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SLM Technique with Hadamard Transform for PAPR Reduction

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ABSTRACT

Peak-to-average power ratio (PAPR) is a major drawback for multicarrier system such as orthogonal frequency division multiplexing (OFDM). Due to increase in PAPR of OFDM signal the power amplifier causes non-linear distortion. In this paper we have proposed a PAPR reduction scheme for OFDM system by modification in conventional selective mapping (SLM) technique with Hadamard transform (HT). Furthermore, the Complementary Cumulative Distribution Function (CCDF) of the PAPR for both the conventional and the Modified SLM are measured and compared.

Keywords: *Hadamard Transform; Selective Mapping; Peak-to-Average-Power Ratio.*

1 INTRODUCTION

The OFDM system is the most promising and effective multi-carrier modulation technique in a digital communication system [1].OFDM is a parallel transmission scheme which employs substantively overlapping subcarriers to achieve very high spectral efficiency. The OFDM happens to be the most efficient and the most widely used technology in the standard broadband wireless transmission system such as IEEE 802.16a standard for Wireless Metropolitan Area Networks (WMAN), the IEEE 802.11a standard for Wireless Local Area Networks (WLAN), Digital Audio Broadcasting (DAB). The OFDM Technology is widely accepted due to its robustness against frequency-selective fading [2]. However, OFDM system suffers from a drawback which is the PAPR. The PAPR distorts the OFDM signals when the signals pass through a power amplifier. To mitigate the effect of the PAPR a very large linear amplifier range is needed, which increases cost and the system complexity [3]. Currently, several techniques have been proposed to achieve more efficient PAPR [4] reduction without distortions in the OFDM signals. Among these techniques the selected mapping (SLM) technique is one of the preferable techniques in reducing the Peak-to-Average Power ratio. The paper analyses performance of the PAPR reduction with respect to SLM technique. The rest of paper is organized as follows; In Section II, we discuss the briefly about PAPR. We comment on the conventional SLM technique in Section III. In Section IV, we summarize Hadamard transform. The proposed scheme is defined in Section V and simulation results are presented in section VI Finally, we conclude the paper in Section VII.

2 THE PEAK VALUES OF THE OFDM SIGNALS

In an Orthogonal frequency division multiplexing (OFDM) system with N number of sub-carriers, the discrete-time OFDM signal can be written as [5].

$$x_m \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} X_n e^{j2\pi mn/QN}, \quad m = 1,2,\ldots\ldots N\text{-}1 \qquad (1)$$

Where $j = \sqrt{-1}$, X_n, n = 0,1,…..N-1 are the input symbols modulated with Quadrature Amplitude Modulation (QAM) and the Phase Shift Keying (PSK) and Q is the oversampling factor which is an integer larger or greater than 1. If the data sequence is,

$$X[X(0), X(1), \ldots\ldots\ldots X(N-1)]^T \qquad (2)$$

The Peak to Average power Ratio of the transmitted signal x_m can be simply defined as

the ratio of the average signal power to the maximum signal. Mathematically, the PAPR of complex pass band signal x_m is given in equation [6].

$$PAPR = \frac{Peak\ Power}{Average\ Power} \quad (3)$$

$$PAPR(x_m) = 10log_{10}\frac{max|x_m|^2}{E[|x_m|^2]} \quad (4)$$

Where $\max|x_m|^2$ is the peak signal power, E[.] denotes the expectation operator and E(|x(t) |2) represents the average power signal. the peak values occurs in the system increases as the number of sub-carriers increases, therefore the peak values is directly proportional to the number of sub-carriers in the system [7].

3 CONVENTIONAL SLM

The SLM technique is one of the preliminary probabilistic methods for PAPR reduction. The selective mapping technique minimizes the peak to average transmit power of multicarrier transmission system with selected mapping. The basic idea of the SLM technique is to generate a whole set of data sequence at the transmitter to represent the original OFDM information and then choose the signal with the least peak values for transmission. The OFDM symbols in the SLM technique is obtained by multiplying data sequence

$$X = [X(0), X(1), \dots\dots X(N-1]^T \quad (5)$$

With the different phase sequences U given as,

$$P^u = \left[P_0^{(u)}, P_1^{(u)}, P_2^{(u)}, \dots\dots P_{N-1}^{(u)}\right]^T \quad (6)$$

the resulted data block can be expressed as,

$$X^u = \left[X_0^{(u)}, X_1^{(u)}, X_2^{(u)}, \dots\dots X_{N-1}^{(u)}\right]^T \quad (7)$$

The resulted independent data sequences are then converted into time domain sequence with the help of the Inverse Fast Fourier Transform (IFFT) operation. The time domain sequence is then expressed as:

$$X^u = \left[X^u[0], X^u[1], X^u[2], \dots\dots X^u[N-1]\right]^T \quad (8)$$

Eventually, the converted candidate sequences with the minimum peak values are chosen and selected for the final transmission. PAPR reduction performance is enhanced as the phase sequences U is increased. The SLM technology effectively enhances the performance of the PAPR reduction without any of the signal being distorted. However, it has a higher computational complexity [8]. The block diagram of SLM technique is shown in Fig. 1.

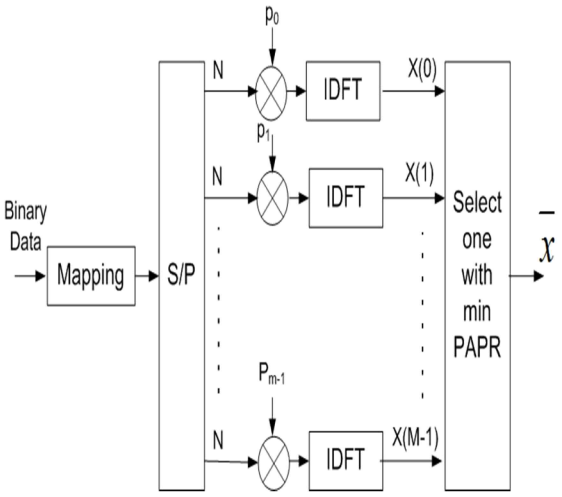

Fig. 1. Block diagram of conventional SLM technique

4 HADAMARD TRANSFORM (HT)

The Hadamard Transform (HT) can be used to reduce the effect of the PAPR. The Hadamard Transform is also used in Digital Signal and Image Processing to make error correction codes. In this modified SLM technique we used HT to minimize the autocorrelation of the input vector to improve the Peak to Average Power Ratio (PAPR)[9]. The Hadamard Transform (H) is a standard orthogonal matrix of n order. A Hadamard Transform (HT) of an order n is an $N \times N$ matrix with the values 1s and -1s such that

$$H_n H_n^t = nI_n \quad (9)$$

The Hadamard matrix of order 3 is expressed as

$$H_3 = \frac{1}{\left(\sqrt{2}\right)^3}\begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 \\ 1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 & 1 & -1 & -1 & -1 \\ 1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 \\ 1 & -1 & 1 & -1 & -1 & 1 & -1 & 1 \\ 1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 \\ 1 & -1 & -1 & 1 & -1 & 1 & 1 & -1 \end{bmatrix} \quad (10)$$

Hadamard matrix (H) of order n can be framed as

$$H_n = H_{n-1} \otimes H_{n-1}$$

$$H_n = \frac{1}{\sqrt{2}}\begin{bmatrix} H_{n-1} & H_{n-1} \\ H_{n-1} & H_{n-1} \end{bmatrix} \quad (11)$$

The vector X is represented as.

$$X = [X_1, X_{2,\dots\dots} X_n] \quad (12)$$

is transformed into a Hadamard matrix of order n, the transformed vector is given as $R = HX$. Finally the signal with the minimum PAPR is selected for transmission.

5 SLM TECHNIQUE WITH HADAMARD TRANSFORM

The modified SLM is to mitigate the effect of the PAPR.. The input data sequence can be written as,

$$X = [X(0), X(1), \ldots \ldots X(N-1]^T \quad (13)$$

if B^u is the phase rotation factor then the rotated vector can be expressed as

$$\bar{X} = [\bar{X}^u(0), \bar{X}^u(1), \bar{X}^u(1), \ldots \ldots \bar{X}^u(N-1)]^T \quad (14)$$

Hence, each of the branched signals can be represented as,

$$S^n = \sum_{n=0}^{N-1} h_{q,n} \bar{X}_n^u \quad (15)$$

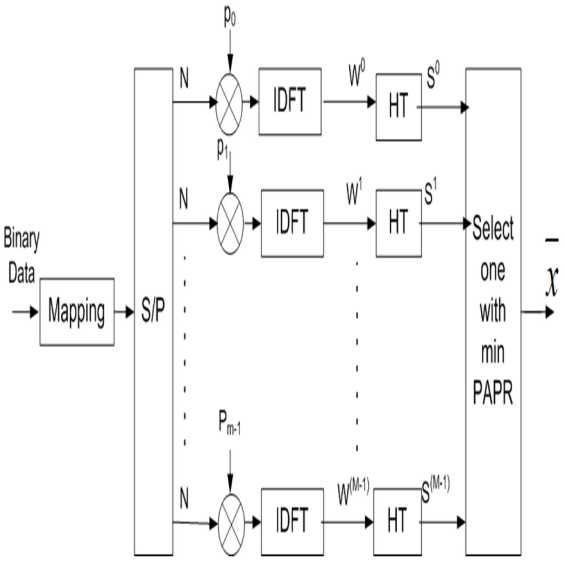

Fig. 2. Block diagram of Modified SLM with Hadamard Transform

6 SIMULATION RESULTS

Computer simulations are performed to compare the performance of conventional SLM with modified SLM. Firstly, we have performed simulation for conventional SLM techniques with different phase factors. It is cleared from the simulation that the PAPR performance of the OFDM system is improved. The simulation results are shown in Fig. 3.

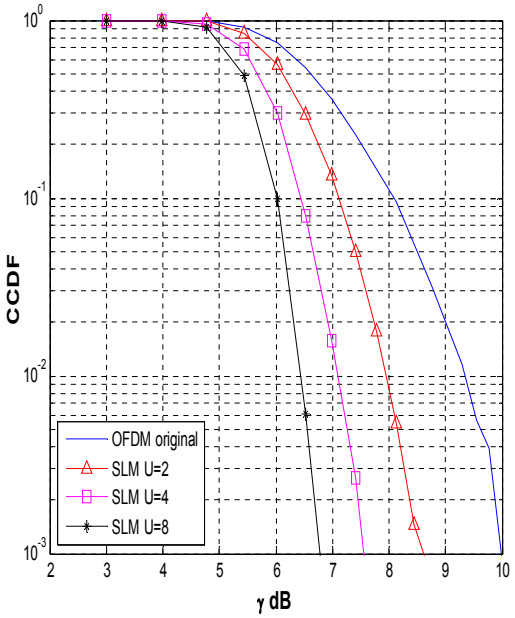

Fig. 3. PAPR comparison for SLM technique

After performing simulation for conventional SLM, we have performed simulation for our proposed technique and compared it with conventional SLM technique. The simulation results shows that the proposed scheme improved PAPR performance. The simulation results are shown in Fig. 4.

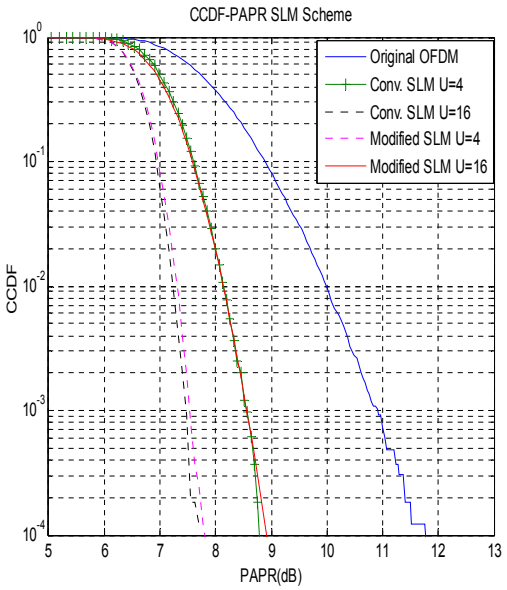

Fig. 4. Comparison of PAPR with SLM and Modified SLM

7 CONCLUSION

As various conventional and hybrid technique has been proposed for PAPR reduction. In this paper we have presented a modified SLM technique for PAPR reduction. We have compared the PAPR performance of the conventional SLM technique with the proposed technique. The simulation result show that the modified SLM technique improved PAPR performance compared to the conventional SLM technique. The several techniques for PAPR reduction have been proposed but every technique has trade-off in terms of PAPR, bit error ratio, computational complexity and data rate. So in our proposed technique, there is also trade-off between PAPR performance and computational complexity of the system. Hence, the PAPR reduction is still an open research area for future work.

8 ACKNOWLEGEMENT

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