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DCT BASED PARTIAL TRANSMIT SEQUENCE TECHNIQUE FOR PAPR REDUCTION IN OFDM TRANSMISSION

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ABSTRACT

OFDM is used as a resource sharing multiple access technique in 4G technology which has several advantages of high data rate, good spectral efficiency, robust against frequency selective fading, etc. Major disadvantage of this system is high peak-to-average power ratio which degrades the performance of power amplifier. In order to overcome this problem, several distortion and distortion-less algorithms have been proposed. Partial Transmit Sequence (PTS) is one of the distortions-less technique which divides the input sequence into subsequences and chooses the phase optimized minimum PAPR signal for transmission. In turn to minimize the PAPR further, signal energy compaction and reduced autocorrelation of input data sequences is required which will be provided by Discrete Cosine Transform. The proposed method combines Discrete Cosine Transform (DCT) with PTS technique. The proposed scheme applies DCT before and after PTS technique. Simulation results shows that DCT before PTS is having better PAPR reduction performance than the DCT after PTS, conventional PTS and conventional OFDM system. The simulation result for the proposed approaches are discussed which reduces PAPR efficiently.

Keywords: PAPR, PTS, OFDM, discrete cosine transform.

1. INTRODUCTION

OFDM system is a combination of digital multi carrier modulation technique and frequency division multiplexing scheme. It converts a modulated wideband signals into multiple narrow band signals. A conventional wideband modulated signal is converted into parallel data streams which in turn are modulated using multiple subcarriers with the help of Fast Fourier Transforms [1]. The transformed signal is multiplexed and transmitted. The main advantage of OFDM is it can overcome the detrimental effects of different channel conditions. OFDM uses multiple subcarrier with the condition of orthogonally which helps to cope with the ICI. The guard intervals are added between symbols to overcome ISI. The main application [5] of OFDM is DVB, ADSL, WLAN, etc.

The main disadvantage of this efficient data transmission method is high Peak-to-Average Power Ratio. The reason is that a multicarrier signal is the sum of many narrowband signals which is actually a wideband signals.

At some time instances, this sum of signal is large due to the addition of in-phase signals, which means that the peak value of the signal is substantially larger than the average value. As a result of increase in the value of PAPR, the signal to quantization noise is degraded in Digital to Analog Converter and Analog to Digital converter and also forces the use of power amplifier with large linear range of peak values which in turn increases the cost of the transmitter, and degrades the BER performance at the receiver.

In order to overcome the problem of high PAPR some of the PAPR reduction techniques are employed [2]. There are two ways in which PAPR can be reduced and they can be grouped as distortion and distortionless techniques. In distortion techniques, the information is distorted by several methods and it will not raise the power of the signal and will not affect the data rate of the signal. The distortion technique includes clipping and filtering, peak windowing, and companding. In distortionless technique, the information undergoes scrambling process and do not have distortion in information. The distortion less technique includes, Selected Mapping (SLM), Partial Transmit Sequence (PTS), coding techniques, interleaving and tone reservation and injection method.

This paper proposes PAPR reduction by PTS with DCT for OFDM system. Here the DCT helps to reduce the autocorrelation between the signals which in turn reduces the PAPR of the OFDM signal. The DCT are positioned at before and after PTS technique are simulated to find the better positioning of it in PTS based OFDM system.

2. CHARACTERISTICS OF OFDM SIGNAL

In an OFDM system a frequency bandwidth B is divided into many N non-overlapping orthogonal subcarriers of bandwidth Δf; where the bandwidth is given by $B = N\Delta f$. The data bits after encoding and modulation are assigned subcarriers which are orthogonal to each other. Let us denote a block of N data sequences as vectors by $X = [X_0, X_1 \ldots X_{N-1}]$. In the time domain, after application of IFFT operation we obtain $x = [x_0, x_1 \ldots x_{N-1}]$. Thus, the sampled sequence is given by,

$$x[n] = \frac{1}{N}\sum_{k=0}^{N-1} X(k)e^{i2\pi\frac{kn}{N}} \quad 0 \le n \le N \tag{1}$$

The PAPR of transmitted OFDM signal is defined as the ratio of the maximum instantaneous power to the average power, defined by:

$$PAPR\{x[n]\} = \frac{\max|x[n]^2|}{E|x[n]^2|} \quad (2)$$

where x[n] is the OFDM of the signal and the operator E[.] gives the average of the OFDM signal**.**

3. COMPLEMENTARY CUMULATIVE DISTRIBUTION FUNCTION

A CCDF [4] is used to know how much time the signal spends at or above a power level. The power level is expressed in dB relative to the average power. A CCDF is basically a plot of relative power levels versus probability. Mathematically CCDF can be explained with a set of data having the probability density function. To obtain the Cumulative Distribution Function (CDF), the integral of the probability density function is computed. Then by complementing the PDF results in the CCDF. It obtains that the CCDF is the complement of the CDF or CCDF = 1 – CDF.

According to the limit central theorem, when N is large, both real and imaginary part of the signal is Gaussian distributed. The mathematical analysis of Cumulative Distributed Function (CDF) of the signal is

$$F[z] = 1 - e^{-z} \quad (3)$$

If there are N subcarriers in an OFDM system, and all the sampling values are completely independent, the CDF of the system is given by the equation:

$$P\{Z \le z\} = F[Z]^N = [1 - e^{-z}]^N \quad (4)$$

So in case of no over sampling, the Complementary Cumulative Distribution Function (CCDF), this is usually used as an important parameter to describe the PAPR of an OFDM signal which is written as follows,

$$P\{PAPR > PAPR_0\} = 1 - [1 - e^{-PAPR_0}]^N \quad (5)$$

where PAPR0 is the clipping level. This equation is used to find the probability that the PAPR of a symbol block exceeds some clip level PAPR0.

4. PARTIAL TRANSMIT SEQUENCE

Partial Transmit Sequence (PTS) algorithm [3] is a technique for improving the statistics of a multicarrier signal. The basic idea of Partial Transmit Sequence algorithm is to divide the original OFDM sequence into several subsequences and for each sub-sequences multiplied by different phase factors until an optimum value is chosen. First, consider the data block as vectors, $X=[X_1, X_2 \ldots\ldots X_{N-1}]^T$. Then, data vector X are partioned into disjoint sets, represented by the vector $\{X_m,$ m=1, 2….M}. Here, we assume that the data clusters consist of a contiguous set of subcarriers and are of equal size.

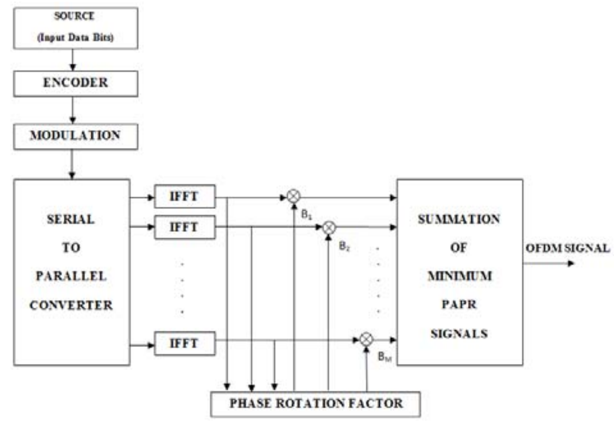

Figure-1. Block diagram for partial transmit sequences.

The objective is to combine the M number of clusters using the equation (6) and to obtain a optimal solution,

$$X' = \sum_{m=1}^{M} b_m X_m \quad (6)$$

where {m=1,2,….M} are weighting phase factors and are assumed to be rotated using different combinations. Here X_m is the partially transmitted sequence. The increase in the number of phase factor decreases PAPR of the OFDM signal but in turn increases the hardware complexity of the system.

a) Discrete cosine transform

The peak value of the auto correlation is the average of the power of the input data sequence. DCT [6] conceptually extends the original N-point data sequence to 2N-point sequence by doing mirror – extension of the N-point data sequence. Since the both end of data is always continuous in the DCT, the lower order of components will be dominated in the transformed domain signal after converted by DCT. The DCT is a Fourier-like transform, which was first proposed by Ahmed et al. The idea to use the DCT transform is to reduce the autocorrelation of the input sequence to reduce the peak to average power problem and the transmitted signal does not require any side information at the receiver. In this section, we briefly review DCT transform. The one dimensional discrete cosine transform (1D-DCT) A[k] is given by,

$$A[k] = \alpha[k]\sum_{n=0}^{N-1} a[n]\cos\frac{\pi(2n+1)k}{2N} \quad (7)$$

For k = 0,1 . . . N- 1 , the inverse DCT is obtained by,

$$\alpha[k] = \frac{1}{\sqrt{N}} \text{ for k=0} \quad (8)$$

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$$\alpha[k] = \frac{\sqrt{2}}{\sqrt{N}} \text{ for } k = 1,2 \ldots\ldots N-1$$

The basis sequences of the 1D DCT are real, discrete-time sinusoids are given by:

$$C_N[N,k] = \cos\frac{\pi(2n+1)k}{2N} \tag{9}$$

The DCT basis consists of the following N real sequences,

$$C_N[N,0], C_N[N,1], \ldots\ldots\ldots\ldots C_N[N,n-1]$$

$$A_N = C_N \alpha \tag{10}$$

where A and α are vectors with Nx1 matrix size and C_N is a DCT transform matrix with N x N size. The rows (or column) of the DCT matrix C_N are of orthogonal matrix vectors. This property of the DCT matrix is used to reduce the PAPR of OFDM signals. DCT can reduce the autocorrelation between the OFDM signals which is the one of the root cause to PAPR problem.

b) DCT before PTS

The first proposed work is that of using Discrete Cosine Transform before the Partial Transmit Sequence. The application of DCT reduces the autocorrelation of conventionally digital modulated data bits after that PTS technique is applied which scrambles the data using different phase factors. Here due to application of DCT and data scrambling the similarity between the data bits are reduced which in turn reduces the PAPR problem. This proposed work is simulated which shows reduction in PAPR compared to conventional PTS technique.

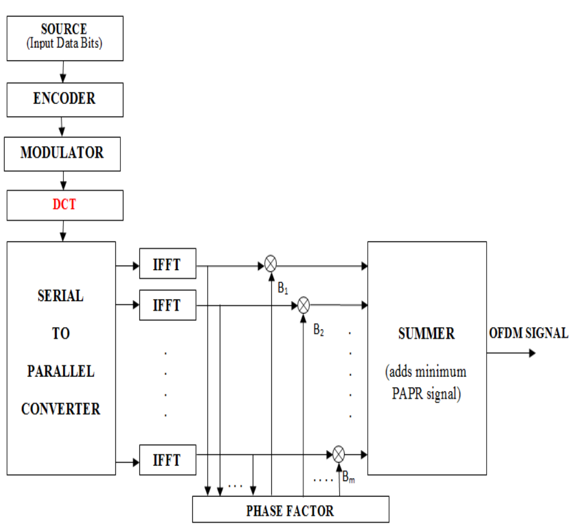

Figure-2. Block diagram of DCT before PTS.

c) DCT after PTS

The second proposed work is that of using the DCT after PTS technique. The conventionally modulated data bits are converted into parallel streams. The parallel converted data bits are applied to PTS technique which reduces the similarity between data by scrambling the data with 'm' number of phase factors. The signals with minimum PAPR are added using summer and the output is given to DCT block. The DCT reduces the autocorrelation between the summed OFDM signals. The simulation result shows that the DCT after PTS reduces PAPR compared to conventional PAPR. But DCT before PTS shows better performance compared to DCT after PTS. This is because DCT after PTS reduces only autocorrelation between minimum PAPR signals where as in the DCT before PTS reduces the autocorrelation between each digital modulated data bits.

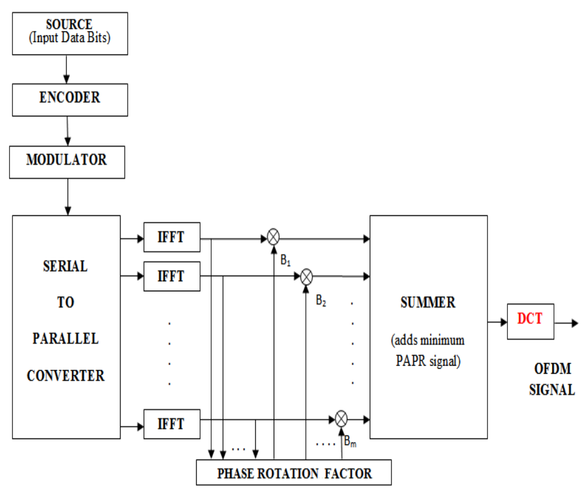

Figure-3. Block diagram of DCT after PTS.

5. SIMULATION RESULTS

The proposed work of DCT after PTS and DCT before PTS in OFDM system is simulated using MATLAB software. The simulation parameters used are discussed in Table-I

The OFDM system is designed by using PTS technique in order to reduce PAPR. The applications of first order DCT used before and after PTS which introduces orthogonality are simulated. The CCDF curve is plotted to find the number of PAPR of the signals greater than clipping level of power amplifier.

Figures-4, 5, 6 gives simulation result of proposed works. In figure 4 the conventional PTS has PAPR of 6.5 dB whereas the DCT before PTS has PAPR of 4.8 dB which has a PAPR reduction of nearly 2 dB. In Fig. 5 the conventional PTS has PAPR of 7 dB whereas the DCT after PTS has PAPR of 5.9 dB which has a PAPR reduction of nearly 1 dB. In fig. 6, comparison of conventional PTS, DCT before PTS and DCT after PTS are made. The PTS has a PAPR of 6.8 dB, DCT before PTS has PAPR of 4.8 dB and DCT after PTS has PAPR of

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5.8 dB. There is a difference of nearly 1 dB between DCT before PTS and DCT after PTS.

Table-1. Simulation parameters.

Simulation parameter	Type/ Value
Number of subcarrier	64
Modulation scheme	QPSK
Number of phase rotation factor	4
Number of phase combinations	256

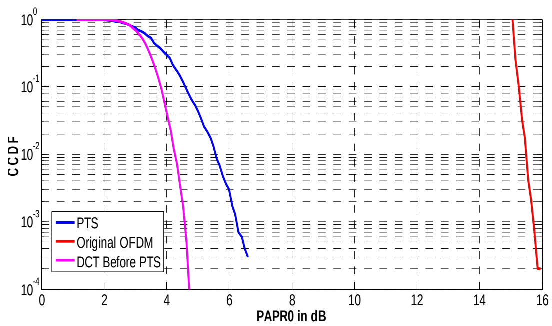

Figure-4. Comparison of OFDM system with PTS and DCT before PTS.

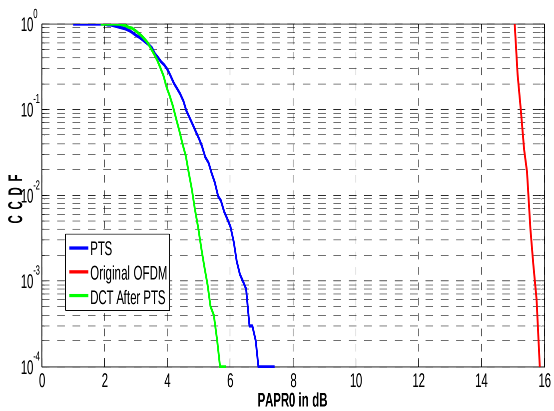

Figure-5. Comparison of OFDM system with PTS and DCT after PTS.

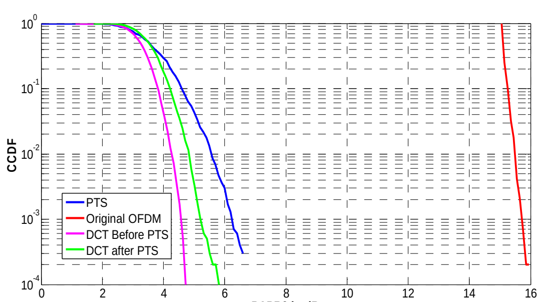

Figure-6. Comparison of OFDM system with PTS, DCT before PTS and DCT.

6. CONCLUSIONS

The paper presents an efficient method to reduce the PAPR of the OFDM signal. The new model combines the features of DCT and PTS techniques. From the above results it is evident that PAPR is reduced by applying DCT with PTS by sacrificing the complexity of the architecture. The computation complexity of the system is increased compared to conventional PTS technique. The usage of DCT in PTS architecture improves the PAPR as is evident that almost PAPR is reduced by 29.41% with DCT before PTS and 14.7% with DCT after PTS compared to conventional PTS technique. Further modifications can be done to improve the reduction performance of this hybrid model using Discrete Wavelet Transform (DWT) [10] instead of using the conventional IFFT.

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