A Novel Approach to Reduce PAPR in OFDM Using combined DCT Precoding Technique and Clipping Method.

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Abstract: One of the major drawbacks in Orthogonal Frequency Division multiplexing(OFDM) is high Peak to Average Ratio (PAPR).Reducing PAPR will not only reduces the complexity of Digital to Analog and Analog to Digital converters but also increases the efficiency of High Power Amplifiers (HPA). In this paper a combination of precoding technique (DCT) and clipping technique has been proposed for PAPR reduction. As well as a comparative analysis has been done between Discrete Fourier Transform (DFT),Discrete Hartley Transform(DHT),Walsh Hadamard Transform(WHT),Discrete Cosine Transform(DCT) precoding techniques . Through simulation results it has been found that the proposed (DCT-Clip) technique provides better PAPR reduction as compared to other conventional precoding techniques.

Keywords- OFDM, PAPR , HPA ,DFT ,DCT ,DHT, DWT.

INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) is a multicarrier transmission scheme has now became the technology for next generation wireless and wired digital communication systems because of its high speed data rates, high spectral efficiency, high quality service and robustness against narrow band interference and frequency selective fading[1]. Despite of several advantages, the OFDM systems also have some major problems like high Peak to Average Power Ratio (PAPR) of transmitted signal, Synchronization (timing and frequency) at the receiver, Inter carrier interference etc.

This paper mainly deals with high peak to average power ratio reduction techniques. Due to the high Peak to average Power Ratio, the quiescent point of the amplifier used in the transmitter section is forced to enter into the saturation region (non-linear region) resulting in reduction in the efficiency of the HPA. Once the amplifier enters its saturation region ,the amplification process no longer remains linear , moreover the orthogonality between the subcarriers gets lost which leads to Intercarrier Interference(ICI).One way to solve this problem is to force the amplifier to work in its linear range or to increase the dynamic range of the amplifier. Unfortunatetly, these solutions are not power efficient and cost efficient. Power efficiency is very much necessary in wireless communication as it saves power, provides adequate area coverage etc. Thus inspite of modifying the amplifier characteristic we prefer to reduce peak power swing with respect to the mean power.

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PEAK TO AVERAGE POWER RATIO (PAPR)

The PAPR of the continuous time baseband OFDM transmitted signal x(t) is the ratio of maximum instantaneous power and the average power. By definition,

$$PAPR = \frac{max[x(t)]^2}{E\{|x(t)|^2\}}, for\ 0 \leq t \leq NT$$

Where, $E\{.\}$denotes expectation operator and $E\{|x(t)|^2\}$is average power of $x(t)$ and T is an original symbol period.

Since, multiple subcarriers are added in this technique to form the transmitted signal therefore OFDM suffers from high Peak to Average Power Ratio (PAPR) value of the transmitted signal. Peak-to-average power ratio (PAPR) is directly proportional to the number of subcarriers used for OFDM systems. In other words Any OFDM system with large number of subcarriers will have a large PAPR as these subcarriers add up coherently which results in high peaks.

DISTRIBUTION OF PAPR

The Cumulative Distribution Function (CDF) is one of the most regularly used parameters to measure the efficiency of any PAPR technique. Normally, the Complementary Cumulative Distribution Function (CCDF) is used instead of CDF which helps us to measure the probability that the PAPR of a certain data block exceeds the given threshold.

CCDF provides an indication of the probability of the OFDM signal's envelope exceeding a specified PAPR threshold within the OFDM symbol and is given by

$$CCDF\ [PAPR\ (x^n(t)] = prob\ [PAPR\ (x^n(t) > \delta]$$

Where PAPR ($x^n(t)$) is the PAPR of the n^{th} OFDM symbol and δ is some threshold value.

PAPR REDUCTION METHODS

Various techniques have been proposed in the literature for PAPR reduction, each having its own advantages and disadvantages. Among them, some are Clipping and Filtering, Partial Transmit Sequence (PTS), Selected Mapping (SLM), Precoding, Tone Injection (TI), Tone Reservation (TR), Companding, Coding Methods or Hybrid Techniques etc [2].

In this paper a novel approach based on Combination of a precoding technique and clipping has been presented for PAPR reduction .We have considered Discrete Cosine Transform as a precoding technique.

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CONVENTIONAL OFDM SYSTEM:

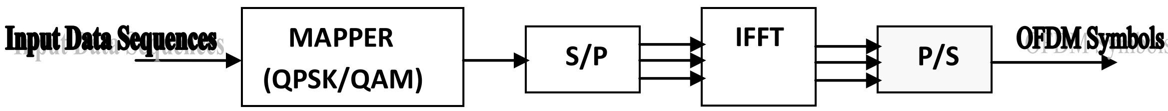

Figure 1: Block diagram of conventional OFDM transmitter section

Fig 1 shows the basic block diagram of an conventional OFDM system. ,Here the Mapper transforms the input bit stream into constellation corresponding to various modulation techniques .Here we have performed our simulations considering two modulation techniques'-QPSK and M-QAM.The baseband modulated symbols are then passed through a serial to parallel converter ,which generates a complex vector of size N. .The complex vector of size N can be written as X = $[X_0, X_1, X_2, \ldots\ldots, X_{N-1}]^T$. This X is then passed through the IFFT block. The IFFT block converts the frequency domain baseband spectrum into its time domain equivalent. After the IFFT operation, the data are transformed and multiplexed to x (n) given by [3]

$$x(n) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X_k \, e^{\frac{j2\pi kn}{N}}, \qquad for\; n = 0, 1, 2, 3 \ldots N-1$$

.

MODEL FOR PRECODED OFDM SYSTEM:

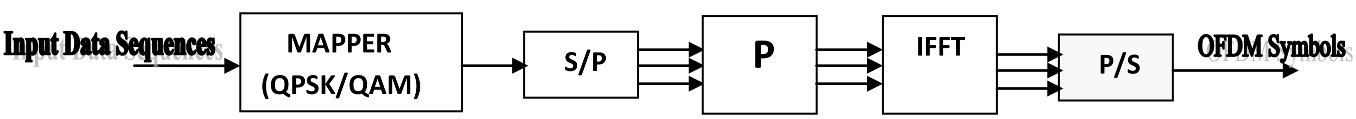

Figure 2 : Block diagram of precoded OFDM transmitter section

Figure 2 shows a precoded OFDM system. In Precoding method, the modulated data is first multiplied with shaping matrix or precoding matrix before the formation of OFDM symbol (before IFFT) . Different methods like pulse shaping function, discrete cosine transformation (DCT) matrix, Hadamard matrix, Zadoff-chu sequence etc. are used to generate precoding matrix. After that these precoded data are transmitted through IFFT to generate OFDM symbols. Each element of precoding matrix should be carefully designed, so that it can reduce the PAPR.In this model a precoding matrix P of dimension N×N has been implemented before the IFFT to reduce the PAPR.

$$P = \begin{bmatrix} p_{0,0} & p_{0,1} & \cdots & p_{0,N-1} \\ p_{1,0} & p_{1,1} & \cdots & p_{1,N-1} \\ \vdots & & \ddots & \vdots \\ p_{N-1,0} & p_{N-1,1} & \ldots & p_{N-1,N-1} \end{bmatrix}$$

Now the modulated OFDM vector signal with *N* the subcarriers can be expressed as follows.

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$$X_n = IFFT \{ P X_n \}$$

DISCRETE FOURIER TRANSFORM (DFT) PRECODING:

For generating the precoding matrix using DFT function ,the size of DFT precoder is kept same as IFFT size. The DFT of a sequence of length *N* can be defined as:

$$X(k) = \sum_{n=0}^{N-1} x(n) \cdot e^{-j2\pi nk} \quad k = 0, 1, \ldots, N-1 \qquad \ldots(6.8)$$

And IDFT for the above can be written as

$$X(n) = 1/N \sum_{n=0}^{N-1} X(K) \cdot e^{-j2\pi nk} \quad k = 0, 1, \ldots, N-1$$

and $p_{mn} = e^{-j2\pi mn} / N$, $k = 0, 1, \ldots, N-1$

Here the '*m*' and ' *n*' are integers from 0 to *N*-1 and the precoding matrix is of size N x N given by

$$P = \begin{bmatrix} p_{0,0} & p_{0,1} & \cdots & p_{0,N-1} \\ p_{1,0} & p_{1,1} & \cdots & p_{1,N-1} \\ \vdots & & \ddots & \vdots \\ p_{N-1,0} & p_{N-1,1} & \ldots & p_{N-1,N-1} \end{bmatrix}$$

THE DISCRETE HARTLEY TRANSFORM (DHT) PRECODING:

The DHT is also a linear transformation of data. In DHT, real numbers[$x_0, x_1, \ldots, x_{N-1}$] are transformed into N real numbers . According to [4], the N-point DHT can be defined as follows:

$$H_k = \sum_{n=0}^{N-1} x_n \left[\cos\left(\frac{2\pi nk}{N}\right) + \sin\left(\frac{2\pi nk}{N}\right) \right]$$

$$= \sum_{n=0}^{N-1} x(n) \cdot cas\left(\frac{2\pi nk}{N}\right)$$

Where,

cas $\Theta = \cos\Theta + \sin\Theta$ and k=0 ,1,…..N-1

$$p_{m,n} = cas\left(\frac{2\pi mn}{N}\right)$$

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DISCRETE WALSH HADAMARD TRANSFORM (WHT) PRECODING:

This is the simplest and linear transformation. WHT does not increase the complexity of the system. Walsh functions are the basis for Walsh transform. Walsh functions are orthogonal and have only +1 and -1 values [5] . In general, the Walsh transform can be generated by the Hadamard matrix as follows:

$$H_{2^k} = \begin{bmatrix} H_{2^{k-1}} & H_{2^{k-1}} \\ H_{2^{k-1}} & -H_{2^{k-1}} \end{bmatrix}$$

For $k = 1,2,3 \ldots\ldots$ and $H_1 = 1$ for $k = 0$

Here in this case the H matrix of eq. becomes precoding matrix.

DISCRETE COSINE TRANSFORM (DCT) PRECODING:

The Cosine Transform technique is based upon the relationship between correlation property of OFDM input sequence and PAPR probability. The average power of the input sequence represents the peak value of the autocorrelation. Hence the peak value of autocorrelation depends on the input sequence. 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 [6].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 transformed domain signal after converted by DCT. The DCT is a Fourier-like transform, which was first proposed by Ahmed et al. Formal definition from one dimension (1-D) DCT with N length is given by,

$$X(k) = \alpha(k) \sum_{n=0}^{N-1} x(n) \cos\left[\frac{\pi(2n+1)k}{2N}\right], \; for\; k = 0, \ldots\ldots, N-1.$$

Where α is defined as follow,

$$\alpha(k) = \begin{cases} \dfrac{1}{\sqrt{N}} & for\; k = 0 \\ \sqrt{\dfrac{2}{N}} & for\; k \neq 0 \end{cases}$$

For this method, the predefined precoding matrix P of dimension $N \times N$ is defined as,

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$$P = \begin{bmatrix} p_{0,0} & p_{0,1} & \cdots & p_{0,\mathrm{N}-1} \\ p_{1,0} & p_{1,1} & \cdots & p_{1,\mathrm{N}-1} \\ \vdots & \vdots & \ddots & \vdots \\ p_{N-1,0} & p_{N-1,1} & \cdots & p_{N-1,N-1} \end{bmatrix}$$

The element of the precoding matrix are determined as,

$$p_{m,n} = \alpha(k)\cos\left[\frac{\pi(2n+1)k}{2N}\right]$$

CLIPPING TECHNIQUE:

The clipping technique employs clipping around the peaks to reduce the PAPR [7]. It is simple to implement. It reduces the PAPR by simply limiting the maximum amplitude of the OFDM signal, such that all signal values are limited to the threshold. Clipping the OFDM signal before amplification is a simple method to limit PAPR. The clipping operation is carried out at the transmitter. The clipping operation on the real band pass signal is given by:

$$y[n\ ] = \begin{cases} -CL, & if\ x[n] < -CL \\ x[n], & if - CL \le x[n] \le\ CL \\ CL\ , & if\ x[n] > CL \end{cases}$$

Where $x[n]$ is the OFDM signal, CL is the clipping level.

PROPOSED MODEL:

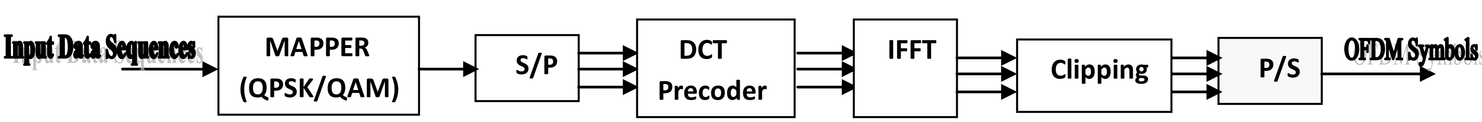

Figure 3: Proposed model of OFDM transmitter section

In our proposed model we have combined two appropriate methods to reduce PAPR in our proposed scheme .One is DCT precoding technique and the other one is Clipping. Simulation result shows that Combining both the methods give better PAPR reduction as compared to other conventional methods.

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SIMULATION RESULS:

In this section we have compared the various precoding techniques mentioned in the above section with our proposed scheme with M-PSK (M=16,32) for subcarriers N=64 and found that combined DCT-Clip technique outperforms the other conventional schemes.

PAPR Reduction Results with M-QPSK Modulation for M = 16

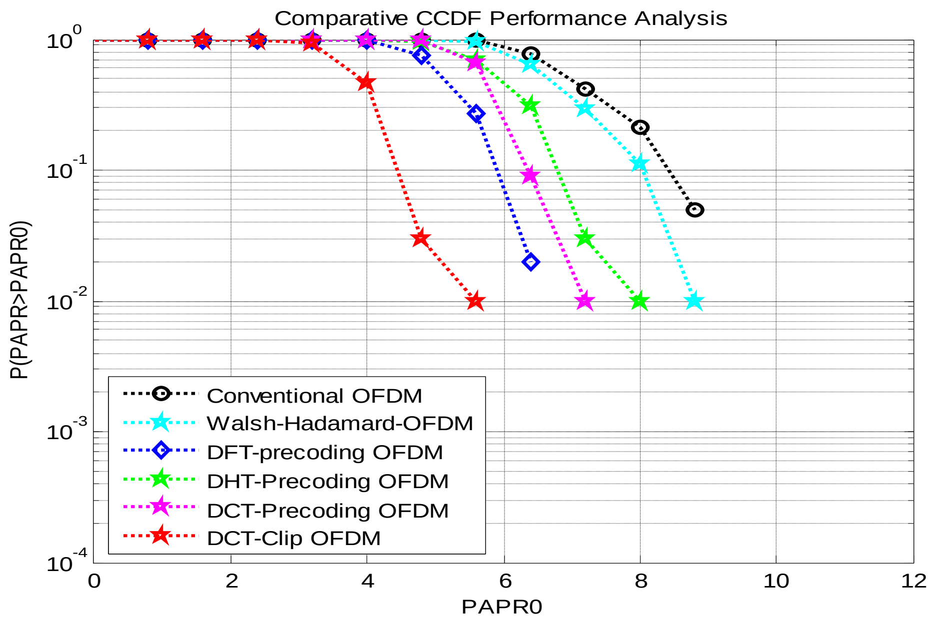

Figure 4: PAPR reduction results for 16- QPSK.

In the above figure , the conventional OFDM has a PAPR of 9.5254 dB whereas the proposed clipped precoded signal has PAPR of 5.662dB.Thus there is a reduction of 3.8634 dB in the PAPR .

PAPR Reduction Results with M-QPSK Modulation for M = 32

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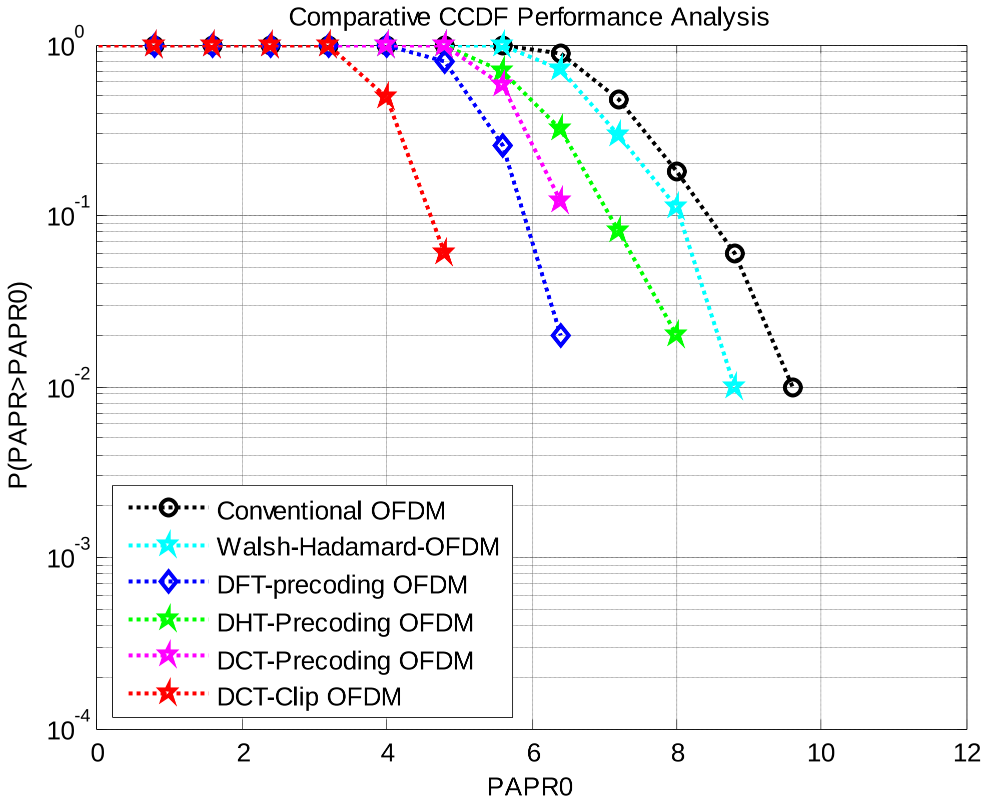

Figure 5: PAPR reduction results for 32- QPSK

In the above figure , the conventional OFDM has a PAPR of 10.232 dB whereas the proposed clipped precoded signal has PAPR of 4.94 dB.Thus there is a reduction of 5.292dB in the PAPR .

CONCLUSION:

Here, we evaluated performance of combined DCT-clipping method. The proposed combined technique is quite simple to implement and has no boundations on the system parameters like modulation order , number of subcarriers etc. The proposed clipped precoded system gives a better PAPR reduction performance than other other precoded techniques.Thus ,we can conclude that the proposed DCT-Clipped scheme is more favourable than other precoded schemes.

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