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A Survey on Peak Windowing Techniques for PAPR Reduction

Nisila Binu [1], Dr. Suriyakala C.D [2]
[1]*ECE Department Sree Narayana Gurukulam College of Engineering,India*
[2]*ECE Department Sree Narayana Gurukulam College of Engineering,India*

Abstract : *Orthogonal Frequency Division Multiplexing (OFDM) is an efficient modulation technique which can be used for both broadband wired and wireless communication. OFDM is now becoming widely 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 has high spectral efficiency. Studies show that high Peak to Average Power Ratio (PAPR) is one of the major drawbacks in multicarrier communication system. PAPR is defined as the relation between maximum powers of the transmitted signal divided by the average power. Through PAPR reduction the efficiency of high power amplifier could be substantially improved and nonlinear distortion noise caused by the HPA could also be significantly reduced. 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. Various approaches have been proposed to reduce the PAPR such as clipping, coding schemes, phase optimization, nonlinear companding transforms, Tone Reservation (TR) and Tone Injection (TI), constellation shaping, Partial Transmission Sequence (PTS) and Selective Mapping (SLM). Among all the PAPR reduction techniques, peak windowing is an effective one for practical implementation as there is no side information and maintain a good spectral characteristic compared with the clipping method.*
Keywords - *BER, CCDF, HPA, ICI, OFDM, PAPR*

I. INTRODUCTION

Mobile communication is getting increased day by day and the need for high speed and high data rate communication. Mobile communication evolved from generations to generations. Multiple access schemes are one of the solutions which can share the limited radio spectrum among multiple users. The transmissions of higher data rate will hostile the radio channel. OFDM can overcome this problem by transmitting high data rate stream into several low rate parallel subcarriers. The first systems using MCM were military HF radio links in 1960s. In a classical MCM system, the total signal frequency band is divided into N non overlapping frequency sub channels. Using a separate symbol each sub channel is modulated and then the N sub channels are frequency multiplexed. Spectral overlap of channels is avoided to eliminate interchannel interference. However, this leads to inefficient use of the available spectrum. To cope with the inefficiency, the ideas proposed from the 1960s were to use multi channel communication system and Frequency Division Multiplexing (FDM) with overlapping subchannels. OFDM is a special case of MCM. 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. But OFDM has a main problem, its high Peak to Average Power Ratio (PAPR).

PAPR is the relation between maximum power 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 become much bigger than the average power of the system. 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 analog 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.

The rest of the paper is organised as follows. Section 2 provides an overview of the existing PAPR reduction techniques, section 3 proposes a new method and section 4 concludes the paper.

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

(i) 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)

(ii) Signal Distortion Techniques
• Peak Windowing
• Envelope Scaling
• Peak Reduction Carrier
• Clipping and Filtering

II. AN OVERVIEW OF PAPR REDUCTION TECHNIQUES

Clipping is a kind of peak windowing technique which introduces self interference. The technique of peak windowing offers better PAPR reduction with better spectral properties. In peak windowing method large signal peak is multiplied with a specific window function. Different windows exists, they are; Gaussian shaped window, cosine, Kaiser, Hamming window etc. The OFDM signal is multiplied with these windows. The spectrum resulted will be a convolution of the original OFDM spectrum with the spectrum of the applied window.

Xiaodong 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. Inorder to address this problem, Xiaodong 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. When the Clipping and filtering processes are combined together, they suppress the dynamic range of the signal amplitudes. The authors related the BER performance with SNR. Xiaodong Li and Leonard J. Cimini concluded that clipping and filtering is an efficient method in reducing the CF using realistic linear amplifiers.

Armstrong[2] showed that repeated clipping and frequency domain filtering process reduces the PAPR of an OFDM signal. The main highlight of this technique is that it does not cause out of band power. In this method he first transformed the input vector using IFFT. He then made the trigonometric interpolation of the time domain signal. This signal is then clipped. The filter used consists of two FFT operations. The filter operates on a symbol by symbol basis, so there was no intersymbol interference. J. Armstrong analysed the performance based on cumulative distribution function. The author designed frequency domain filter to reject out of band discrete frequency components. The main loophole of this method was the distortion of inband signals resulting in the shrinking of the overall signal constellation which causes an added noise like effect.

Y.-C. Wang[3] 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.The advantage of this method is that it decreases the number of iterations used as in the other methods. In each filtering iteration, Y.-C. Wang proposed to choose a filter that minimizes the current symbol's EVM subject to the desired PAPR. The authors have also given a brief notes about the OFDM parameters they used for simulation. The author then compared the performance of his method with that of the classic ICF method. They 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.

The window should be as narrow band as possible, also the window should not be too long in the time domain because various signal samples are affected, which results an increase in bit error rate (BER). The loss in signal to noise ratio (SNR) due to signal distortion can also be reduced.

An advanced Peak Windowing Technique [10] is proposed by Harish Kumar Pal, Anand Kumar Singh. The authors proposed the method to overcome the drawback of the conventional method when successive peaks emerge within a half of the window size. In order to maintain the out-of-band radiation within a certain level, the authors increased the window length. The APW is aiming towards detecting the high instantaneous signal peaks and suppressing them to the exact threshold level even in case of consecutive peaks. The proposed method effectively suppresses the peak signals to the desired threshold level in case that successive peak occurs within a half of the window length.

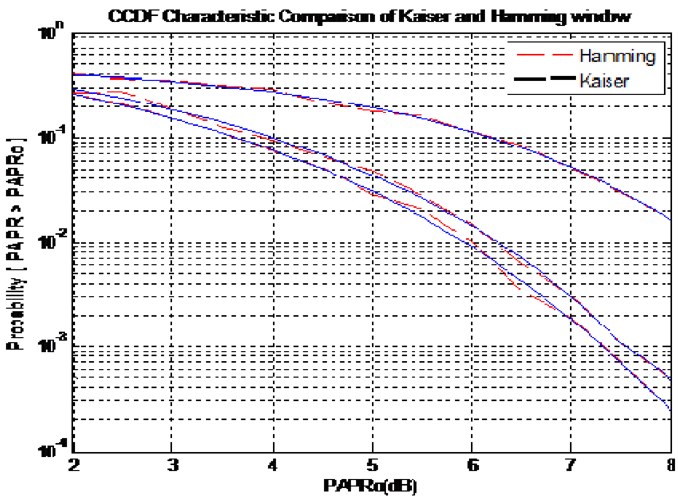

Figure.1. Comparison of CCDF characteristic between Hamming and Kaiser Window technique

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 method. K. M. Kawsar Pervez, and Md. Mahbub Hossain plotted CCDF plots for the performance comparison.

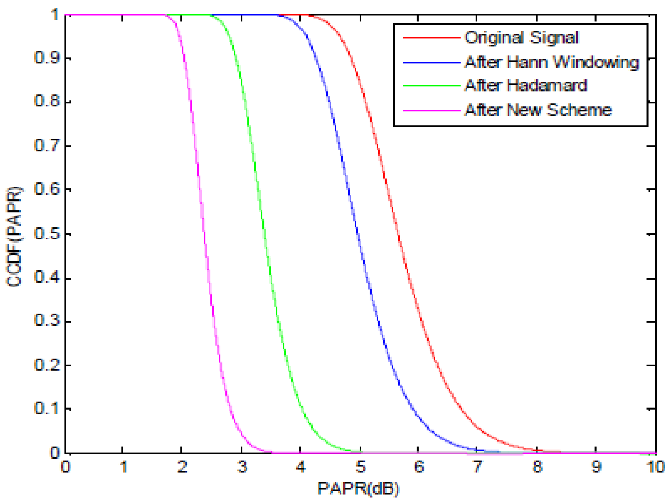

Figure.2. The Simulation result of PAPR for original OFDM signal and the signal after the application of proposed scheme[8]

The table provided below compares different PAPR reduction techniques:

Table1. Comparison of different PAPR reduction techniques [9]

	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

III. SOLUTION PROPOSED

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

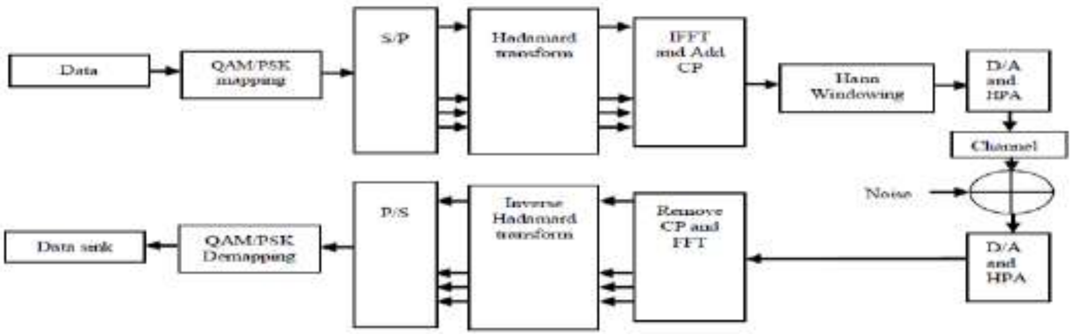

Figure 3. Block diagram of OFDM system employing window technique [8]

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 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 PTS - 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.

IV. 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 Peak to Average Power Ratio. 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.

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