International Journal of Research Studies in Science, Engineering and Technology
Volume 2, Issue 8, August 2015, PP 79-83
ISSN 2349-4751 (Print) & ISSN 2349-476X (Online)

Significance and Effects of Peak to Average Power Ratio Reduction Techniques in an OFDM System

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Abstract: *Orthogonal frequency division multiplexing used for high data rate communication is a multicarrier modulation technique widely used in almost all applications. It has several advantages including reduced inter carrier interference, inter symbol interference, immunity to multi path fading etc. OFDM signal which is a sum of several sinusoids has high peak to average power ratio (PAPR). This is a challenging issue since it causes serious performance degradation and power inefficiency. Therefore the use of proficient PAPR reduction techniques is very important when considering an OFDM system. Here we combine hadamard transform, hann peak windowing along with partial transmit sequence (PTS) and selective mapping (SLM) technique for efficient PAPR reduction. All the simulations are performed on MATLAB platform to analyse PAPR reduction performances. The proposed system provides reduced computational complexity and better PAPR reduction.*

Keywords: *PAPR,PTS, SLM, BER, hadamard transform, hann windowing*.

1. Introduction

Orthogonal frequency division multiplexing is a form of multicarrier modulation that divides a high data rate modulating stream, placing them on to many narrowband close spaced subcarriers, making it less sensitive to frequency selective fading. OFDM has been adopted in many of the latest wireless and telecommunication standards. Its advantages include high spectral efficiency; multi path delay spread tolerance, immunity to frequency selective fading and power efficiency. But one of the challenging issues of an OFDM system is its high peak to average power ratio (PAPR). High PAPR can cause problems such as out of band and in band distortion [1], and if the high power amplifier used is not operated in its linear region, it is not possible to keep out of band power below specified limits [5][3] .This can cause inefficient amplification and lead to the use of expensive transmitters.

Peak to average power ratio (PAPR) is generally used to characterize the envelope fluctuation of the OFDM signal and is defined as the ratio of the maximum instantaneous power to its average power. Also, OFDM system requires tight frequency synchronization in comparison to single carrier systems because, the subcarriers are narrowband. Therefore, it is sensitive to a small frequency offset between the transmitted and the received signal. The frequency offset may arise due to Doppler Effect or due to mismatch between transmitter and receiver local oscillator frequencies. The carrier frequency offset disturbs the orthogonality between the subcarriers, and therefore the signal on any particular subcarrier will not remain independent of the remaining subcarriers. This effect is known as inter-carrier interference (ICI), which is a big challenge for error-free demodulation and detection of OFDM symbols. PAPR reduction uses signal scrambling techniques which scramble the codes and signal distortion techniques which distort peak valued portion of the signal [3] to achieve better performance. Coding techniques belong to scrambling techniques and commonly adopted distortion techniques are clipping, windowing etc.

This work focuses on combining hadamard transform, hann windowing, partial transmit sequence (PTS) and selective mapping (SLM) to achieve better reduction in peak to average power ratio.

2. System Using Hadamard Transform and Hann Window for PAPR Reduction

Existing system makes use of hadamard transform and hann peak windowing to obtain reduced PAPR [1]. Hadamard transform also known as Walsh hadamard transform is a generalized class of transforms. The Hadamard transform share significant computational advantages over DFT, DCT, and DST transforms. Their unitary matrices consist of +1 and -1 and the transforms are computed via additions and subtractions only, with no multiplications being involved. Hence, for processors for which multiplication is a time-consuming operation a sustained saving is obtained. In signal processing, a window function (also known as an apodization function or tapering function) is a mathematical function that is zero-valued outside of some chosen interval. For instance, a function that is constant inside the interval and zero elsewhere is called a rectangular window, which describes the shape of its graphical representation. When another function or waveform/data-sequence is multiplied by a window function, the product is also zero valued outside the interval. The existing system makes use of this hann window to distort the peak valued portion of the signal and hadamard transform to prevent data loss.

2.1. Block Diagram of Existing System

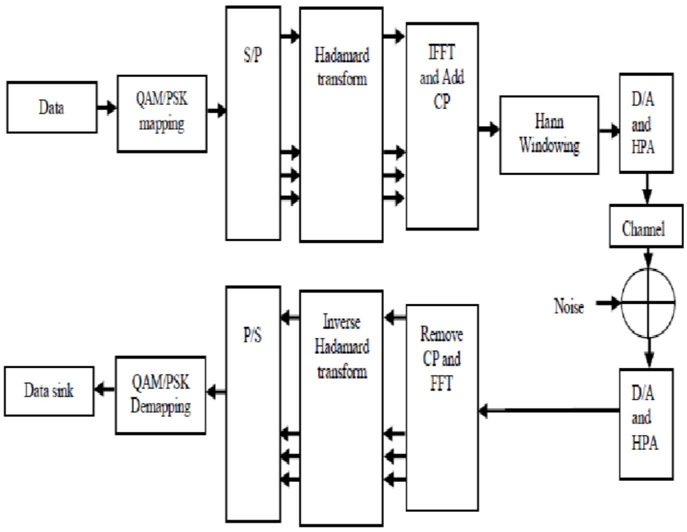

Fig1. *System using hadamard transform and hann windowing.*

Here the input data is mapped by digital to analog mapping. The mapped data is then modulated and hadamard transformed. The hadamard transformed data is then given IFFT operation which convert frequency domain signal to time domain signal. This signal is then hann windowed and transmitted through channel. The signal is decoded by performing inverse hadamard transform after FFT operation. This signal is then given to parallel to serial converter and gets demapped to recover the original signal [1].

2.2. Quantifying PAPR

Peak to average power ratio also called crest factor is the measurement of a waveform from the peak power of the waveform divided by the average power of the waveform. Peak-to-Average ratio actually denotes the envelope fluctuation. The system should operate in the linear region. Large peaks lead to saturation in the power amplifiers and amplifier saturation causes nonlinear distortion.

When we consider a signal x(t), its peak to average power ratio is given by,

PAPR = Maximum power of signal x(t) / Average power of signal x(t) where

Maximum power of signal = max(x(t)*conjugate of x(t)).

Average power of signal = E(x(t)*conjugate of x(t)).

2.3. Problem Identification

High PAPR in an OFDM system has two major drawbacks; in band distortion and out of band distortion. As mentioned, when the peak value of the signal is larger than average value, at the time of peak amplitude the power amplifier operates in its nonlinear region. Due to the non-linearity of amplifier gain different frequency components spread out and interfere with other subcarrier channels. This is termed as out of band distortion. Again because of the non-linearity of power amplifier used, instead of getting an amplified version of the input signal, distorted form of input signal is obtained as the power amplifier output. Since these are some serious issues attention is given to adopt and combine other techniques for obtaining PAPR reduction.

3. Enhanced Version with PTS and SLM

Partial transmit sequence technique (PTS) [2][4]and selective mapping(SLM) [2][4] is combined along with hadamard transform and hann windowing to get more optimum PAPR. In PTS technique, input data consisting of N symbols is divided into various sub-blocks and the subcarrier in each sub-block are weighted by a phase factor. The selection of phase factors play a vital role in PTS technique and the phase factors that gives optimum PAPR is usually selected. In conventional PTS approach [6], it is necessary to calculate the PAPR value at each step of the algorithm. So we need to send the phase factors used, as a side information in order to recover original information. Phase factors area discrete set of values and long computations are needed if the phase collection is large.

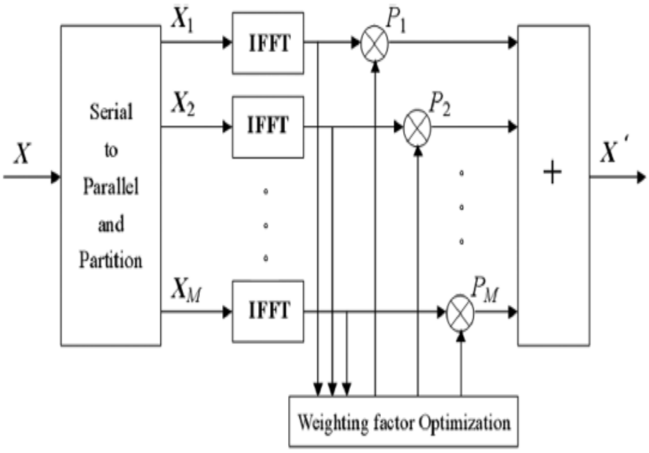

Fig2. *PTS technique.*

In SLM (selective mapping) technique a series of codes are used to generate multiple copies of the original signal. Here the signal selected for transmission is the signal with lowest PAPR. Also it is required to send the side information about the transmitted signal for recovering original information. High computational complexity and the use of side information are the major drawbacks of SLM technique.

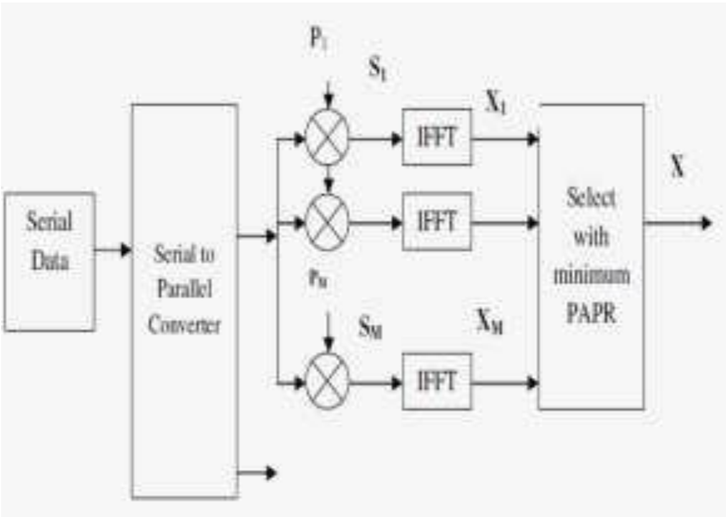

Fig3. *SLM technique.*

3.1. System Description

Here an approach which uses PTS and SLM along with hadamard transform and hann windowing is put forward for getting optimization in peak to average power ratio. The system description can be given as follows:

The data given as input is modulated using QAM modulation technique. The modulated data is converted to parallel blocks and is hadamard transformed to reduce data loss. This hadamard transformed data is then hann windowed after performing IFFT operation. To reduce PAPR this data is given to PTS and SLM blocks for selecting the signal with lowest PAPR.

3.2. Simulation Results

The system simulation is performed on MATLAB platform. QAM is the type of modulation used by the system. Cumulative Complementary Distributive Function (CCDF) is used to analyse performance PAPR reduction techniques.

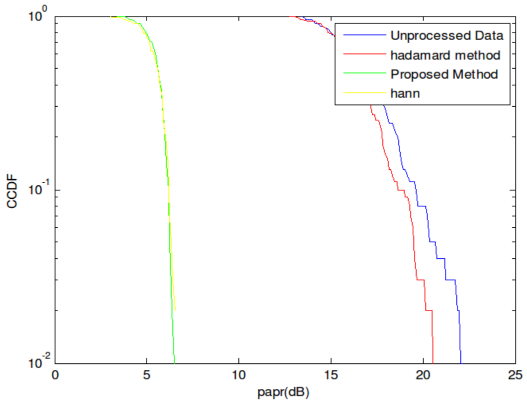

Fig4. *CCDF of PAPR with hadamard transform and hann windowing*

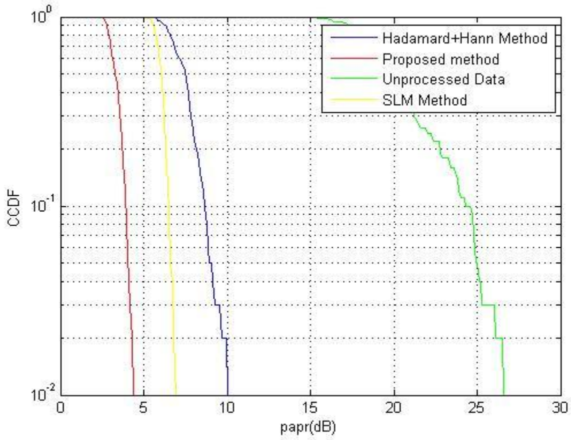

Fig5. *CCDF of PAPR using PTS and SLM along with hadamard transform and hann windowing*

4. Significance of PAPR Reduction Techniques

As per simulation there is not much variation in PAPR by the use of hadamard transform and its complexity increases with number of data bits leading to delay. But hann windowing which makes better PAPR reduction can cause self-interference. PTS is more efficient technique than SLM. The problem is that by combining these four techniques BER of the system is very high. So any further enhancements should be focused in adopting techniques which reduce bit error rate of the system.

5. Conclusion

Peak to average power ratio (PAPR) can be described as the maximum power in the OFDM transmission to its average power. It is mandatory to reduce the peak to average power ratio since it seriously affect system performance and cause BER degradation. PAPR reduction involves the use of various techniques such as clipping, filtering, PTS, SLM [5] etc. It is noted that the technique should not cause any degradation in system performance and should maintain PAPR within specified limits. Here we have combined hadamard transform, hanning window, partial transmit sequence technique and selective mapping techniques in order to get more optimization in the peak to average power ratio. In hadamard transform technique, the input data is multiplied using hadamard matrix before IFFT operation. Hannpeak windowing provides better spectral result than simple clipping method. Peak windowing gives a smooth peak to the signal whereas clipping gives flat top to the signal. PTS is a widely used technique which offers high efficiency in PAPR reduction compared to other techniques. SLM is also added here to get more PAPR reduction. The use of these four techniques can lead to more reduced PAPR. All simulations here are performed using MATLAB tool.

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