# OFDM 시스템에서 변형된 QPSK 신호 매핑 방법에 의한 PAPR 감소 효과

# PAPR reduction effects in the OFDM by the modified QPSK signal mapping method

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## 요약

OFDM 시스템에 있어서 송신 신호의 큰 PAPR는 비선형 증폭기를 통과할 때 심각한 신호 왜곡을 일으킨다. 이러한 PAPR을 감소하는 방법으로, 본 논문에서는 가장 간단한 클리핑 방법을 사용하여 시스템에 미치는 영향을 BER 특성의 기준으로 나타내고 제안된 시스템과 다른 여러 가지 시스템들을 비교하였다. 본 논문에서 제안한 방법은 QPSK 매핑후에 매핑된 신호사이에 0을 삽입하는 방법을 사용하여 동일한 PAPR 조건하에서 시스템에 미치는 영향을 비교하였다. 또한 다른 시스템들과의 BER 성능에 대한 데이터 전송률과 대역폭 관계의 trade-off가 있음을 보였다.

## Abstract

One of the important problems of OFDM system is the large PAPR of the output signal, which can result the significant signal distortion in presence of nonlinear amplifiers. To reduce the PAPR, we use fundamentally the level clipping and propose the modified mapping/demapping method for effective reducing the PAPR of the OFDM signals with level clipping. We can significantly improve the BER performance characteristics for the OFDM system. We discussed, through extensive computer simulations, the effects of level clipping and modified mapping/demapping method on the performance of OFDM system including the trade off between bandwidth expansion and BER performance and between bandwidth efficiency and BER performance.

**Key words**- OFDM, PAPR, level clipping, modified mapping/demapping

## Ⅰ. Introduction

Wireless communications is rapidly expanding, resulting in a demand for wireless system that are reliable and have a high spectral efficiency.

Orthogonal frequency division multiplexing (OFDM) is an attractive multicarrier modulation technique for high speed wireless access due to its strong immunity to multipath fading and high spectral efficiency[1].

However, one of the main disadvantages of OFDM is its high peak-to-average power ratio(PAPR). These large PAPR increase the amount of intermodulation distortion in the presence of nonlinear ampilfier resulting an increase the error rate. And OFDM signals exhibit a large PAPR which requires a highly linear amplifier. It is therefore important to reduce properly the PAPR.

There exist basically two classes of possible solutions

which are intended to reduce the PAPR. The first is based on coding and the second is based on amplitude processing such as level clipping[5-7]. Probably the simplest for the PAPR reduction is level clipping of the OFDM signal.[1-3]. However level clipping suffers from three problems: in-band distortion, which degrades the bit error rate(BER) performance, out-of-band radiation, which reduces the spectral efficiency, and peak regrowth after digital to analog conversion, which results in an increase of PAPR[4].

This paper propose the modified mapping/ demapping mathod for effective reducing the PAPR of OFDM signal with level clipping.

Computer simulation results show that the modified mapping sequence improve BER performance significantly and reduce PAPR effectively. There are two kinds of trade off. One is the trade off between bandwidth expansion and BER improvement, the other is the trade off between bandwidth efficiency and BER improvement.

This paper is organized as follows: section II introduces the OFDM signals and PAPR. In section III and setion IV, level clipping and modified mapping/demapping method are briefly discussed. Simulation results are presented in section V, and finally, section VI concludes this paper.

## II. Definitions and system description

The complex envelope of an OFDM signal with N subcarriers is given by,

$$s(t)=\sum_{n=0}^{N-1} c_n e^{j2\pi n f_0 t} \quad , \quad 0\le t\le T. \qquad (1)$$

where $f_0$ is the subchannel spacing, T is the data symbol period, and $c_n$ is the sequence after binary to complex mapping. We can assume that $f_0=1/T$. Also, for mathematical convenience, we will normalize the time axis by T and substitute $\theta=2\pi f_0 t$ to get,

$$s(\theta)=\sum_{n=0}^{N-1} c_n e^{jn\theta} \quad , \quad 0\le\theta\le 2\pi. \qquad (2)$$

Obviously, N samples per symbol is equivalent to Nyquist sampling frequency.

The envelope variations of the signal can be characterized by peak to average power ratio(PAPR) defined as [1] and [5]

$$PAPR \equiv \max_{0\le\theta\le\pi} \frac{|s(\theta)|^2}{P_{av}} \qquad (3)$$

Where $P_{av}=E\{|s(\theta)|^2\}$ is the average power of the signal. It is evident that a signal with N subcarriers and equal weight constellation exhibits a PAPR of up to N.

## III. Level clipping

Here we will consider a case when the time domain symbols $a_k=|a_k|\exp[j\varphi_k]$ are clipped in absolute v alue at a level $th$ The clipped symbol is defined according to:

$$a'_k=\begin{cases} th\cdot\exp[j\phi_k] & \text{if } |a_k|>th \\ a_k & \text{if } |a_k|\le th \end{cases} \quad k=0,1\cdot\cdot N-1 \qquad (4)$$

Such an amplitude clipped sequence is no longer orthogonal and as a consequence, the probability of error is greater than that of the non-clipped sequence $a_k$. For any N, the total probability of error for the clipped sequence is equal to

$$P_e'=P_1 P_r[\Gamma\le\gamma]+P_2 P_r[\Gamma>\gamma] \qquad (5)$$

where $\Gamma$ is PAPR of $a_k$, $\gamma=th^2/2\sigma_a^2$ and $P_1$, $P_2$ are the bit-error and $P_1=P_r[error \mid |a_k|\le th]$, $P_2=P_r[error \mid |a_k|>th]$. Note that $P_1$ denotes just the probability of error for the non-clipped case[2].

## IV. Modified mapping/demapping method

To increase the distance between signal constellation points of QPSK signal, we consider the modified signal mapping method which is zero insertion between signal mapping points. The modified mapping signal constellation for QPSK is represented in Table. 1.

Table. 1 Modified signal constellation of QPSK

| before | after |
|---|---|
| -0.70711 - 0.70711i | -0.70711 - 0.70711i |
| | 0 |
| -0.70711 + 0.70711i | -0.70711 + 0.70711i |
| | 0 |
| 0.70711 -0.70711i | 0.70711 - 0.70711i |
| | 0 |
| 0.70711 + 0.70711i | 0.70711 + 0.70711i |
| | 0 |

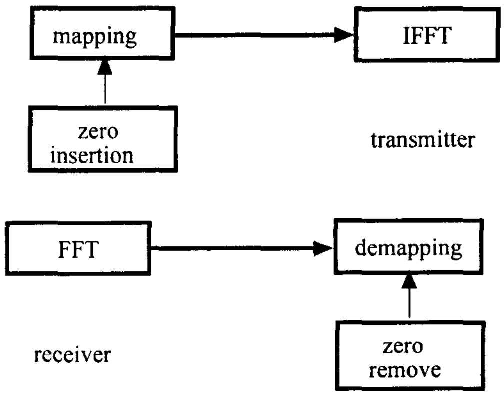


Fig. 1. Modified mapping/demapping by zero insertion/remove

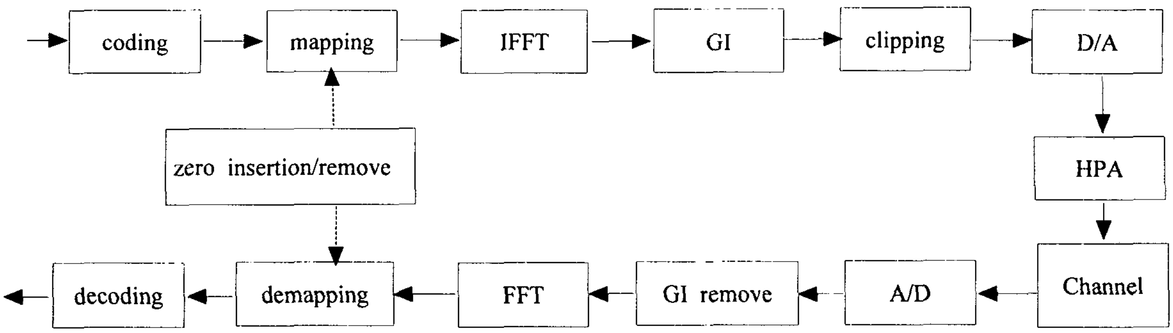


Fig. 2. Simulation model of an OFDM system

The modified signal mapping/demapping method which using the zero insertion/remove in the signal constellation showed in Fig. 1.

The modified signal constellation method improve the BER performance in AWGN and Multipath channel. Fig. 2 is the simulation model of an OFDM transmitter and receiver with level clipping.

## V. Simulation results

In order to certify the effectiveness of the propose method, the BER performance characteristics of the modified mapping are evaluated at the multipath channel of 18 path ray as in Fig. 3. The simulation results show the trade off between BW efficiency/ BW expansion and BER performance.

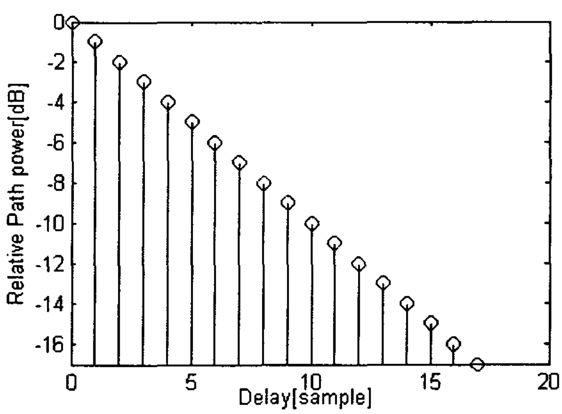


Fig. 3. Multipath channel model

### 5.1 Simulation results on the BW efficiency

Design parameters of proposed OFDM system are shown in Table. 2.

Table. 2. OFDM system parameters

| parameter | without modified block | with modified block |
|---|---|---|
| maximum delay spread | 200ns | |
| data bit rate | 20Mbps | 10Mbps |
| IFFT/FFT | 128 | |
| modulation | QPSK | |
| code rate | 1/2 | |
| BW | 40MHz | |

Fig. 4 shows the results of simulation with/without modified block in case of nonclipping in Fig. 2. The BER performance of the modified system has 4 dB improvement.

In addition to, PAPR value of without modified block system is 14.2877 dB and with modified block system is 11.2475 dB, which has more PAPR gain of 3 dB than without modified block.

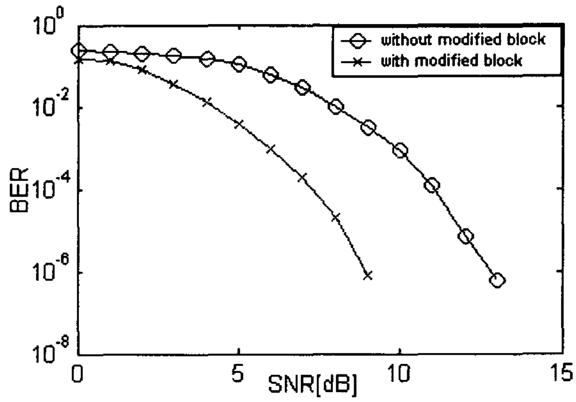


Fig. 4. BER performance without clipping block

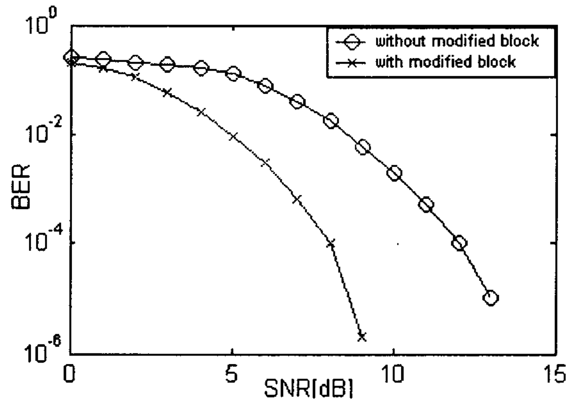


Fig. 5. BER performance with clipping block (PAPR: 3.5 dB)

Fig. 4 shows the results of simulation with/without modified block in case of clipping at the PAPR of 3.5 dB, which shows the improvement of BER performance about 4 dB.

Fig. 6 shows the compared results between Fig.4 and Fig. 5 at PAPR of 3.5 dB. This Fig. 6 exhibits that the difference width of the BER performance characteristic curves with modified block is smaller than that of without modified block.

5.2 Simulation results on the BW expansion

OFDM system parameters is shown in Table 3.

Table. 3. System parameters

| parameter | without modified block | with modified block |
|---|---|---|
| maximum delay spread | 200ns | |
| data bit rate | 10Mbps | |
| IFFT/FFT | 64 | 128 |
| modulation | QPSK | |
| code rate | 1/2 | |
| BW | 20MHz | 40MHz |

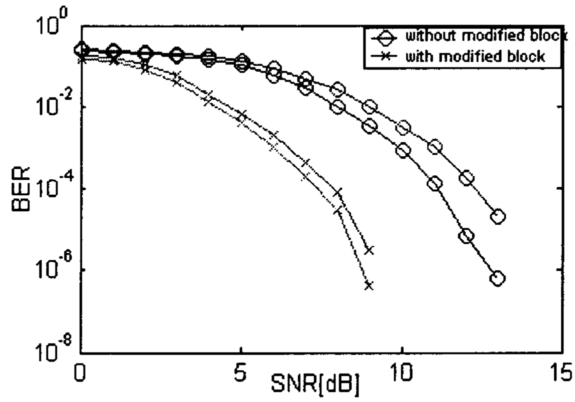


Fig. 6. BER performance with/without clipping block (PAPR: 3.5 dB)

In Fig. 7, the BER performance of the system with modified block has 3 dB improvement than without modified block. However, PAPR value is similar to each other. (system without modified block: 11.2349 dB, system with modified block: 11.2475 dB).

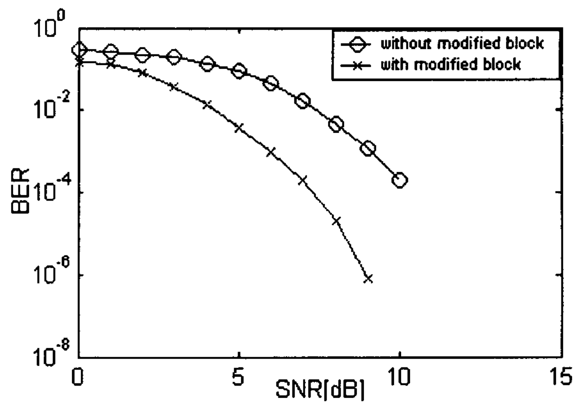


Fig. 7. BER performance without clipping block

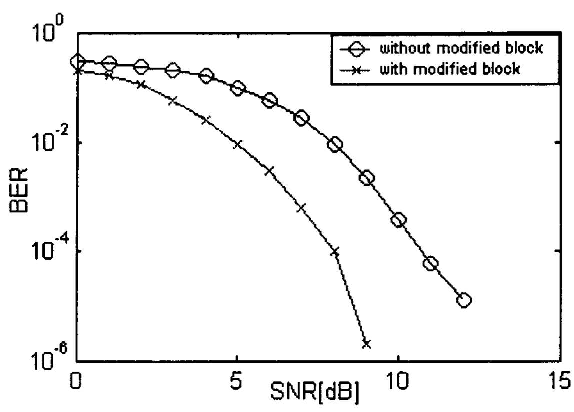


Fig. 8. BER performance with clipping block (PAPR: 3.5 dB)

Fig. 8 shows the BER performance results of the system with/without modified block at the PAPR of 3.5 dB, which shows the improvement of BER performance about 3 dB.

Fig. 9 shows the compared results between Fig. 7 and Fig. 8 at PAPR of 3.5 dB. This Fig. 8 exhibits that the difference width of the BER performance characteristic curves with modified block is smaller than that of without modified block.

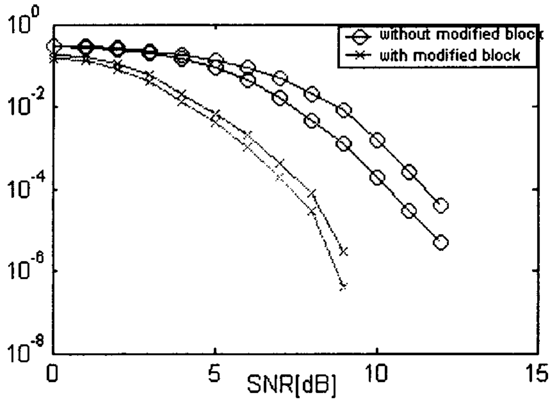


Fig. 9. BER performance with/without clipping block (PAPR: 3.5 dB)

## Ⅵ. Conclusions

In this paper, modified mapping/demapping of OFDM signals is considered. There are three issues to be addressed for the OFDM system model. One is the BER performance with modified mapping/demapping block in case of nonclipping, another is the BER performance with modified mapping/ demapping block in case of clipping and the other is the comparison of BER performance between with/without clipping at difference PAPR.

Considering the BER performance characteristics of the system with modified mapping/ demapping, it show not only the improvement of BER performance but also excellency in PAPR reduction.

Through the simulation results, we showed the trade off beween bandwidth efficiency and BER performance, also we presented the trade off between bandwidth expansion and BER performance.

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