International Journal of Advanced Scientific Technologies , Engineering and Management Sciences (IJASTEMS-ISSN: 2454-356X) Volume.3,Special Issue.1,April.2017

PEAK TO AVERAGE POWER REDUCTION TECHNIQUES IN OFDM : A REVIEW

Revathy G Nair, PG Student, Dept. of ECE, College of Engineering Kidangoor, Jismi Babu, Faculty of Electronics & Communication, College of Engineering Kidangoor

Abstract— Orthogonal- frequency division multiplexing is a multicarrier modulation. It has high data rate and ability against frequency selective fading. OFDM is a promising technique in the current broadband wireless communication system. A major drawback in OFDM system is high peak to average power which distort the signal. The peak to average power ratio is more important problem in uplink .Many techniques available for PAPR reduction. In this paper discuss about different PAPR reduction techniques and conclude an overall comparison of these techniques.

Index Terms—orthogonal frequency division multiplexing(OFDM),Peak-to-average ratio(PAPR)

I. INTRODUCTION

. The term wireless communication was introduced in 19th century and wireless communication technology has developed over the subsequent years. Wireless services have been growing rapidly with each passing year. Present tele- communication system provides a more flexible data rate, a higher capacity and a tightly integrated service. OFDM transmission scheme is a multichannel system. .Orthogonal frequency division multiplexing is most attractive technology
for fourth generation (4G) wireless communication in terms of high data rate and spectral efficiency. It also provide reliable transmission. OFDM transmit signal through multiple carriers. The basic idea of OFDM is to divide the available spectrum into several sub carriers. The subcarriers have different frequency and orthogonal to each other therefor reduce the inter carrier interference. Discrete Fourier transform and inverse Fourier transform process is useful for implementing these orthogonal signals. OFDM signal are time and frequency synchronized to each other, allowing the interference between subcarrier to be carefully controlled.

OFDM system has high peak values in time domain since many subcarrier components are added via an inverse discrete Fourier transform operation. Therefore, OFDM systems are known to have a high PAPR, compared to single carrier transmission. High value PAPR is the major drawback of OFDM system.[1]. The use of large number of subcarriers introduces a high PAPR in OFDM system. PAPR can be defined as the relationship between the maximum power of a sample in a transmit OFDM symbol and its average power.

$$PAPR=10\log_{10}\frac{P_{peak}}{P_{average}}(dB) \quad (1)$$

High PAPR in OFDM cause RF power amplifiers should be operated in a very linear region. Otherwise the signal peak gets into non-linear region of the power amplifier causing signal distortions.[2] This signal distortion introduces intermodulation among the subcarriers and out of band radiation. On other hand lead this lead to very inefficient amplification and expensive transmitters. The PAPR problem important in the uplink since the efficiency of power amplifier is critical due to the limited battery power in a mobile terminal.

The selection of PAPR reduction technique is based on following factors.

i) PAPR reduction technique with as few harmful side effects such as in-band and out-of-band radiation.

ii)Low average power: PAPR can be reduced by increasing average power of original signal then it requires a large linear operation region in high power amplifier and thus resulting in the degradation of BER performance.

iii) Low implementation complexity: The time and hardware requirements for the PAPR reduction should be minimal.

iv) No bandwidth expansion: The bandwidth expansion effect the data code rate loss due to side information.

v) No BER performance degradation

vi)Power requirement: the PAPR reduction technique should be design without any additional power.

PAPR reduction techniques can be broadly divided into three major classes.[2]. First one is signal distortion techniques, it reduce the PAPR by distorting the transmitted OFDM signal before it passes through the power amplifier. Second one is multiple signalling and probabilistic techniques. This method either generate multiple permutation of the OFDM signal and transmit the one with minimum PAPR or to modify the OFDM signal

by introducing phase shift, adding peak reduction carrier or changing constellation points. Third one is coding techniques. This technique is to select the code word that reduces the PAPR for transmission.

2. SIGNAL DISTORTION TECHNIQUES

2.1 CLIPPING AND FILTERING

The clipping approach is the simplest PAPR reduction scheme, which limit the maximum of transmit signal to a pre-specified level. It causes in-band signal distortion, resulting in BER performance degradation and also causes out-of-band radiation. Out-of-band radiation can be reduced by using filtering, it may effect high-frequency components of in-band signal.[5] Filtering and clipping can reduce out-of-band radiation at the cost of peak growth. Iterative clipping and filtering can reduce large PAPR, this technique increase the complexity of the OFDM system although it can reduce high PAPR problem.

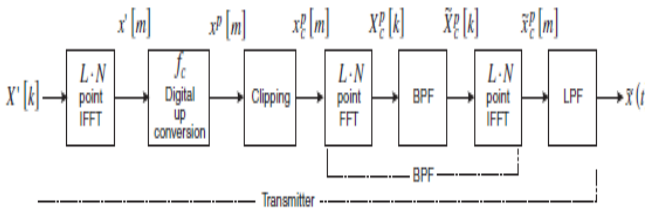

Fig1: Block diagram of a PAPR reduction scheme using clipping and filtering

It show block diagram of a PAPR reduction scheme using clipping and filtering where L is the over sampling factor and N is the number of carriers. In this scheme, the L-times oversampled discrete –time signal x'[m] is generated from the IFFT operation and is modulated with carrier frequency f_c to yield a passband signal $x^p[m]$. $x_c^p[m]$ denote the clipped version of $x^p[m]$, which is expressed as

$$x_c^p[m] = \begin{cases} -A & x_c^p[m] \le -A \\ x_c^p[m] & |x^p[m]| < A \quad (2) \\ A & x^p[m] \ge A \end{cases}$$

2.2 PEAK WINDOWING

This technique is an improved clipping technique which attenuate peak signal by using narrowband windows. Normally used windows are Gaussian window, Cosine window, Kaiser window or Hamming window. This reduces out-of-band radiation. The OFDM signal multiplied with these window get a spectrum, which is a convolution of the spectrum of original OFDM signal and spectrum of applied window. The window should be narrow band as possible, it results better performance in PAPR reduction.[7] PAPR at the cost of increasing BER performance degradation and out-of-band radiation. This technique provides better PAPR reduction with better spectral properties than clipping.

2.3 COMPANDING TRANSFORM

This technique mainly applied for audio signals. Companding involve compression and expansion. After companding the lower values are increased and higher values remain constant which results increased average power of OFDM signal. µ-law of companding is used for PAPR reduction .his method is based on increasing average power of OFDM signal to reduce PAPR ,[8] which increases burden on transmitter then it require more power to transmit a signal. This method rarely used for PAPR reduction.

3. .MULTIPLE SIGNALLING AND PROBAILISTIC TECHNIQUES

3.1 TONE RESERVATION

A tone reservation technique partitions the N subcarriers in to data zones and peak reduction tones . Symbols in peak reduction tone are chosen such that OFDM signal in time domain has a lower PAPR. The advantage of TR method is that it is less complex, no side information and also no additional operation is required at the receiver of the system. Tone reservation method is based on adding a data block and time domain signal. A data block is dependent time domain signal to the original multicarrier signal to minimize the high peak[3]. This time domain signal can be calculated simply at the transmitter of system and stripped off at the receiver.

The PAPR reduction depends on number of reserved tones ,location of reserved tones and allowed power on reserved tones. It does not require additional complexity for reducing PAPR in OFDM system.

3.2 TONE INJECTION

This technique can be used to reduce the PAPR without reducing data rate. This method based on increase the constellation size. Then ,each point in original basic constellation can be mapped into several equivalent point in the extended constellation points.[4] The additional amount of freedom can be used for PAPR reduction.The drawback of this method are, need to side information for decoding signal at the receiver side, and cause extra IFFT operation which is more complex.

3.3 SELECTIVE MAPPING

Selective mapping is to produce alternative transmit sequence from the same data source and then to select the

transmit signal exhibiting lower PAPR. The PAPR determined by multiplying the data vector by some random phase will change PAPR properties after the IFFT. Let us assume that the the original output input signal X=[X_1 ,X_2- - --,X_{N+1}] multiplied with independent phase sequence after multiplication IFFT is applied to each sequence then to convert signal from frequency domain to time domain. [9]The last step comparing PAPR among different independent data block and transmit candidate with lower PAPR. It is distortion less technique and reduce PAPR efficiently without increased power requirement.

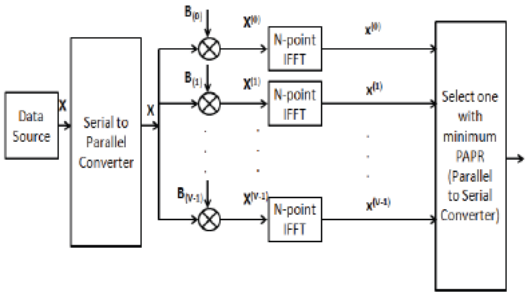

Fig2: Block diagram of a PAPR reduction scheme using SLM technique

3.4 INTERLEAVED OFDM

The technique is very similar to selective mapping the only difference is that interleaver is used instead of phase sequence. Interleaver is a device operate on a N block of symbol and reorder or permutated them in specific manner. Interleaving and de-interleaving done simply and amount of PAPR reduction depend on number of interleaver and design of interleaver.[2] It is a distortion less technique but it require transmission of side information caused reduced bandwidth efficiency.

3.5 PARTIAL TRANSMIT SEQUENCE

This technique is based on phase shifting of sub-block of data and multiplication of data structure by random vectors. This method flexible and effective for OFDM system.[3] The main purpose behind this method is that the input data frame is divided into non-overlapping sub blocks and each sub block is phase shifted by a constant factor to reduce PAPR.

It is a probabilistic method for reducing the PAPR problem ,modified method of selective mapping .The main advantage of this method is that there is no need to send any side information to the receiver of the system, when differential modulation is applied in all sub block.

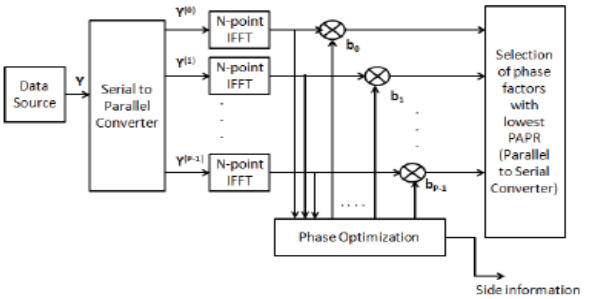

Fig3: Block diagram of a PAPR reduction scheme using PTS technique

3.6 ACTIVE CONSTELLATION EXTENSION

This technique is similar to tone injection. The only difference is that in ACE, only outer constellation points are dynamically extended from the original constellation. Extending outer point from decision boundary increases the spacing between the constellation point and reduce BER.

An adaptive clipping control algorithm is proposed in [2-3] to achieve better PAPR as compared to clipping based ACE at reduced number of iterations. In this way ACE offers dual advantage of BER and PAPR reduction. ACE technique does not require transmission of sideinformation and hence there is no data rate loss too. Only the drawback of this scheme is that it increases the requirement of transmission power.

4. CODING TECHNIQUES

4.1 LINEAR CODING

In [10], a simple linear block coding (LBC) was proposed 3 bits are mapped into 4 bits by adding a parity bit. A simple rate- ¾ cyclic code is used in [11] for any number of subcarriers that is a multiple of 4 to reduce PAPR by more than 3 dB. A combined (8,4) LBC is used in [12] to provide error control capability and reduce PAPR of a multicarrier modulation by 4 dB. Reference [13] proposed an another simple LBC based on the observation that regardless of the number of subcarriers, codewords with equal odd and even bit values have high PAPR. Therefore, eliminating these code words by adding a simple bit code, PAPR can be reduced easily. In [14], a low complexity complement block coding (CBC) scheme is proposed where few complement bits are inserted in the middle of the information bits to form a code word with reduced PAPR. A standard arrays of linear block codes are used in [15] for PAPR reduction which may be regarded as a modified version of SLM. In this scheme the coset leaders of a linear code are used for scrambling, hence no side information is required to be transmitted and the received signal can be decoded by syndrome decoding. To control PAPR of OFDM signals the authors proposed the use of fountain codes in [16]. LT codes [17] was the first practical realization of fountain codes and later a further enhancement was proposed by the Raptor codes [18].The

best fountain coded OFDM packets can be generated with a low PAPR which is the motivation behind this scheme

4.2 GOLAY COMPLEMENTARY SEQUENCE

Golay Complementary Sequences [19] can be used as codewords to modulate the subcarriers of the OFDM systems, resulting a signal of PAPR with an upper bound of 2. In [20], relation between Golay complementary sequences and second order Reed-Mullar code is exploited to achieve low PAPR of almost 3dB. In [21-24], Golay codes were further investigated for PAPR reduction for various constellation sizes such as 16-QAM and 64-QAM .

5. OVER ALL ANALYSIS OF DIFFERENT TECHNIQUE

Name of schemes	Name of parameters					
	Power increase	Implementation complexity	Bandwidth Expansion	BER Degradation	Distortion less	Data rate loss
Clipping and filtering	No	Low	No	Yes	No	No
Tone reservation	Yes	High	Yes	No	Yes	Yes
Tone injection	Yes	High	Yes	No	Yes	No
Partial transmit sequence	No	High	Yes	No	Yes	Yes
Selective mapping	No	High	Yes	No	Yes	Yes
Interleaving	No	High	Yes	No	Yes	Yes
Coding	No	Low	Yes	No	Yes	Yes

Table 1

6. CONCLUSIONS

Multicarrier transmission such as OFDM is one of the most attractive techniques for both wired and wireless applications due to its high data rates, stability against to multipath fading and spectral efficiency. The major drawback of OFDM system is high peak-to-average ratio. PAPR can be reduced by different techniques and each technique have their own advantages and disadvantages. The selection criteria for PAPR reduction techniques mainly depend on the transmission requirements. In clipping technique, clipping is done around the predefined peaks value but at the cost of increased distortion. The probabilistic scrambling techniques do not suffer from the out-of-band radiation but spectral efficiency decreases and complexity increases with increase in number of subcarrier. These techniques include selective mapping (SLM), partial transmit sequence (PTS), interleaved OFDM, Tone Reservation (TR) and Tone Injection (TI).
SLM algorithm adapted to any length of route number that means it can be used for different OFDM systems with different number of carriers. It is particularly suitable for the OFDM system with a large number of sub-carriers.PAPR reduction using coding technique results high complexity and lower band width efficiency. All of proposed techniques have the ability to reduce PAPR effectively but at the cost of loss in data rate, transmit signal power increase, BER increase, computational complexity increase and so on. Thus, the PAPR reduction technique should be chosen carefully according to various system requirements

ACKNOWLEDGEMENT

We would like to acknowledge the funding provided from TEQIP PhaseII of College of Engineering Kidangoor for the publication of this paper.

REFERENCES

[1] V.N. Richard and R. Prasad, “OFDM for Wireless Communication”, Bosten: Artech House, (2004).
[2] S.H. Han and J.H. Lee, “An Overview of Peak-to-Average Power Ratio Reduction Techniques for Multicarrier Transmission”, IEEE Transaction on Wireless Communications, vol. 12, no. 2, (2005), pp.
[3] Y. Rahmatallah and S. Mohan, “Peak-to-Average Power Ratio Reduction in OFDM System: A Survey and Taxonomy”, IEEE
Communication Surveys and Tutorials, vol. 15, no. 5, (2013), pp. 1567-1592.
[4] J. Heiskala and J. Terry, “OFDM Wireless LANs: A theoretical and Practical Guide”, Sams Publishing, (2002).
[5] H. Ochiai and H. Imai, “One the Clipping for Peak Power Reduction of OFDM Signal”, Proc. IEEE Global Communications Conference (GLOBECOM), San Fransisco, USA, (2000).
[6] H. Ochiai and H. Imai, “Performance Analysis of Deliberately Clipped OFDM Signals”, IEEE Trans. Commun., vol. 50, no. 1, (2002), pp-89-101.
[7] M. Ojima and T. Hattori, “PAPR Reduction Method using Clipping and Peak-Windowing in CI/OFDM System”, Proceedings of IEEE 66th Vehicular Technology Conference, (2007) Sept. 30-Oct. 3.
[8] T. G. Pratt, N. Jones, L. Smee, and M. Torrey, “OFDM Link Performance With Companding for PAPR Reduction in the Presence of Nonlinear Amplification”, IEEE Trans. Broadcast., vol. 52, no. 2, (2006), pp. 261– 267
[9] H. B. Jeon, J. S. No and D. J. Shin, “A Low-Complexity SLM Scheme using Additive Mapping Sequences for PAPR Reduction of OFDM Signals”, IEEE Transactions on Broadcasting, vol. 57, no. 4, (2011), pp. 866-875.
[10] E. Jones, T. A. Wilkinson and S. K. Barton, “Block Coding Scheme for Reduction of Peak to Mean Envelope Power Ratio of Multicarrier Transmission Scheme”, IEE Electronic Letters, vol. 30, no. 22, (1994), pp. 2098–2099
[11] D. Wulich, “Reduction of Peak to Mean Ratio of Multicarrier Modulation using Cyclic Coding”, IEE Electronic Letters, vol. 32, no. 29, (1996), pp. 432–433.
[12] E. Jones and T. A. Wilkinson, “Combined Coding for Error Control and Increased Robustness to System Nonlinearities in OFDM”, Proc. IEEE Vehicular Technology Conference (VTC), Atlanta, GA, (1996).
[13] S. Fragicomo, C. Matrakidis and J. J. Oreilly, “Multicarrier Transmission Peak-to-Average Power Reduction using Simple Block Code”, IEEE Electronic Letters, vol. 34, no.14, (1998), pp. 953–954.

[14] T. Jiang and G. Zhu, "Complement Block Coding Scheme for Reducing Peak-to-Average Power Ratio of OFDM Systems", J. Electronics, vol. 21, no. 5, (2004), pp. 413–420.

[15] K. Yang and S. Chang, "Peak-to-Average Power Control in OFDM using Standard Arrays of Linear Block Codes", IEEE Commun. Lett., vol. 7, no. 4, (2003), pp. 174–176.

[16] 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, (2010), pp. 3779–378.

[17] M. Luby, "LT codes", Proc. 43rd Annual IEEE Symposium on Foundations of Computer Science, Vancouver, BC, Canada, (2002) November, pp. 271–280.

[18] Shokrollahi, "Raptor Codes", IEEE Trans. Inf. Theory, vol. 52, no. 6, (2006), pp. 2551–2567.

[19] M. Golay, "Complementary Series", IEEE Trans. Inf. Theory, vol. 7, no. 2, (1961), pp. 82–87.

[20] J. A. Davis and J. Jedwab, "Peak-to-Mean Power Control and Error Correction for OFDM Transmission using Golay Sequences and Reed-Muller Codes", Electronics Letters, vol. 33, no. 4, (1997), pp. 267-268.

[21] J. A. Davis and J. Jedwab, "Peak-to-Mean Power Control in OFDM, Golay Complementary Sequences, and Reed–Muller Codes", IEEE Trans. Info. Theory, vol. 45, no. 7, (1999), pp. 2397–2417.

[22] K. Patterson, "Generalized Reed-Muller Codes and Power Control in OFDM Modulation", IEEE Trans. Info. Theory, vol. 46, no. 1, (2000), pp. 104–120.

[23] V. Chong and V. Tarokh, "A Simple Encodable/Decodable OFDM QPSK Code with Low Peakto- Mean Envelope Power Ration", IEEE Trans. Info. Theory, vol. 47, no. 7, (2001), pp. 3025–3029.

[24] Z. Taha and X. Liu, "Low PMEPR Code Based on STAR-16-QAM Constellation for OFDM", IEEE Communication Letters, vol. 11, no. 9, (2007), pp. 747–749.