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A New DCT Precoding Based RSLM Method for PAPR Reduction in OFDM System

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Abstract - **Orthogonal Frequency Division Multiplexing (OFDM) is one of promising techniques that has the problem of high Peak-to-Average Power Ratio (PAPR) which limits its applications in communications system. In this paper, we present a new Discrete cosine Transform (DCT) precoded based Recursive Selected Mapping (RSLM) technique for PAPR reduction in OFDM system. The proposed system is based on precoding the constellation symbols with DCT precoder after the multiplication of phase rotation factor and before the Inverse Fast Fourier Transform (IFFT) in RSLM-OFDM Systems. By using this technique, the proposed scheme achieves much better PAPR reduction performance as compared to Recursive SLM technique. The performance of the proposed hybrid technique (DCT-RSLM) is verified through the simulations.**

Keywords - **Orthogonal Frequency Division Multiplexing (OFDM), Peak-to-Average Power Ratio (PAPR), Direct Cosine Transform (DCT), Recursive Selected Mapping (RSLM).**

I. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) is a promising technique for high-data-rate transmission in frequency-selective fading channels [1][12]. A major drawback of OFDM is the high Peak-to-Average Power Ratio (PAPR) of the transmitted signal [11]. Thus, it is highly desirable to reduce the PAPR of OFDM signals.

In last few years various techniques to reduce the PAPR of OFDM signals have been proposed such as clipping [2], active constellation extension (ACE) [3], coding [4], tone reservation (TR) [5], partial transmit sequence (PTS) [6],[7], and selected mapping (SLM) [8]. In SLM scheme, an input symbol sequence is multiplied by each of phase rotation vectors to generate alternative input symbol sequences. Then alternative input symbol sequences are in-verse fast Fourier transform (IFFT) and the one with the minimum PAPR is selected for transmission. In PTS scheme, an input symbol sequence is partitioned into a number of disjoint subblocks. Then, IFFT is applied to each subblock and the resulting IFFT subblocks are multiplied by phase rotation vectors and summed. Among them, the one with the minimum PAPR is selected for transmission. SLM and PTS schemes require many IFFTs, which causes high computational complexity. Many PAPR reduction schemes with lower complexity than the conventional SLM scheme have been proposed [6],[7],[8], but they have several shortcomings such as degradation of PAPR reduction performance and bit error rate (BER) performance.

In this paper, a new DCT Precoding RSLM scheme is introduced, which generates alternative OFDM signal sequences by properly cyclically shifting the connections in each subblock at an intermediate stage in IFFT of input symbol sequence without additional IFFTs after the signal is passed through the DCT Precoder. In the proposed system we make use of DCT based precoder which is less complex then other precoders [9] after the multiplication of phase rotation factor and before the IFFT in the RSLM-OFDM system. Our proposed DCT precoder based RSLM technique is signal independent and it does not require any complex optimization technique.

This paper is organized as follows: Section I gives the introduction about the paper, Section II describes the basics of the OFDM system and relative PAPR reduction techniques, In Section III, we present the proposed system model for PAPR reduction, and Section IV presents computer simulation results and section V concludes the paper.

II. OFDM System & PAPR Reduction

A. OFDM System and PAPR

The OFDM system splits the high speed data stream into a number of parallel low data rate streams and these low rates data streams are transmitted simultaneously over a number of orthogonal subcarriers.

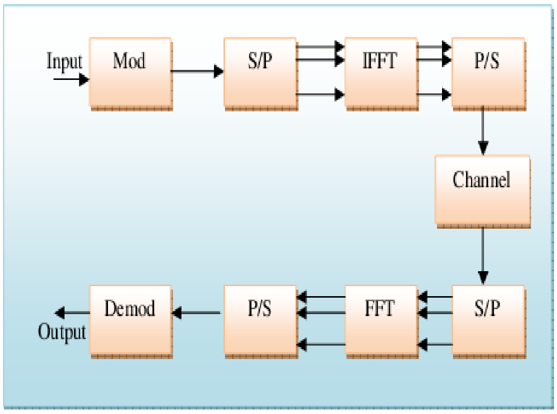

Fig.1.Block diagram of General OFDM system

Figure 1 illustrates the block diagram of an OFDM system [10,14]. The baseband modulated symbols are passed through serial to parallel converter which generates complex vector of size N. We can write the complex vector of size N as $X = [X_0, X_1, X_2 \ldots X_{N-1}]^T$ and then X is then passed through the IFFT block. The complex baseband OFDM signal with N subcarriers can be written as

$$x_n = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X_k \, . \, e^{j2\pi \frac{n}{N} k}, n = 0, 1, 2 \ldots . N-1 \ldots\ldots (1)$$

Where $j = \sqrt{-1}$ and the PAPR of OFDM signal in above equation can be written as

$$PAPR = \frac{max|x_n|^2}{E[|x_n|^2]} \quad \text{………………. (2)}$$

Where E [.] denotes expectation and the Complementary Cumulative Distribution Function (CCDF) for an OFDM signal can be written as

$$P(PAPR > PAPR_0) = 1 - (1 - e^{-PAPR_0})^N \quad \text{...(3)}$$

Where $PAPR_0$ is the clipping level and this equation can be read as the probability that the PAPR of a symbol block go over some clipping level $PAPR_0$.

B. DCT Precoder Based OFDM System

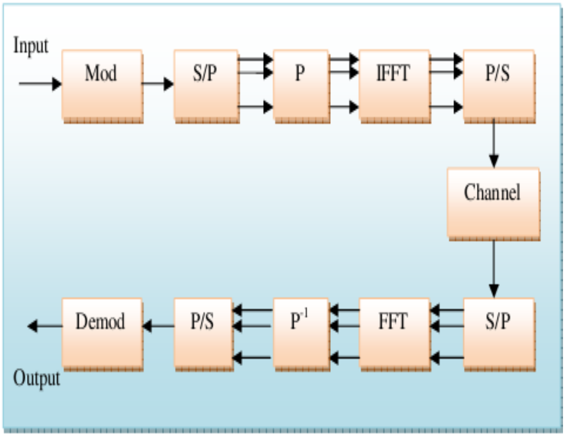

Fig.2. Block diagram of Precoding based OFDM system.

Figure 2 shows a precoding based OFDM system. In this system a precoding matrix P of dimension N x N is constructed which is based on DCT. P is applied to constellations symbols before IFFT to reduce the PAPR. DCT matrix P of size N-by-N can be created by using equation (4)

$$P_{ij} = \begin{cases} \frac{1}{\sqrt{N}} & i = 0, \quad 0 \le j \le N-1 \\ \sqrt{\frac{2}{N}} \cos\frac{\pi(2j+1)i}{2N} & \begin{matrix} 1 \le i \le N-1 \\ 1 \le j \le N-1 \end{matrix} \end{cases} \quad \text{…. (4)}$$

and DCT can be defined as

$$X_k = \sum_{n=0}^{N-1} x_n \cos[\frac{\pi}{N}(n + 0.5)k] \quad \text{………(5)}$$

Where k=0, 1... N-1. In precoding based OFDM system baseband modulated data is passed through S/P convertor which generates a complex vector of size N that can be written as X = $[X_0, X_1, X_2… XN\text{-}1]^T$. Then precoding is applied to this complex vector which transforms this complex vector into new vector of length N that can be written as Y=PX= $[Y_0, Y_1, Y_2………….Y_{N-1}]^T$. Where P is a DCT based precoding Matrix of size M = N×N. With the use of reordering as given in equation (6)

k = mN + n ………(6)

And the matrix P is given by

$$\begin{vmatrix} p_{00} & p_{01} & \cdots & p_{0(N-1)} \\ p_{10} & p_{11} & \cdots & p_{1(N-1)} \\ \vdots & \vdots & \ddots & \vdots \\ p_{(N-1)0} & p_{(N-1)1} & \cdots & p_{(N-1)(N-1)} \end{vmatrix}$$

Accordingly, precoding X gives rise to Y as follows:

Y=PX ……………(7)

$$Y_m = \sum_{l=0}^{N-1} p_{m,l} X_n \quad m = 0,1,2, \dots \dots .., N-1$$

…………..(8)

$p_{m,l}$ means l^{th} row and m^{th} column of precoder matrix. The complex baseband OFDM signal with N subcarriers can be written as

$$X_n = \sum_{m=0}^{N-1} Y_m e^{j2\pi\frac{n}{N}m} \quad n = 0,1,2, \dots \dots .., N-1$$

……………….(9)

PAPR for the above signal can be given by

$$PAPR = \frac{max|x_n|^2}{E[|x_n|^2]} \quad \text{………..(10)}$$

Here α is defined as the probability that the PAPR of a candidate signal is higher than the threshold, it is given by[11]

$$\alpha = P(PAPR > Threshold) = 1 - (1 - e^{Threshold})^N$$

………….... (11)

After applying RSLM to X, the OFDM signal becomes as

$$x_n^{(c)} = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X_k^{(c)} . e^{j2\pi\frac{n}{N}k}, n = 0,1,2 \dots . N-1$$

…………. (12)

C. RSLM Based OFDM System

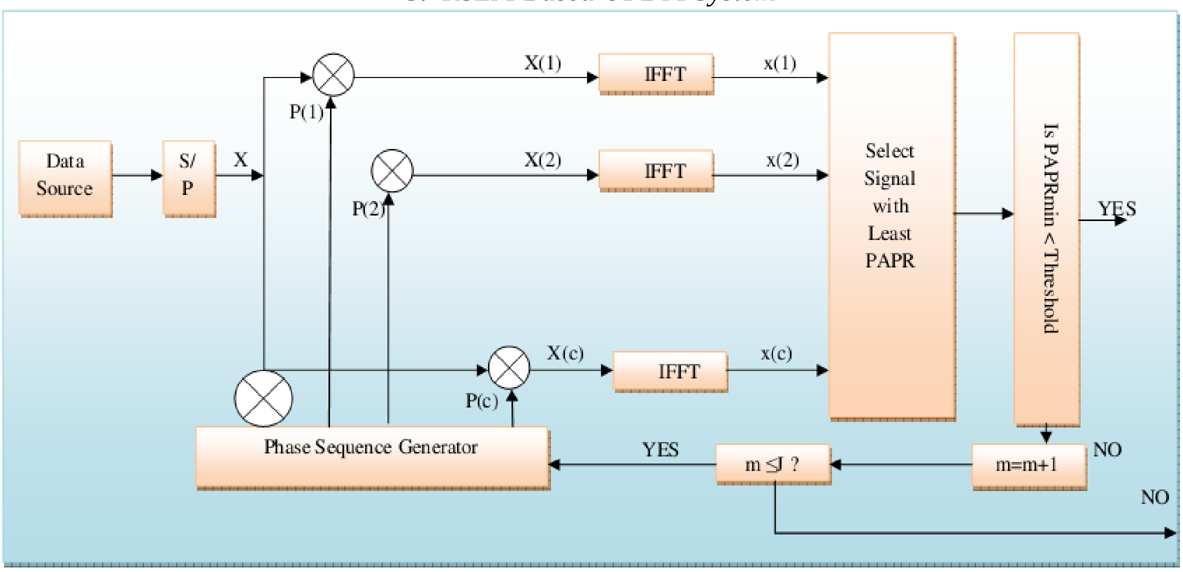

Fig.3. Block diagram of RSLM based OFDM system.

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In RSLM technique the whole optimization process is divided into the limited number of stages, say J stages. The number of candidate signals in each stage should be same and C candidate signals are generated by using different phase factor set in each stage. Then a PAPR threshold is introduced. Once the lowest PAPR of the candidate signal from the m[th] stage is below Threshold, this candidate signal will be transmitted directly without any other processing; otherwise, the input signal will be sent to the following stages to go on with the process of PAPR reduction until its lowest PAPR is below Threshold. After all J stages, if the lowest PAPR is still higher than Threshold, the candidate signal with the lowest PAPR from the last stage will be transmitted.

Where c=1, 2, 3…………, c.

PAPR of RSLM based OFDM for the above equation is given by

$$PAPR = \frac{max|x_n|^2}{E[|x_n|^2]} \quad \ldots\ldots\ldots\ldots\ldots \ (13)$$

III. Proposed Model

DCT Precoder Based RSLM System

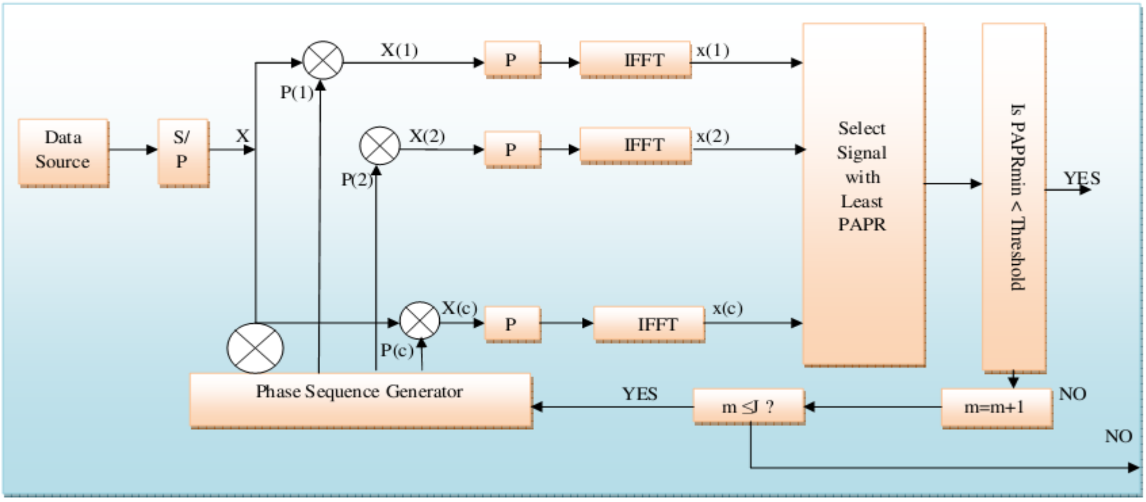

Fig.4. Block diagram of DCT Precoder based RSLM-OFDM System

The block diagram of the proposed DCT Precoder based RSLM-OFDM system can be shown in fig. 4. Suppose data stream after Serial to parallel conversion is $X = [X_0, X_1, X_2 \ldots X_{N-1}]^T$ and each data block is multiplied by C dissimilar phase sequences in RSLM block , each length equal to N, $D^{(C)} = [d_{C0}, d_{C1}, d_{C2} \ldots \ldots \ldots, d_{C(N-1)}]$, c = 1, 2, 3………C , which result in altered data block and let us denote the altered data block for C[th] phase sequence by the equation

$$x_n^{(c)} = \left[X_0 P_{c,0}, X_1 P_{c,1}, \ldots \ldots \ldots, X_{N-1} P_{c,(N-1)}\right]$$
$$, n = 0, 1, 2 \ \ldots . N-1 \qquad \ldots\ldots\ldots\ldots \ (14)$$

Each X_n^C is denoted by $X_n^C = X_n P_{c,n}, \ 1 \le c \le C$

Now we pass the signal in above equation through our DCT precoder and the resultant signal can be written as

$$Y_m^{(c)} = \sum_{n=0}^{N-1} p_{m,n} X_k^{(c)} .,$$
$$m = 0, 1, 2 \ \ldots . N-1 \qquad \ldots\ldots\ldots\ldots.. \ (15)$$

Where $p_{m,l}$ means l[th] row and m[th] column of precoder matrix. The signal in equation (14) after performing the IFFT can be written as

$$x_n^{(c)} = \frac{1}{\sqrt{N}} \sum_{m=0}^{N-1} Y_m^{(c)} . e^{j2\pi \frac{n}{N} k},$$
$$n = 0, 1, 2 \ \ldots . N-1 \quad \ldots\ldots\ldots\ldots.. \ (16)$$

Where c = 1, 2… C and the PAPR of OFDM signal in (18) can be written as

$$PAPR = \frac{max|x_n|^2}{E[|x_n|^2]} \quad \ldots\ldots\ldots\ldots \ (17)$$

The PAPR reduction for Precoding based SLM technique depends on the number of phase sequences C and the output data with lowest PAPR is selected by the transmitter for transmissions. Precoding based RSLM technique is applicable for any number of subcarriers and all types of modulation techniques.

IV. Simulation Results

The Complementary Cumulative Distribution Function (CCDF) of Normal OFDM system, RSLM method, and proposed precoder base RSLM technique is as shown in figure 5.

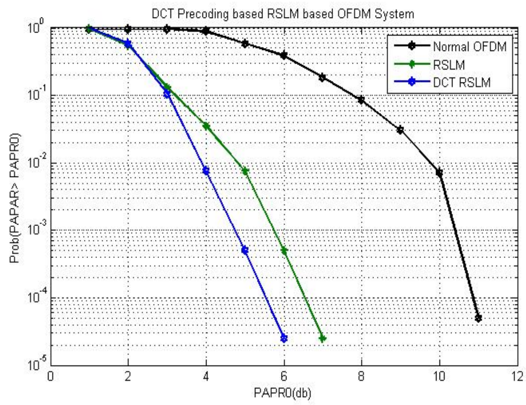

Fig.5. The CCDF of Normal, RSLM and precoder based RSLM OFDM system

As it is shown in Figure 5, the PAPR of the original OFDM signal is almost 11dB at CCDF = 0.01%. When the conventional RSLM method applied the PAPR of scheme is improved to 6dB, respectively. Figure 5 shows the CCDF comparisons of Normal OFDM system, RSLM OFDM system and our proposed DCT precoding based RSLM-OFDM system with OFDM original system for N=256 and C=4. The PAPR gain of 4dB is achieved when we compare RSLM system with OFDM Original System, PAPR gain of 5dB is achieved when we compare our proposed DCT precoder based RSLM-OFDM system with OFDM Original System.

V. Conclusions

In this paper, we proposed a DCT precoder based RSLM technique to reduce the high PAPR generated by multicarrier modulation in the OFDM system. Our proposed technique can reduce more PAPR if we increase the value of C. Furthermore, a proper threshold is introduced to further reduce computational complexity.

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