PAPR REDUCTION IN OFDM SYSTEMS BY SIMPLIFIED CLIPPING AND FILTERING WITH BOUNDED DISTORTION

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ABSTRACT

This paper is focused in the domain of Peak to Average Power Ratio (PAPR) reduction in Orthogonal Frequency Division Multilpex (OFDM) system. The method based on simple time domain signal limitation with bounded distortion for better noise immunity is used. The performance is also evaluated in AWGN channel.

1. INTRODUCTION

Orthogonal Frequency Division Multipex (OFDM) is a multicarrier modulation method with orthogonality of individual subcarriers [1]. The use of this modulation allows to extend symbol time interval by splitting the input bit stream into N parallel streams. As a result of symbol time extension and the orthogonality, the OFDM signal is not influenced by multipath propagation and higher spectral effenciency is obtained. Data on each subcarriers are mapped according suitable constellation (M-PSK or M-QAM for example). Main drawback of OFDM is its high dynamics expressed by the Peak to Average Power Ratio (PAPR) [1] of transmitted signal $s(t)$ on time interval τ. PAPR is defined by following relationship:

$$PAPR\{s(t),\tau\} = \frac{\max\limits_{t\in\tau}[s(t)]^2}{E\{[s(t)]^2\}} \tag{1}$$

where: $\max\limits_{t\in\tau}[s(t)]^2$ is the peak signal power

$E\{[s(t)]^2\}$ is the average signal power

There are many methods for PAPR reduction. Some of these methods are distortionless methods (SLM, PTS, tone reservation), some of them introduce distortion to OFDM signal (clipping and its modifications).

Our paper is focused to PAPR reduction by simplified clipping and filtering method with bounded distortion. This method is based on simple time domain signal limitation - clipping. Clipped signal $s_c(t)$ can be expressed by followings relationship:

$$s_c(t) = \begin{cases} A.e^{j\phi(t)}, & |s(t)| > A \\ s(t), & |s(t)| \le A \end{cases} \quad (2)$$

where: $s_c(t)$ is the clipped signal

$s(t)$ is the original signal

A is the clipping level

$\phi(t)$ is the phase of $s(t)$

By this limitation, the peak values of signal are removed that results in PAPR reduction. However, the clipping introduces signal distortion resulting in adjacent channel emissions. This undesirable effect can be suppressed by lowpass filtering of clipped signal, that unfortunately further increases the PAPR.

Armstrong [2] described a method based on *K*-times repetition of the clipping and filtering process and named this method as repeated clipping and filtering. Therefore both PAPR and adjacent spectral emissions are reduced, although the PAPR reduction is far from simple clipping case. The main drawback of repeated clipping and filtering method is its high complexity. For each frequency domain filtering, two FFT calculations are necessary.

A method named simplified clipping and filtering [4] gives almost the same PAPR reduction as repeated clipping and filtering, but the complexity is significantly reduced. Only 3 FFT's are required for the PAPR reduction equivalent to iterative method using arbitrary *K*.

Finally, we have implemented into this method the block to bound distortion (BD) to ensure higher noise immunity of transmitted signal.

2. METHOD DESCRIPTION

The simple block sheme of simplified clipping and filtering method with bounded distortion (SCAFBD) is shown on the Fig.1.

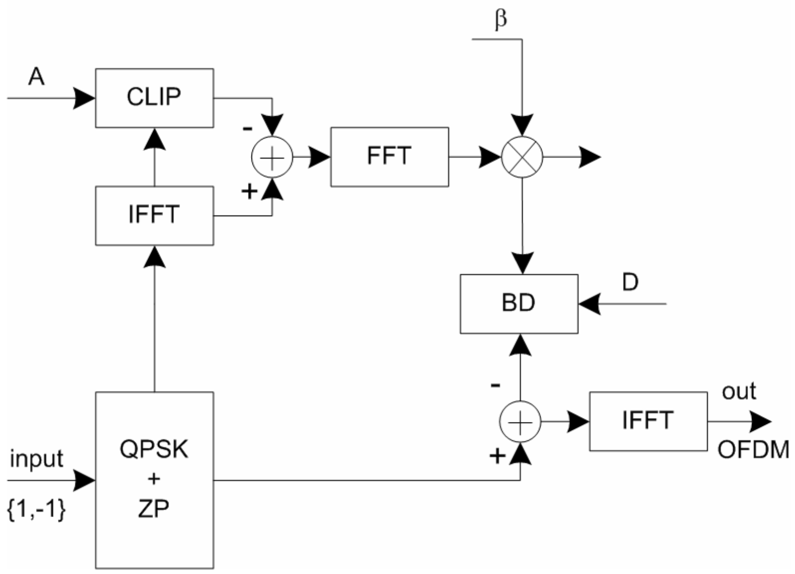

Fig. 1: Block scheme of SCAFBD.

The input dara are mapped according the selected constelation (QPSK). Then, Z zero subcarriers are inserted to zero-pad the signal. Resulting data are transformed into time domain using the IFFT. Subsequently, the signal is clipped to level A. The error signal is computed as the diference between the original and clipped signal. This error signal is transformed back into frequency domain and multiplied by the constant β, corresponding choosen number of clipping and filtering stages. The constant β is calculated according [4]. The modified error signal in the frequency domain is then passed through the block ensuring the distortion bounding (limitation of I (real) and Q (imaginary) part of the error signal separately to value D).

2.1. SIMULATION AND RESULTS

For the simulation, the OFDM signal with 64 data subcarriers modulated by the QPSK has been used. The signal is 3-times oversampled by zero-padding, normalized to 0dB in the time domain and clipped to A=3dB. The constant β is set as the equivalent to 3-times repetiton of clipping and filtering process. The distortion bound is devined using constant D=10.

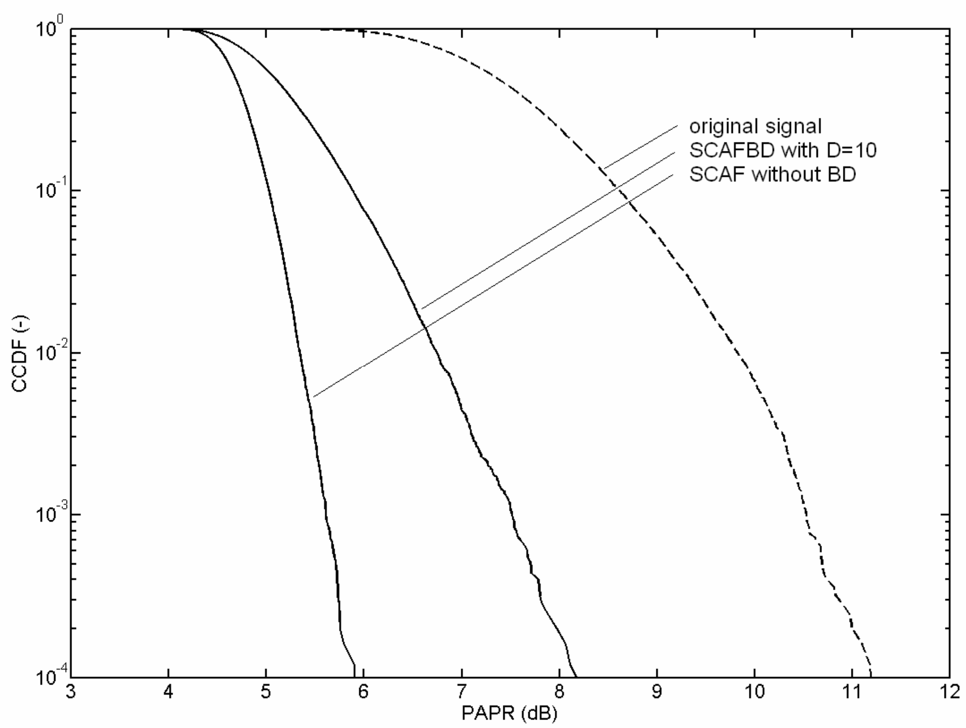

Fig. 2: CCDF functions for PAPR.

The Complementary Cumulative Distribution Function (CCDF) of PAPR is shown in Fig.2. As expected, the best PAPR reduction is achieved with the clipping with no distortion bound, at the expense of the worse bit error probability.

The constelation diagrams for above presented cases are shown on Fig. 3. It is possible to use them for visually judge the imunity of additive noise.

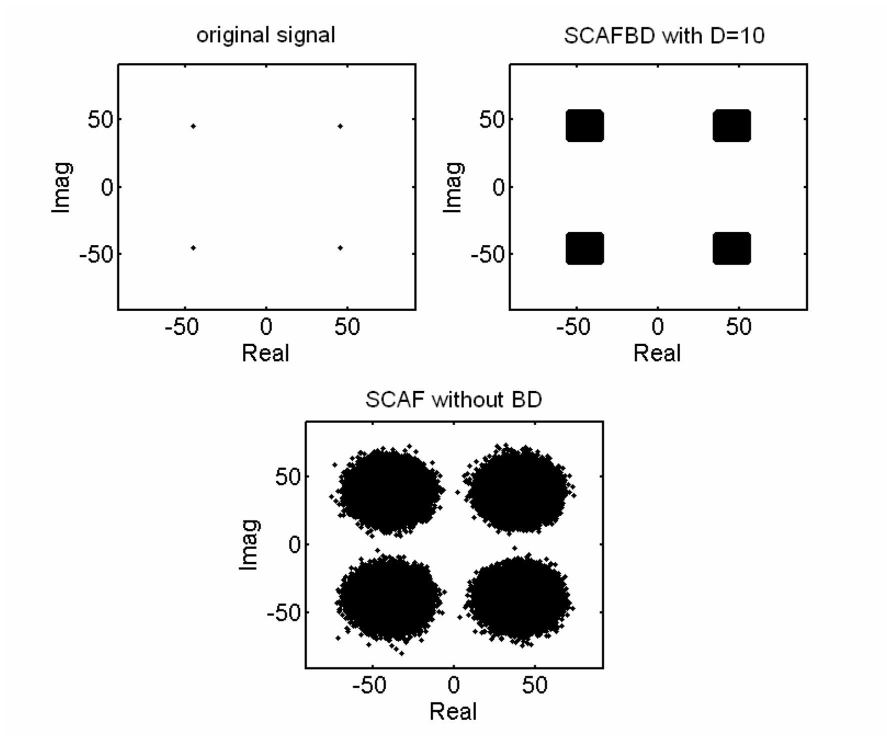

Fig. 3: Constelation diagrams.

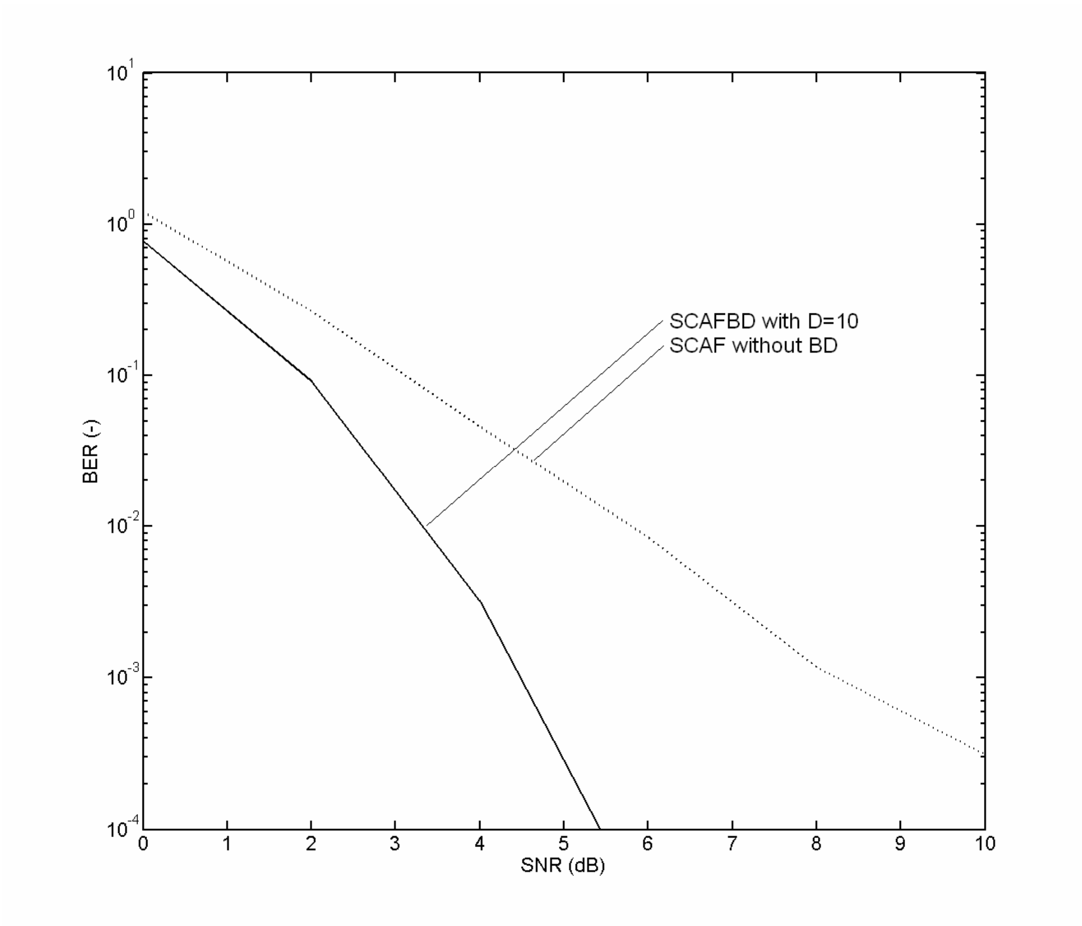

Fig. 4: BER as a function of SNR.

The Bit Error Rate (BER) as the function of Signal to Noise Ratio (SNR) is shown on the Fig. 4. As expected, the clipping and filtering method with bounded distortion results in the best BER performance.

3. CONCLUSION

In this paper, the method for PAPR reduction OFDM signal by the time domain clipping with bounded distortion has been described. This method provides good PAPR reduction and increase signal noise immunity.

ACKNOWLEDGEMENTS

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