 dB at CCDF = 10^{-1} than 16 QAM and 64 QAM.

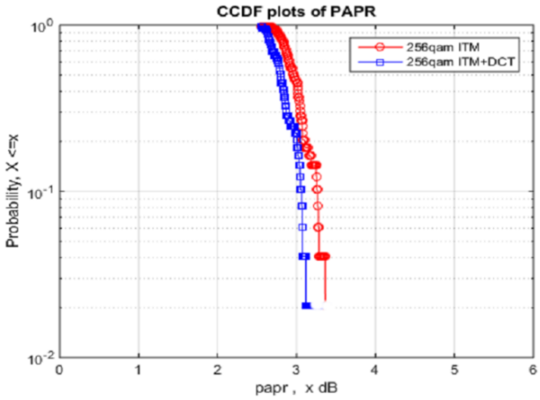

Figure 5 PAPR comparison of ITM and DCT combined ITM for 256 QAM

VI.CONCLUSION

The combined DCT and improved two μ-law companding techniques has been proposed to reduce the PAPR in OFDM systems. The simulation results shows that ITM with DCT has reduced PAPR better than ITM without DCT. The evaluation of proposed scheme for different modulation is analyzed for both lower and higher orders. The analysis of CCDF Vs PAPR for higher order of QAM has reduced PAPR than lower order of QAM modulation. The tradeoff between bit rate and PAPR is achieved in higher orders of QAM modulation and it provides high speed. The ITM technique is used to reduce the power consumption and charging frequency in OFDM system of handheld devices. Further reduction of PAPR achieved by DCT combined ITMtechnique leads to further reduction in power consumption and it is similar to adaptive technique provides various design requirements of OFDM system.

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