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Mitigation of PAPR in OFDM Using the Combination of Discrete Cosine Transform-II and Partial Transmit Sequence Techniques

Ramanjeet Kaur *, Charanjit Singh **, Amandeep Singh***
*(Department of Electronics and Communication Engineering, Punjabi University, Patiala, Punjab, India)
** (Department of Electronics and Communication Engineering, Punjabi University, Patiala, Punjab, India)
*** (Department of Electronics and Communication Engineering, Punjabi University, Patiala, Punjab, India)

ABSTRACT
Orthogonal frequency division multiplexing (OFDM) is a peculiar case of multicarrier transmission technique for high speed data transmission over multipath fading channels. The high Peak to Average Power Ratio (PAPR) is one of the most detrimental aspects in the OFDM system, as it degrades the efficiency of the power amplifier in the transmitter. Discrete Cosine Transform-II (DCT-II) is a less complex and distortion less method used to mitigate the PAPR. In this paper, a combination of Discrete Cosine Transform-II and Partial Transmit Sequence (PTS) is used to reduce the PAPR of the transmitted OFDM signal and results are compared with DCT-II and normal OFDM signal. Simulation results show that the combination of DCT-II and PTS shows better PAPR reduction.
Keywords- CCDF, DCT-II, OFDM, PAPR, PTS

I. INTRODUCTION

Orthogonal frequency division multiplexing (OFDM) is one of the most promising techniques for high data rate transmission systems. It is currently the standard of IEEE 802.11a, g, j, n (Wi-Fi) Wireless LANs and is also being used for digital terrestrial television transmissions as well as digital audio broadcasting (DAB) digital radio [1]. It is a parallel transmission scheme in which a single channel utilizes multiple sub-carriers on adjacent frequencies. It uses the spectrum much more efficiently by spacing all the channels more close and orthogonal. It offers high spectral efficiency, high data rate, low complexity for receivers and robustness against narrow band interference and frequency selective fading.

In spite of the advantages listed above, High Peak to Average Power Ratio (PAPR) is the major drawback of OFDM at the transmitter side [2]. These peak values in the signal may make the high power amplifiers in the non-linear region and hence distort the signal. So, reduction in the value of PAPR is the major concern. Many PAPR reduction methods are proposed for its mitigation. These methods are divided into three categories. The first category is signal distortion techniques under which clipping [3], peak windowing [4] techniques are included. The second category includes coding techniques like Block Coding [5], Transform techniques like Hadamard Transform, Companding [6], and Discrete Cosine Transform (DCT) [6] [7] [8]. The third category is scrambling techniques which includes selected mapping (SLM) [9] [10] and Partial Transmit Sequence (PTS) [2] [11] [12]. This paper focuses on the Discrete Cosine Transform-II (DCT-II) and Partial Transmit sequence (PTS) for PAPR reduction in OFDM. The hybrid model that combines these two powerful PAPR reduction schemes is used for PAPR reduction.

Paper is organized as follows. In Section 2, we review OFDM, PAPR, DCT and PTS. In Section 3 we described a combined scheme of DCT-II with PTS. The results are evaluated in terms of CCDF plot. Section 4 presents conclusion. Finally Section 5 presents the acknowledgement.

II. PRELIMINARIES

2.1 OFDM

Orthogonal frequency division multiplexing (OFDM) transmission scheme is a type of multichannel system that employs multiple subcarriers on adjacent frequencies. These subcarriers are orthogonal to each other and their overlapping maximizes the spectral efficiency without interfering. In OFDM, block of N symbols, $\{X_n, n = 0,1,........,N-1\}$ are formed after the modulation of each of the symbols, where N is the number of subcarriers. These subcarriers are chosen to be orthogonal, that is, $f_n = n\Delta f$ where Δf is the subcarrier spacing and NT is the OFDM symbol period. The resulting OFDM signal after IFFT operation [13] can be written as:

$$x(t) = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} X_n e^{j2\pi f_n t} \quad , 0 \le t \le NT \tag{1}$$

2.2 PAPR

Peak to Average Power Ratio (PAPR) is the ratio of the maximum power of the transmitted OFDM symbol to the average power of that OFDM symbol. High PAPR exists due to the coherent addition of the independently modulated sub-carriers. When N signals are added with the same phase they produce a peak power that is N times that of the average power of the signal. The PAPR of the transmitted signal in (1) is defined in the form of equation as under [13]:

$$PAPR = \frac{\max_{0\le t\le NT} x(t)^2}{1/NT \cdot \int_0^{NT} |x(t)|^2 \, dt} \tag{2}$$

High PAPR leads to the saturation in the power amplifiers, inefficient amplification, and increase in complexity of analog to digital and digital to analog convertors and expensive transmitters.

2.3 Discrete Cosine Transform

The discrete cosine transforms (DCT) [14] belongs to the group of sinusoidal unitary transforms. It is a close relative of the Discrete Fourier Transform (DFT). A DCT, also called as DCT-II is a technique used for converting signal into elementary frequency components. It is applied to reduce the autocorrelation of the input sequence before the IFFT operation is applied. It compresses the data passing through it as it leads to redundancy and irrelevancy reduction. It is a real, orthogonal and separable transform with fast algorithm for its computation [7].

The formal definition of a one-dimensional DCT-II of length N is given by the following formula:

$$y(k) = w(k)\sum_{n=1}^{N} x(n)\cos\left(\frac{\pi(2n-1)k}{2N}\right) \tag{3}$$

for, $k = 1,2,.....,N$

Similarly, the inverse transform is defined as:

$$x(n) = \sum_{k=0}^{N-1} w(k)y(k)\cos\left(\frac{\pi(2n-1)k}{2N}\right) \tag{4}$$

for, $n = 1,2....,N$

Where,

$$w(k) = \begin{cases} 1/\sqrt{N} & k = 1 \\ \sqrt{2/N} & 2 \le k \le N \end{cases}$$

$w(k)$ = Scaling parameter.

The matrix representation of equation (3) is:

$$Y = H_N . X \tag{5}$$

Where, H_N is the DCT-II matrix of dimension $N \times N$. Y and X are the matrix representation of $y(k)$ and $x(n)$ [6]. The rows or columns of the DCT-II matrix H_N are orthogonal matrix vector in nature and by using this property it is possible to reduce the autocorrelation of the sequence and thus peak power of OFDM signals.

In 2011, Z. Wang [6] suggested the combined method of DCT and Companding for PAPR reduction. A DCT may reduce the PAPR of an OFDM signal but does not increase the BER of system. Companding technique reduces the distortion of the signal. The results of the suggested method shows that the PAPR reduction is improved when compared with those of companding transform. In 2013, N. kaur et al [7] reduced the PAPR of OFDM signal through Discrete Cosine Transform-II. Using DCT-II, the system produces the lowest PAPR and is efficient, distortion less. This is a better PAPR reduction method than others because it does not require any power increment, complex optimization and side information to be sent to the receiver.

Fig.1 shows the OFDM model in which DCT-II is introduced before the IFFT at the transmitter side and IDCT-II is used at the receiver side. Fig.2 shows the normal OFDM generated without using any PAPR reduction technique. Fig.3 shows the OFDM signal generated when we use DCT-II as a PAPR reduction technique at the transmitter side. This figure shows that DCT-II compresses the bandwidth of the signal before transmission and because of this it is used for PAPR reduction.

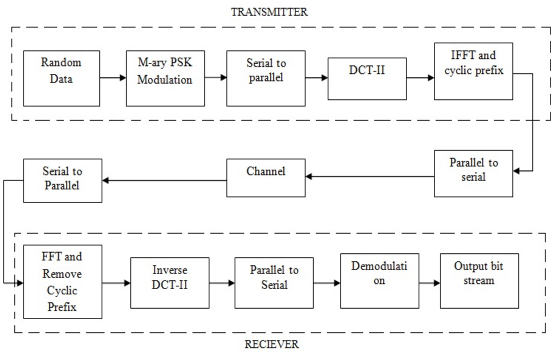

Fig.1 OFDM Model using DCT-II

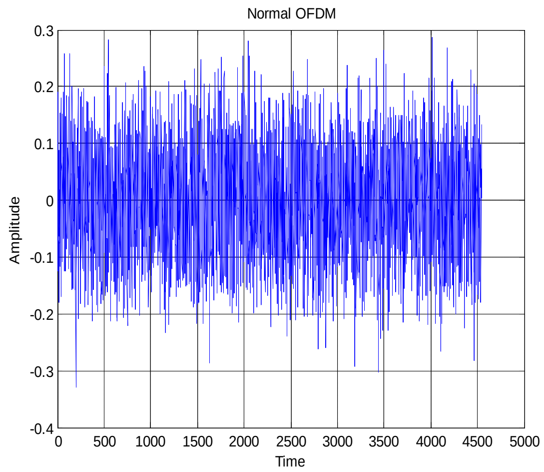

Fig.2 Normal OFDM signal

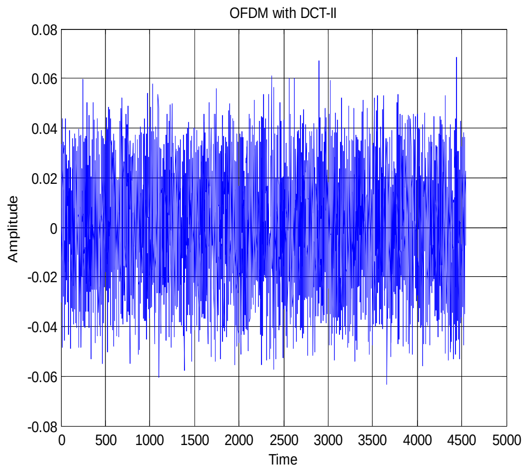

Fig.3 OFDM signal with DCT-II

2.4 Partial Transmit Sequence

In ordinary PTS scheme as shown in fig.4, the input sequence is partitioned into a number of different sub-blocks. IFFT operation is then applied to each of these sub-blocks individually and then multiplied with the distinct rotating vectors [2] [3]. Then PAPR is computed after combining the sub-blocks, and then the resulting sequence with minimum PAPR is transmitted. Main objective of the PTS is to select the phase factors for the sub-block that minimizes the PAPR.

The input data block X is partitioned into M sub-blocks $X(m) = X(1), X(2),.....,X(M)$, $m = 1,2,...,M$ such that $\sum_{m=1}^{M} X(m) = X$. Zero padding of these sub-blocks is done before the IFFT operation to increase the sampling rate for better resolution of signals. The oversampled time domain signal x_m is obtained by taking an IFFT on $X(m)$ concatenated with zeros. These are called the partial transmit sequences. Complex phase factors, $b(m) = e^{j\phi_m}, m = 1,2,...,M$, are introduced to combine the PTS. The set of phase factors is denoted as a vector $b = [b_1, b_2,...,b_M]^T$. The time domain signal [2] after combining is given by:

$$x'(b) = \sum_{m=1}^{M} b(m).x_m \qquad (6)$$

The search complexity increases exponentially with the number of sub-blocks M. PTS needs M IDFT operations for each data block, and the number of required side information bits is $\lfloor \log_2 W^{M-1} \rfloor$, where W is the number of allowed phase factors [13]. The amount of PAPR reduction depends on the number of sub-blocks M and the number of allowed phase factors W.

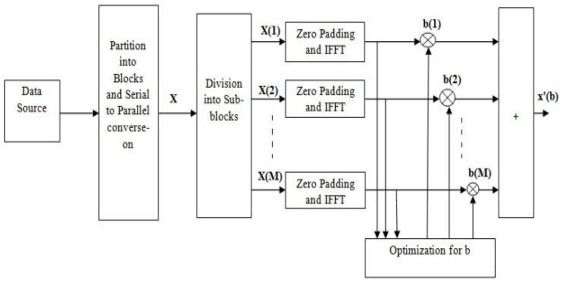

Fig.4 Block diagram of PTS technique

III. SIMULATION

In OFDM system, in order to reduce the PAPR of the signal, DCT-II technique is applied as shown in fig.1 and results are compared with the normal OFDM signal. DCT-II reduces the PAPR without increasing much computational intricacy and without destroying the orthogonality between the subcarriers. To further reduce the value of PAPR, PTS is combined along with the DCT-II. The data is transformed first by the DCT –II and then further by Partial transmit sequence (PTS) as in fig.4.

3.1 CCDF

Cumulative distribution function (CDF) is one of the most regularly used criterions to measure the performance of PAPR technique. In [1] the CDF of the amplitude of a signal is given by:

$$F(z) = 1 - \exp(z) \qquad (7)$$

The complementary CDF (CCDF) is used instead of CDF, which helps us to examine the probability that the PAPR of a certain data block exceeds the given threshold.

$$P(PAPR > z) = 1 - P(PAPR > z) = 1 - (1 - \exp(-z))^N \qquad (8)$$

3.2 Performance Analysis

We consider an OFDM system with 4096 data points which are randomly generated by the computer and are modulated using M-ary PSK, where M = 32, 64, 128, 256. The number of subcarriers is taken as 64. The channel modelled is an additive white Gaussian noise (AWGN). The PAPR reduction capability is measured by the complementary cumulative distribution using the simulation. We compared the simulation results of the combination of DCT-II and PTS with the DCT-II and with the normal OFDM signal. The results are presented in following figures and then the reduction in PAPR value was observed by varying the modulation of the system.

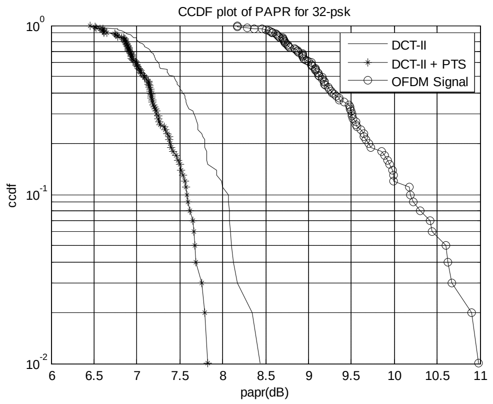

Fig.5 CCDF plot of PAPR for 32-PSK

Fig.5 shows the CCDF performance of the combination of DCT-II and PTS with DCT-II and normal OFDM signal for 32-PSK modulation. DCT-II with PTS reduces the PAPR of the system by around 0.6dB more at CCDF = 10^{-2} when compared with the DCT-II.

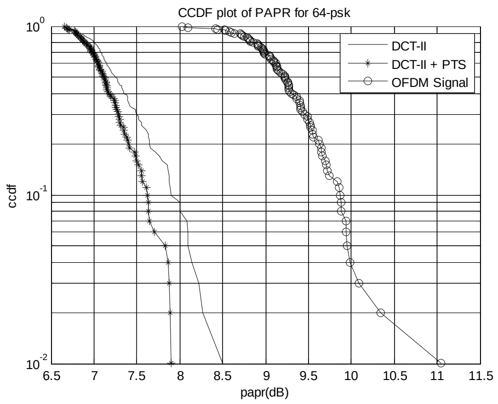

Fig.6 CCDF plot of PAPR for 64-PSK

Fig.6 shows the CCDF performance of the combination of DCT-II and PTS with DCT-II and normal OFDM signal for 64-PSK. DCT-II with PTS reduces the PAPR of the system by around 0.6dB more at CCDF = 10^{-2} when compared with the DCT-II.

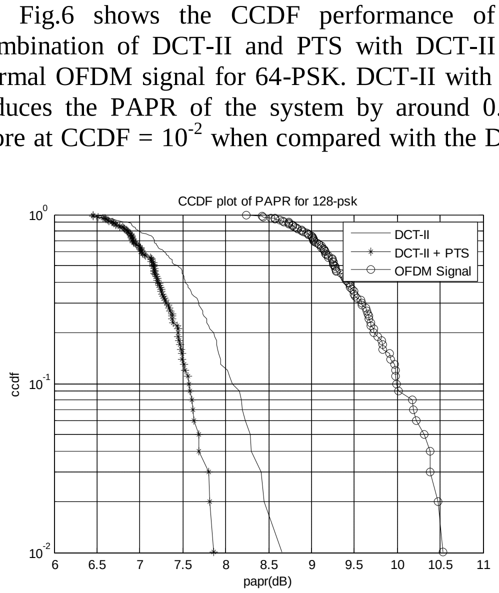

Fig.7 CCDF plot of PAPR for 128-PSK

Fig.7 shows the CCDF performance of the combination of DCT-II and PTS with DCT-II and normal OFDM signal for 128-PSK. DCT-II with PTS reduces the PAPR by 0.7dB more at CCDF = 10^{-2} when compared with the DCT-II.

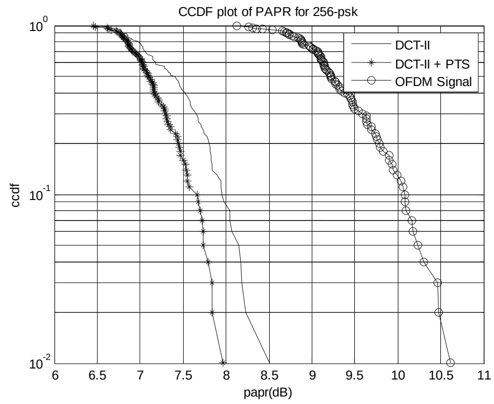

Fig.8 CCDF plot of PAPR for 256-PSK

Fig.8 shows the CCDF performance of the combination of DCT-II and PTS with DCT-II and normal OFDM signal for 256-PSK. DCT-II with PTS reduces the PAPR by 0.5dB more at CCDF = 10^{-2} when compared with the DCT-II.

TABLE 1: Comparison of PAPR values using different Modulation Technique

Modulation Technique	**PAPR Reduction Technique**	**PAPR Value**
32-PSK	DCT-II	8.4dB
	DCT-II + PTS	7.8dB
64-PSK	DCT-II	8.5dB
	DCT-II + PTS	7.9dB
128-PSK	DCT-II	8.6dB
	DCT-II + PTS	7.9dB
256-PSK	DCT-II	8.5dB
	DCT-II + PTS	8.0dB

Table 1 shows the comparison of the PAPR values of the combination of DCT-II with PTS and DCT-II. DCT-II + PTS show better PAPR reduction than the DCT-II technique.

IV. CONCLUSION

The OFDM symbols are independent equally distributed Gaussian random variables. This correlation characteristic is responsible for the high instability of the OFDM signal and due to this PAPR is increased. Considering this analysis, we used a combined DCT-II and PTS technique, while taking PAPR into account. Simulation results shows that the combination of DCT-II and PTS technique shows better PAPR reduction than DCT-II and normal OFDM signal.

V. ACKNOWLEDGEMENT

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