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A PARTITION DUMMY SEQUENCE INSERTION PAPR REDUCTION METHOD OF THE OFDM SYSTEM

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Key words: OFDM, PAPR, power amplifier.

ABSTRACT

OFDM (Orthogonal Frequency Division Multiplexing) technique has been widely adopted in many wireless communication systems due to its high data-rate transmission ability and robustness to the multipath fading channel. One major drawback of the OFDM signal is the high peak-to-average power ratio (PAPR) problem. The high PAPR results in the in-band distortion and out-of-band radiation when the OFDM signal is fed into a nonlinear power amplifier (PA). In this paper, we propose a partition dummy sequence insertion (PDSI) method to reduce the PAPR problem. Simulation results of the PAPR reduction and bit error rate (BER) performance for the proposed method are evaluated to demonstrate its capabilities.

I. INTRODUCTION

OFDM technique has been adopted in many wireless communication systems due to its high data-rate transmission ability and robustness to the multipath fading, such as digital audio broadcasting (DAB), digital video broadcasting-terrestrial (DVB-T), very-high-rate digital subscriber lines (VDSL), and the IEEE802.11a wireless local area network (WLAN). However, a serious drawback of the OFDM system is the high peak-to-average power ratio (PAPR) of the transmitted signal. The high PAPR results in the nonlinear effects of the in-band distortion and out-of-band radiation when the OFDM signal is fed into a nonlinear power amplifier (PA). In literatures, many methods have been proposed to solve the high PAPR problem [1-7]. Two categories of the PAPR reduction methods can be classified: the first kind is distortionless and the second one is distorted. For example, the selected mapping (SLM) [2, 6], partial transmit sequence (PTS) [7] and the coding scheme [11] are the distortionless PAPR reduction methods. And the distorted PAPR reduction methods include the clipping method [1, 3], companding transform (CT) [4, 5, 10] ..etc. The distortionless methods will not distort the original OFDM waveform. However, these methods have to transmit the additional side information (SI) along with the OFDM signal. Hence, the distortionless methods have the disadvantage of reducing the system throughput. On the contrary, the distorted methods will not reduce the throughput. However, they are nonlinear and suffers the bit error rate (BER) degradation of the system.

In this paper, we propose a partition dummy sequence insertion (PDSI) method to ease the PAPR problem of the OFDM signal. The proposed method is distortionless and can effectively reduce the PAPR problem. Besides, the BER performance is very robust regardless of the nonlinearity of different kinds of PAs. This paper is organized as follows: Section II describes the proposed method in detail and illustrates a Dummy Sequence Insertion (DSI) method [8] for comparison. Simulations of the PAPR reduction and the BER performance of the proposed method are evaluated under the Rayleigh fading channel in Section III. Finally, some conclusions of this paper are given in Section IV.

II. METHOD DESCRIPTION

In this section, we first review several PAPR reduction methods including the Selective Mapping (SLM), Partial Transmit Sequence (PTS) and the Dummy Sequence Insertion method (DSI). Then, we propose a Partition Dummy Sequence Insertion (PDSI) method to reduce PAPR.

1. Selective Mapping (SLM) [6]

Fig. 1 depicts the operation of the SLM method for the OFDM system. After the serial to parallel conversion (S/P), the modulated data sequence x_n, Eq. (1), is multiplied by U different phase vectors to have U different output signals $\bar{x}_n$, Eq. (2).

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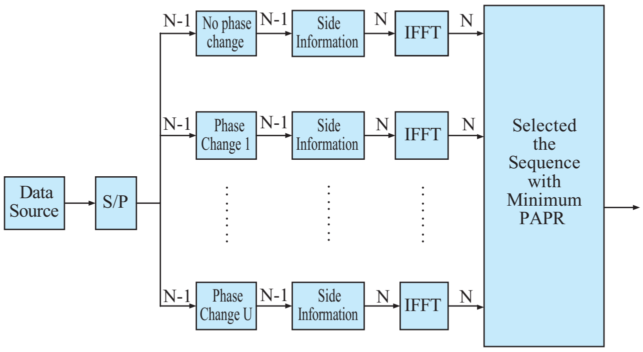

Fig. 1. The SLM PAPR reduction method.

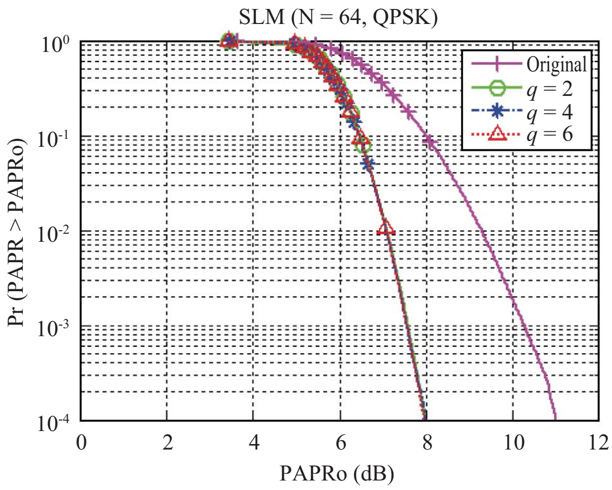

Fig. 2. PAPR reduction for different number of *q*.

$$x_n = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X_k e^{\frac{j2\pi kn}{N}}$$
$$= \frac{1}{\sqrt{N}} [X_0 e^{j2\pi\frac{0n}{N}} + X_1 e^{j2\pi\frac{1n}{N}} + \ldots + X_{N-1} e^{j2\pi\frac{(N-1)n}{N}}] \quad (1)$$

$$\bar{x}_n = \frac{1}{\sqrt{N}} [X_0 e^{j2\pi\frac{0n}{N}} e^{j\phi_1} + X_1 e^{j2\pi\frac{1n}{N}} e^{j\phi_2} + \ldots + X_{N-1} e^{j2\pi\frac{(N-1)n}{N}} e^{j\phi_N}],$$
$$\phi_j \in [0, 2\pi) \quad (2)$$

The transmitter (T_X) transmits the output signal with the lowest PAPR. In a practical implementation, the number q of the available phase shift ϕ_j is countable. Fig. 2 is a PAPR reduction results for different number of q; q = 2:{0,π}, $q = 4: \left\{0, \pi, \frac{\pi}{2}, -\frac{\pi}{2}\right\}$, $q = 6: \left\{0, \pi, \frac{\pi}{2}, -\frac{\pi}{2}, \frac{\pi}{4}, -\frac{\pi}{4}\right\}$. Results reveal that q = 2 is good enough to scramble the phase of the OFDM signal.

In addition, system can achieve a better PAPR result as the number of U increases (Fig. 3). However, the increase of

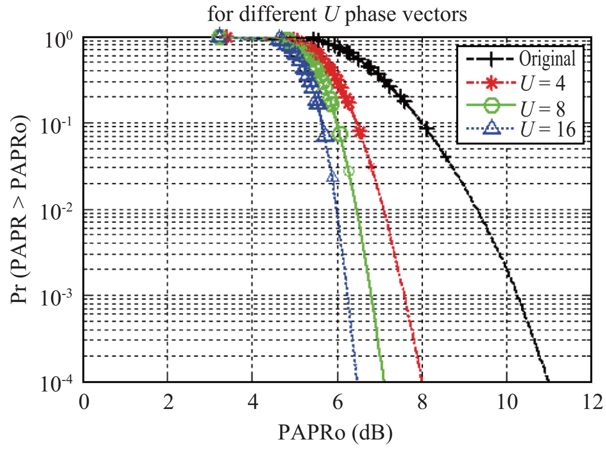

Fig. 3. PAPR reduction for different number of *U*.

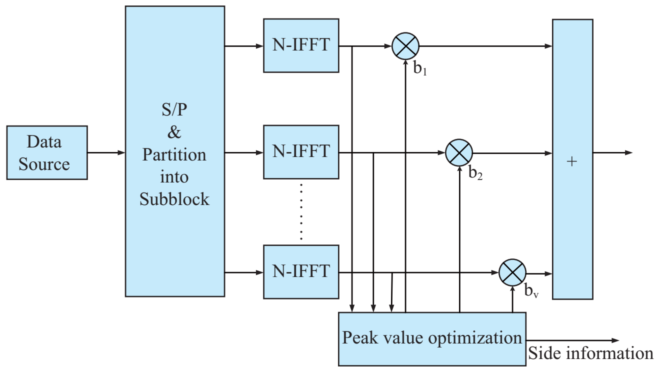

Fig. 4. The PTS PAPR reduction method.

U will reduce the system throughput because more side information bits ($\log_2^U$) are needed to be transmitted for the phase recovery at the receiver (R_X).

2. Partial Transmit Sequence (PTS) [2]

Similar as the SLM method, the PTS method achieves the PAPR reduction by scrambling the phase of the signal with different phase vectors. In Fig. 4, let the original input sequence be $X = [X_0\ X_1 \ldots X_{N-1}]$, after the S/P, partition and zero padding, input sequence can be divided into V independent sub-block $X_v = [X_0^{(v)}\ X_1^{(v)} \ldots X_{N-1}^{(v)}]$, v = 1, 2, … V. Each sub-block contains part of the input sequences. By multiplying each sub-block with different phase vector and summing up, T_X transmits the output signal with the lowest PAPR. As the number of phase vector increases, the system can achieve better PAPR improvement (Fig. 5). However, more side information bits are needed to be transmitted.

3. Dummy Sequence Insertion (DSI) Method [8]

In [8], the authors present a Dummy Sequence Insertion (DSI) method depicted in Fig. 6. The modulated data sequence x_n of length L ($L = N - M$) is duplicated into 2^M copies and inserted the M-bits dummy sequences to have the data

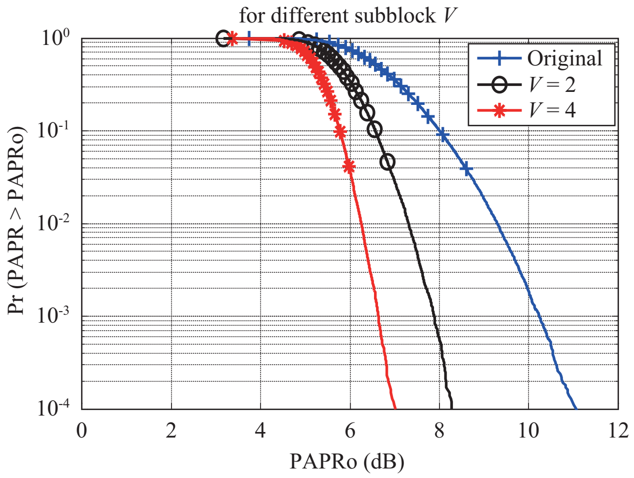

Fig. 5. PAPR reduction simulation for different *V*.

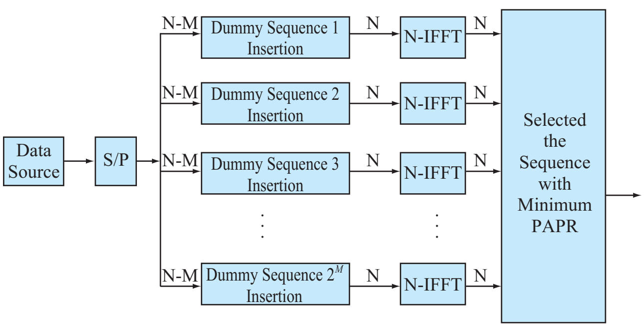

Fig. 6. The Dummy sequence insertion method.

X: IFFT Input						
Data Carriers				Dummy Sequence		
1	2	...	N-M	1	...	M

Fig. 7. Data format of the DSI method.

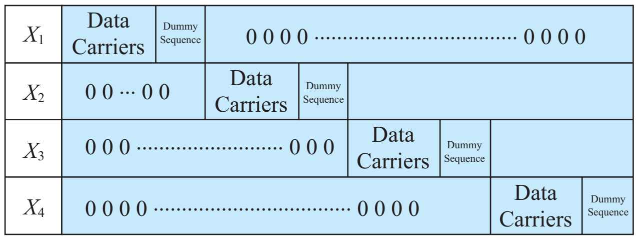

Fig. 8. Data block of PDSI method.

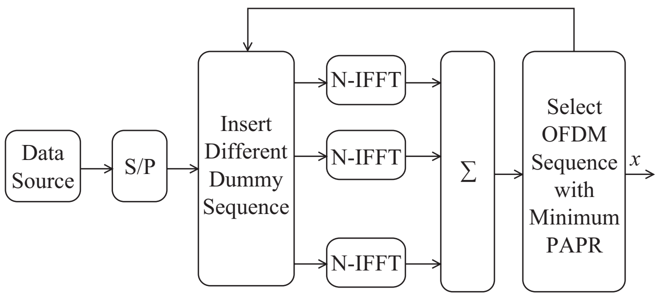

Fig. 9. The Partition dummy sequence insertion method.

format in Fig. 7. After the *N* points IFFT, the OFDM data signal with the lowest PAPR in time-domain is transmitted.

Basically, the DSI method is a modification of the SLM method. Rather than the phase multiplication of the SLM method, the DSI method reduces the PAPR via the *M*-bits dummy sequences. Each dummy sequence can be either 0 or 1. Unlike the conventional PTS and SLM, it is needless to transmit the side information and conducts the phase recovery at the R_X.

4. A Proposed Partition Dummy Sequence Insertion (PDSI) Method

The proposed Partition Dummy Sequence Insertion (PDSI) method is a combination of the DSI and the PTS methods. The procedures of the PDSI method are as follows:

After the S/P, partition and zero padding, the original N-dimension data sequence $X = [X_0\ X_1\ \ldots\ X_{N-1}]$ is partitioned into *V* disjoint N-dimension subblock $X_v = [X_0^{(v)}\ X_1^{(v)}\ \ldots\ X_{N-1}^{(v)}]$, v = 1, 2, … *V*. Each sub-block contains part of the data sequences and the inserted dummy sequence (Fig. 8).

The inserted dummy sequence can be either 0 or 1. Fig. 8 is an example if we perform the original data into 4 disjoint subblocks. Other than the data sequence and the dummy sequence, the rest of the signals are set to zero to have the length of N for each subblock.

After the IFFT of each subblock, Tx sums up the time domain waveform, calculates the PAPR and informs the partition device to test different dummy sequence combinations. The estimated PAPRs of different sequence are recorded. The sequence with the lowest PAPR is selected to be transmitted (Fig. 9).

The effect of the dummy sequence insertion at the frequency domain is to rotate a phase shift for the corresponding time domain waveform. With the phase shift, the OFDM waveform can avoid the coherent summation for different frequency components and thus reduce the PAPR.

The main difference between the DSI and the PDSI is that the PDSI method divides the information data into subblocks firstly and inserted the dummy sequence in each subblock. For the DSI method, the dummy sequences are inserted consecutively at the end of the data block. That is, PDSI method rotates the phase in each subblock rather than the whole data sequence. Therefore, it is more flexible than the compared DSI method. Resides, results in Section III demonstrates that the proposed method has a better and robust BER behavior than the DSI. The PDSI method will also reduce the system throughput because of the dummy sequence

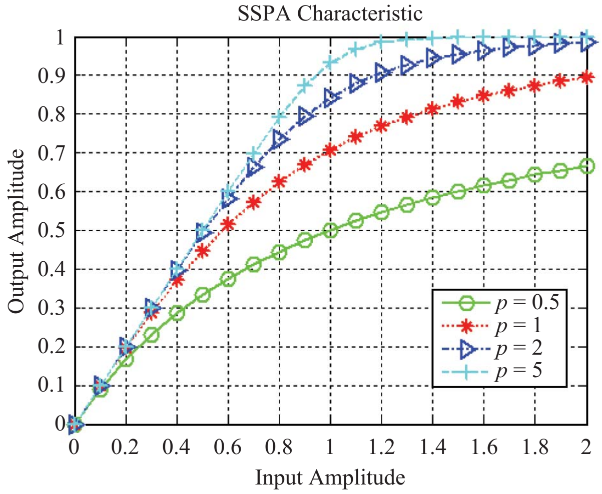

Fig. 10. AM/AM for the SSPA with different *p* (A_0 = 1).

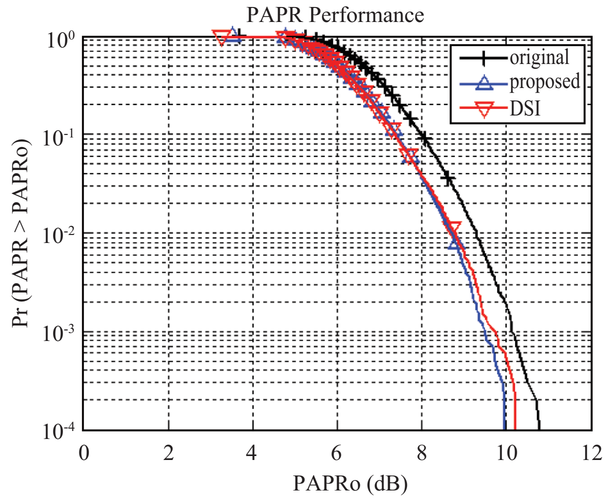

Fig. 12. PAPR performance (QPSK).

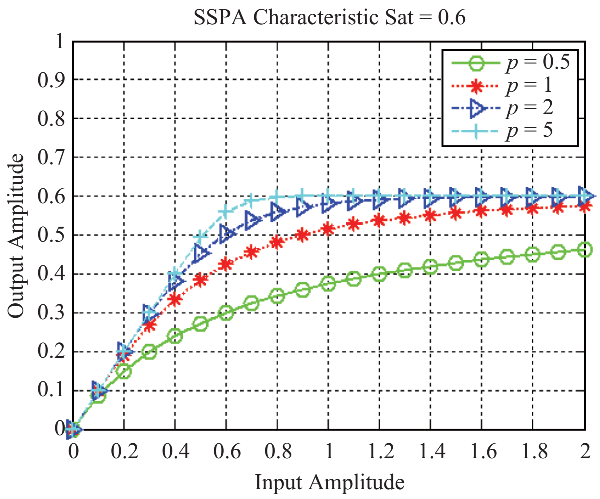

Fig. 11. AM/AM for the SSPA with different *p* (A_0 = 0.6).

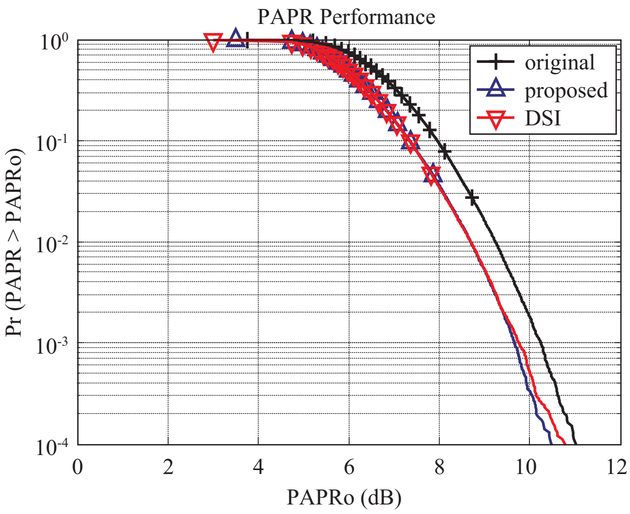

Fig. 13. PAPR performance (16 QAM).

insertion. However, this disadvantage can be eased if we insert the dummy at the unused subcarriers of a OFDM system.

III. SIMULATION RESULTS

In this section, we evaluate both the PAPR reduction and the BER performance of the DSI and the PDSI methods under the Rayleigh fading channel. The nonlinear effect of the PA is modeled by using a conventional Solid Stated PA (SSPA). The AM/AM and AM/PM conversions of the SSPA can be described in Eq. (3) and Eq. (4) respectively. The parameter p relates to the AM/AM nonlinearity, A_0 denotes the saturation point and $r(t)$ is the amplitude of the input signal. Fig. 10 and Fig. 11 show the nonlinear effects for different p and A_0.

$$\frac{AM}{AM}: A[r(t)] = \frac{r(t)}{[1+(\frac{r(t)}{A_0})^{2p}]^{1/2p}} \tag{3}$$

$$\frac{AM}{PM}: \Phi[r(t)] = 0 \tag{4}$$

1. PAPR Reduction Performance

In the PAPR simulation, we divide the 64 subcarriers into 4 subblocks, i.e., V = 4 for the PDSI. Each subblock has one subcarrier to insert the dummy sequence. To have a fair comparison, the DSI method also has 4 subcarriers to insert the dummy sequence. Fig. 12 is the PAPR simulation results for the original OFDM signal, the DSI method and the proposed PDSI method if all the symbols are QPSK modulated. Fig. 13 is another case if all symbols are 16 QAM modulated. Results reveal that both the PDSI method and the DSI method have very similar PAPR reduction capability.

2. BER Performance Evaluation

In addition to the PAPR comparison, we further compare

Table 1. Simulation parameters (IEEE 802.11a WLAN).

Modulation	QPSK, 16 QAM
Method	PDSI (V = 4), DSI (B = 4)
Number of data subcarrier	48
Number of FFT point	64
Number of sub-block	4
HPA model	SSPA (A_0 = 1, 0.6, p = 1)
Channel model	Rayleigh fading channel

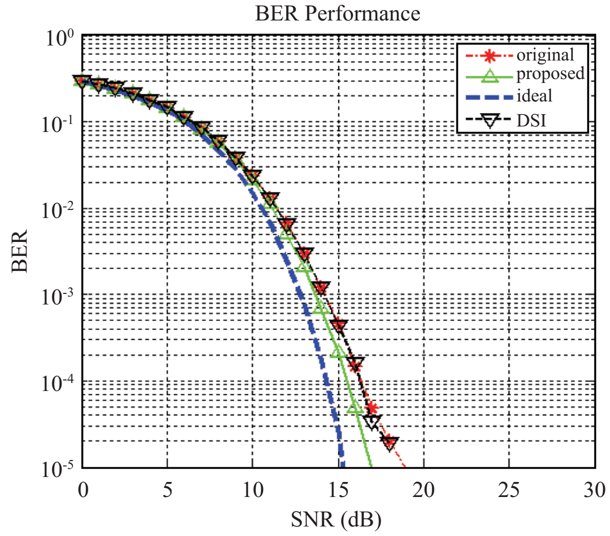

Fig. 14. BER under rayleigh fading channel (QPSK, A_0 = 1).

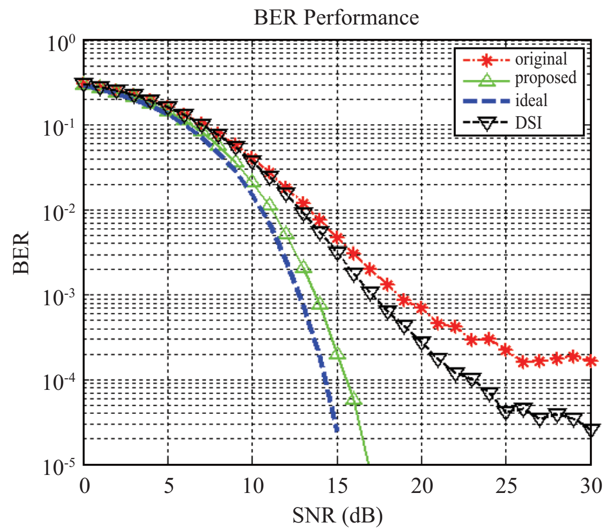

Fig. 15. Rayleigh fading channel (QPSK, A_0 = 0.6).

the BER of the PDSI method with the DSI method under the Rayleigh fading channel. R_X adopts a zero forcing (ZF) equalizer to compensate the channel fading. Table 1 lists the parameters in this simulation. All the parameters are based on the wireless local area network (WLAN) 802.11a.

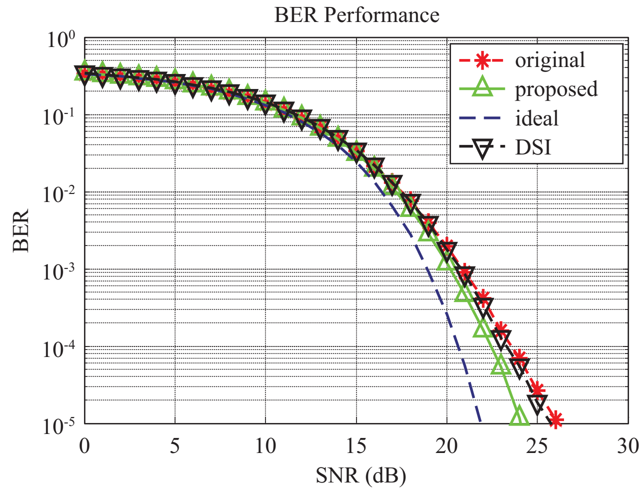

Fig. 16. Rayleigh fading channel (16 QAM, A_0 = 1).

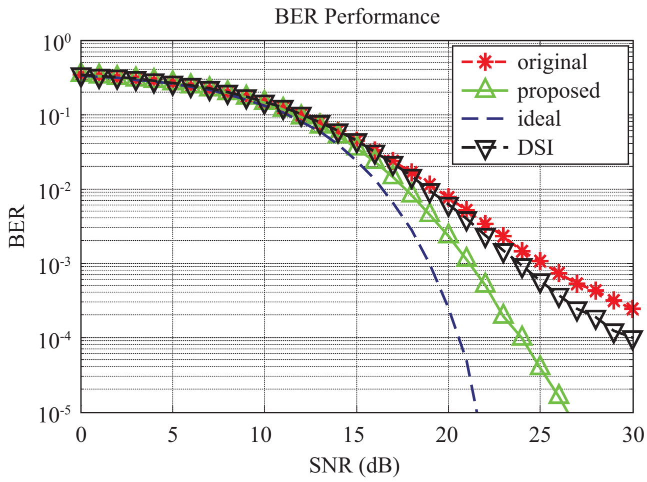

Fig. 17. Rayleigh fading channel (16 QAM, A_0 = 0.6).

Figs. 14 and 15 are the BER results for the case if we consider different saturation points for the QPSK modulated symbols. While Figs. 16 and 17 are the BER results if the symbols are 16QAM modulated. The ideal curve denotes the case when the OFDM signals do not suffer the nonlinear distortion of the PA. The original curve is the case when considering the nonlinear distortion to the ideal case. Results show that the proposed PDSI method outperforms than the DSI method. Besides, we can note that the BER performance of the proposed PDSI method is not sensitive for different saturation point A_0. However, the BER performance of the DSI method will be degraded severely when A_0 are small for the adopted PA.

IV. CONCLUSION

In this paper, a PDSI PAPR reduction method is proposed. The BER performance of the proposed method outperforms the DSI method according to the simulation results. Furthermore, the proposed method can avoid the BER degradation for different saturation point A_0. That is, the issue of choosing an appropriate PA will not affect the PAPR and BER performance significantly for the proposed method.

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