ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 2, Issue 3, May 2013

An Overview of PAPR Reduction Techniques in OFDM system

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Abstract: ***Orthogonal Frequency Division Multiplexing (OFDM) is a multicarrier modulation technology used in many wireless digital communication systems. It has many advantages such as bandwidth efficiency, and less impact of Intersymbol Interference (ISI) but one of its drawbacks is high Peak to Average Power Ratio (PAPR). When these high peak signals are passed through power amplifiers they cause the non-linear distortion of the signals. Also they increase the dynamic range of amplifiers. In this paper, PAPR problem is defined and this paper present different PAPR reduction techniques and conclude an overall comparison of these techniques.***

Index terms: **Orthogonal Frequency Division Multiplexing (OFDM), Peak to Average Power Ratio (PAPR).**

I. INTRODUCTION

In high-speed wireless and mobile communications era, OFDM technology is a special Multi-Carriers Modulation transmission scheme which can be seen as either a modulation technology or a multiplexing technology enabling transmission of multiple signals simultaneously, over a single transmission path. In OFDM a high rate data stream is divided into many low data streams and these steams are then multiplied by corresponding carrier frequency signals that are [1] orthogonal to each other. A composite signal so formed by multiplexing these modulated signals is called the OFDM signal. A simple OFDM system is shown in figure (1).

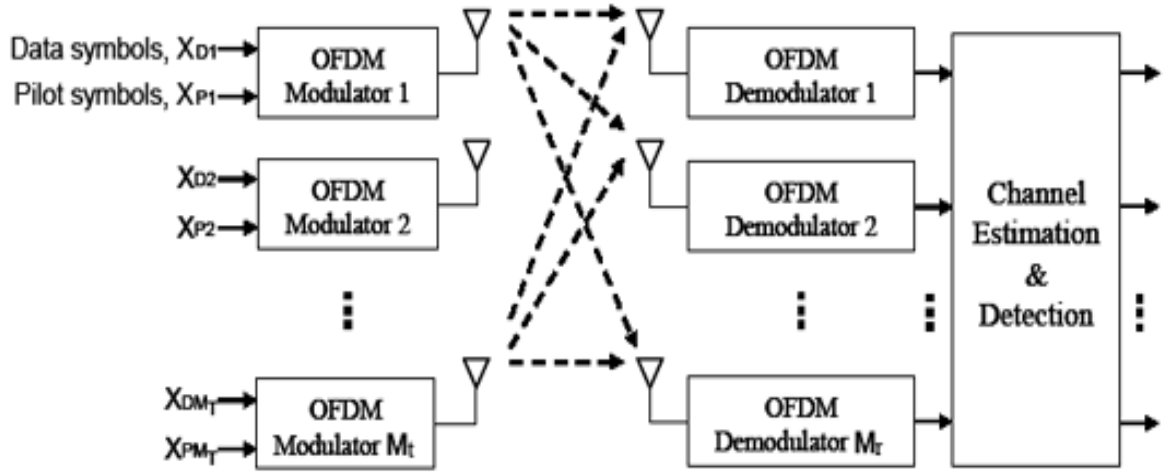

Fig 1: OFDM system [1]

It is advancement over traditional Frequency Division Multiplexing (FDM) technique which is used to carry only one signal over one path. The lower rate data stream so formed from the higher rate data stream (after serial to parallel conversion) has large symbol duration so Inter Symbol Interference (ISI) is reduced in OFDM. In other words, there is less dispersion in time domain due to multipath delay spread as in Time Division Multiplexing (TDM). The condition for maintaining the orthogonality is that the frequency spacing between the carrier signals must be an integer multiple of the lowest carrier frequency. That is, each sub carrier has an integer number of cycles in time period T. The numbers of cycles in adjacent sub carriers differ by exactly one. This technique provides high data rate even if relatively small frequency bandwidth is available. Also, OFDM based system has other favourable properties such as high spectral efficiency, robustness to channel fading and

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ISO 9001:2008 Certified
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impulse interference. Because of these advantages, OFDM has been adopted in both wireless and wired applications in recent years [1]. OFDM-based systems are more immune to impulse noise, fast fades and can be of greater pursuit for wireless applications as they eliminate the need for equalizers. Also, efficient hardware implementations can be realized using Fast Fourier Transform (FFT) techniques for small numbers of carriers. So, OFDM has emerged as the standard of choice in a number of important high data applications in past few decades [1].

II. PEAK TO AVERAGE POWER RATIO

The major drawback of OFDM system High Peak to Average Power Ratio (PAPR).It is one of major practical complications of uncoded OFDM signal. Figure 2 shows OFDM signal with PAPR problem.

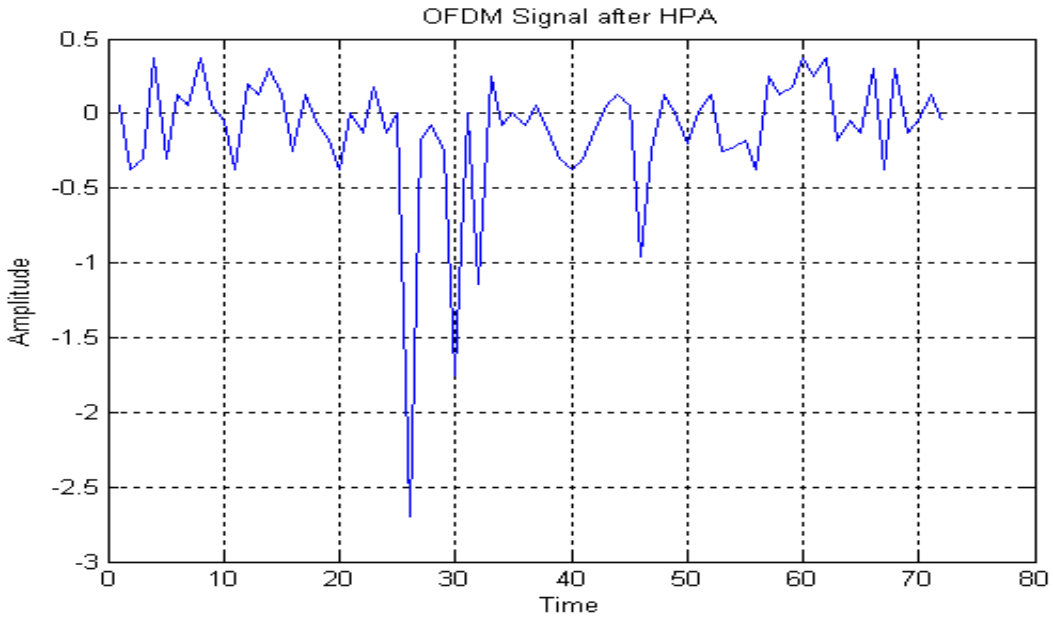

Fig 2: Amplitude of OFDM symbol showing large peak [2]

The PAPR of the transmit signal $x(t)$ is the ratio of the square of maximum instantaneous power and the average power square [1].

By definition, $\text{PAPR} = \frac{\max [x(t)]^2}{E\{|x(t)|^2\}}$

where $E\{.\}$ denotes expectation operator.

x(t) is the transmitted signal.

The peak to average power ratio (PAPR) is a very important attribute of a communication system as it degrades the performance of High power amplifier (HPA). A low PAPR allows the transmit power amplifier to operate efficiently, where as a high PAPR forces the transmit amplifier to have a large back off in order to ensure linear amplification of the signal. HPA non- linearity introduces out of band and in band distortion, which may result in ACI and BER degradation. Simplest way to deal with HPA distortion is just to decrease the input back off (IBO) [2], making HPA operate far from the saturation point and work in the linear region (power back-off technique). This significantly degrades the HPA efficiency. Alternate is to make HPA linearization using algorithms such as Envelop elimination and restoration, Cartesian feedback technique ,feed forward technique, linear amplification with non linear components (LINC). Both approaches resulting in a significant power efficiency penalty. To reduce PAPR, several techniques have been proposed, which basically can be divided in three categories. First, there are signal distortion techniques, which reduce the peak amplitudes simply by

ISSN: 2319-5967
ISO 9001:2008 Certified
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nonlinearly distorting the OFDM signal at or around the peaks. Examples of distortion techniques are clipping, peak windowing, and peak cancellation. Second technique scrambles each OFDM symbol with different scrambling sequences and selecting the sequence that gives the smallest PAPR. Third, there are coding techniques that use a special FEC code set that excludes OFDM symbols with a large PAPR. For good performance of OFDM system, clearly it would be desirable to have the average power and peak power values as close together as possible. Depending upon the reduction in PAPR level and computational complexity, different techniques have been surveyed.

III. PAPR TECHNIQUES

Many techniques have been used to reduce the PAPR in OFDM system. Now as per the below table we can see how many techniques can be used. There are basically two types of PAPR reduction techniques: Signal scrambling techniques and Signal distortion techniques [3].

SIGNAL SCRAMBLING TECHNIQUES

A. BLOCK CODING TECHNIQUES:

Main objective of this technique is to reduce PAPR using different block coding & set of code words. This scheme is widely used to reduce the peak to mean envelope power ratio. While selection of the suitable codeword many things must be considered like M-ray phase modulation scheme, any type of coding rate, suitable for encoding –decoding & also main thing is that error Correction /error decoding [3].

B. SUB BLOCK CODING TECHNIQUES:

To reduce PAPR more than 3db sub block coding technique is widely used. But this can be achieved at ¾ code rate. This techniques based on ¾ code rate systematically [5] with added last odd parity checking bit to develop lowest peak envelope power. This coding scheme is termed as systematic odd parity checking coding (SOPC). Large reduction in PAPR can be obtained by the divided large frame into sub block encoded with SOPC.

C. SELECTED MAPPING (SLM):

In particular SLM technique whole set of signal represent the same signal but form it most favourable signal is chosen related to PAPR transmitted. The side information must [6] be transmitted with the chosen signal. This technique is probabilistic based will not remove the peaks but prevent it from frequently generation. This scheme is very reliable but main drawback that is side information must be transmitted along with chosen signal.

Table 1: Classifications of PAPR Techniques [3]

PAPR techniques	
Signal scrambling techniques	Signal distortion techniques
Block Coding	Signal Clipping
	Peak Windowing
Sub block coding	Envelope scaling
Selective level mapping	
Partial transmit sequence	
Interleaving	
Linear block coding	
Tone reservation	
Tone injection	

D. PARTIAL TRANSMIT SEQUENCE (PTS):

Partial transmit sequence is also one of the Probabilistic based. Main idea of this scheme is data block divide into non overlapping sub block with independent rotation factor. This rotation factor generates time domain data with lowest amplitude [9]. This is modified technique of SLM scheme and gives better performance than SLM. Because of differential modulation there is no need to transmit the side information. PTS are more effective in reducing PAPR for OFDM rather than for WP-MCM.

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E. LINEAR BLOCK CODES:

This technique also known as standard array of linear block codes in this scheme distinct U signal is transmitted along with transmitted sequence. U distinct signal is used constructed using proper select co –set words. Using scrambling codes no needs to transmit side information and received signal can be easily decoded. Main thing is that to select standard array of codes to reduce the PAPR. This technique is also modification of the SLM techniques [8]. In this transmitted signal with minimum PAPR using scrambling code. Technique has better performance than SLM technique.

F. INTERLEAVING:

In this technique highly correlated data frame .in this adaptive technique also reduces the complexity. Adaptive interleaving is to establish an early terminating threshold. So the searching process is terminated when the value of PAPR reaches below the threshold value. So, these low threshold force the AIL to search for all interleaving sequence. This technique is less complex than PTS [7].

G. TONE RESERVATION:

This technique contains some set of reservation of tones. By using this technique reserved tones can be used to minimize the PAPR. This method is used for multicarrier transmission and also shows the reserving tones to reduce the PAPR. This technique is depends on amount [8],[9] of complexity. When there is number of tone is small reduction in PAPR may represent non negligible samples of available bandwidth. Advantage of this tone reservation is very positive that no process is needed at receiver end and also do not need to transmit the side information along with the transmitted signal in this data block is added to the time domain signal to reduce the peak leads.

H. TONE INJECTION:

This method is generally used additive method for PAPR reduction. Using this method data rate loss is very less. This method used the set of active constellation point for an original constellation point to reduce the PAPR. In this each unit all original constellation is mapped on the several equivalent constellation point. & this extra point freedom can be easily used to reduce the PAPR. This method is popularly used as the tone injection method because of the newly applying points into basic constellation for the new points for larger constellation. Main thing is injecting tone of appropriate phase and frequency in OFDM symbol. Main demerits are that transmission of side information is necessary at the receiver side.

SIGNAL DISTORTION TECHNIQUES

I. CLIPPING AND FILTERING:

Clipping and filtering techniques is mostly effective techniques to reduce the high PAPR in OFDM system. Here clipping is the nonlinear process in which increase the band noise distortion, also increase in the bit error rate also decrease the spectral efficiency. Here using with filtering this techniques will give better performance. Filtering after clipping will reduce out of band radiation. This technique will reduce the PAPR without spectrum expansion. Here if the OFDM signal is over sampled then the scheme of correction is suitable with the clipping so that each sub carrier generated with the interference. So for proposed this scheme each signal must be over sampled by factor of four. This scheme is more compatible with the PSK modulation scheme.

J. PEAK WINDOWING:

Here peak windowing technique is very similar to the clipping technique bit it will give better performance with adding some self interference and increasing in BER (bit error rate). Due to this out band radiation is also increased in this method we multiply different windows with large signal peaks like Gaussian shaped window, cosine, Kaiser and Hamming window. OFDM signal is multiplied with several of these windows, the resulting spectrum is a convolution of the original OFDM spectrum with the spectrum of the applied window. Means the windows should be narrow as possible. By using this technique PAPR can be reducing to 4db of each subcarrier.SNR is limited to 3db due to signal distortion [3].

K. ENVELOPE SCALING:

This technique is related to scaling means before OFDM signals sent to the IFFT all sub carrier is scaled the input envelope. In this technique 256 sub carrier is used so all sub carrier will remains equal. Main idea is that to scheme is that the input envelope in some sub carrier is scaled to achieve the smallest amount of PAPR at the output of the IFFT. Here receiver does not need any side information at the receiver end for decoding. This scheme is suitable for the PSK modulation. When it is applied with the QAM high degradation is occurred in the BER [3].

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IV. OVERALL ANALYSIS OF DIFFERENT PAPR REDUCTION TECHNIQUES IN OFDM

The PAPR reduction technique should be chosen with awareness according to various system requirements. We have studied several techniques in the previous section. Each technique has their own advantages and disadvantages. We have studied different PAPR reduction techniques in OFDM, such techniques are selective mapping (SLM), Partial transmit sequence (PTS), Block coding, Interleaving, Tone reservation, Tone injection, Sub block coding, Linear block coding. These are the Signal Scrambling Techniques [4]. Signal clipping and filtering, Peak windowing, Envelope Scaling are the Signal distortion techniques which are used to reduce peak average to power ratio (PAPR) in an Orthogonal Frequency Division Multiplexing (OFDM). **Table 2**: shows the different PAPR reduction techniques. This table shows the parameters of different PAPR techniques on which the reduction of PAPR depends. These parameters are decrease distortion, Power raise, Defeat data rate.

Table 2: Comparison of PAPR techniques [4]

Reduction technique	Parameters			Operation required at transmitter(Tx) and Receiver(Rx)
	Decrease distortion	Power raise	Defeat data rate	
Clipping and filtering	No	No	No	Tx : Clipping Rx: Noise
Selective mapping (SLM)	Yes	No	Yes	Tx: M times IDFT's operation Rx: side information extraction, inverse SLM .
Block coding	Yes	No	Yes	Tx: coding or table searching Rx : decoding or table searching.
Partial transmit sequence (PTS)	Yes	No	Yes	Tx: V times IDFT's operation. Rx: side information extraction, inverse PTS.
Interleaving	Yes	No	Yes	Tx: D times IDFT's operation and D-1 times interleaving. Rx: side information extraction and deinterleaving.
Tone Reservation	Yes	Yes	Yes	
Tone Injection	Yes	Yes	No	

V. CONCLUSION

In this paper, peak to average power ratio and its various reduction techniques are reviewed. Orthogonal frequency division multiplexing technique is modulation technique which provides high speed communication in both wired and wireless systems. PAPR is major drawback of Orthogonal Frequency Division Multiplexing technique which degrades the performance of OFDM. Various techniques are developed to improve PAPR reduction and all these techniques have its own advantages and disadvantages. Basically as per the information about all above described techniques to reduce the PAPR in OFDM system all techniques is different in their way and using each technique PAPR will be reduced at some level. To reduce the PAPR , Partial transmit technique can be used. Research is going on to further improve PAPR reduction and improving the performance of OFDM systems.

ACKNOWLEDGMENT

The Authors appreciate the Help given by the guide Mrs. Sonia Singla and Electronics & Communication Department, Punjabi university Patiala for the Technical Assistance.

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ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
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