Modified SLM Method by Using Phase Label Insertion for PAPR Reduction in OFDM Systems

Shu-Hong Lee
Department of Electronic Engineering, Chienkuo Technology University

Chu-Hsuan Cheng
Institute of Communication Engineering, National Chi Nan University

Jyh-Horng Wen
Institute of Electronic Engineering, National Chung Cheng University
wen@ee.ccu.edu.tw

Abstract

High peak-to-average power ratio (PAPR) is a major drawback in OFDM systems, which increases complexity of the analog-to-digital converter and reduces efficiency of the high power amplifier (HPA). In this paper, we propose a modified selected mapping (SLM) method without side information by means of cyclically shifting the transmission data and inserting corresponding phase label in an OFDM symbol to mitigate the PAPR and lessen the complexity of computation . Simulation results show that the proposed method has better bandwidth efficiency than that of SLM-based dummy sequence insertion (DSI) method, but it has to pay the penalties of losing a little bit performance in terms of the bit error rate (BER).

Keywords: OFDM, PAPR, SLM

摘要

高的峰均功率比(PAPR)是正交分頻多工(OFDM)的主要缺點。它會增加類比數位轉換器的複雜度，並減低高功率放大器的效率。本論文提出一不需輔訊(side information)的選擇性映對(SLM)的修改方法，藉由循環位移傳送的資料及插入相應的相位標誌，達到減少正交分頻多工信號的峰均功率比及降低原來的運算複雜度。模擬結果顯示，所提方法比基於選擇性映對架構的仿序列插入法(DSI)有較好的頻寬使用效率，但要付出增加一點位元錯誤率(BER)的代價。

關鍵詞：正交分頻多工，峰均功率比，選擇性映對。

1. Introduction

Orthogonal frequency division multiplexing (OFDM) is an attractive transmission technique for high-bit-rate communication systems [1]. It has many well-know advantages such as the high bandwidth efficiency and robustness to the inter-symbol interference (ISI) and frequency-selective fading [2]. Consequently, OFDM has been adopted in many wireless standards, for example, digital audio broadcasting (DAB), terrestrial digital video broadcasting (DVB-T), the IEEE 802.11a standard for wireless local area networks (WLANs), and the IEEE 802.16a standard for wireless metropolitan area networks (WMANs). However, one major drawback of OFDM is the high peak-to-average power ratio (PAPR), which results in some clipping distortion caused by the nonlinear power amplifier, and degrades the system performance.

To account for this issue, there are many approaches have been proposed to reduce the PAPR of an OFDM signal such as signal amplitude clipping, partial transmitting sequence (PTS) and selective mapping (SLM) [3].

For selective mapping (SLM) method [4], the transmitter generates a set of sufficiently different candidate signals, which all represent the same information data sequence, and then selects the sequence with the lowest PAPR for transmission. Every candidate signal is the output of inverse fast Fourier transform (IFFT) of the original data sequence multiplied by an individual phase rotation vector. In order to recover original data, the receiver must have knowledge about the operation process of OFDM signal and phase information. This information is known as side information (SI), which results in some loss of bandwidth efficiency. Besides, the entire data signals may be lost if the side information is received in error, which will increase the bit error rate (BER) .

The dummy sequence insertion (DSI) method proposed by H.G. Ryu et al. [6][7] for PAPR reduction in OFDM system can improve the BER performance than conventional SLM and have higher transmission efficiency than the conventional block coding methods for PAPR reduction. DSI method inserts dummy sequence into the transmission data block directly for the PAPR reduction before the IFFT stage. In [7], a complementary sequence and the combination of the correlation sequence are considered as dummy sequence, which will be discarded at receiver, that is, the side information is not necessary. Thus the BER of the DSI method is better than that of the conventional SLM method.

In this paper, we propose a modified SLM method which can improve the transmission efficiency as compared with the method in [7] for PAPR reduction. In the proposed method, a set of different sequences are generated by cyclically shifting the data bits and inserting different phase labels in the bottom of the transmission data block. The proposed method needs not any side information because the phase label has contained the phase shift message for data recovery.

2. System model

2.1 PAPR definition

In OFDM systems, the transmitted signal consists of a sum of orthogonal subcarriers that are modulated by complex data symbols. For an OFDM system with *N* subcarriers, the complex baseband signal can be written as

$$x(t) = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} X_n \exp(j2\pi n \Delta f t), \quad 0 \le t \le T \quad (1)$$

where X_n is the data symbol at *n*-th subcarrier, Δf is the subcarrier frequency spacing, and *T* is the OFDM symbol duration.

The PAPR of the transmitted signal in (1) is defined as

$$\text{PAPR} = \frac{\max_{0 \le t \le T} |x(t)|^2}{E\left[|x(t)|^2\right]} \quad (2)$$

where $E[\bullet]$ denotes the expected value.

2.2 Selective mapping

In the conventional SLM method, the input data sequence $X=[X_0, X_1, \ldots, X_{N-1}]^T$ is multiplied element by element with phase sequences $P^{(v)} = [P_0^{(v)}, P_1^{(v)}, \ldots, P_{N-1}^{(v)}]^T$, $1 \le v \le V$, where the *n*-th element $P_n^{(v)} = e^{j\theta_n^{(v)}}$ with

random-generated phase $\theta_n^{(v)} \in [0, 2\pi\}$, to make the V phase rotated OFDM data sequences $\mathrm{X}^{(v)} = [X_0^{(v)}, X_1^{(v)}, \ldots, X_{N-1}^{(v)}]^T$, $1 \le v \le V$, where the n-th element $X_n^{(v)} = X_n P_n^{(v)}$. The V phase rotated data sequences represent the same information as the unchanged OFDM data sequence provided that the phase sequence is known. In order to include unchanged data sequence in the set of the phase rotated data sequences, the first phase sequence $\mathrm{P}^{(1)}$ is usually set all one vector of length N. After applying the SLM approach to OFDM symbol, (1) becomes

$$x^{(v)}(t) = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} X_n P_n^{(v)} \exp(j2\pi n \Delta f t), \quad 0 \le t \le T,\ 1 \le v \le V. \qquad (3)$$

The V phase rotated OFDM data sequences are transformed into the time-domain and the one with the lowest PAPR is selected for transmission. To recover the data, the receiver must have known knowledge about the generation process of the transmitted OFDM data sequence. The information about the selected phase sequence should be transmitted to the receiver as side information, resulting in some loss of bandwidth efficiency. Therefore, some modified SLM methods for PAPR reduction have been proposed later [7-9].

3. Proposed method

Fig. 1 shows the block diagram of OFDM transmitter for the proposed method. The scheme of proposed method is a variation of SLM, in which V different sequences are generated from the same original data sequence of $L=N-M$ symbols, where N is the number of total subcarriers in OFDM, M is the length of the phase label and L denotes the size of transmission data sequence. To generate different sequences, V numbers of information data sequences of length L are cyclically shifted downwards in different steps, respectively. The information data sequence of v-th branch, $1 \le v \le V$, is shifted downwards v-1 steps. Thus the data sequence of the first branch is unchanged. In addition, the different phase labels d_i are inserted into the bottom of every one of V shifted data sequences respectively, and d_i is a M bits sequence, $0 \le i \le V-1$. The number of total phase labels is 2^M. Also, V is the number of branches, which is the same as that of phase labels. The data sequence with the lowest PAPR is selected and transmitted after IFFT. At the receiver, the information data can be recovered by means of the phase label, which will be discarded easily after the sequence is placed at the pre-assigned subcarriers. Although the BER performance of proposed method may be degraded due to errors in the phase label, the proposed method improves the efficiency of spectrum usage and reduces the IFFT computation amount than the PAPR reduction method that based on SLM using dummy sequence scheme [7]. There the spectrum efficiency can be defined as

$$\text{Spectrum efficiency} = \frac{L}{N} \times 100[\%] \qquad (4)$$

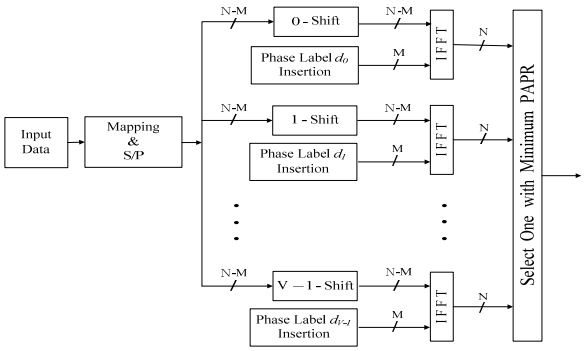

Fig. 1 Block diagram of OFDM transmitter for the proposed method.

4. Simulation results

The PAPR reduction and BER performance of the proposed method are evaluated by computer simulation. The considered OFDM system here is with N=64 and 256 subcarriers and both BPSK modulation and AWGN channel are applied. Fig. 2 shows the complement cumulative distribution function (CCDF) of the PAPR of the OFDM signal, where method 1 (M1), method 2 (M2) in [7] and the proposed method are used for PAPR reduction. M is length of the inserted sequence. In Fig. 2, the PAPR reduction performance of proposed method is similar to M1 and M2 for N=64 subcarriers (about 2.2dB reduction at 0.1% PAPR) when the inserted sequence length M for M1, M2 and the proposed method are 16, 8 and 5, respectively. That is to say that the proposed method has better spectrum efficiency on a similar performance. For N=64, the spectrum efficiency is increased from 0.75 and 0.875 to 0.921. Also, the methods have similar PAPR reduction performance for N=256 (about 1.8dB reduction at 0.1% PAPR) when the inserted sequence length for M1, M2 and the proposed method are 32, 12 and 7, respectively. The spectrum efficiency is increased from 0.875 and 0.953 to 0.973. From the simulation results, it appears that the proposed method has better spectrum efficiency when the number of subcarriers is increased.

Fig. 3 shows a comparison of BER performance of the normal OFDM and the proposed method. From the results, the proposed method has about 1dB SNR loss compared with normal OFDM for N=64, M=5 and N=256, M=7 as BER is 0.1%. The BER performance of proposed method has a slight degradation due to the error in the inserted phase label.

5. Conclusions

In this paper, we propose a modified SLM method for PAPR reduction in OFDM systems. A set of different sequences are generated by cyclically shifting the data bit and using phase label insertion. The sequence with the lowest PAPR is transmitted after IFFT. At the receiver, the information data can be recovered by phase label. The proposed method improves the efficiency of spectrum usage and reduces the IFFT computation amount compared with that based on SLM using dummy sequence insertion. The proposed method has better spectrum efficiency when increasing the number of subcarriers. Although the BER performance of proposed method has a slight degradation, the spectrum efficiency has been improved well. The proposed method is rather attractive for use in OFDM-based communication systems.

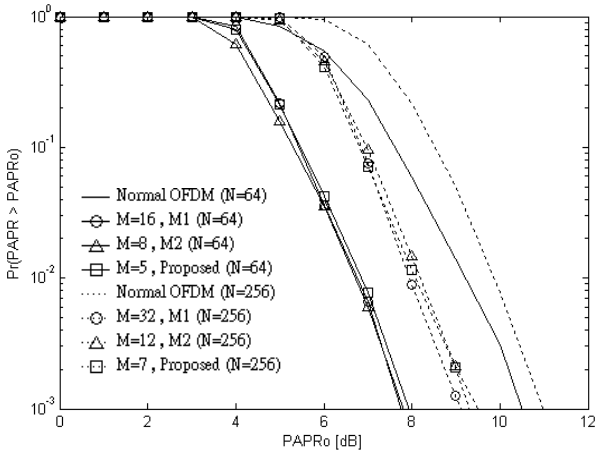

Fig. 2 Comparison of PAPR reduction performance at BPSK and *N*=64, 256.

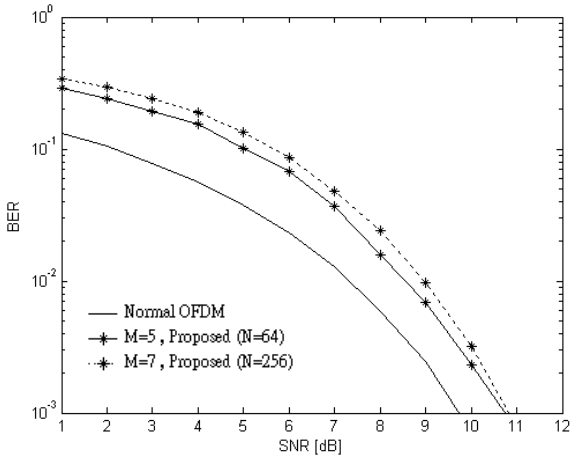

Fig. 3 BER of proposed method at BPSK and *N*=64, 256.

References

[1] Richard van Nee, and Ramjee Prasad, OFDM for wireless multimedia communications. *Artech House Boston London*, 2000.

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

[3] Han, S.H., and Lee, J.H., "An overview of peak-to-average power ratio reduction techniques for multicarrier transmission," *IEEE Wirel. Commun.*, 12, (2), pp. 56–65, 2005.

[4] Bauml, R.W., Fischer, R.F.H., and Huber, J.B., "Reducing the peak-to-average power ratio of multicarrier modulation by selected mapping," *Electron. Lett*, 32, (22), pp. 2056-2057, 1996.

[5] Muller, S.H. and Huber, J.B., "OFDM with reduced peak-to-average power ratio by optimum combination of partial transmit sequences," *Electron. Lett*, 33, (5), pp. 560-561, 1997.

[6] Heung-Gyoon Ryu, Jae-Eun Lee, and Jin-Soo Park, "Dummy sequence insertion (DSI) for PAPR reduction in the OFDM communication system," *IEEE Trans. on Consum. Electron*, 50, (1), pp.89-94., 2004.

[7] Sang Woo Kim, Heui Seop Byeon, Jin Kwan Kim, and Heung-Gyoon Ryu, "An SLM-based Real-time PAPR Reduction Method Using Dummy Sequence Insertion in the OFDM Communication," *Fifth Int. Conf. on Information, Comm. and Sig. Proc.*, Dec., 2005, pp.258-262.

[8] Seung Hee Han and Jae Hong Lee, "Modified selected mapping technique PAPR reduction of coded OFDM signal", *IEEE Trans. on Broad.*, 50, (3), pp.335-341, 2004.

[9] Sumathi, S., "Peak to Average Power Ratio Reduction of OFDM Signal", *IEEE Indicon conf.*, 11-13, Dec., 2005, pp.241-244.