A Review of PAPR Reduction Techniques for OFDM Systems

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Abstract*: Orthogonal frequency division multiplexing (OFDM) is a type of multicarrier modulation technique in which entire bandwidth is divided into large number of small sub-carriers and each subcarrier is transmitted parallel to achieve higher data rates. It is used in various applications like Digital audio broadcasting (DAB), Digital video broadcasting (DVB) & wireless LAN. OFDM is a attractive modulation scheme with strongly efficient in bandwidth usage, immunity against multipath fading environment. It has less ICI and ISI and provides better spectral efficiency. Although it has various advantages but still certain disadvantages are: high Peak to average Power ratio, high bit error ratio (BER) & synchronization problem. This paper will focus on various PAPR reduction techniques and conclude with comparison between various techniques.*

Keywords: *Orthogonal Frequency division multiplexing (OFDM), Wireless LAN, Bit Error ratio (BER), Peak to average power ratio (PAPR), Multipath fading.*

I. INTRODUCTION

Due to the advances in communication technology, there is a demand for very higher data rate, the efficient modulation technique is used which is known as OFDM. OFDM stands for orthogonal frequency division multiplexing which is multicarrier modulation technique and have efficient use of bandwidth.

The basic idea of OFDM is to divide a high-rate data stream into a number of lower rate streams which are transmitted simultaneously over a number of subcarriers. These parallel subcarriers are overlapped with each other. The problem of Inter- symbol interference (ISI) is also eliminated by introducing a guard time in every OFDM symbol [7]-[8].

OFDM faces several problems. The first problem is ISI which is due to multipath. It has large peak to average ratio which results in non linearity's of amplifier. It also has phase noise problems of oscillator, OFDM also deals with synchronization problem both in terms of timing & frequency High peak-to-average power (PAP) ratio results in the distortion of signal if the transmitter contains nonlinear components such as power amplifiers (PAs). The nonlinear effects on the transmitted OFDM symbols results in large dynamic range of the high power amplifier which results in distortion. The nonlinear distortion causes both in-band and out-of-band

The remainder of this paper is organized as follows. In section II, deals with the PAPR problem in OFDM. Section III describes various effects of PAPR. Section IV describes various PAPR reduction techniques. Section V describes comparison between various PAPR reduction techniques. Section VI describes the Conclusions.

II. PAPR PROBLEM IN OFDM

PAPR stands for Peak to average power ratio. It is defined as the ratio of Peak power to the average power[16].

$$PAPR_{dB} = 10 \log \left(\frac{\max[x\ (t)x^*(t)]}{E[x(t)x^*(t)]} \right)$$

Where ()* corresponds to the conjugate operator.

PAPR is a measure of the envelope fluctuations of a Multicarrier signal and it is used as figure of merit. As OFDM signal consists of a number of independently modulated symbols. The sum of independently modulated subcarriers can have large amplitude variations which results in a large *peak-to-average-power ratio* (PAPR).

III. EFFECTS OF PAPR

As PAPR increases it results in the following effects [21]:

- It results in a **large dynamic range** of the D/A and A/D converters will be required; if the dynamic range is not increased then the peak values could be clipped, which results in signal distortion.
- If A/D and D/A converters with large working ranges are chosen, **quantization noise** will increase and the system performance will degrade.
- In addition, the choices of power amplifier and up-converters will also be crucial when PAPR problem occurs. The working range of Power amplifier & up converters is required, so that the nonlinear distortion would not be introduced which results in decreasing the **power efficiency** of Power amplifier. For example, the maximum power efficiency of a Class B power amplifier drops from 78.5% to 4.6%, when the PAPR increases 0dB to 17dB, as stated in the IEEE 802.11a standard.

IV. PAPR REDUCTION TECHNIQUES

PAPR reduction techniques can be divided into two types . These are signal scrambling techniques and signal distortion techniques [24].

The signal scrambling techniques are classified as:

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

The Signal Distortion Techniques are classified as:

- Peak Windowing
- Envelope Scaling
- Clipping

Signal Scrambling Technique Block Coding Technique

It is a type of signal scrambling techniques. In this technique PAPR is reduced by using different block coding & various set of code words. This scheme is most commonly used to reduce the peak to mean envelope power ratio.

Selective Mapping Technique

The input data sequences are multiplied by each of the phase sequences to generate alternative input symbols sequences [1]. Then for the IFFT operation each of these alternative input data sequence is used , and then the one with the lowest PAPR is selected for transmission as shown in Fig. 1.

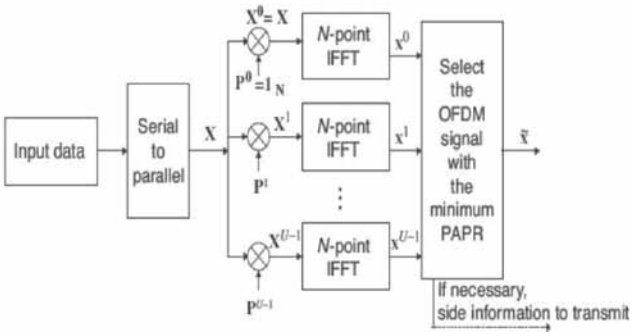

Fig. 1: Selective Mapping Method

Partial Transmit Sequences

It divide the original OFDM sequence into several sub- sequences and then for each sub-sequence is multiplied by different weights until an optimum value is chosen shown in Fig. 2.[6]

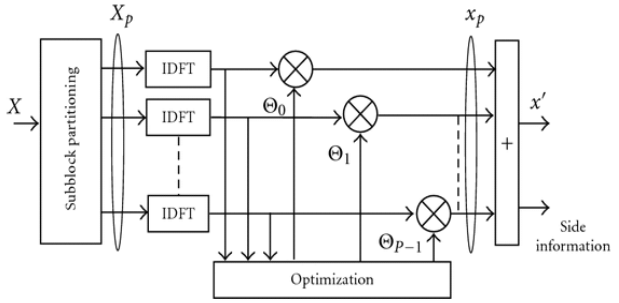

Fig. 2: Partial Transmit Sequence Method

Interleaving Technique

It is a type of phase rotation method which is widely used to reduce PAPR (peak to average power ratio) in orthogonal frequency-division multiplexing (OFDM) system. This method reduces the PAPR without spectrum distortion. As it requires many IFFT blocks and the side information must be additional included for the correct data recovery. As the side information is used so the data rate and spectral efficiency decreases which degrades the BER performance.

Tone Reservation

It requires some set of reservation of tones. Reserved tones can be used to minimize the PAPR & it is used in multicarrier systems. If number of tone is small then reduction in PAPR may represent non negligible samples of available bandwidth. In this method there is no requirement of side information and no process is required at the receiver. In this method the data block is added to the time domain signal to reduce the peak leads.

Tone Injection

It uses additive method for PAPR reduction .This method leads to less data rate loss. This method used the set of active constellation point for an original constellation point to reduce the PAPR. In this method for each unit, all original constellations is mapped on the several equivalent constellation point & this extra point freedom can be easily used to reduce the PAPR. This method is widely used as the tone injection method because of the newly applying points into basic constellation for the new points for larger constellation. This method deals with injecting tone of appropriate phase and frequency in OFDM symbol. The limitation of this method is the requirement of side information at the receiver side.

Signal Distortion Techniques

Peak windowing

This technique is similar to the clipping technique but it gives better performance by adding some self interference and increasing in BER (bit error rate& out band radiation) .In this method we multiply different windows with large signal peaks e.gs Gaussian shaped window, cosine, Kaiser etc. OFDM signal is then multiplied with several of these windows, the resulting spectrum which is obtained is a convolution of the original OFDM spectrum with the spectrum of the applied window (as mentioned earlier). Means the windows should be narrow as possible. By using this technique PAPR can be reduced to 4db of each subcarrier.

Envelope Scaling

This technique is related to scaling means before OFDM signals sent to the IFFT, the input envelope for some subcarriers are scaled. This technique uses 256 sub carrier so that all sub carrier will remains equal. In this method the input envelope in some sub carrier is scaled to achieve the smallest amount of PAPR at the output of the IFFT. The receiver does not need any side information at the receiver end for decoding. This method is suitable for the PSK modulation but when it is applied with the QAM high degradation is occurred in terms of BER

Clipping Technique

The Clipping based techniques clips the time domain signal to predefined level. The OFDM signal contains high peaks so it is transferred from the clipping. In this when amplitude crosses the threshold or cut off level, the amplitude is clipped off while saving the phase. It is easier and simpler but it is a cause for decreasing the performance of system [5].

V. COMPARISON OF VARIOUS REDUCTION TECHNIQUES

The comparison of various PAPR reduction techniques is given below in Table 1. The various PAPR reduction technique should be chosen with awareness according to the system requirements. Each method has their own advantages & disadvantages. As Selective Mapping method & Partial transmit method are distortion less methods, so it is more commonly used for PAPR reduction. SLM technique is a very efficient technique for reducing PAPR. SLM can be used for any number of subcarriers and for any signal constellation. It provides significant gain with moderate complexity. In SLM method, Channel coding is needed to protect the side information. While on the other hand PTS is probabilistic method for reducing the PAPR problem. It can be said that PTS method is a modified method of SLM. PTS method works better than SLM method. The main advantage of this scheme 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 blocks. Transmitting only part of data of varying

sub-carrier which covers all the information to be sent in the signal as a whole is called Partial Transmit Sequence Technique. Table 1 shows the parameters of different PAPR techniques on which the reduction of PAPR depends. These parameters are distortion, power level, data rate & BER.

Table 1: Analysis of various Reduction Techniques

Reduction Techniques	Distortion Level	Power Rate	Data	BER
Block Coding Technique	Decreases	Decreases	Decreases	Decreases
Selective Mapping Technique	Decreases	Decreases	Decreases	Decreases
Partial Transmit Sequence	Decreases	Decreases	Decreases	Decreases
Interleaving Technique	Decreases	Decreases	Decreases	Decreases
Tone Reservation	Decreases	Increases	Decreases	Decreases
Tone Injection	Decreases	Increases	Increases	Increases
Peak Windowing	Increases	Decreases	Increases	Increases
Envelope Scaling	Decreases	Decreases	Increases	Increases
Clipping Technique	Increases	Decreases	Increases	Increases

VI. CONCLUSIONS

In this paper, we discuss various PAPR reduction methods. Orthogonal frequency division multiplexing technique is high speed modulation technique which provides high data rate and used in both wired and wireless systems. The major problem of OFDM system is PAPR which affects the performance of OFDM. Various techniques are available for improving PAPR and all these techniques have its own advantages and disadvantages. Every technique will minimize PAPR to some level but the best technique will be considered which not only minimize PAPR but also reduce complexity& BER.

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