www.ijecs.in
International Journal Of Engineering And Computer Science ISSN: 2319-7242
Volume 5 Issue 12 Dec. 2016, Page No. 19401-19404

A survey on different PAPR reduction techniques in OFDM systems

Manjula A V [#1] ***Dr.K.N.Muralidhara*** [#2]
Asst.Professor
[#1]M.Tech,Ph.D(Pursuing), Department of E&C
NIEIT,Mysore

Prof. And Head
[#2]M.E.,Ph.D, Department of E&C,
P.E.S College of Engineering, Mandya,India

***Abstract*—Orthogonal Frequency Division Multiplexing is considered as one of the most promising technology for future communication technology as it provides spectral efficiency robustness against multipath fading & avoids inter symbol interference. However one of the major drawbacks of OFDM system is high PAPR resulting in performance degradation of DAC & decreases efficiency of power amplifier. In this paper we review on OFDM system, its different types of PAPR reduction techniques and comparison of different PAPR reduction techniques.**

Index Terms – Orthgonal Frequency Division Multiplexing(OFDM), Peak-to-Average Power Ratio(PAPR), Complimentary CumulativeDistribution Function(CCDF), Selective mapping(SLM)

I. INTRODUCTION

Modern wireless communication systems offers different services such as voice communication & multimedia services to the users. As it requires high data rate, this is not achieved by single carrier communication as it suffers from multipath fading & inter symbol interference . Therefore Orthogonal Frequency Division Multiplexing(OFDM) is considered as the better candidate for recent technology as it provides high spectral efficiency ,robustness against multipath fading & avoid inter symbol interference using cyclic prefix concept. As a result OFDM has been chosen for high data rate communication & widely deployed in many wireless communication standards such as DAB , DVB & WIMAX etc.[1].However OFDM systems suffers from high PAPR, requires tight synchronization between transmitter & receiver & carrier frequency offset errors. In this paper we review different PAPR reduction techniques and comparison of different types of PAPR reduction techniques.

High peak values in OFDM system results from superposition of large number of statistically independent sub channels that can constructively sum up high peaks[2] .It is shown that as number of carriers increases ,PAPR also increases. The PAP ratio is approximately equal to N, where N is the number of sub carriers. High PAPR results in decrease in SQNR(signal to quantization noise ratio) of ADC (Analog to Digital Converter & DAC(Digital to Analog) while degrading the efficiency of HPA(High Power Amplifier).The PAPR problem is more important in the uplink since the efficiency of power amplifier is critical due to the limited battery power in a mobile terminal[3]
Therefore it is important and necessary to research on the PAPR reduction techniques & its effects on DAC,ADC& power amplifier. As PAPR distribution is stochastic in nature usually is expressed in terms of CCDF(Complimentary cumulative distributive function)plots. Various PAPR reduction techniques are Clipping & filtering[4-8], nonlinear companding[20-22], selective mapping [9-11],Partial transmit sequence[12-15] ,Tone Injection[29], Tone Reservation[16], Active Constellation[17] and coding techniques[25-26]. Although many techniques found in the literature to reduce PAPR ratio in OFDM systems ,have its own advantages & disadvantages in terms of computational complexity, increase in BER, power increase & bandwidth expansion. An effective PAPR reduction technique should be given the best tradeoff between implementation complexity, data rate loss transmission power & BER performance[1]

This paper is organized as follows Section II provides definition of OFDM, PAPR and CCDF, , Motivation of PAPR reduction technique in section III, PAPR reduction techniques comparison of different PAPR techniques discussed in section IV , followed by conclusion in section V

II. BASICS OF OFDM, PAPR AND CCDF

A .Basics of OFDM

OFDM is multicarrier modulation technique where high bit rate data stream is transmitted in parallel over a lower data rate sub carriers . These subcarriers are orthogonal to each other. Advancement in digital signal processing and Very Large Scale Integrated Circuit ,implementation of FFT/IFFT highly simplified the implementation of OFDM system.

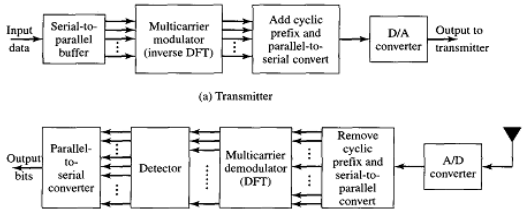

Fig. 1 Block diagram of OFDM system

Consider an OFDM system as shown in Fig.1 consisting of N subcarriers; Let a block of N symbols X= $\{X_k, k=0,1,---N-1\}$is

DOI: 10.18535/ijecs/v5i12.23

a data block, each symbol modulating on one set of subcarriers. The complex base band representation of multicarrier signal consisting of N subcarriers is given by

$$x(t) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X_k \, e^{j2\pi f_k t} \;, \quad 0 \le t \le NT \qquad (1)$$

Where X_k is transmitted symbol on k^{th} subcarrier and $j=\sqrt{-1}$, Δf is the sub carrier spacing and NT denotes useful data block period.

B. PAPR

In general the PAPR of OFDM signal is defined as the ratio of the maximum instantaneous power to its average power.

$$PAPR[x(t)] = \frac{\max_{0 \le t \le NT} [|x[t]|^2]}{P_{av}} \qquad (2)$$

To better approximate the PAPR of continuous signals, the OFDM signals are L times oversampled. From the literature
It is studied that L is approximately equal to 4 is sufficient to get accurate PAPR results. Therefore the L-times oversampled time domain OFDM signal samples can be defined as

$$x[n] \triangleq \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X_k \, e^{\frac{j2\pi nk}{LN}} \;, 0 \le n \le LN-1 \qquad (3)$$

Where E{.} denotes the expectation operator

C. Complimentary Cummulative Distribution Function(CCDF)

It is a statistical technique that provides the amount of time ,a signal spends above given power level. In modern communication CCDF measurement is considered as one of the precious tool offers comprehensive analysis of signal power peaks. For sufficient large number of sub carriers ,the amplitude of multicarrier signal, CCDF expression for OFDM signal can be written as

$$\begin{aligned} P(PAPR > z) &= 1 - P(PAPR \le z) \\ &= 1 - F(z)^N \\ &= 1 - (1 - exp(-z))^N \end{aligned} \qquad (4)$$

Where N signal samples are statistically independent uncorrelated.

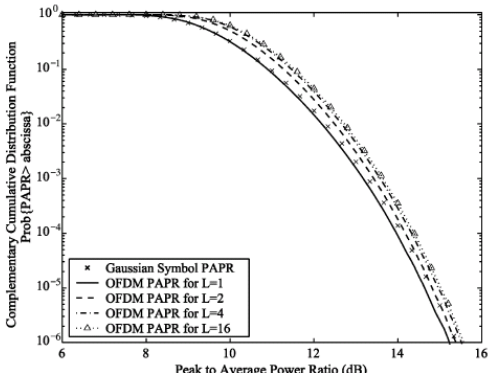

Fig 2. Distribution of PAPR of OFDM signal samples oversampled by different L.

III. MOTIVATION OF PAPR REDUCTION

A. Nonlinear Characteristics of HPA and ADC

Transmitted signals in an OFDM can have high peak values in the time domain since many carriers added up via IFFT operation. These OFDM systems known to have high PAPR compared to single carrier system. The High PAPR makes the power amplifier to work with large dynamic range & decreases SQNR(Signal to quantization noise ratio) of ADC/DAC. Therefore it motivates to reduce PAPR ratio before applying it to DAC and Power amplifier

B. Power Saving

From the Literature[1] it can be shown that by reducing the PAPR would result in increase in efficiency. For linear model of HPA efficiency is given by

$$\eta = 0.5/PAPR \qquad (5)$$

where η is HPA efficiency and is given by P_{out}/P_{DC}
P_{DC} is constant amount of power regard less of input power.
P_{out} is average output power.
OFDM signals with 256 subcarriers and its CCDF has been shown in Fig. 2. In order to guarantee that probability of the clipped OFDM frames is less than 0.01%, we need to apply an input back off (IBO) equivalent to the PAPR at the 10^{-4} probability level,PAPR=14.02 dB i.e.(25.235), referring to Fig. 2, and thus the efficiency of HPA becomes η=.5/25.235≈1.98%. Therefore, so low efficiency is a strong motivation to reduce the PAPR in OFDM systems[1].

IV. PAPR REDUCTION TECHNIQUES

In the literature several techniques have been proposed to reduce PAPR of OFDM system. These are broadly classified as signal scrambling, signal distorted and other techniques. In signal scrambling, signals are scrambled to minimize the PAPR of time domain OFDM signal, where codes can be scrambled or by modifying the phase of the signal. Shape of the signal is distorted in distortion based methods

A.Signal distortion based Technique

Clipping is one of the Signal distortion based techniques used to clip the signal amplitude to desired level. Although clipping is less complex and simplest solution to reduce PAPR which results in BER degradation and also introduces out of band interference signals to adjacent channels while destroying the orthogonality among subcarriers.

For amplitude clipping, that is

$$C(x) = \begin{cases} x, & x < A \\ A, & x > A \end{cases} \qquad (6)$$

Where A is preset clipping level and it is a positive real number.

Filtering can reduce out of band radiation and clipping of the signal amplitude causes peak re growth . To reduce peak re growth, repeated clipping and filtering technique is used[4].

The other techniques such as peak windowing ,peak cancellation & optimization along with clipping is proposed in the literature[26-29]

B.Signal scrambling techniques

This is used to scramble an input data block OFDM Symbols and transmit one of them with the minimum PAPR. So that PAP ratio can be reduced. This approach includes SLM, PTS, Tone reservation and Tone injection techniques.

DOI: 10.18535/ijecs/v5i12.23

1) PTS and SLM technique.

Muller and Huber [13] propose a method for reduction of peak using PTS method. The input data block in X is portioned into M disjoint sub blocks which are represented by the vectors $\{X^{(m)}, \quad m = 0,1, \ldots M-1\}$ as shown in Fig3 Therefore

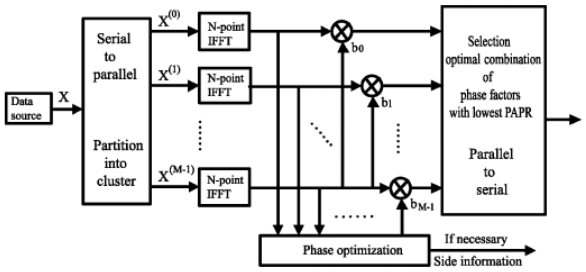

Fig. 3 Block diagram of PTS technique

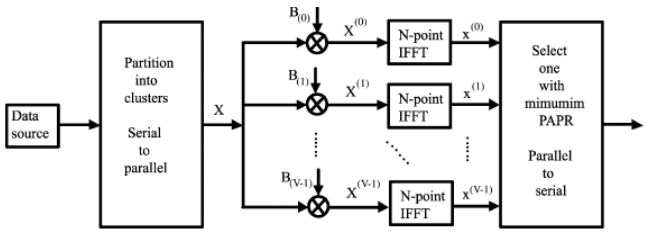

Fig.4 Block diagram of SLM technique

Subblock partining can be categorized into adjacent partition, interleaved partion and pseudo random. Among these pseudo random provides the best performance random partition. Then, the subblocks are transformed into M time-domain partial transmit sequences.

$$x^{(m)} = IFFT_{LNXN}\left[X^{(m)}\right] \qquad (7)$$

$$x = \sum_{m=0}^{M-1} b_m x^{(m)} \qquad (8)$$

M subblocks are multiplied with independently rotated with phase sequences. The resultant signal will give minimum PAPR. Here PTS suffers from complexity of searching for the optimum set of phase factor ,especially when sub blocks increases. In the literature various schemes have been proposed to reduce this complexity[9-15]

	Power increase	Implementation complexity	Band width expansion	BER degradation
Clipping	No	Low	No	Yes
Coding	No	Low	Yes	No
PTS/SLM	No	High	Yes	No
NCT	No	Low	No	No
TR/TI	yes	High	Yes	No

In SLM technique as shown in Fig. 4 the data block $X = [X[0], X[1], \ldots \ldots \ldots, X[N-1]]$ is multiplied with different phase sequences $[b_0, b_1, \ldots . b_{v-1}]$ which produces modified data block . Among which the signal with minimum PAPR is selected. In this method the phase sequences must be known to both transmitter and receiver. In the literature different methods which does not require side information are proposed

2)Tone reservation and Tone injection technique.

Tone reservation technique partions N sub carrier into data tones and peak reduction tones (PRT).Symbols in PRT are chosen such that OFDM signal in time domain has a lower PAPR. The positions of PRT are known to receiver and transmitter. With this technique additional power is required for transmitting PRT symbols and effective data rate decreases since PRT tones are not carrying any information it is considered as overhead.

In tone injection method, PRTs to be overlapped with data tones, data rate is not decreased. This is also requires additional power.

C.Other Techniques

1)The coding technique used to select code words that minimize or reduce PAPR .It causes no distortion and no out of band radiation but it suffers from bandwidth efficiency and also suffers from cmplexity to find the best code ,to store look up table for encoding and decoding.Golay complimentary codes,Reed Muller code and Hadamard code are used proposed in the literature[25-26].

2)Non linear companding technique.

This is the most attractive, low implementation complexity offers better BER performance than clipping technique, this based on µlaw companding with various types of distribution without the sacrifice of bandwidth[20-22].

There are many hybrid PAPR reduction techniques are proposed in the literature such as SLM and clipping DCT precoded SLM/PTS. These techniques applicable to MIMO OFDM,LTE and WIMAX environment.

D.Criteria for selection of PAPR Reduction Techniques

Selection of PAPR reduction techniques based on following parameters

1)PAPR reduction technique should be computationally Less complex , no in band and out of band radiation

2) It should use less average power, it results amplifier to work in less dynamic linear range it leads to minimize the cost of power amplifier

3) Since bandwidth is limited , in probabilistic and coding technique it requires more bandwidth which should be minimized

4) Selection of PAPR reduction should not lead to BER Degradation

5) It should not require additional power

Based on the above factors , comparision of different PAPR reduction techniques are compared in the table11 provided

TABLE I
COMPARISION OF DIFFERENT PAPR REDUCTION TECHNIQUES

V. CONCLUSION

OFDM is a very promising technique for wireless communications due to its spectrum efficiency and channel robustness. One of the major drawback of OFDM is it exhibits high PAPR. In this paper we reviewed the importance of OFDM system, its draw back i.e. exhibits PAPR. Many techniques to reduce PAPR, comparison of PAPR reduction techniques. Although many techniques available in literature there is scope to propose new simplified low complexity, hybrid techniques to improve the performance of OFDM system.

DOI: 10.18535/ijecs/v5i12.23

References

[1] Jiang T., Wu Y., "An Overview: Peak-to-average power ratio reduction techniques for OFDM signals", IEEE Transactions on Broadcasting, vol. 54, no. 2, pp. 257–268, Jun 2008.

[2] S. H. Han and J. H. Lee, "An overview of peak-to-average power ratio reduction techniques for multicarrier transmission," *IEEE Wireless Commun.*, vol. 12, no. 2, pp. 56–65, Apr. 2005.

[3] Nee, R. V. and R. Prasad, *OFDM for Wireless Multimedia Communications*, ArtechHouse Publishers, Norwood, MA,January 2000.

[4] J. Armstrong, "Peak-to-average reduction for OFDM by repeated clip-ping and frequency domain filtering," *IEEE Electron. Lett.*, vol. 38, pp. 246–247, May 2002

[5] Sungkeun Cha, Myonghee Park, Sungeun Lee, Keuk-joon Bang, and Daesik Hong, "A New PAPR Reduction Technique for OFDM Systems Using Advanced Peak Windowing Method "

[6] Xiaodong Li and Cimini, L.J. Jr., "Effects of clipping and filtering on the performance ofOFDM," *IEEE Communications Letters*, pp.131- **133,** May 1998

[7] L. Wang, C. Tellambura, "A simplified Clipping and Filtering Technique for PAR Reduction in OFDM Systems,"IEEE Signal Processing Lett., vol.12,no. 6, pp.453–456, Jun. 2005

[8] Z. Kollár, L. Varga, and K. Czimer, "Clipping-based iterative PAPRreduction techniques for FBMC," in Proceedings of the OFDM-Workshop (InOWo '12), pp. 139–145, August 2012.

[9] R. Bauml, R. Fischer, and J. Huber, "Reducing the peak-to-average power ratio of multicarrier modulation by selected mapping," *Electronic Letters*, vol. 32, pp. 2056–2057, 1996.

[10] S. H. Han and J. H. Lee, "Modified selected mapping technique for PAPR reduction of coded OFDM signal," *IEEE Trans. Broadcast.*, vol. 50, no. 3, pp. 335–341, Sept. 2004

[11] S. J. Heo, H. S. Noh, J. S. No, and D. J. Shin, "A modified SLM scheme with low complexity for PAPR reduction of OFDM systems," *IEEE Trans. Broadcasting*, vol. 53, no. 4, pp. 804–808, Dec. 2007.

[12] Alavi, C. Tellambura, and I. Fair, "PAPR reduction of OFDM signals using partial transmit sequence: An optimal approach using sphere decoding," *IEEE Trans. Communications Letters*, vol. 9, no. 11, pp. 982–984, Nov. 2005

[13] Muller S. H., Huber J. B., "OFDM with reduced peak-to-average power ratio by optimum combination of partial transmit sequences", Electronics Letters, vol. 33, no. 5,pp. 36–69, Feb. 1997

[14] A. D. S. Jayalath and C. Tellambura, "SLM and PTS peak-power reduction of OFDM signals without side information," *IEEE Trans. Wireless Commun.*, vol. 4, no. 5, pp. 2006–2013, Sept. 2005.

[15] L. J. Cimini, Jr. and N. R. Sollenberger, "Peak-to-Average Power Ratio Reduction of an OFDM Signal Using Partial Transmit Sequences," *IEEE Commun. Lett.*, vol. 4, no. 5, pp. 86–88, Mar. 2000

[16] B. Krongold and D. Jones, "An active-set approach for ofdm par reduction via tone reservation," *IEEE Trans. Signal Processing*, vol. 52, pp. 495–509, Feb. 2004.

[17] B. Krongold and D. Jones, "Par reduction in ofdm via active constellation extension," *IEEE Trans. Broadcasting*, vol. 49, pp. 258–268, Sept.2003.

[18] T. Jiang and G. X. Zhu, "Complement block coding for reduction in peak-to-average power ratio ofOFDMsignals," *IEEE Communications Magazine*, vol. 43, no. 9, pp. S17–S22, Sept. 2005.

[19] K.Yang and S. Chang, "Peak-to-average power control inOFDM using standard arrays of linear block codes," *IEEE Communications Letters*, vol. 7, no. 4, pp. 174–176, Apr. 2003

[20] Wang X. B., Tjhung T. T., Ng C. S., "Reduction of peak-to-average power ratio ofOFDM system using a companding technique", IEEE Transactions on Broadcasting, vol.45, no. 3, pp. 303–307, Sept. 1999.

[21] Jiang T., Xiang W., Richardson P. C., Qu D., Zhu G., "On the Nonlinear Companding Transform for Reduction in PAPR of MCM Signals", IEEE Transactions on Wireless Communications, vol. 6, no. 6, pp.2017-2021, June 2007.

[22] Jiang T., Yang Y., Song Y., "Exponential companding transform for PAPR reduction in OFDM systems", IEEE Transactions on Broadcasting, vol. 51, no. 2, pp. 244–248, June 2005.

[23] Baig, I. – Jeoti, V."PAPR Reduction in OFDM Systems: Zadoff-Chu Matrix Transform Based Pre/Post-Coding Techniques," *2nd InternationalConference on Computational Intelligence,Communication Systems and Networks*, (*CICSyN*), Liverpool, UK, pp. 373–377, 28–30 July 2010

[24] Zhongpeng Wang, "Reduction of PAPR of OFDM Signals by Co mbining SLM with DCT Transform",,Int. J. Communications, Network and System Sciences, 2010, 3, 888-892.

[25] Houshou Chen and Hsinying Liang, "PAPR reduction of OFDM signals using partial transmit sequences and reed-muller codes", IEEE Communications Letters, Vol. 11, No. 6, pp. 528-530,2007

[26] Sharma, P.K., Seema Verma and Basu, A.O. "Modified clipping and filtering technique for peak-to-average power ratio reduction of OFDM signals used in WLAN", International Journal of Engineering Science and Technology, Vol. 2(10), 2010.

[27] C.L.Wang and Y. Ouyang, "Low-complexity selected mapping schemes for peak-toaverage power ratio reduction in OFDM system", IEEE Transactions on Signal Processing,vol. 53, Dec 2005.

[28] M. Park, J. Heeyong, N. Cho, D. Hong and C. Kang, "PAPR Reduction in OFDM Transmission Using Hadamard Transform," *EEEInternational Conference of Commu- nications*, Vol. 1, 2000, pp. 430-433

[29] J. Tellado, *Peak to average power reduction for multicarrier modulation*, Ph.D. thesis, Stanford University, 2000.

Manjula A.V. received her B.E degree in Electronics and Communication Engineering from Dayanandasagar College of Engg. under Bangalore university and M.tech from NIE,Mysore under VTU Belgaum. Presently working as Assistant Professr in NIEIT,Mysore in E&C department ansd also pursuiung her PhD in Electronics under University of Mysore. Her area of research interest includes Wireless communication,Digital signal processing ,OFDM tecnology .

Dr.K.N.Muralidhara obtained his B.E.degree in E&C during 1981,ME during 1990 from from PES college of Engg , Mandya under University of Mysore and PhD during 2002 from university of Roorkee. His field of interest is on semiconductor devices and presently working as Professor and Head of the Department. He is guiding 5 candidates for PhD program and actively participated in all the developmental activities of the college He has about 35 publications to his credit