Comparison of Different PAPR Reduction Schemes in OFDM System

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Abstract - *Orthogonal frequency division multiplexing (OFDM) is a frightfully organized multicarrier modulation techniques for high speed data transmission over a multipath channel. Grater peak-to-average power ratio (PAPR) is one of the main disadvantage of OFDM scheme. Different techniques are there to reduce PAPR of OFDM. In this paper, clipping and filtering, selective mapping (SLM), partial transmit sequence (PTS) techniques are implemented for PAPR reduction in OFDM signal at transmitter. Also, compared of these techniques based on CCDF of system.*

Key Words: **Orthogonal frequency division multiplexing (OFDM), Peak-to-average power ratio (PAPR), Selective mapping (SLM), Partial transmit sequence (PTS), Complementary cumulative distribution function (CCDF).**

1. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) [3] has advantages like multiuser diversity and robustness against frequency-selective fading. Due to these advantages like multiuser diversity and robustness against frequency-selective fading, OFDM technique has been widely used in many wireless communication systems, such as Wireless Local Area Networks (WLAN), Wireless Metropolitan Area Networks (WMAN) and Digital Audio Broadcasting (DAB) [1-2]. OFDM system has disadvantage. The OFDM signal is generated from the linear addition of independently modulated subcarriers. Grater amplitude peaks occur when the number of subcarriers is more which results in large Peak-to-Average Power Ratio (PAPR) [4]. Generally the OFDM signal is passed through a non-linear power amplifier before its transmission over the channel. Due to these high PAPR value introduces adjacent channel interference.

In this paper, Different PAPR reduction techniques are used for PAPR reduction in OFDM system [5]. Clipping and filtering method, selective mapping (SLM), and partial transmit sequence (PTS) [6-8] .The PAPR reduction is assess using CCDF plots and compared its performance. This paper is organized as follows. Section II about the OFDM system model and the PAPR. In section III, the PAPR reduction techniques are explained. In section IV, Simulation results are explained. Finally, conclusions are explained in section V.

2. OFDM MODEL AND PAPR

Fig.l shows the basic block diagram of OFDM system .The input data sequences (X) are passes through serial to parallel convertor.

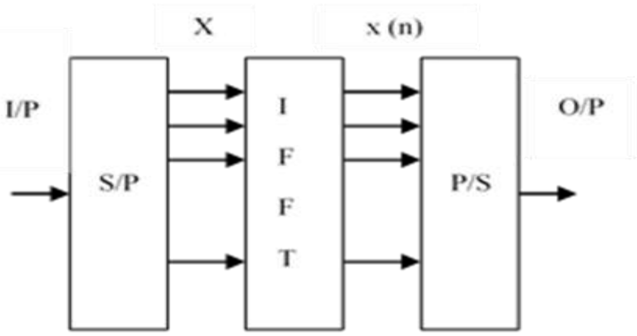

Fig.1: Basic Block Diagram of OFDM System

It converts input sequence in to parallel complex symbols of size 'N' i.e. $X=[X_0, X_1, \ldots X_{N-1}]^T$, where 'N' is total number of sub carriers used for parallel transmission then do IFFT for all the symbols. In discrete time domain, OFDM signal x (n) with N sub carriers can be expressed as

$$x(n) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X_k \, e^{\frac{j2\pi kn}{N}} \quad n = 0,1,2, \ldots N-1 \qquad (1)$$

Where, X_k = kth QPSK or 16PSK or 16QAM modulated data symbol in frequency domain and N= number of sub carriers. From (1) it can understand that N modulated data symbols are summed up to give one time domain sample of OFDM signal, as a consequence some samples of OFDM signal [1] would have large peaks at some instances. These samples would give more instantaneous power than average power. Normally this can be measured as PAPR of the OFDM signal, and it can be expressed as

$$PAPR[x(n)] = \frac{\max_{0 \le n \le N-1} |x(n)|^2}{E[|x(n)|^2]} \qquad (2)$$

Where E $[|x(n)|^2]$ denotes average power of OFDM symbol. The complementary cumulative distribution function (CCDF) of the PAPR is one of the most frequently used performance measures for PAPR reduction techniques.it is the probability that the PAPR exceeds a certain threshold $PAPR_0$. Where, $PAPR_0$ denote threshold value of PAPR.

CCDF (PAPR(x (n))) =Pr [PAPR(x (n)) > $PAPR_0$]

Pr [PAPR(x (n)) > $PAPR_0$] =1-$(1 - e^{-PAPR_0})^N$ (3)

3. PAPR REDUCTION TECHNIQUES

3.1 Clipping and filtering

Clipping and filtering is the simplest techniques to reduce PAPR among all these available techniques, in which OFDM signals are clipped to a predefined level and then passed through a filter to reduce the out-of-band radiation. By increase in spectral radiation, clipping operation reduce the PAPR. The spectral radiation is reduced by filtering operation with moderate increase in PAPR. The noise introduced because of clipping and spectral growth owing by filtering operation can be reduced by repeating the clipping and filtering operation. The L-times oversampled discrete-time signal x` [m] is produced due to IFFT operation. Then it is modulated with carrier frequency f_c to get a pass band signal x^p [m]. The clipped version of signal x^p[m] is expressed as x_c^p [m] given in equation (4).

$$x_c^p[m] = \begin{cases} -A & xp[m] \le -A \\ xp[m] & |xp[m]| < A \\ A & xp[m] \ge A \end{cases} \quad (4)$$

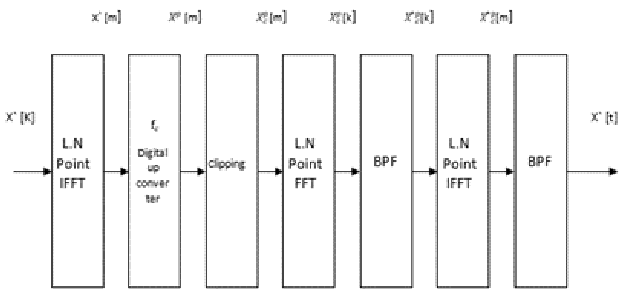

Fig. 2: Block Diagram of clipping and filtering

PAPR obtained is also depends upon clipping ratio (CR) which is defined as the ratio of clipping level normalized to the RMS value σ of OFDM signal given in equation (5).

$$CR = \frac{A}{\sigma} \quad (5)$$

3.2 Selective mapping(SLM)

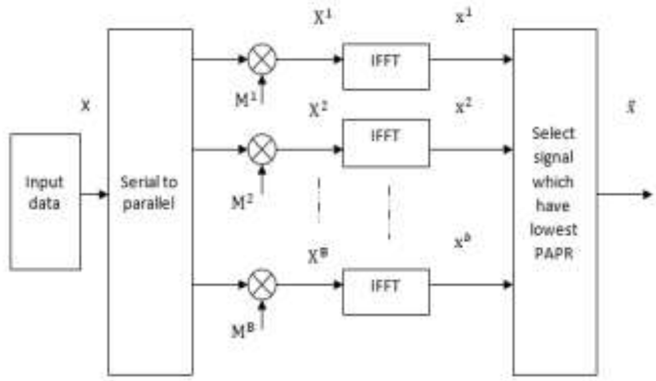

Fig. 3: Block diagram of SLM technique

In SLM method statistically independent alternative OFDM symbols are generated from the same OFDM symbol. These alternative OFDM symbols are generated by multiplying the N modulated data symbols with B different phase vectors component wise and then input to the IFFT blocks of block size N. Alternative OFDM signals are generated as

$$x^b = \text{IFFT}(X^b) \quad 1 \le b \le B \quad (6)$$

Finally, OFDM signal which has lowest PAPR is selected among x^b alternative signals and then transmitted. Choosing a phase sequence set is a crucial aspect in SLM method because of OFDM signal is periodic but alternative sequence obtained by multiplying less correlated sequence could be aperiodic. The phase sequence vectors are generated randomly from $\{\pm 1, \pm j\}$ possess a good correlation properties. But the four elements $\{\pm 1, \pm j\}$ can generate 4^N possible combinations of phase sequence vectors needs $\log_2 4^N$ bits per OFDM symbol as side information (SI), which results in high data rate loss.

In rows of Riemann matrix are taken as phase sequence set. This phase sequence set changes power of some modulated data symbols it increases average power of alternative frequency domain OFDM signal. This phase sequences reduces PAPR significantly compare to all other phase sequence set.

3.2 partial transmit sequence (PTS)

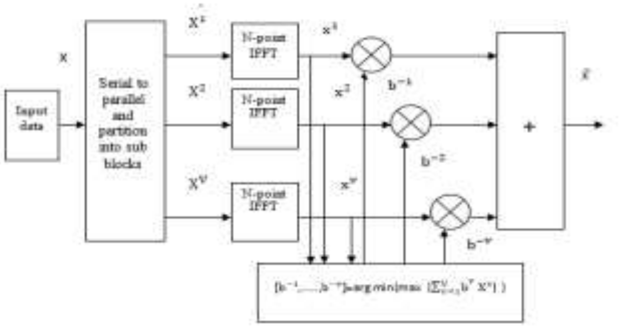

Fig. 4: Block diagram of PTS technique.

Fig (4) is the block diagram of Partial Transmit Sequence(PTS) in which input data block of 'N' symbols are divided in to 'V' number of sub-blocks i.e. V=1,2,4,8, and 16.As X=[X^1, X^2, ... , X^{v-1}]^T .Where X^{i} s are equal size sub blocks, Then IFFT is taken for all the sub-blocks

$$x=IFFT\{\sum_{v=1}^{V} b^{v}X^{v}\}=\sum_{v=1}^{V} b^{v}IFFT\{X^{v}\} \quad (7)$$

Then each sub block is multiplied with complex phase vector $b^v = e^{j\varphi v}$, v =1, 2, ...V. The phase vector should be properly selected in order to get minimum PAPR

$$[b^{-1},.....,b^{-V}]=\arg\ \min(\max|\sum_{v=1}^{V} b^{v}X^{v}|) \quad (8)$$

Then time-domain signal with minimum PAPR vector can be written as $\overline{x}=\sum_{v=1}^{V} b^{-v}X^{v}$ PAPR reduction is good when number of sub-block increases from v=l, 2, 4, 8, and 16.

4. RESULTS AND DISCUSSION

Fig. 4 to Fig. 8 shows the graph for the complement cumulative distribution function (CCDF) of PAPR in original, clipping and filtering, SLM and PTS techniques. Different PAPR reduction techniques are used for PAPR reduction

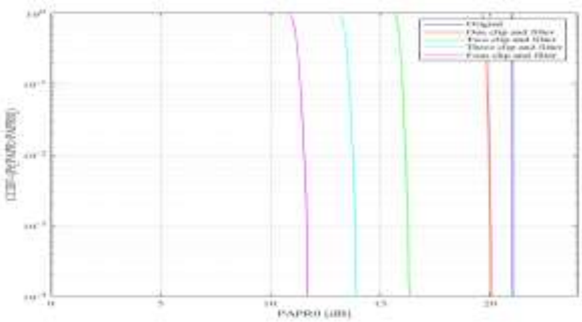

Fig. 4: CCDF of PAPR in clipping and filtering technique

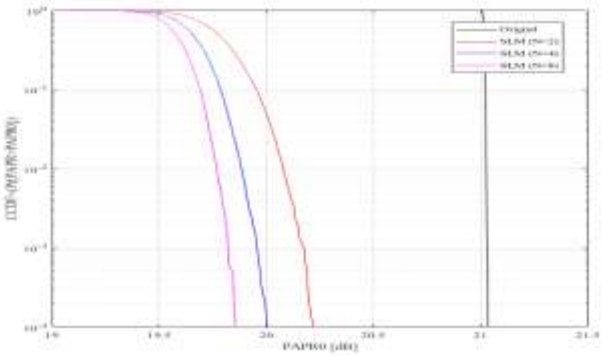

Fig. 5: CCDF of PAPR in Selective mapping technique.

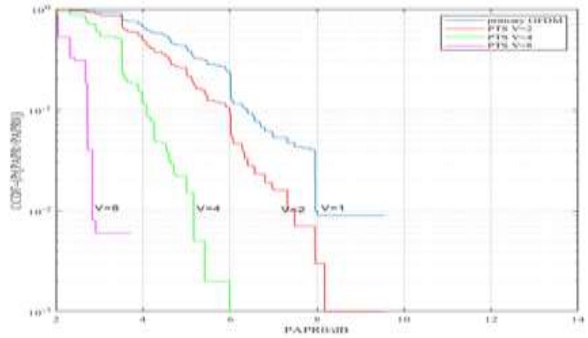

Fig. 6: CCDF of PAPR in partial transmit technique.

Fig. 4 shows the CCDF of PAPR in clipping and filtering technique. For getting 10^{-2} of CCDF the PAPR values are 22dB, 20dB, 16dB, 14dB, 12dB for unclipped ,one clip and filter, two clip and filter, three clip and filter, four clip and filter respectively by consider CR=4. Fig. 5 shows the CCDF of PAPR in selective mapping (SLM) technique. For getting 10^{-2} of CCDF the PAPR values are 21dB, 20.2dB, 20dB, 19.8dB for number of symbols N is 2, 4, and 8 respectively Fig. 6 shows the CCDF of PAPR in partial transmit sequence (PTS) technique. For getting 10^{-2} of CCDF the PAPR values are 8dB, 7.5dB, 5dB, 3dB for number of sub blocks V are 1,2,4 and8 respectively.

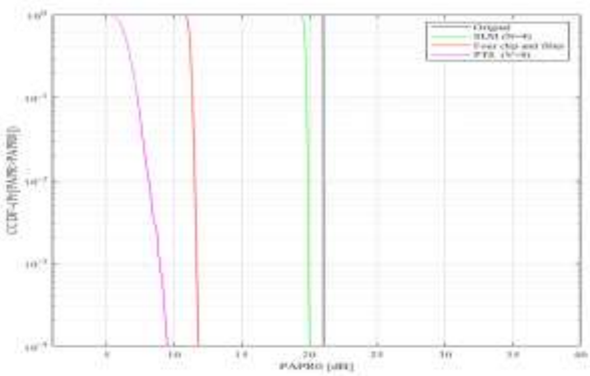

Fig. 7: CCDF the PAPR in original, SLM method when N=4, four clip and filter and PTS method when V=4.

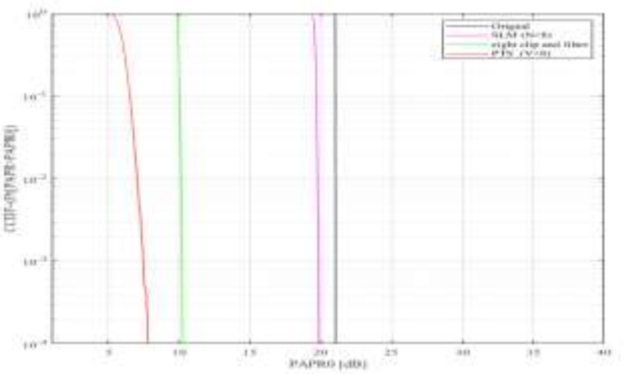

Fig. 8: CCDF the PAPR in original, SLM method when N=8, eight clip and filter and PTS method when V=8

Fig. 7 and Fig. 8 shows the graphs for various PAPR reduction techniques. In Fig. 7 for getting 10^{-2} of CCDF the PAPR values are 21dB, 20dB, 12dB, and 9dB for original, SLM method when N=4, four clip and filter and PTS method when V=4 respectively. And in Fig. 8 for getting $10^{-2}$of CCDF the PAPR values are 21dB, 19dB, 10dB, 7dB for original, SLM method when N=8, eight clip and filter and PTS method when V=8 respectively.

4. CONCLUSION

OFDM is a very attractive technique for multicarrier transmission and has become one of the standard choices for high speed data transmission over a communication channel. It has various advantages; but also has one major drawback: it has a very high PAPR. Some of the techniques for reducing the high PAPR of the system were analyzed and compared. Among the three techniques that were analyzed, it was found out that PTS is more effective in PAPR reduction

REFERENCES

[1]. Andrew Goldsmith, Wireless Communication, Stanford University,2004
[2]. J. Bingiham, "Multicarrier modulation for data transmission: an idea whose time has come," IEEE Commune. Mag., vol. 28, no. 5, pp. 5-14, May 1990.
[3]. L. J. Cimini, "Analysis and Simulation of a Digital Mobile Channel Using Orthogonal Frequency Division Multiplexing," IEEE Trans. Commun., vol. 33, no. 7, pp. 665-675, July 1985.
[4]. Yasir Rahmatallah,Seshadri Mohan, "Peak-to-Average Power Ratio Reduction in OFDM Schemes: A Survey And Taxonomy, " IEEE Communications Surveys and Tutorials, vol. 15, no. 4, 2013.
[5]. Han SH, Lee JH. "An overview of peak-to-average power ratio reduction techniques for multicarrier transmission," IEEE Wirel Commun, vol. 12, no. 2, pp. 56-65, April 2005.
[6]. Wang and Tellambura, "A Simplified Clipping and Filtering Technique for PAR Reduction in OFDM Systems", IEEE Signal Processing Letters, VOL. 12, NO. 6, June 2005.
[7]. Bauml. R.W, Fisher R.F.H, and Huber. J.B, "Reducing the peak-to-average power ratio of multicarrier modulation by selected mapping," IEEE Electronics Letters, vol.32, no.22, pp.2056-2057, October.1996.
[8]. Cimini Jr, Leonard 1. And Nelson R. Sollenberger. "Peak-to-average power ratio reduction of an OFDM signal using partial transmit sequences." Communications Lellers, IEEE 4.3 (2000): 86-88.