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Performance of PAPR Reduction in OFDM System with Complex Hadamard Sequence using SLM and Clipping

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Abstract—Orthogonal Frequency Division Multiplexing (OFDM) is an efficient method of data transmission for high speed communication systems. However, the main drawback of OFDM system is that, it exhibits high Peak to Average Power Ratio (PAPR) of the transmitted signals. OFDM consist of large number of independent subcarriers, as a result of which the amplitude of such a signal can have high peak values. The Selected Mapping (SLM) technique is one of the promising PAPR reduction techniques for OFDM. This technique however increases the computational and phase search complexity and PAPR reduction performance is largely dependent on the selection of random phase sequences. In this paper, a new SLM method which rotates the phase of input data after IFFT by using matrices generated from complex Hadamard code is proposed. After phase rotation, clipping technique is used to further reduce the PAPR. From simulation results, we can find that the proposed method has lower PAPR than conventional SLM combined with clipping technique.

Index Terms—. OFDM-Orthogonal frequency division multiplexing, Clipping, SLM-Selected Mapping, Hadamard Sequence.

I. INTRODUCTION

OWING to the high spectral efficiency and the immunity to multipath channels, orthogonal frequency-division multiplexing (OFDM) is a promising technique for high rate data transmission [1], [2]. This transmission technique has been adopted for a number of applications, such as the standard for digital radio audio broadcasting (DAB), the standard for digital video broadcasting (DVB), the standard for asymmetric digital subscriber line (ADSL) service over twisted-pair phone lines , and the IEEE 802.11a standard for wireless local area networks.

One major disadvantage associated with an OFDM system is the high peak-to-average power ratio (PAPR) of the transmitters output signal, where the range of PAPR is proportional to the number of subcarriers used in the system. Due to the high PAPR feature, an OFDM signal may suffer from significant intermodulation distortion and undesired out-of-band radiation [3], when it is passed through a nonlinear device, such as a transmit power amplifier.

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The conventional solution to the PAPR problem is to back-off the operating point of the nonlinear power amplifier. Although simple, this approach usually causes a significant power efficiency penalty.

There have been a number of methods proposed for reducing the PAPR in OFDM systems [4]. Of them, the clipping method is to deliberately clip the peak amplitude of the OFDM signal to some desired maximum level [5]-[8]. Since the clipping procedure is a nonlinear process, it may result in in-band distortion (self-interference) and out-of-band radiation. Another method for PAPR reduction is peak windowing [9]. Here the OFDM symbol is multiplied by a window function. Unlike clipping this technique maintains the spectral properties of the signal and limits the in band distortion and out of band radiation. Various coding schemes are used to reduce the PAPR [10], where the original data sequence is mapped onto a longer sequence with a lower PAPR in the corresponding OFDM signal. Basically, a coding scheme would involve a large look-up table and is more suitable for those OFDM systems with a small number of subcarriers.

Another method is Tone Reservation [11] in which the basic idea is to reserve a small set of tones for PAPR reduction. The problem of computing the values for these reserved tones that minimize the PAPR can be formulated as a convex problem and can be solved exactly. The amount of PAPR reduction depends on the numbers of reserved tones, their location within the frequency vector, and the amount of complexity. Active Constellation Extension [12] proposes a technique for PAPR reduction similar to Tone Injection Technique. In the active constellation extension technique, some of the outer signal constellation points in the data block are dynamically extended towards the outer side of the original constellation such that the PAPR of the data block is reduced.

The selected mapping (SLM) [13], [14] and partial transmit sequences (PTS) [15], [16] approaches have received considerable attention in recent years for providing improved PAPR statistics of an OFDM signal. In the SLM approach, one OFDM signal with the lowest PAPR is selected for transmission at the transmitter from a set of sufficiently different candidate signals, which all represent the same data sequence. Each candidate signal is actually the inverse fast Fourier transforms (IFFTs) of the original data sequence multiplied by an individual phase rotation vector. In the PTS approach, the transmitter partitions the original data sequence into a number of disjoint sub blocks and then optimally combines the IFFTs of all the sub blocks to generate an OFDM signal with low PAPR for transmission.

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Unlike the clipping method, PTS and SLM do not have adverse effects on the signal spectrum, but they require a bank of IFFTs to generate a set of candidate signals. To detect the OFDM signal at the receiver, appropriate side information indicating how the transmitter generates the output signal is embedded in the transmitted signal with error control codes. In general, the SLM and PTS techniques can provide pretty good PAPR reduction performance, but each of them may require a high computational load due to the need of a bank of IFFTs. If the same number of IFFT blocks is used, PTS may generate more candidate signals for selection and would achieve better performance than SLM, at the cost of a more complicated optimization process for combining IFFTs of all the sub blocks.

In this paper, we proposed a new PAPR reduction technique. This technique is based on SLM combined with clipping [17]. A new SLM method which rotates the phase of input data after IFFT by using complex Hadamard code to solve the computational complexity of conventional SLM technique is used. Complex Hadamard code can be generated by [18]. By using the DFT characteristics of these cyclic sequences, we can make several simple matrixes. These matrixes can be used after IFFT to rotate the phase of input data. Therefore, many copy branches are made after IFFT process. In this paper, we compare the proposed method with SLM combined with clipping technique about PAPR and BER.

The paper is organized as follows in section 2 we briefly review System Model i.e. OFDM system, PAPR of the OFDM signal, SLM method. In Section 3 the proposed method is explained. The performance with simulation result is discussed in section 4. Finally, conclusions are drawn in section 5.

II. OFDM AND SLM METHOD

The input data symbols are first passed through serial to parallel converter, forming a complex vector of size N. We call the vector as $X = [X_0, X_1, \ldots\ldots X_N]^T$. After IFFT the signal can be written as equation (1)

$$x(t) = 1/\sqrt{N}\sum_{k=0}^{N-1} Xn \exp(j2\pi n \Delta f t) \qquad 0 < t \leq NT \quad (1)$$

Δf is the subcarrier spacing and NT is the OFDM symbol Period.

PAPR can be written as in (2)

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

where E[.] is the average power

A. *SLM METHOD*

SLM (selective mapping) method is a kind of phase rotation method. Phase-rotated data of the lowest PAPR will be selected to transmit.

Fig. 1 is block diagram of SLM method. Let's define data stream after S/P conversion as $X = [X_0, X_1, \ldots\ldots, X_{N-1}]^T$ .Then phase-rotated data due to the phase rotation factor B^u can be written as $\hat{X}_U = [X_0^U, X_1^U, \ldots\ldots\ldots X_{N-1}^U]^T$. Each X^U can be defined as equation (3).

$$\hat{X}_U = X_n . b_n^u \quad (3)$$

After passing through IFFT,

$$S_U(t) = 1/\sqrt{N}\sum_{k=0}^{N-1} \hat{X}_K^U \exp(j2\pi k \Delta f t) \quad 0 < t \leq NT \quad (4)$$

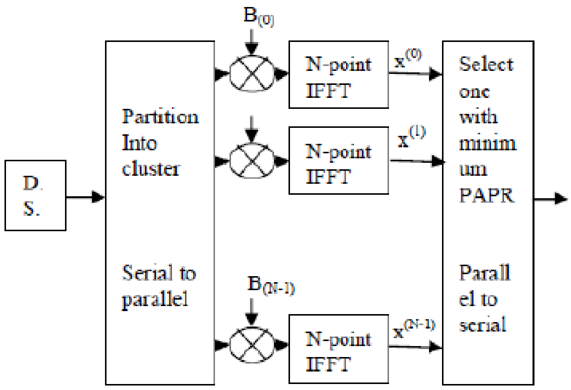

Figure 1. Block diagram of conventional SLM.

Output data of the lowest PAPR is selected to transmit. PAPR reduction effect will be better as the copy block number U is increased. SLM method can effectively reduce PAPR without any signal distortion. But it has higher system complexity and computational burden.

III. PROPOSED METHOD

The common SLM method multiplies several phase rotation sequences in front of each IFFT block. This phase rotation process can be moved to back of IFFT block like as Fig. 2.Then clipping technique is carried out for further PAPR reduction.

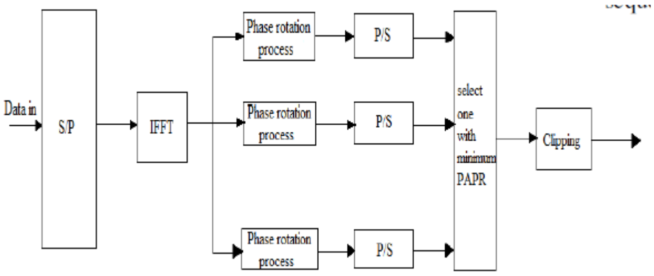

Figure 2. Proposed system.

A. *MODIFIED SLM*

The phase rotation process are different matrices generated from rows of complex hadamard matrix. They are multiplied as shown below. If we assume no over-sampling, N point DFT can be expressed like as follow matrix Q.

$$Q = \begin{bmatrix} 1 & 1 & \cdots & 1 \\ 1 & W^1 & \cdots & W^{N-1} \\ \vdots & \vdots & \ddots & \vdots \\ 1 & W^{N-1} & \cdots & W^{(N-1)(N-1)} \end{bmatrix} \quad (5)$$

$W = \exp\left(\frac{-j2\Pi}{N}\right)$ and, N point IDFT is changed to follow matrix Q^{-1}.

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$$Q^{-1} = \begin{bmatrix} 1 & 1 & \cdots & 1 \\ 1 & W^{-1} & \cdots & W^{-(N-1)} \\ \vdots & \vdots & \ddots & \vdots \\ 1 & W^{-(N-1)} & \cdots & W^{-(N-1)(N-1)} \end{bmatrix} \qquad (6)$$

Therefore, in figure 2, output of IFFT is

$x = Q^{-1} X \Rightarrow X = Q x$ (7)

Output signal changed by phase rotation process is

$x = Q^{-1} B X = Q^{-1} B Q x = T x$ (8)

From equation (8), we can know that phase rotation process of figure 2 is $T = Q^{-1} BQ$ and B is

$$B = \begin{bmatrix} b_0 & 0 & \cdots & 1 \\ 0 & b_1 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & b_{(N-1)} \end{bmatrix} \qquad (9)$$

The phase rotation process are different matrices generated from rows of complex hadamard matrix. They are multiplied using alternate rows of 8 point complex hadamard matrix generated using[18].Each element in a row becomes a non-zero element in the matrix B. The matrix generation is given in[14].Complex hadamard matrix are used to reduce the correlation between various OFDM symbols and thus reduce PAPR much better than using random phase sequences. This is shown in figure 3.

$$H_8 = \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & j & j & -1 & -1 & -j & -j \\ 1 & j & -1 & -j & 1 & j & -1 & -j \\ 1 & j & -j & 1 & -1 & -j & j & -1 \\ 1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 \\ 1 & -1 & j & -j & -1 & 1 & -j & j \\ 1 & -j & -1 & j & 1 & -j & -1 & j \\ 1 & -j & -j & -1 & -1 & 1 & -j & j \end{bmatrix} \qquad (10)$$

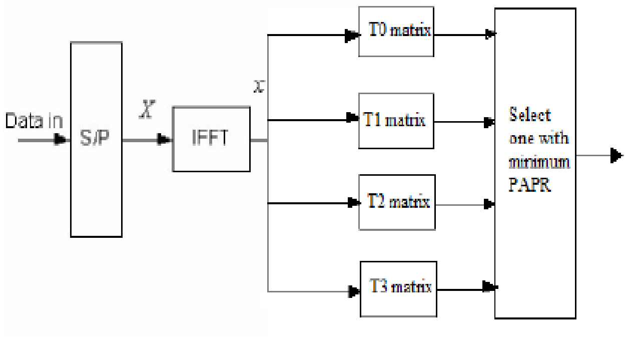

Figure 3. Modified SLM using 4 copy branches

B. CLIPPING

The OFDM symbol which is multipled by the T matrix is then clipped at a given threshold and the clipped signal can be represented as shown below. This will reduce the PAPR further.

$$x_c(n) = \begin{cases} A & \text{if } x_u(n) > A \\ x(n) & \text{if } x_u(n) \le A \end{cases} \qquad (11)$$

IV. PERFORMANCE ANALYSIS

In this paper, Matlab simulations are used to evaluate the peak to average power ratio reduction capability and bit error rate of the proposed method. The channel is corrupted by an additive white Gaussian noise(AWGN). In simulation an OFDM system is considered with N = 8, where N is the number of OFDM subcarriers and QPSK modulation is used for encoding the information. We have used a threshold value of 0.2 for clipping.

We can evaluate the performance of the proposed scheme using CCDF plots, which helps to measure the probability that PAPR of a certain block exceeds the given threshold. From fig. 4, it shows that PAPR of the OFDM has reduced considerably by the proposed method. We can see that with a probability of 10-2 , the PAPR of the original signal is more than 9dB, while that of conventional SLM is 7 dB, SLM technique combined with clipping is 6.8dB and the proposed

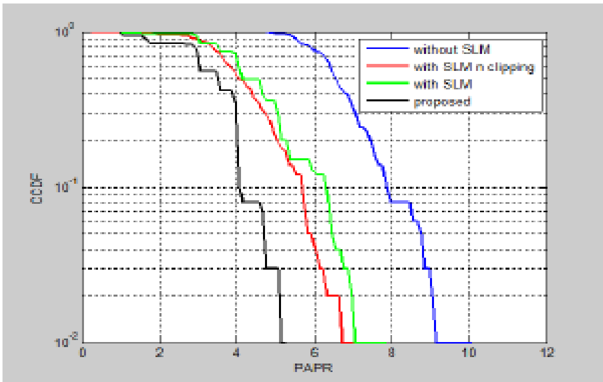

Figure 4. OFDM system using selective mapping method.

The BER curve of OFDM system and proposed scheme is also plotted. The proposed scheme maintains BER performance close to the conventional OFDM system. At the same time it serves an important role to reduce the PAPR considerably.

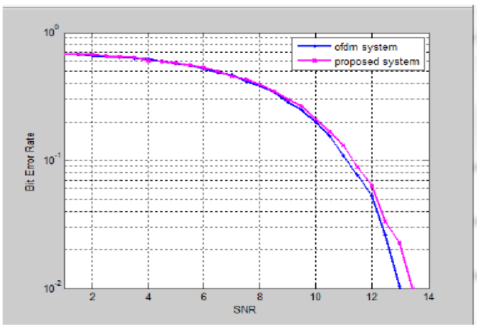

Figure 5. BER of the proposed technique for QPSK modulation ,N=8

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V. CONCLUSION

In this paper, a new SLM method using complex Hadamard code is combined with clipping to reduce the PAPR in OFDM. Because the SLM method can rotate the phase of input data after the IFFT process by transforming a Complex Hadamard code into several simple matrices, the computational complexity is highly reduced. The proposed method can reduce the PAPR more than the conventional SLM method combined with clipping technique and also got an affordable BER performance. scheme has a PAPR of 5.1dB.The CCDF curve has nearly 3.9 dB improvement for the proposed system.

REFERENCES

[1] Y. Wu and W. Y. Zou, "Orthogonal frequency division multiplexing: a multi-carrier modulation scheme," IEEE Transactions on Consumer Electron, Aug. 1995.

[2] L. J. Cimini Jr., "Analysis and simulation of a digital mobile channel using orthogonal frequency division multiplexing," IEEE Trans. Commun., vol. COM-33, pp. 665-675, July 1985.

[3] Dov Wulich,"Definition of Efficient PAPR in OFDM ," IEEE communication Letters, vol. 9, no. 9, Sept 2005

[4] R. van Nee and A. de Wild, "Reducing the Peak-to-Average Power Ratio of OFDM," in Proc. of Vehicular Technology Conference, IEEE, vol. 3, pp. 2072-2076.May 1998.

[5] L. Wang and C. Tellambura, "A simplified clipping and filtering technique for par reduction in ofdm systems, "IEEE Signal Process. Lett, vol. 12, no. 6, pp. 453–456, 2005

[6] J. Armstrong, "Peak-to-average power reduction for ofdm by repeated clipping and frequency domain filtering," Electron. Lett, vol. 38, no. 5, pp. 246–247, 2002.

[7] Xiaodong Li and Leonard J. Cimini, Jr. "Effects of Clipping and Filtering on the Performance of OFDM, "IEEE Comm. Letters vol. 2, no. 5, pp. 131-133,1998

[8] Steve C. Thompson, John G. Proakis, and James R. Zeidler, "The Effectiveness of Signal Clipping for PAPR and Total Degradation Reduction in OFDM Systems," IEEE Globecom., vol. 30, pp. 2807-2811, 2005.

[9] Guoguang Chen, Rashid Ansari, Yingwei Yao," Improved Peak Windowing for PAPR Reduction in OFDM," IEEE Conference Publications pp. 1-5,2009.

[10] A. E. Jones, T. A. Wilkinson, and S. K. Barton, "Block coding scheme for reduction of peak to mean envelope power ratio of multicarrier transmission schemes," Electron. Lett., vol. 30, pp. 2098-2099, 1994.

[11] Wattanasuwakull, T. ; Benjapolakul, W,"PAPR Reduction for OFDM Transmission by using a method of Tone Reservation and Tone Injection" in proc. of Information, Communications and Signal Processing, Conference, IEEE ,pp. 273 - 277,2005

[12] B. S. Krongold and D. L. Jones. "PAR reduction in OFDM via active constellation extension,"IEEE Trans. Broadcasting, April 2002.

[13] R.W. Bguml, R.F.H. Fischer and J.B. Huber "Reducing the peak-to-average power ratio of multicarrier modulation by selected mapping," Electronics letters, vol. 32, no. 22, pp. 259– 268, October 1996.

[14] Sang -Woo Kim, Jin-Kwan Kim and Heung-Gyoon Ryu "A Computational Complexity Reduction Scheme Using Walsh Hadamard Sequence in SLM Method. " IEEE conference Publications, pp. 762-766, 2006

[15] S.H. Muller and J.B. Huber "OFDM with reduced peak to-average power ratio by optimum combination of partial transmit sequences" Electronics letters, vol. 33,no. 5 ,pp. 368- 369, february 1997.

[16] Asma Latif; N. D. Gohar, "Reducing Peak-to-Average Power Ratio (PAPR) Using Partial Transmit Sequence in OFDM Systems, " Proc of lEEE, pp. 126-130,2003

[17] Aparna P. More, Sunil B. Somani, "The Reduction of PAPR in OFDM Systems Using Clipping and SLM Method, " Proc on lEEE conference, pp. 593-597,2013

[18] Aye Aung, Boon Poh Ng, and Susanto Rahardja,"Sequence- Ordered Complex Hadamard Transform Properties,Computational Complexity and Applications" ,IEEE Transactions on signal processing , vol. 56, no. 8,pp. 3562-3571 , 2008

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