Peak-To-Average Power Ratio Reduction In OFDM Systems By Using SLM and CDS Techniques

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Abstract- *High peak to average power ratio(PAPR) is one of the main challenges of orthogonal frequency division multiplexing (OFDM) systems. This paper proposes techniques called Selected Mapping(SLM)algorithm;and Clipping and Differential Scaling (CDS)to reduce PAPR effectively. In this technique space frequency block coded(SFBC)-OFDM system with two transmitting antennas is used. Blind detection of optimum phase sequence is used to detect the transmitted symbols at the receiver side. It is proved that, the Clipping and Differential Scaling method is superiorto SLMin reducing the complexity and increasing system performance.*

Keywords- Peak to average power ratio (PAPR), orthogonal frequency division multiplexing (OFDM), selected mapping (SLM) algorithm, space frequency block coded (SFBC)-OFDM system, Clipping and Differential Scaling(CDS).

I. INTRODUCTION

OFDM supports high data-rate transmission [1], [2]. It is currently being implemented in some of the newest and most advanced communication standards like WLAN IEEE 802.11, WiMAX, IEEE 802.16 and 4G. Unlike single carrier schemes, OFDM uses multiple orthogonal subcarriers. Superimposition of these sub-carriers to form the OFDM signal results in high PAPR which drives the transmit power amplifier (TPA) into saturation. In the saturation region nonlinearities are introduced into the signal. The signal is distorted and efficiency is reduced. Therefore, PAPR reduction is inevitable for reliable transmission. A number of techniques have been proposed to reduce the PAPR,like clipping [3], companding [4], [5] selective mapping(SLM)[6], [7] partial transmit sequences (PTS) [8], [9], tone reservation [10] etc. However, there are some limitations with these techniques. Significant PAPR reduction can be achieved with SLM and Clipping. But both the techniques introduce significant distortion, which results in increased BER. On the contrary, SLM without side index scheme do not degrade the BER performance much. However this scheme requires excessive amount of IFFT calculations and therefore the complexity associated is very large. In this paper, a simple PAPR reduction technique based on Clipping and Differential Scaling method is proposed. First the amplitudes are clipped and confined in a certain amplitude range. Thereafter, the amplitudes of the signal are scaled in a way to reduce the PAPR. The threshold values are determined for clipping and scaling using Monte Carlo simulations and by using these values, PAPR and BER for the proposed technique and SLM without side information are obtained. Finally SLM and CDS are compared with respect to complexity, BER and PAPR.

The rest of the paper is organized as follows. Section-II describes the system model and in Section-III, details of the existing SLM without side index and the proposed CDSare presented. In Section-IV, simulation results of the proposed technique are presented and concluded in Section-V.

II. SYSTEM MODEL

Orthogonal frequency division multiplexing (OFDM) is a well-known technique for transmission of high rate data over broadband frequency – selective channels [5]. One of the drawbacks of OFDM systems is high – peak – to – average power ratio (PAPR), which leads to the saturation of the high – power amplifier. Thus, a high dynamic – range amplifier isrequired, which increases the cost of the system. The frequency – domain symbols of an OFDM frame is denoted by

$$X = [X(0), X(1), ...X(N_C - 1)]^T \text{.................(1)}$$

where N_C number of subcarriers. It is assumed that X (k) ϵ C where C is the set constellation points of the signal. This vector

$X = [x(0), x(1), ...x(N-1)]^T$ Contains the time - domain samples of the complex baseband OFDM signal as given by

$$x(n) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N_C-1} X(k) e^{j2\pi nk/N} \text{....................(2)}$$

Where $j = \sqrt{-1}$ and N/N_C is the oversampling ratio. It is clear that x = IFFTN{X} where IFFTN {} is N – point inverse fast Fourier transform (IFFT) operation.

The PAPR of the OFDM frame is defined by

$$PAPR(x) = \frac{\max\{|x(n)|^2\}}{E\{|x(n)|^2\}} \quad ....(3)$$

Where $E\{\cdot\}$ is mathematical expectation according to Equation (1). The time domain samples are the sum of Nc independent terms. When Nc is large, based on the central limit theorem, the time – domain samples have a Gaussian distribution; thus, they may have large amplitudes [7].To overcome this problem , some algorithms have been proposed which reduce the PAPR of the baseband OFDM signal [7] –[12]. Some of these methods need side information (SI) to be transmitted to the receiver, such as partial transmit sequence [7],[8] and selected mapping (SLM) [9] – [11].Using several transmitter antennas, as in fig(1), one can improve the data rate or bit error rate (BER) of wireless systems. In spatial multiplexing systems, independent symbols are transmitted from several antennas, and this leads to the increase in data rate. A simplified SLM method has been introduced for PAPR reduction of spatially multiplexed OFDM systems. If spatial diversity techniques are used in wireless systems with several transmitter antennas, the BER can be reduced. The space-time codes to achieve the full transmission diversity have been introduced in [6]. Through a combination of spatial diversity and OFDM techniques, a higher capacity can be achieved over broadband multipath fading wireless channels. The two possible combinations of spatial diversity and OFDM techniques are space-time-block-coded (STBC) OFDM and space-frequency-block- coded (SFBC) OFDM systems. Both combinations suffer from high- PAPR problem. In [13], PAPR reduction in SFBC-OFDM systems with two transmitter antennas and an iterative method has been proposed to compensate for the effect of clipping the noise at the receiver.

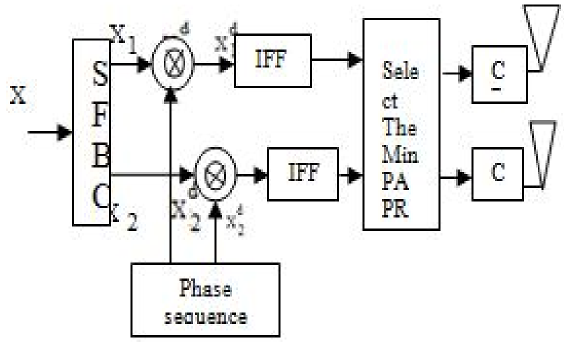

Fig1: Block diagram of the SFBC-OFDM transmitter withtwo transmitter antennas and the SLM method for PAPR reduction.

3.1 SELECTED MAPPING WITHOUT SIDE INDEX:-

The SLM technique was first described by Bauml *et al.* In the SLM, the input data sequences are multiplied by each of the phase sequences to generate alternative input symbol sequences. Every alternative input data sequences is made by the IFFT operation, and then the one of the lowest PAPR is selected for transmission..*X* is the OFDM data block, *u* are the phase and the modified data vectors. Then the time domain signal is

$$X_u(t) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X_k B_u e^{j2\pi k\Delta ft}, 0 \le t \le NT$$

Where u=1, 2,...*u* and is length of *X* and also the number of sub-carriers *N*.Among the modified data blocks, the one with the lowest PAPR is selected for transmission. The amount of PAPR reduction for SLM depends on the number of phase sequences U and the design of the phase sequences.

3.2CLIPPING AND DIFFERENTIAL SCALING

Now, the CDS technique called Clipping and Differential Scaling is proposed. The probability distribution of amplitudes of the OFDM signal follows Rayleigh distribution and thus the probability of high peaks is very less. An upper threshold above which the signal amplitudes do not contribute much to the signal is determined as follows. Using simulations, BER for the modified signals along with PAPRare determined.The clipping threshold is selected at which the BER is degraded from1.5×10^{-3} to 3.5×10^{-3}at SNR of10dB and the amplitudes above this clipping threshold are clipped.

Instead of clipping the signal further to reduce the PAPR, a reversible process Differential Scalingis considered which would reduce the PAPR but not deteriorate the BER. Since different ranges of amplitudes of the signal are scaled in a different manner,it is called Differential Scaling. Three types of scaling is considered as described below. The incoming data bits are mapped onto the constellation plane for the corresponding M-PSK or M-QAM scheme and complex symbols are generated. These symbols are to be transmitted independently on to the sub-carriers. To achieve this, they are fed parallel to the input of the N-point IFFT. They represent the frequency domain data set. Inverse Fourier transform converts this frequency domain data set into its corresponding time domain representation. Specifically, IFFT is useful for OFDM because it generates samples of waveforms with orthogonal frequency components. PAPR reduction is applied at the output of the IFFT block and the OFDM symbols are then transmitted over the channel with energy per bit as E_b. The channel considered here is an Additive White Gaussian Noise (AWGN) channel with mean zero and variance N_o. At the receiver the inverse PAPR reduction technique is applied and FFT block is used to get the frequency domain data set from the time domain values. The signal in frequency domain represents the data symbols which were mapped to M-PSK or M-QAM. After parallel to serial conversion, these symbols are used to estimate the original data values. Let N denote the number of subcarriers used for the parallel information transmission and let S_k $(0 \leq k \leq N - 1)$ denoted the k^{th} mapped symbol in a block of N information symbols. The outputs of the N- point IFFT of S_k are OFDM signal samples over one symbol interval, or mathematically where X_p is the amplitude peak value occurring in an OFDM symbol block, α is the factor that decides the clipping threshold in terms of percentage of the peak value and β is the scaling factor for the range [0, A) whose value is greater than one. The values of the parameters used are mentioned at the end of this section.

3.3SCALE-DOWN:

In this method, the higher amplitudes of the signal are scaled down by a factor of γ. This leads to decrease the peak value. Although the average value would also degrade, the resulting PAPR reduces, because the reduction in peak power is greater than the reduction in the average power. Then the PAPR reduction function can be defined as

$$h(x) = \alpha x_p, \text{ if } x > \alpha x_p$$
$$= \gamma x \text{ if } B \leq x \leq \alpha x_p$$
$$= x \text{ if } x < B$$

Where x_p is the amplitude peak value that occurring in an OFDM symbol block, α is the factor that deciding the clipping threshold in terms of percentage of the peak value and γ is the scaling actor for the range [β,αx_p]whose value is less than unity.

3.4 SCALE-UP:

In this method, lower amplitudes of the signal are scaled up by a factor of β. This leads to increase the average value without affecting the peak value, therefore the resulting PAPR reduces. The PAPR reduction function can be defined as

$$h(x) = \alpha x_p, \text{ if } x > \alpha x_p$$
$$= \beta \text{ if } x>A$$
$$= x \text{ if } A \leq x \leq \alpha x_p$$

3.5 SCALE-UPAND DOWN:

In this method, both the above-mentioned approaches are combined. This method exploits the advantages of both the methods. Hence, PAPR can be reduced considerably. The PAPR reduction function can be defined as

$$h(x) = \alpha x_p, \text{ if } x > \alpha x_p$$
$$= \gamma x \text{ if } B \leq x \leq \alpha x_p$$
$$= \beta x \text{ if } x < A$$
$$= x \text{ if } A \leq x \leq B$$

Where x_p is the amplitude peak value occurring in an OFDM symbol block, α is the factor thatis deciding the clipping threshold in terms of percentage of the peak value. β is the scaling factor for the range [0, A) and γ is the scaling factor for the range[B , αx_p].

IV. SIMULATION RESULTS

In this section, simulation results for the proposed techniques are presented. The simulation is based on the system model in Fig. 3. PAPR reduction is achieved by clipping and there-after scaling the signal based on this algorithm. This signal is also generated depending on whether the signal value has been scaled or not. N = 4 and QPSK constellation are considered. The average SNR per bit is shown As E_b /No in dB.the BER performance and PAPR performance by means of complementary cumulative distribution function (CCDF) on values of the signal PAPR are shown. The CCDF describes the probability that a real-valued random variable X with a given probability distribution will be found at a value greater than x i.e. P [X > x]. The CCDFs in Fig. 1 and Fig. 4 indicate the probabilities of signal PAPR occurring above certain thresholds. Fig. 4 shows the CCDF with Scale up, Scale down and Scale up-down techniques. The performance without PAPR reduction technique is also shown. It can be seen that all the three techniques significantly reduce the PAPR and the best PAPR reduction is achieved by Scale up-down technique as expected.Fig.4 shows the BER with Scale up, Scale down and Scale up-down.

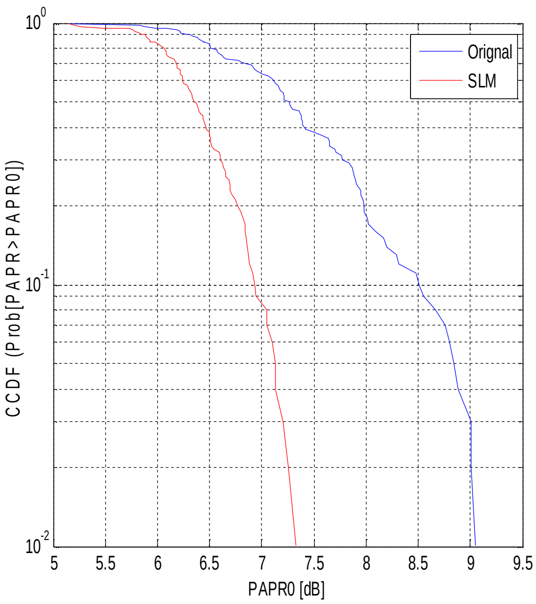

Fig 2: Original, SLM

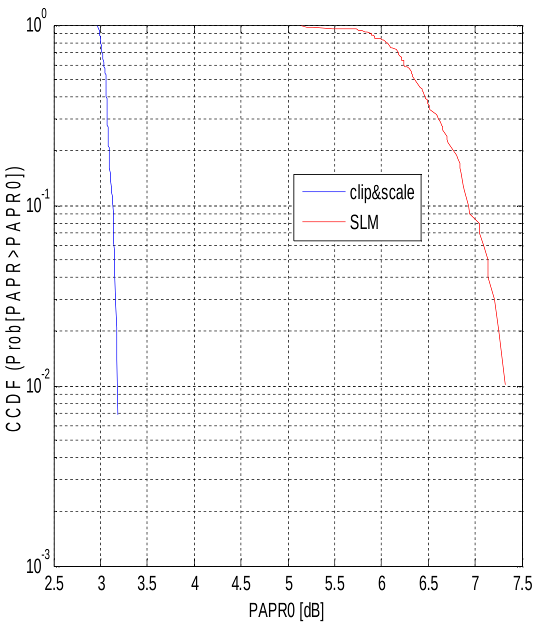

Fig3: Clip & scale, SLM

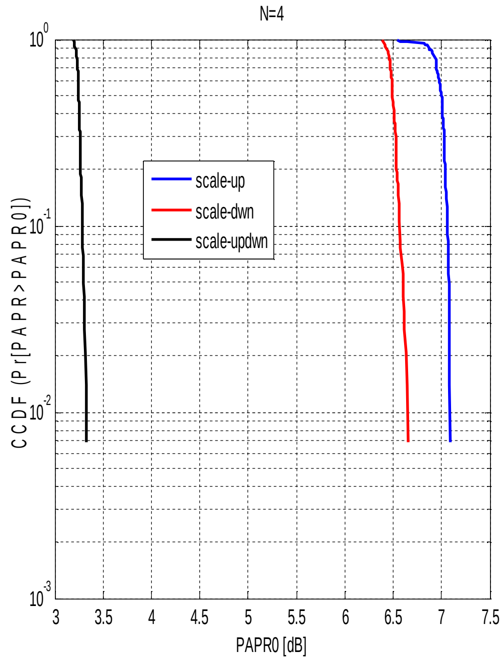

Fig 4: Scale-up, scale-down, scale-up-down

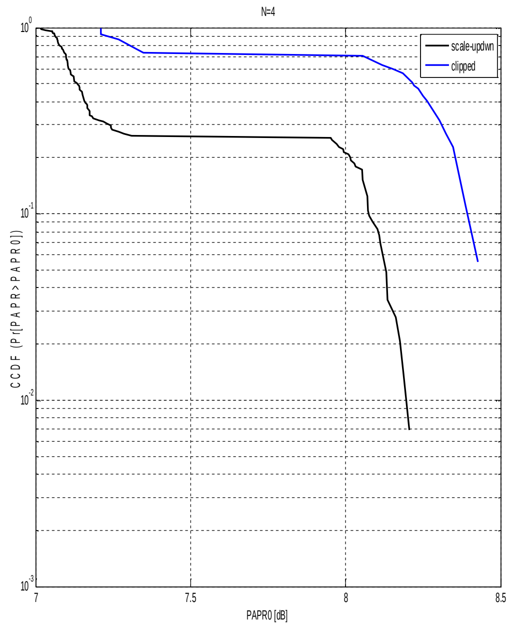

Fig5: Scale up-down, clipped

V. CONCLUSION

In this paper, an approach based on Clipping and Differential Scaling to reduce the PAPR of OFDM signals is proposed. The Clipping is done by using three different scaling methods, namely up-scaling, down-scaling, up-down scaling. By using MATLAB simulations, the values of threshold for clipping and parameters for scaling with a view to reduce PAPR without degradation in BER are obtained. The PAPR and BER performance for all the techniques considered are presented. The proposed up-down scaling technique is able to achieve PAPR reduction of the order of 8.5dB from 12dB PAPR initially. The proposed technique is able to achieve a PAPR of 3.5dB while maintaining the BER within a margin of 3 times the BER value at the performance bound at an SNR of 10dB. PAPR and BER of the up-down scaling with the existing SLM without side index techniques are also compared.

REFERENCES

[1] Y. Wu and W. Y. Zou, "Orthogonal frequency division multiplexing a multi-carrier modulation scheme," IEEE Transactions on Consumer Electron, Aug. 1995

[2] R. V. Nee and R. Prasad, "OFDM for Wireless Multimedia Communications," Artech House, 2000.

[3] A. Jha, Md. Tariq Hasan, and S.M., Reduction of PAPR in OFDM: A novel approach based on clipping and amplification," IEEE Computer Society, 2009.

[4] T. Jiang and G. Zhu, "Nonlinear companding transform for reducing speak-to-average power ratio of OFDM signals," IEEE Transactions on Broadcasting, Sept. 2004.

[5] T. Hwang, C. Yang, G. Wu, S. Li, and G. Y. Lee, "OFDM and its wireless application: A survey," *IEEE Trans. Veh. Technol.*, vol. 58, no. 4, pp. 1673–1694, May 2009.

[6] D. Brilliance, *Time Series Data Analysis and Theory*. Philadelphia, PA: SIAM, 2001.

[7] S. H. Müller and J. B. Huber, "OFDM with reduced peak-to-average power ratio by optimum combination of partial transmit sequences, "*Electron. Lett.*, vol. 33, no. 5, pp. 368–369, Feb. 1997.

[8] G. Lu, P. Wu, and C. Carlemalm-Logothetis, "Peak-to-average powerratio reduction in OFDM based on transformation of partial transmitsequences," *Electron.Lett.*, vol. 42, no. 2, pp. 105–106,Jan. 2006.

[9] R. W. Bauml, R. F. H. Fischer, and J. B. Huber, "Reducing the peak-to-average power ratio of multicarrier modulation by selected mapping, "*Electron.Lett.*, vol. 32, no. 22, pp. 2056–2057, Oct. 1996

[10] S.-J. Kim, E. Dall'Anese, and G. Giannakis, "Cooperative spectrum sensing For cognitive radios using krigedKalman filtering." *IEEE J. Sel. Topics Signal Process.*, vol. 5, no.1, pp. 24–36, Feb. 2011.

[11] T. Hwang, C. Yang, G. Wu, S. Li, and G. Y. Lee, "OFDM and its wireless Application: A survey," *IEEE Trans. Veh. Technol.*, vol. 58, no. 4, pp. 1673–1694, May 2009.

[12] D. Brillinger, *Time Series Data Analysis and Theory*. Philadelphia, PA: SIAM, 2001.

[13] N. Chen and G. T. Zhou, "Peak-to-average power ratio reduction inOFDM with blind selected pilot tone modulation," *IEEE Trans. WirelessCommun.*, vol. 5, no. 8, pp. 2210–2216, Aug. 2006.

[14] S.-H. Wang and C.-P.Li, "A low-complexity PAPR reduction scheme for SFBC MIMO-OFDM systems," *IEEE Signal Process.Lett.*vol. 16, no. 11, pp. 941–944, Nov. 2009

[15] T. Jiang and X. Li, "Using fountain codes to control the peak-to-average power ratio of OFDM signals," *IEEE Trans. Veh. Technol.*, vol. 59, no. 8, pp. 3779–3785, Oct. 2010