A Weighted OFDM Scheme with Signal Clipping and Windowing Techniques for PAPR Reduction-Study

Nisila Binu
Department of ECE, SNGCE Kadayiruppu, India.

Dr.C.D Suriyakala
Professor, Department of ECE, SNGCE Kadayiruppu, India.

Abstract – Orthogonal Frequency Division Multiplexing is an efficient modulation technique which can be used for both broadband wired and wireless communication. OFDM, known to be robust against multipath fading, can transmit high speed data using a number of orthogonal carriers. OFDM is becoming increasingly popular among the multicarrier communication systems because of its immunity to Inter Symbol Interference (ISI), Inter Carrier Interference (ICI), impulse noise etc. and also it is known for high spectral efficiency. Studies shows that the major drawback of such communication systems is the time domain OFDM signal which is the sum of several sinusoids leads to high Peak to Average Power Ratio (PAPR). By PAPR reduction spectral efficiency can be increased and system will be more energy efficient. High PAPR will reduce the BER performance of the system .There are several methods to reduce PAPR. The survey report highlights PAPR reduction scheme based on a weighted OFDM signal with windowing technique. This paper surveys a review of causes and its possible solutions to reduce the PAPR.

Index Terms – Complementary cumulative distribution function (CCDF), high power amplifier (HPA), orthogonal frequency division multiplexing (OFDM), inters channel interference (ICI), Bit error rate (BER), peak-to-average power ratio (PAPR).

1. INTRODUCTION

Mobile communication is increasing day by day and the need for high speed and high data rate communication .Mobile communication evolved from generations to generations. The 4G framework accomplish new levels of user experience and multi-service capacity by also integrating all the mobile technologies that exist .Wi-Fi, LTE; Long Term Evolution, and many other radio, wireless and RF technologies use OFDM technology to increase the capacity, spectral efficiency and link reliability. Multiple access schemes are one of the solutions which can share the limited radio spectrum among multiple users .The transmission of higher data rate will hostile the radio channel .Orthogonal frequency division multiplexing(OFDM) can overcome this problem by transmitting high data rate stream into several low rate parallel subcarriers. A large number of closely spaced orthogonal sub-carrier signals are used to carry data on several parallel data streams or channels. Each sub-carrier is modulated with a conventional modulation scheme (such as quadrature amplitude modulation or phase-shift keying) at a low symbol rate, maintaining total data rates similar to conventional single-carrier modulation schemes in the same bandwidth .In OFDM, the carriers are arranged such that the frequency spectrum of the individual carriers overlap and the signals are still received without adjacent carrier interference .Along with this ,there are many other advantages of OFDM as a transmission technique ,such that robustness against frequency selective fading channel, high speed transmission ,etc.

The features of OFDM are:

- High spectral efficiency as compared to other double sideband modulation schemes, spread spectrum, etc.
- Can easily adapt to severe channel conditions without complex time-domain equalization.
- Robust against narrow-band co-channel interference.
- Robust against intersymbol interference (ISI) and fading caused by multipath propagation.
- Efficient implementation using Fast Fourier Transform (FFT).
- Low sensitivity to time synchronization errors.
- Flexibility.
- Easy equalization.

But the main limitation of OFDM is its high Peak to Average Power Ratio (PAPR).

PAPR is the relation between maximum powers of the transmitted signal divided by the average power. Multicarrier system consists of independently modulated subcarriers which has different amplitudes and phases. The subcarriers occupy different spectra in the frequency domain and are transmitted at the same time .When those subcarriers are added up coherently the instantaneous peak power of a multicarrier system will be much bigger than the average power .So multicarrier communication system has high PAPR than single carrier communication system. Reduction of PAPR is a must because lower the PAPR higher will be the efficiency of high power amplifiers and analogy to digital converters and also leads to low power consumption since power saving is directly proportional to the average output power . Modulation techniques with low crest factor transmit more bits per second .By PAPR reduction spectral efficiency can be increased and system will be more energy efficient .High PAPR will reduce the BER performance of the system .Along with this the average input power must be reduced. Otherwise signal distortion will occur which in turn causes out of band spectral regrowth [9].

1.1. Effects of PAPR

- RF power amplifiers should be operated in a very large linear region. Otherwise, the signal peaks get into non-linear region of the power amplifier causing signal distortion. This signal distortion introduces intermodulation among the subcarriers and out of band radiation. Thus, the power amplifiers should be operated with large power back-offs. On the other hand, this leads to very inefficient amplification and expensive transmitters. Thus, it is highly desirable to reduce the PAPR [9].
- These large peaks cause saturation in power amplifiers, leading to intermodulation products among the subcarriers and disturbing out of band energy. Therefore, it is desirable to reduce the PAPR [9].

The rest of the paper is organised as follows. Section 2 will describe the related works, section 3 proposes a new method and section 4 concludes the paper.

2. RELATED WORKS

Different PAPR reduction techniques exist. These are grouped into two [9].They are:

2.1 Signal Scrambling Techniques

- Block Coding Techniques
- Block Coding Scheme with Error Correction
- Selected Mapping (SLM)
- Partial Transmit Sequence (PTS)
- Interleaving Technique
- Tone Reservation (TR)
- Tone Injection (TI)

2.2 Signal Distortion Techniques

- Peak Windowing
- Envelope Scaling
- Peak Reduction Carrier
- Clipping and Filtering

Xiao dong Li and Leonard J. Cimini [1] presented a paper on the effects of clipping and filtering on the performance of OFDM .To realize the OFDM modulation the authors used QPSK and IFFT .Authors noted the problem that if clipping is done directly, clipping noise will be present. In order to address this problem, Xiao dong Li and Leonard J. Cimini oversampled the OFDM signal by a factor of 8.To reduce the out of band noise filtering after clipping is used .This paper concentrated on three performance parameters such as ,power spectral density(PSD),crest factor(CF), and bit error rate(BER).The simulation showed that filtering is necessary to suppress the spectral splatter .Filtering causes peak regrowth. Clipping and filtering together suppresses the dynamic range of the signal amplitudes .The authors related the BER performance with SNR. Xiao dong Li and Leonard J. Cimini concluded that clipping and filtering is an efficient method in reducing the CF using realistic linear amplifiers.

Y.-C. Wang [2] has beautifully introduced an optimized iterative clipping and filtering method for PAPR reduction of OFDM signals .The author replaced the fixed rectangular window method used in the classic iterative clipping and filtering method with one designed by convex optimization method. This method decreases the number of iterations used .In each filtering iteration, Y.-C. Wang proposed to choose a filter that minimizes the current symbol's EVM subject to the desired PAPR .He has also given a brief notes about the OFDM parameters .The author then compared the performance of his method with that of the classic ICF method .He also proposed an optimized procedure .Y.-C. Wang carried out the simulation in QPSK modulated symbols .The author then analysed the PAPR based on CCDF,BER and SNR .The highlights in this method is the number of iterations required to reach a particular PAPR is less and the processed OFDM symbols had less distortion and better out of band radiation.

R .W. Bguml, R.F.H. Fischer and J.B. Huber [3] proposed a method which reduces PAPR by selected mapping. The method leads to significant gains .The authors considered statistically independent OFDM frames that represent same information .The frame with low PAPR for transmission was selected .For the simulation work 4-ary PSK was used .The authors analysed PAPR using CCDF .Before IDFT differential encoding is done .At the receiver ,after DFT differential decoding is done .For the receiver to know which vector is transmitted ,the authors sent the number of the vector as a side information .The method is applicable for all kind of multiplexing schemes.

S.H. Muller and J.B. Huber[4] introduced a PAPR reduction technique which reduces PAPR by optimum combination of partial transmit sequences .The authors used arbitrary numbers of subcarriers .In this method PAPR is minimised by combining partial transmit sequences .In the work the authors divided the information bearing subcarriers into disjoint subcarriers .Then a rotation factor and modified subcarrier amplitude vector for each sub block was introduced .The subcarrier amplitude vector represents the same information as the information bearing sub blocks which was obtained after dividing the signal initially .Then the optimum parameters for the OFDM signal resulting in the peak power optimized transmit sequence was calculated .Thus the authors obtained low crest factor .The method did not use actual multiplication .So this method has implementational advantages .The authors compared the method with that of selected mapping.

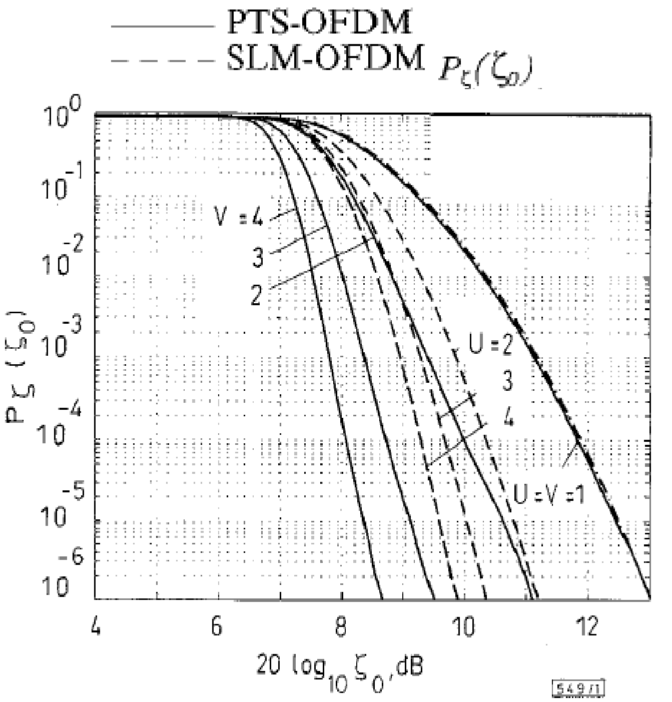

Fig 1 Probability that **P** $_{\zeta}$ **(ζ_0)** OFDM symbol with D = 512 exceeds crest factor **ζ_0** if PTS or SLM is used with V, U E {1, 2, 3, 4} [4]

A.D.S. Jayalath and *C.* Tellambura [5] presented an interleaver based technique for reducing the PAPR .The work is based on the fact that highly correlated data frames have large PAPs .The PAPRs were minimised by breaking the long correlation pattern .The authors used (k-1) random interleavers to produce (k-1) permuted sequences .Then the authors calculated the PAPR of the permuted sequences and the original information sequence .For computing the PAPR the authors used k Oversampled Fast Fourier Transforms. A.D.S. Jayalath and C. Tellambura chose the signals with low PAPR for transmission .At the receiver to recover the data ,a pointer to the selected interleaver is needed which is a minimal overhead .The authors simulated the work separately for symbol interleaver and bit interleaver .The results were compared with that of the PTS method.

Seungsoo Yoo , Sun Yong Kim[6] presented a novel scheme called selective mapping of partial tones(SMOPT).In this work the authors produced a set of modified OFDM symbols with reduced PAPRS .For this the authors added a set of mapping symbols to the original OFDM symbols. Seungsoo Yoo, Sun Yong Kim et.al simulated the work based on the sensitivity to (Peak Reduction Tones) PRT positions, multiplication complexity .The authors compared the proposed system with that of conventional Tone Reservation scheme .The simulation is based on the IEEE 802.11a WLAN and ETSI EN 300 401DAB physical layer models .For both schemes continuous subcarrier and randomly optimized sets are used. The author’s claims, from the observed results, that SMOPT have lower sensitivity to PRT positions, lower complexity and more design flexibility than the tone reservation scheme.

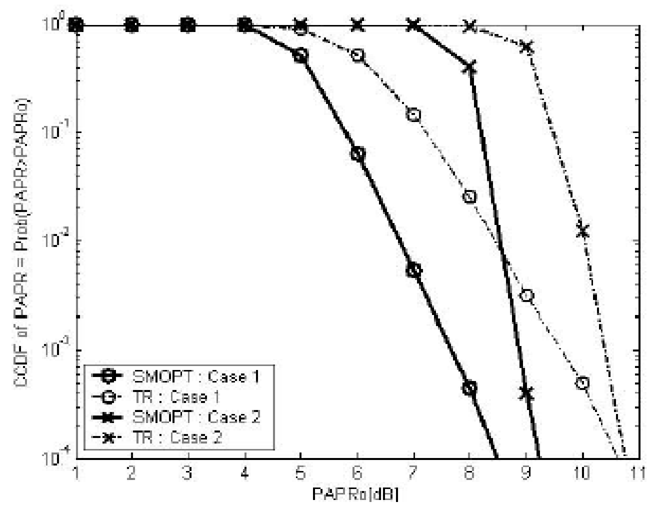

Fig 2 PAPR reduction performances of the SMOPT and TR schemes [6]

Chang Eon Shin, Kyung Soo Rim, and Youngok Kim[7] introduced a method for PAPR reduction in which weighted OFDM is used for transmission. The authors used weighted OFDM in order to reduce the distortion. The authors added a weight which is been derived from a suitable band limited signal at the transmitter and removed this weight at the receiver without signal distortion. To improve BER performance, Chang Eon Shin, Kyung Soo Rim, and Youngok Kim used modified weight. The authors also provide the condition for a function to be a weight function. The authors highlight the advantage of weighted OFDM over other methods by providing a mathematical explanation.

Authors compared the work with that of clipping and filtering by plotting BER, CCDF plots.

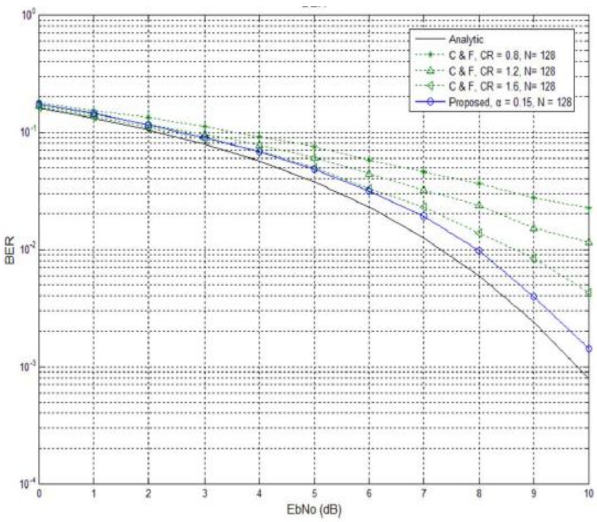

Fig 3 CCDF and BER of the C&F and proposed methods for *N* = 128[7]

K. M. Kawsar Pervez, and Md. Mahbub Hossain [8] presented a paper on the PAPR reduction which combines Hadamard transform and Hanning window. For mapping the authors used BPSK modulation. Before doing IFFT the signal is transformed using Hadamard transform at the transmitter. After IFFT using Hanning window, the peak amplitudes of the signal is clipped. Then inverse Hadamard transform is done after doing FFT.The results were compared with other methods. The authors simulated the method with Hadamard transform and Hanning window separately. Then the authors compared the BER of the method with these methods. K. M. Kawsar Pervez, and Md. Mahbub Hossain plotted CCDF plots for the performance comparison.

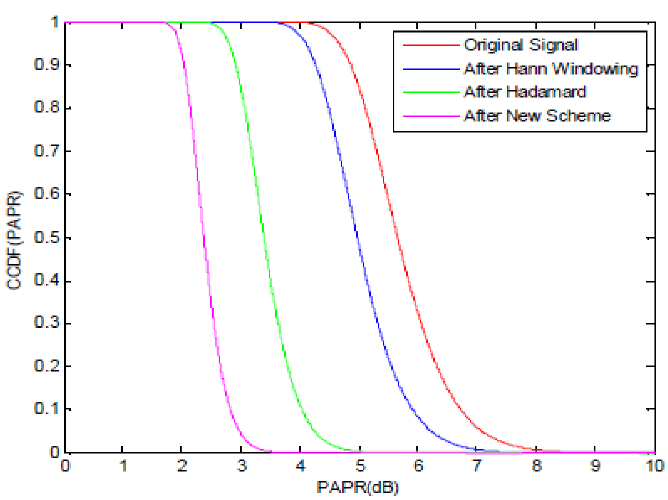

Fig 4 Simulation result of PAPR for original OFDM signal and signal after applying proposed scheme [8]

The table provided below compares different PAPR reduction techniques:

	Power Increase	Implementation Complexity	Bandwidth 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

Table 1 Comparison of different PAPR reduction techniques [9]

3. PROPOSED MODELLING

The survey includes different methods of PAPR reduction done by various researchers. All the reports showed that PAPR reduction is a must in data transmission through multicarrier communication. Also the reports pointed out that PAPR must be reduced without signal distortion, BER performance degradation, data missing etc.

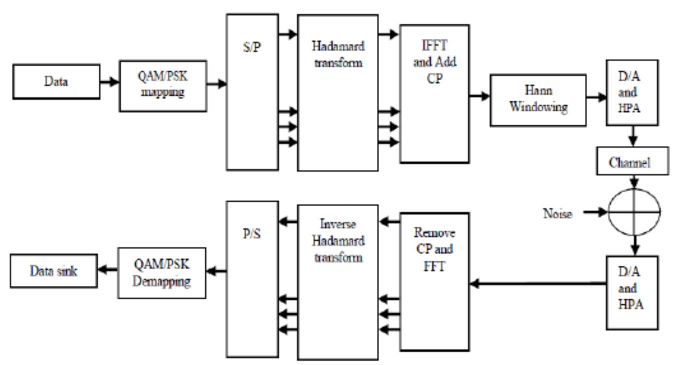

Fig 5 Block diagram of OFDM system employing window technique [8]

From the literature review done we can understand that PAPR is an important factor in determining the performance of an OFDM system. Many PAPR reduction schemes have been proposed, some have many merits along with some draw backs. Clipping and filtering [1] is an example for this. It reduces the PAPR for a desired value. But as a result of this data loss occurs. Another efficient method is reducing PAPR by partial transmit sequence [4].But this method is complex in calculations. In the new method suggested, it reduces the PAPR to a desired value with low complexity and without data loss.

4. CONCLUSION

In OFDM, the subcarriers occupy different spectra in the frequency domain and are transmitted at the same time .When those subcarriers are added up coherently the instantaneous peak power become much bigger than the average power and causes high PAPR. In this paper weighted OFDM scheme is used to reduce PAPR with signal clipping and windowing techniques. The weighted OFDM signal will give better performance than other OFDM signals. In order to reduce the distortion of signals Hadamard transform will be used. The windowing technique going to use is a hanning window which gives better BER performance. Peak windowing gives much better spectral result than that of simple clipping. It gives a smooth peak for the clipped signal in contrast with normal flat top achieved by simple clipping. The author strongly believe that the above suggested method will give a better performance than the existing other methods.

REFERENCES

[1] Li, Xiaodong, and Leonard J. Cimini Jr. "Effects of clipping and filtering on the performance of OFDM." In Vehicular Technology Conference, 1997, IEEE 47th, vol. 3, pp. 1634-1638. IEEE, 1997.

[2] Wang, Y. C., and Z. Q. Luo. "Optimized iterative clipping and filtering for PAPR reduction of OFDM signals." Communications, IEEE Transactions on 59, no. 1 (2011): 33-37.

[3] Schmidt, Heiko, and Karl-Dirk Kammeyer. "Reducing the peak to average power ratio of multicarrier signals by adaptive subcarrier selection." In Universal Personal Communications, 1998. ICUPC'98. IEEE 1998 International Conference on, vol. 2, pp. 933-937. IEEE, 1998.

[4] Schmidt, Heiko, and Karl-Dirk Kammeyer. "Reducing the peak to average power ratio of multicarrier signals by adaptive subcarrier selection." In Universal Personal Communications, 1998. ICUPC'98. IEEE 1998 International Conference on, vol. 2, pp. 933-937. IEEE, 1998.

[5] Jayalath, A. D. S., and Chintha Tellambura. "Reducing the peak-to-average power ratio of orthogonal frequency division multiplexing signal through bit or symbol interleaving." Electronics Letters 36, no. 13 (2000): 1161-1163.

[6] Yoo, Seungsoo, Seokho Yoon, Sun Yong Kim, and Iickho Song. "A novel PAPR reduction scheme for OFDM systems: Selective mapping of partial tones (SMOPT)." Consumer Electronics, IEEE Transactions on 52, no. 1 (2006): 40-43.

[7] Shin, Chang Eon, Kyung Soo Rim, and Youngok Kim. "A Weighted OFDM Signal Scheme for Peak-to-Average Power Ratio Reduction of OFDM Signals." Vehicular Technology, IEEE Transactions on 62, no. 3 (2013): 1406-1409.

[8] K. M. Kawsar Pervez, and Md. Mahbub Hossain, “A New Proposed Scheme for PAPR Reduction of OFDM System Combining Hadamard Transform and Hann Peak Windowing”, IJCIT,2012.

[9] Gangwar, Arun, and Manushree Bhardwaj. "An overview: Peak to average power ratio in OFDM system & its effect." International Journal of Communication and Computer Technologies 1, no. 2 (2012): 22-25.

Authors

Nisila Binu has graduated from KMEA Engineering College of Mahatma Gandhi University in Electronics & Communication Engineering in 2013. She is currently pursuing her M-Tech Degree in Communication Engineering from Sree Narayana Gurukulam College of Engineering, Kadayiruppu.Her research interest includes multicarrier communication especially OFDM.

Suriyakala.C.D is an Engineering Graduate in Electronics and Communication Engineering from Manipal Institute of Technology, Manipal. Did her Masters M.S. (By Research) from Anna University, Chennai & PhD from Sathyabama University. At present, she is associated with Electronics and Communication Department, SNGCE, Kolencherry, Kerala. She has a total experience of 24 years, which includes teaching as well as research. Received Two sponsored projects (NRSC& DRDO) and good number of published in refereed conferences and journals added credit in her career. Her research area is in software Agents for Communication Engineering.