CMA Technique: A Solution for Minimum PAPR in OFDM

constant modulus algorithm,
CMA，恒模算法，常数模算法

Mandeep Kaur
Dept. of Electronics and Communication
UIET, Panjab University
Chandigarh, India
kaur.mandeep1591@gmail.com

Preeti Singh
Dept. of Electronics and Communication
UIET, Panjab University
Chandigarh, India
preets.singh.82@gmail.com

Sarvjit Singh
Dept. of Electronics and Communication
UIET, Panjab University
Chandigarh, India
sarvjit100878@yahoo.co.in

***Abstract*—OFDM (Orthogonal Frequency Division Multiplexing) has been raised a new modulation technique for next generation 4G networks e.g. LTE. But OFDM has a major drawback that is high value of PAPR at the transmitter end. Since OFDM is only used in the downlink of 4G networks therefore to reduce the problems of high PAPR (Peak to Average Power Ratio) in OFDM, some techniques e.g. SLM, PTS, Clipping, Coding, & Pre-coding etc. are suggested but none of them reduces the PAPR to an acceptable value. But a new reduction technique based on constant modulus algorithm shows great improvement in the PAPR value which has been discussed in this paper.**

Keywords—WPACMA (weight pattern adaptive constant modulus algorithm); OFDM (Orthogonal Frequency Division Multiplexing); PAPR (Peak to Average Power Ratio); CMA (Constant Modulus Algorithm); PTS (partial transmit sequence); SLM (selective mapping); SQP (Sequential Quadratic Programming); LSE (Least Square Error); PSO (Particle Swarm Optimization); SDCMA (Steepest Descent Constant Modulus Algorithm; RB (Resource blocks)

I. INTRODUCTION

With the increase in communications technology, multimedia services over both wired and wireless links needs higher data rate. New modulation schemes are being proposed now days to transfer data in bulk amount to provide higher data rate, Orthogonal Frequency Division Multiplexing is one of them. As a result, OFDM has been used for the purpose of digital audio, video broadcasting and for Asymmetric Digital Subscriber Line (ADSL). For the wireless networking standard HIPERLAN2 in Europe and as the IEEE 802.11a, g standard in the US OFDM has been standardized as the physical layer, promising the data rates between 6 and 54Mbps. Orthogonal Frequency Division Multiplexing is a digital transmission scheme developed to meet the growing petition for higher data rates in communication systems which can be used in both wired and wireless settings [1].

II. PAPR

There are several factors that degrade the performance of OFDM. The performance may be due to the frequency errors (Tx. & Rx. offset) or Inter-carrier Interference (ICI) between the subcarriers. A famous problem of OFDM is that the amplitude of the time domain signal varies intensely with the transmitted symbols modulated on the subcarriers in the frequency domain which results in a 'peaky' signal. In OFDM due to IFFT (Inverse Fast Fourier Transform) process at transmitter end sinusoidal signals are summed with superposition, some combinations among them generates large peaks, these peaks creates problem at different stages of OFDM [2]. A lot of work has been reported in the literature but still effort is required to bring the PAPR and BER (Bit Error Rate) curve to an acceptable level [4]. In this paper, some of the PAPR reduction techniques are discussed as per literature and compared with a technique showing better results.

A. PAPR Reduction techniques

There are several techniques which have been proposed for PAPR reduction in an OFDM system. These techniques can be divided in two major categories as Signal Distortion and Signal Scrambling Techniques [3].

(a) Signal distortion techniques:

These are the most commonly used techniques for PAPR reduction. It includes different techniques such as clipping, joint clipping and filtering technique, peak cancellation technique, peak windowing technique and nonlinear companding transform etc. [4]. In clipping technique, nonlinear saturation is employed around

978-1-4673-8253-3/15/$31.00 ©2015 IEEE

the peaks of the signal to reduce the peaks formation before HPA (High Power Amplifier) which results in low PAPR value. This is simple technique but introduce Out-of-Band (OOB) Radiation and In-Band (IB) Distortion in Signal. It also destroys the orthogonality of OFDM signal [4]. The signal parts which are above the allowed region are clipped in a simple clipping technique. Joint clipping and filtering technique reduce OOB radiation but IB distortion are still there since this method degrades OFDM system performance [5]. Pre-coding combined with clipping gives low PAPR value as compare to conventional techniques but it degrades the BER performance of the system [6]. Another PAPR reduction technique is Peak Windowing which improves the spectral efficiency but it also increases the OOB radiation and BER. Modulation Envelop Scaling is used for PAPR reduction due to equality envelop properties of all subcarriers input [5]. For QAM (Quadrature Amplitude Modulation) based OFDM system, this technique increases the BER. Non Linear Companding transform is suggested as a good way to reduce PAPR due to best performance obtained e.g. no bandwidth expansion, less BER degradation, and less complexity. But this technique give worst performance due to boost in transmit signal beyond the saturation region of HPA. Since this technique is not applicable for PAPR reduction. These distortion techniques degrades the BER performance of system as they causes out of band radiations [7].

(b) Scrambling Techniques:

Scrambling Techniques i.e. SLM (Selective Mapping Technique) & PTS (Partial Transmit Technique) uses the concept of phase rotation. These techniques are very popular technique for PAPR reduction. The increase in number of phase rotations increases the complexity for the system. Side information also needed for receiver to decode signal in these techniques [3].

- *SLM (Selective Mapping)*

It has been reported in the literature that SLM is an excellent technique to reduce PAPR in an OFDM system. A set phase rotation of the signal is performed and every different phase signal gives different value of the PAPR parameter [4]. The signal with low PAPR value is selected for the transmission. Conventionally selective mapping method uses phase sequence of [1.-1, j,-j] but in various proposed schemes selective mapping technique has been used with various phase sequences but it is not suitable for systems with high complexity [8]. Turbo codes combined with selective mapping also reduces the PAPR in the system up to some level [9,10] but it makes the system quite complex due to large computations. Combination of Selective mapping with cyclic codes for BPSK (Binary Phase Shift Keying) OFDM system produces great results in PAPR reduction and also increases the bandwidth efficiency but computation increases as the number of iterations are increased which results in complex system [11]. SLM with Logarithmic companding achieve better results as compared to conventional SLM [12] with a phase sequence up to 16 and leads to less complexity of the system. Phase sequences generated are sent with Riemann matrix pattern that results in good PAPR reduction as compared with Hadmard and Chaotic [13]. With some novel conversion matrices, a new modified SLM technique is proposed in which without transmitting the side information we can achieve similar PAPR performance with low computational complexity as in the ordinary SLM [14]. A new SLM scheme is proposed in which alternate signal sequences are generated by the addition of mapping sequences to an OFDM signal sequence. In this technique phase and amplitude changes are carried over alternative symbols .The proposed scheme lessens the computational complexity without losing BER and PAPR reduction performance [15].

- *PTS (Partial Transmit Sequence)*

PTS is a multiple signal representation technique in which the input data block of the system is divided into number of disjoint sub blocks. These sub blocks are then transformed into same number of Partial Transmit Sequences in time domain [3]. This transformation can be achieved with the help of Inverse Fast Fourier Transform called Partial Sequences (PS). These PS are then rotated by some phase factors independent of each other. Then these signals after rotation are optimally combined to obtain the OFDM signals in time domain with the lowest PAPR value. The optimization techniques such as Particle Swarm Optimization can be used for reducing the complexity of the technique. Comparison of partial transmits sequence with conventional SLM technique results in greater reduction of PAPR upon same parameters [16]. Hybrid of PTS, an adaptive peak power reduction and genetic algorithm is used in OFDM that results in a great reduction in PAPR value and also exhibits high performance of BER of the system; parameter used for simulation is of standard WLAN in IEEE802.11a system [17].

B. CMA (Constant Modulus Algorithm)

Constant Modulus algorithm is also a promising technique for PAPR reduction. Many communication signals have the constant modulus property e.g. frequency modulation, phase modulation, frequency shift keying, phase shift keying [21]. Weight matrix is selected by an extensive examination between the discrete set of phases, and are sent as side information to the receiver. Accordingly, all combinations of the available phase weights need to be calculated and then multiplied with an IDFT (Inverse Discrete Fourier Transform) summation matrix, which has the same size as matrix. Finally, one sequence with the least PAPR metric is chosen with the

978-1-4673-8253-3/15/$31.00 ©2015 IEEE

corresponding phase weights but this method is not preferred if the channel estimation exploits the smooth changes of the channel coefficients over the complete OFDM block [22]. In this paper CMA technique is used to calculate the PAPR value of OFDM system by changing weight pattern adaptively.

C. *Other methods*

Low crest mapping technique is also proposed for the PAPR reduction in which the power of individual carrier is normalized and then the maximum peak envelop power is used as the parameter for the selection of the system with minimum PAPR but it is suitable for less subcarriers only[18]. Wavelet based OFDM systems are also promising for the better performances as compared to conventional OFDM [19, 20]. Sequential Quadratic Programming technique is proposed for the PAPR reduction and is compared with PTS which results in better performance on the given system with less complexity as the number of computations performed in proposed method is less [22].

III. SIMULATION RESULTS

Test system [22, 23, 24] under study is OFDM system. PAPR is calculated using Weight Pattern Adaptive CMA (WPACMA) on OFDM system. WPACMA is successfully developed and tested on OFDM system. In table I, PAPR is investigated with weight pattern. Weight pattern values w1=0.3, w2=0.7 are chosen to reach at optimal solution with fast convergence. PAPR value comes out to be 5.213dB. It shows different PAPR values with different weight patterns and best results was observed at (0.3, 0.7) pair. The more reduction of PAPR is possible by increasing iterations, but it will result in increased complexity of the system during implementation.

TABLE I. WEIGHT PATTERN WITH PAPR

Weight -w1	Weight -w2	PAPR(dB)
0.45	0.55	5.6
0.25	0.75	5.5
0.3	**0.7**	**5.2**
0.4	0.6	5.9
0.6	0.4	5.5
0.75	0.25	5.9
0.8	0.2	5.8

Fig.1 shows CCDF (Complementary Cumulative Distribution Function) variation with PAPR values. With proposed technique WPCMA, CCDF decreased with PAPR as compared to PAPR of the system before applying proposed technique i.e. original PAPR value of the system. The default curve shows the original PAPR of the system with no signal processing algorithm.

In table II, PAPR value is derived with WPACMA after couple of iterations and compared with other methods in literature. It is compared with methods like PTS, SDCMA, CP-PTS, PSO, SQP, and LSE used on the same system. Test result shows that PAPR values come out to be far less than other existing methods.

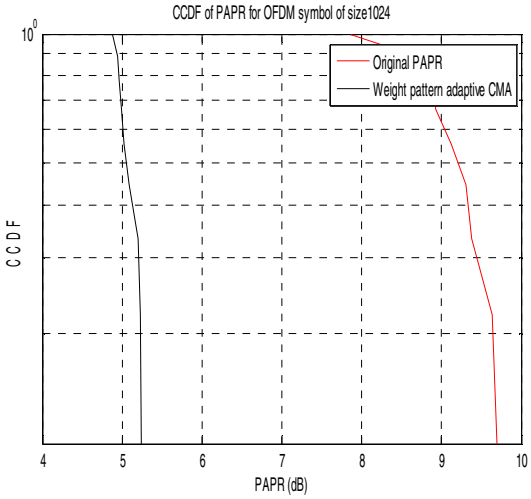

Fig.1 CCDF vs. PAPR

TABLE II: COMPARATIVE ANALYSIS WITH OTHER TECHNIQUES FOR PAPR

Technique	PAPR Value(dB)
Advanced SQP[23]	6.28
CP-PTS[22]	6.23
PTS[24]	7.71
SDCMA[22]	6.25
UCCMA[22]	7.26
PSO[20]	8.24
LSE[23]	8.10
WPACMA	5.213
SQP[24]	6.44

IV. CONCLUSION

In this paper, WPACMA technique is proposed to solve PAPR reduction problem in OFDM system. Weight pattern functionality is incorporated to enhance the solution search capability of proposed method. Proposed method is tested on OFDM case study. Test results show the reduced PAPR value as compared to other methods like PSO, SQP, Advanced SQP, PTS, CP-PTS as

978-1-4673-8253-3/15/$31.00 ©2015 IEEE

reported in the literature. Hence, CMA is effective in solving the problem of PAPR in OFDM system. Further, more hybrid algorithms can be developed with incorporation of more constraints to solve the problem of PAPR in OFDM system.

References

[1] Dae-Woon Lim, Seok-Joong Heo, and Jong-Seon No, "An Overview of Peak-to-Average Power Ratio Reduction Schemes for OFDM Signals," Journal of Communications and Networks, Vol. 11, NO. 3, pp.229-239, June 2009.

[2] Arun Gangwar, Manushree Bhardwaj, "An Overview: Peak to Average Power Ratio in OFDM system & its Effect," International Journal of Communication and Computer Technologies Vol. 01 – No.2, Issue: 02 September 2012.

[3] Yasir Rahmatallah, Seshadri Mohan, "Peak-To-Average Power Ratio Reduction in OFDM Systems: A Survey And Taxonomy," IEEE Communications Surveys & Tuttorials, Vol. 15, NO. 4, pp. 1567-1592 ,Fourth Quarter 2013.

[4] Tao Jiang and Yiyan Wu, "An Overview: Peak-to-Average Power Ratio Reduction Techniques for OFDM Signals," IEEE Transactions on Broadcasting, Vol. 54, NO. 2, pp. 257-268, June 2008.

[5] Y.-C. Wang, and Z.-Q. Luo, "Optimized Iterative Clipping and Filtering for PAPR Reduction of OFDM Signals," IEEE Transactions on Communications, Vol. 59, NO. 1, pp. 33-37, january 2011.

[6] Hem Dutt Joshi and Rajiv Saxena, "PAPR Reduction in OFDM systems using Precoding with clipping,", Communications, Computing and Control Applications (CCCA), International Conference 2011.

[7] Tao Jiang, Yang Yang, and Yong-Hua Song, "Companding Technique for PAPR Reduction in OFDM Systems Based on An Exponential Function," Global Telecommunications Conference, 2005. GLOBECOM '05. IEEE ,Volume:5 , 2 Dec. 2005.

[8] By Matthias Gay , Alexander Lampe and Marco Breiling, "An Adaptive PAPR Reduction scheme for OFDM using SLM with Clipping At the Transmitter, and Sparse reconstruction at the receiver,", Signal and Information Processing (ChinaSIP), IEEE China Summit & International Conference 2014.

[9] Shweta Jain, Vikas Gupta and Divya Jain, "PAPR Reduction in using modified selective mapping technique and turbo coding", International Journal of Advanced Engineering Technology Volume 02 , Issue: 04 ,December 2011.

[10] Pawan Sharma and Seema Verma, "PAPR Reduction of OFDM signals using selective mapping with turbo codes,", International Journal of Wireless and Mobile networks, Volume 03, Issue: 04 August 2011.

[11] Houshou Chen and Hsinying Liang, "A modified selective mapping with PAPR Reduction and Error correction in OFDM systems,", Wireless Communications and Networking Conference, 2007.WCNC 2007. IEEE.

[12] .Gurtej Singh Toor, Harjinder Singh and Amandeep Singh Bhandari ," PAPR Reduction and BER Improvement by using Logarithmic companding hybrid with SLM Technique in Interleved COFDM System," Confluence The Next Generation Information Technology Summit (Confluence), 2014 5th International Conference .

[13] N.V Irukulapati, V.K. Chakka and A.Jain ,"SLM based PAPR Reduction of OFDM signal using new phase sequence,", Electronics letters , Vol:45, No. 24., 19th November 2009.

[14] Jinwei Ji and Guangliang Ren," A New Modified SLM Scheme for Wireless OFDM Systems Without Side Information", IEEE Signal Processing Letters, Vol. 20, NO. 11, pp. 1090-1093 , November 2013.

[15] Hyun-Bae Jeon, Jong-Seon No, and Dong-Joon Shin," A Low-Complexity SLM Scheme Using Additive Mapping Sequences for PAPR Reduction of OFDM Signals," IEEE Transactions on Broadcasting, Vol. 57, NO. 4, PP.866-875, December 2011.

[16] Gagandeep kaur and Rajbir kaur , "Comparative study of SLM and PTS techniques for PAPR Reduction of an MC-CDMA system," International Journal Engineering Research and Application , Volume 02 – No.2, Issue: 04 August 2012.

[17] By C. Pradabpet, S. Yoshizawa, Y. Miyanaga and K. Dejhan,"Searching Phase Optimize in PTS-APPR method by GA for PAPR reduction in OFDM-WLAN Systems," , Conference on Innovative Technologies in Intelligent Systems and Industrial Applications (CITISIA 2009) IEEE.

[18] V.Vijayarangan, R.Kalidoss, Dr.(Mrs.)R.Sukanesh, "Low Crest Mapping for PAPR Reduction in OFDM systems.", Wireless, Mobile and Multimedia Networks, 2006 IET International Conference IEEE.

[19] By Manuvinakurike Narasimhasastry Suma, Somenahalli Venkatarangachar Narasimhan, Buddhi Kanmani ,"Orthogonal frequency division multiplexing peak-to-average power ratio reduction by best tree selection using coded discrete cosine harmonic wavelet packet transform,", Communications, IET 2014 Volume: 8 , Issue: 11 pp. 1875–1882, 2014.

[20] Mohan Baro and Jacek Ilow, "Improved PAPR Reduction for wavelet packet modulation using multi-pass tree pruning",The 18th Annual IEEE International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC'07).

[21] Narmatha.T, Sathish Kumar.K, "An Enhanced Algorithm for PAPR Reduction in MIMO OFDM/A", International Journal of Advanced Research in Computer Science & Technology (IJARCST 2014), Vol. 2 Issue Special 1 Jan-March 2014.

[22] Seyran Khademi and Alle-Jan van der Veen,"Constant Modulus Algorithm for Peak-to- Average Power Ratio (PAPR) Reduction in MIMO OFDM/A," ,IEEE Signal Processing Letters, Vol. 20, No. 5, pp.531-534, May 2013.

[23] Seyran Khademi and Alle-Jan van der Veen,"Precoding technique for Peak-to-Average Power Ratio (PAPR) Reduction in MIMO OFDM/A," ,ICASSP, pp.3005-3008, May 2012.

[24] Seyran Khademi and Alle-Jan van der Veen," Peak-to-Average Power Ratio (PAPR) Reduction in WiMax and OFDM/A," ,European Journal of Advance Signal Processing, Vol. 20, No. 5, pp.1-18, 2011.

978-1-4673-8253-3/15/$31.00 ©2015 IEEE