OFDM PAPR reduction using scale down and restoration

Tao Lu, Myoung-seob Lim
Dept. of Electronics Information Engineering
Chonbuk National University

e-mail : *lutao@chonbuk.ac.kr*, *mslim@chonbuk.ac.kr*

Abstract

A novel method using scaling down and restoration to reduce the PAPR of OFDM signal is proposed. This method shows a better BER performance than clipping method. And also the throughput efficiency is better than SLM.

I. Introduction

Orthogonal Frequency Division Multiplexing (OFDM) suffers the high time-domain peak-to-average power ratio (PAPR) that limits the transmitter power efficiency.

Among the methods focusing on reducing PAPR of OFDM signals, clipping technique [1] clips off OFDM signal peaks larger than some threshold. While it introduces in-band distortion and out-of-band noise. In Selective Mapping (SLM) scheme [2],the sequence with the lowest PAPR after making the U different phase changes on the identical input data sequence is selected and transmitted. The use of side information results in some loss of throughput efficiency.

In this paper, we propose a novel approach, named scale down and restoration (SDR). The high peak OFDM signal is scaled down under some clipping thresholds. Those compressed signals are transmitted over the additional sub-carrier, which makes the proposed OFDM signal's bandwidth expanded by one sub-carrier spacing larger than the normal OFDM signal's bandwidth. At the receiver ,the compressed portion in the OFDM signal is detected by tone detector and restored to the original amplitude with the reverse operation of scale up.

II. System Model

The OFDM transmitter diagram proposed in this paper is shown in Fig.1. High peak signal above the clipping level is scaled down with fixed ratio which is known to the receiver for the restoration of the original value. An additional sub-carrier is used by the transmitter in order to send the information that indicates which signal was scaled down. The normal OFDM signal will be multiplied with carrier $\cos\omega_c t$. While the scale downed OFDM signal will be multiplied with carrier $\cos(\omega_c+\Delta\omega)t$, whose frequency deviation is sub-carrier spacing from $f_c=\omega_c/2\pi$.

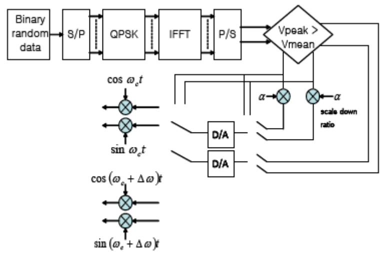

Figure 1. Block Diagram of OFDM System Transmitter

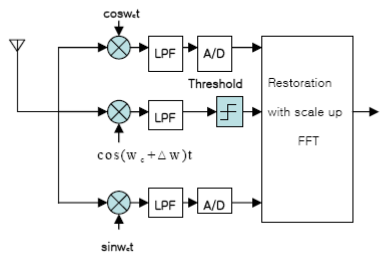

Figure 2. Tone discrimination filter detection

Fig.2 shows the block diagram of the receiver. The shifted carrier is detected at the receiver after scaling up operation for the restoration of the original signal. The transmitted signal in case of normal OFDM signal can be defined as:

$$x(t)=m_I(t)\cos 2\pi f_c t - m_Q(t)\sin 2\pi f_c t \qquad (1)$$

Where, $t=nT/N$

$$m_I(t)=\sum_{k=0}^{N-1}X_k\cos 2\pi\frac{k}{T}t \qquad m_Q(t)=\sum_{k=0}^{N-1}X_k\sin 2\pi\frac{k}{T}t \qquad (2)$$

In case of compressed OFDM signal, considering only the real part, we have normal signal:

$m_I(t)\cos 2\pi f_c t$ and the compressed signal: $m_I(t)\cos 2\pi (f_c+\Delta f)t$. Obviously that they are orthogonal with each other during time $T=1/\Delta f$. Thus we multiply carrier $2\cos 2\pi (f_c+\Delta f)t$ to received signal before throughout LPF. Consequently, the orignal signal can be restored by scaling up the compressed signal.

Ⅲ. Analysis

Note that a high value of scale down ratio will magnify the channel noise at the receiver side and thus degrade the SNR. For low scale down ratio case, clipping off some of high peak signal that is still out of the linear region of power amplifier after scaling down sacrifices the performance of BER. We analyze the BER performance and find out the optimum value.

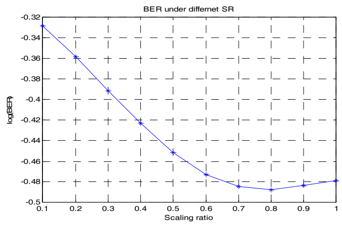

Figure 3.BER performance of different scale down ratio

Fig.3 shows the BER performance according to the variation of scale down ratio. it is shown that the optimum point is reached at approximately 0.8 with the lowest BER.

In terms of bandwidth efficiency, our proposed method requires one additional sub-carrier for the transmission of scaling down information. While SLM scheme also introduce the use of side information transmitted to receiver. To simplify the comparison, we assume N sub-carriers correspond to N data symbols and $(N+1)\Delta f$ bandwidth.

In case of SLM scheme, if β bits are used as the side information, then efficiency is $(N-\beta)/[(N+1)\Delta f]$. For our proposed method, the total bandwidth is $(N+2)\Delta f$ and efficiency will be $N/[(N+2)\Delta f]$ .Comparing the ratio of the two cases, we derive:

$$\frac{N/[(N+2)\Delta f]}{(N-\beta)/[(N+1)\Delta f]}=\frac{N(N+1)}{(N-\beta)(N+2)} \qquad (3)$$

Based on (3), we may safely conclude that, as long as β is greater than $N/(N+2)$,the efficiency of SDR will be better than SLM.

Ⅳ.Simulation Result

We set the threshold to the normalized average power of OFDM signal. QPSK and 128 sub-carriers are used throughout computer simulations.

Figure 4 shows the influence of scale down ratio on the CCDF performance of SDR method. It is clear that with the decrease of ratio, CCDF performance becomes better.When scaling ratio=0.4, it can achieve a PAPR reduction about 4dB better than original OFDM signal.

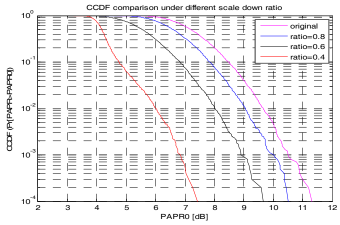

Figure 4.CCDF performance with different scaling ratio

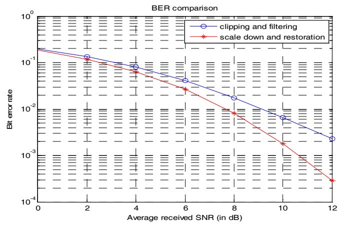

Figure 5. BER comparison

Fig.5 shows that SDR method outperforms the clipping method in terms of BER performances for AWGN channel sunder the same clipping level. This is mainly due to that our SDR method restores the original amplitude of the clipped signal.

Ⅴ.Conclusions

In this paper, a novel SDR method is presented. We analysed the influence of scale down ratio used in our model and found out the optimum value through simulation .The analysis results show that SDR has a better bandwidth efficiency compared to SLM. And also the BER performance outperforms the clipping method.

References

[1] X. D. Li, et.al “Effects of clipping and filtering on the performance of OFDM” IEEE Comm. Letters, Vol.2 ,May .1998

[2] R.W.Bauml,et.al“Reducing the peak-to-average power ratio of multicarrier modulation by selected mapping,”Elec.letters, Oct.1996.