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Papr Reduction In Ofdm Systems: Using DCT

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***Abstract*— In this paper, a symple technique for the reduction of PAPR in OFDM systems is proposed. In this technique the Descrete cosine transform of the signal is calculated. Orthogonal Frequency Division Multiplexing is a widely used data transmission technique, which has high data rate. Using DCT we can attain significant reduction in PAPR with out affecting the BER performance of the signal. The outputs for defferent techniques are compared.**

***Keywords*—** Orthogonal Frequency Division Multiplexing, Descrete Cosine Transform, Peak to Average Power Ratio

I. Introduction

During the last decade wireless communication have been developed rapidly. OFDM[1] is acommunication technique that use a number of subcarriers which are orthogonal to each other. OFDM systems are mainly used in high speed digital communication applications. In most of the transmitters we use high power amplifiers (transmit power amplifier TPA). Usualy they work near saturation region. When the subcarriers are super imposed to get the OFDM signal the TPA tends to operate in saturation, which create nonlinearities in the signal resulting in degradation of its performance. One of the disadvantages of OFDM is high PAPR, means Peak to Average Power Ratio,

There are a number of techniques exist for the reduction of PAPR for example clipping [3], companding [4], [6] selective mapping(SLM) [7], [8], partial transmit sequences (PTS) [9], [10], tone reservation [11] etc. But there are some limitations. Using clipping the signal power can be reduced significantly but degrade the BER performance, causing spectral spreading. When using SLM, PTS the data rate is reduced due to the transmission of side information.

In this paper a novel approach based on DCT is used for the reduction of PAPR. It can reduce PAPR without increasing the BER.

II. PAPR in OFDM Systems

OFDM is a special case of multicarrier transmission, where a single data stream is transmitted over a number of lower-rate subcarriers. One of the main reasons to use OFDM is to increase robustness against frequency selective fading or narrowband interference. In a single-carrier system, a single fade or interferer can cause the entire link to fail, but in a multicarrier system, only a small percentage of the subcarriers will be affected. An OFDM signal consists of a number of independently modulated subcarriers which can give a large peak-to-average power ratio (PAPR) when added up coherently. When N signals are added with the same phase, they produce a peak power that is N times the average power. A large PAPR brings disadvantages like an increased complexity of the analog-to-digital (A/D) and digital-to-analog (D/A) converters and a reduced efficiency of the RF power amplifier.

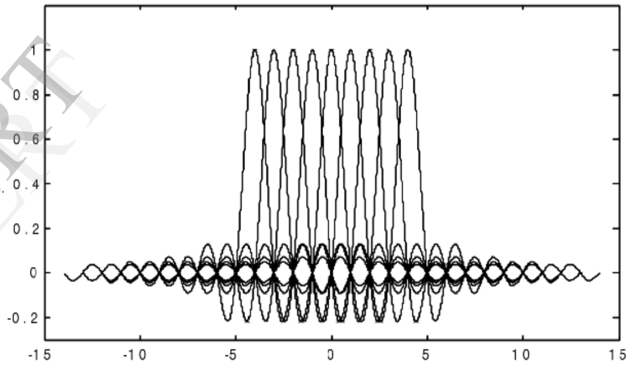

Fig. 1. Spectrum of OFDM signal

An OFDM signal consists of N symbols $X = \{X_k, k = 0, 1, 2, \ldots, N-1\}$ and each symbol is modulated by one of a set of sub carriers $\{f_k, k = 0,1,2 \ldots N-1\}$, where N is the number of sub carriers. The 'N' sub carriers are chosen to be orthogonal, that is $f_k = k\Delta f$ where Δf is given by,

$$\Delta f = \frac{1}{NT_s} \qquad (1)$$

and Ts (sec) is the original symbol period. Thus OFDM signal x(t) for a block of duration NTs can be written as

$$x(t) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X_k \, e^{j2\pi f_k t}, 0 \le t \le NT_s \quad (2)$$

The PAPR of OFDM signals x(t) is defined as the ratio between the maximum instantaneous power and its average power during its OFDM symbol.

$$PAPR[x(t)] = \frac{max_{0\le t \le NT_s} [|x(t)|^2]}{\frac{1}{NTs} \int_0^{NT_s} |x(t)|^2} \quad (3)$$

where, Pavg is the average power of x(t) and is expressed as

$$P_{avg} = \frac{1}{NTs} \int_0^{NT_s} |x(t)|^2 \quad (4)$$

PAPR of continuous-time OFDM is generally defined as,

$$PAPR[x(t)] = \frac{max_{0\le t \le NT_s} [|x(t)|^2]}{P_{avg}} \quad (5)$$

PAPR reduction of OFDM signals is mainly achieved by minimizing the maximum instantaneous signal power

III. SYSTEM MODEL

The input bits are mapped onto the constellation plane for the corresponding M-PSK or M-QAM scheme. These symbols are then converted to parallel stream of data using a serial to parallel converter. Next step is to determine the discrete cosine transform of these bits.

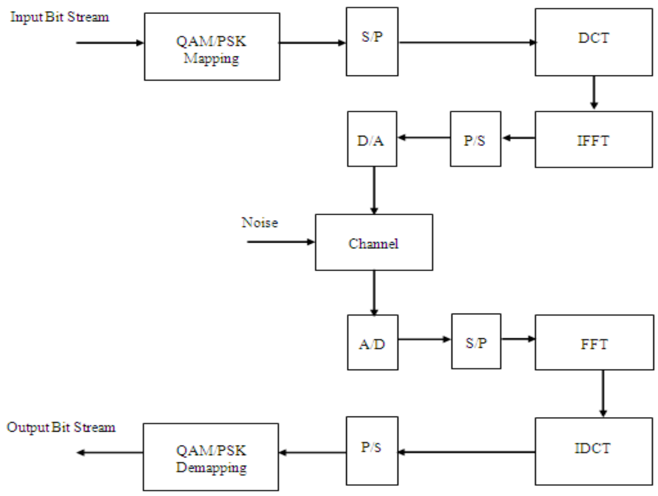

Fig. 2. System model

Then the bits are transmitted on to the sub-carriers. To achieve this, they are fed parallel to the input of the N-point IFFT. They represent the frequency domain data set. At the receiver Inverse Fourier transform converts this frequency domain data into its corresponding time domain representation. IFFT is very useful for OFDM because it generates samples of waveforms with orthogonal frequency components. The OFDM symbols are then transmitted over the channel with energy per bit as E_b. The channel considered here is an Additive White Gaussian Noise (AWGN) channel with mean zero and variance N_o. At the receiver FFT block is used to get the frequency domain data set from the time domain values. Then the inverse DCT is determined and QAM demapping is performed. Finally these symbols are used to estimate the original data values.

Let N be the number of subcarriers used for the parallel Information transmission and let S_k $(0 \le k \le N-1)$ denote the k_{th} mapped symbol in a block of N symbols. The outputs s_n of the N- point IFFT of S_k are OFDM signal samples over one symbol interval,

$$s_n = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} S_k \, e^{j2kn\pi/N}, 0 \le n \le N-1 \quad (6)$$

The amplitude of the OFDM signal sn is given by

$$|s_n| = \sqrt{R_e\{s_n\}^2 + I_m\{s_n\}^2} \quad (7)$$

The amplitude |sn | has Rayleigh distribution. The PAPR of OFDM signals in one symbol period is then defined as

$$PAPR = 10log_{10} \frac{|s_{max}|^2}{E[|s_n|^2]} dB \quad (8)$$

IV. DESCRETE COSINE TRANSFORM

The Discrete Cosine Transform is a Fourier-like transform, which was first proposed by Ahmed et al. (1974). 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 it requires no side information to be transmitted to the receiver. DCT 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 transform domain signal after converted by DCT. To reduce the PAPR in an OFDM signal, DCT is applied to reduce the autocorrelation of the input sequence before the IFFT operation. The one-dimensional DCT with length N is expressed as,

$$X[k] = \propto(t) \sum_{n=0}^{N-1} x(n) \cos\left\{\frac{(2n+1)\pi k}{2N}\right\} \quad 0 \le k \le N-1 \qquad (9)$$

Where,

$$\propto(k) = \sqrt{\frac{1}{N}} \quad if\ k = 0 \qquad (10)$$

$$\propto(k) = \sqrt{\frac{12}{N}} \quad if\ k \ne 0 \qquad (11)$$

And at the receiver inverse descrete cosine transform is calculated. The IDCT is expressed as

$$x[n] = \propto(t) \sum_{k=0}^{N-1} X(k) \cos\left\{\frac{(2n+1)\pi k}{2N}\right\} \quad 0 \le n \le N-1 \qquad (12)$$

V. Simulation Results

In this section, we present simulation results for the proposed technique. The simulation is based on the system model shown in Figure.

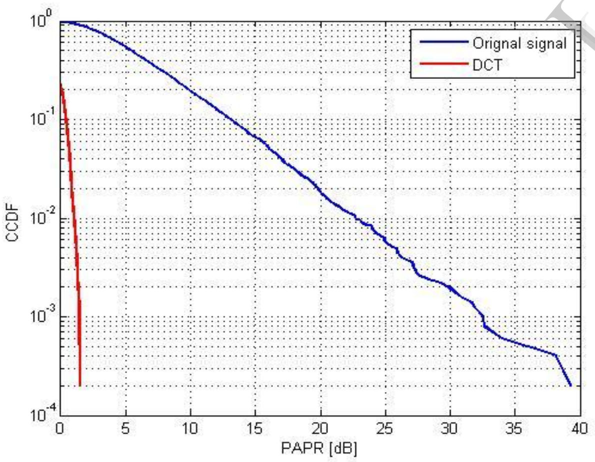

Fig. 3. comparison of PAPR of original signal with DCT

The plot shows the PAPR performance by means of complementary cumulative distribution function (CCDF) on values of the signal PAPR. The CCDF describes the probability that a real-valued random variable X with a given probability distribution will be found at a value greater than x i.e. P [X > x]. From the figure it is clear that the PAPR of the original signal is around 40 dB. We also obtain another plot showing the CCDF performance of scaling technique used for PAPR reduction. In this method different ranges of amplitudes of the signal are scaled in a different manner, that is why it is called Differential Scaling. Here we consider three types of scaling. They are scale up, scale down, and scale up down. Of all the three scaling techniques scale up down is the best method for PAPR reduction. By comparing the two plots we can see that the method using DCT has better PAPR reduction than scaling technique.

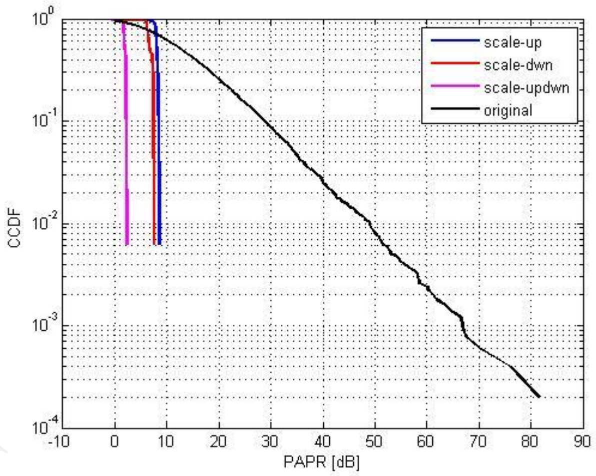

Fig. 4. comparison of PAPR performance(CCDF) of different PAPR reduction techniques

VI. CONCLUSION

In this paper, we have used a simple approach based on Descrete Cosine Transform to reduce the PAPR of OFDM signals. For the analysis we use the CCDF performance of the signal. Complementary cumulative distribution function (CCDF = 1-CDF) is used to evaluate the performance in PAPR reduction which denotes the probability that the PAPR exceeds a certain threshold. CCDF values are obtained by checking how often PAPR exceeds the threshold values.The DCT –OFDM system has the advantage of low hardware complexity and no side information. The simulation results show that the PAPR reduction is improved when compared with other techniques.

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