Overview of Various PAPR Techniques in OFDM Systems

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Abstract –For high data rate communication system, OFDM has been introduced as a modulation technique. Data can be transmitted over a dispersive channel at high speed using OFDM. One of the limitations of OFDM is Peak to Average Power Ratio (PAPR). If the value of PAPR is large, then the signal becomes vulnerable to non-linearity's present during the transmission. There are a number of PAPR reduction techniques such as Selective Mapping (SLM), Tone Reservation (TR), Clipping, Partial Transmit Sequence (PTS), Companding, Tone Injection (TI) and Interleaving. In this paper, we will have a review on traditional methodologies used in the reduction of PAPR.

Index Terms – OFDM System, PAPR, Tone Reservation, Partial Transmit Sequence.

1. INTRODUCTION

A new modulation technique has been introduced known as Orthogonal Frequency Division Multiplexing (OFDM) in broadband wireless communication system. Digital data has been encoded on multiple carrier frequencies using OFDM. In OFDM, a high rate data stream is splitted into a number of low rate data streams so that they can be transmitted simultaneously over a number of sub carriers. Appropriate frequency space is being chosen between the carriers so that they can be made orthogonal. Orthogonality of sub carriers is an important concept. The carriers are sine and cosine waves so area is zero under 1 period. Hence, they are orthogonal. A number of sub carriers are being transmitted simultaneously without any interference when they are in tight frequency space. One of the important features of orthogonality is high spectral efficiency.

No Inter Symbol Interference is the main advantage of OFDM. High Peak to Average Power Ratio (PAPR) is one of the main limitations of OFDM. When PAPR is passed through High Power Amplifier (HPA) and Digital to Analog Converter (DAC), distortion is caused in the signal. Hence, it will be having low mean power level. PAPR may be defined as the ratio of peak power to the average power. With the increase in the signal power, PAPR cannot be increased. There are a number of PAPR reduction techniques such as Selective Mapping (SLM), Tone Reservation (TR), Clipping, and Partial Transmit Sequence (PTS), Companding, Tone Injection (TI) and Interleaving. These methods are having reduced PAPR. PTS is the most suitable method for reducing PAPR in OFDM systems. Some of the PAPR reduction techniques can degrade the performance.

2. OFDM SYTEM MODEL

OFDM is a technique of digital modulation where a signal is being splitted/ divided at different frequencies into a number of narrowband channels. In this, data stream is given as input which is being converted into N parallel data streams using serial to parallel convertor and each of these is having a symbol period Ts. When parallel data streams are generated, modulation is performed on each data stream. After modulation, these data streams are carried at different frequencies. Then mapping of N data symbols is done to Inverse Fast Fourier Transform (IFFT) which is further followed by cyclic prefix (CP). Frequency components are converted into time domain symbols using an IFFT transform which will add a prefix to it. And at last resulting signal is transmitted over the channel.

Consider number of sub carriers i.e. 'N' and modulation of each sub carriers is being done. Hence, represent OFDM as [19]:

$$x(n)=\frac{1}{N}\sum_{k=0}^{N=1} X(k)e^{j\,2\pi nk\,/N} \qquad (1)$$

Where, N= number of sub carriers

X (k)= symbols to be transmitted on each sub carriers.

At the receiving end, the prefix is canceled by the receiver. If the receiver wants to transform the received signal into frequency domain then Fast Fourier Transform is being used. Represent expression as [19]

$$y(m)=\sum_{n=0}^{N=1} y(n)exp^{-j\,2\pi nm\,/N}+n(m) \qquad (2)$$

Where, y (m) = symbol being received

N (m) = additive noise.

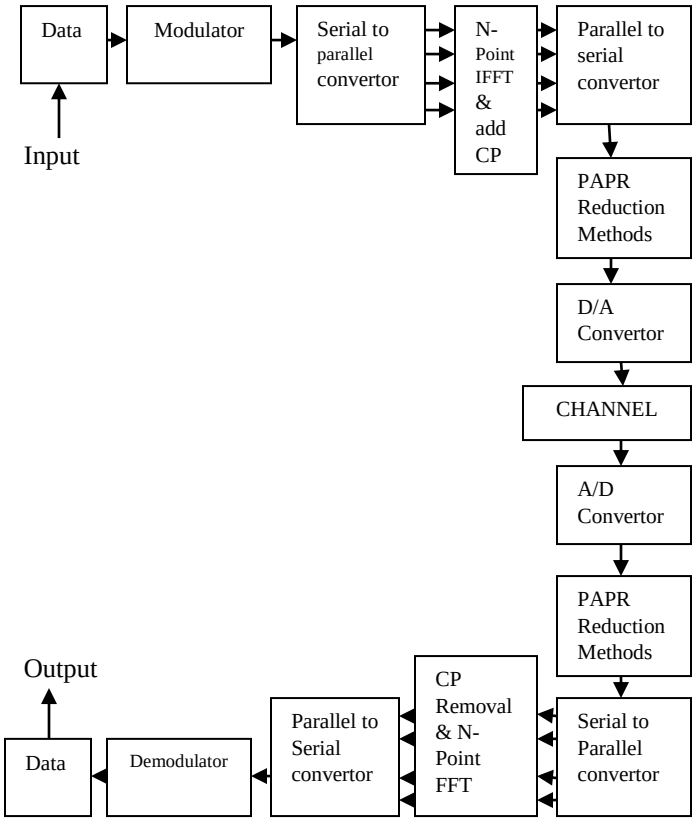

Figure 1 Block Diagram of OFDM System [18]

2.1. Peak to Average Power Ratio(PAPR)

PAPR is one of the limitations of OFDM systems and hence, PAPR is represented as the maximum power divided by the average power.[19]

The Peak Power may be defined as the sum of all the N sub carriers in an OFDM system and hence we add up all the sub carriers constructively. The Average Power may be defined as the summation of all the N values of any particular signal which is divided by total number of N sub carriers in an OFDM system.

Represent maximum PAPR as [19]:

$$PAPR\ (max) = N^2/N = N \qquad (3)$$

Complimentary Cumulative Distributive Function (CCDF) is used to measure the reduction capability of PAPR. If PAPR exceeds a certain limit of threshold then CCDF is used to indicate the probability. The CCDF is also used to find the bounds if redundant bits are minimum.

The Complimentary Cumulative Distributive Function (CCDF) is represented as [19]:

$$CCDF = Pr\ (PAPR > PAPR_o) \qquad (4)$$

$$Pr\ (PAPR > PAPR_o) = 1-(1-e^{-PAPR_o})^N \qquad (5)$$

Where, $PAPR_o$ = threshold level.

3. PAPR REDUCTION TECHNIQUES

There are a number of PAPR reduction techniques such as Selective Mapping (SLM), Tone Reservation (TR), Clipping, Partial Transmit Sequence (PTS), Companding, Tone Injection (TI) and Interleaving.

3.1. Clipping

One of the simplest techniques used for the reduction of PAPR is clipping technique. In this, there is a predetermined value of threshold for some particular signal level. Orthogonality of sub carriers is destroyed as it is having both in-band and out-of-band distortion. Filtering is used to reduce the out-of-band radiation from the signal that has been clipped. Large peaks are reduced if we non-linearly distort the signal with the help of clipping. No additional information is required with the signal. If the peaks are too large then their probability will be low and signals are seldom distorted. In this, amplitude A's maximum peak value is taken so that OFD signal will remain within the particular region and the symbols going beyond the specified region will be clipped. Signal is made narrow in clipping. If there is oversampled signal then clipping operation is always performed on it. Sometimes peak re-grows in an OFDM system due to clipping so several methods are applied to reduce it. These methods are Repeated Clipping and Filtering (CAF), Deep Clipping, combined CAF and Interleaving etc. in this noise distortion is there which results in degradation of the system.

Clipping and Filtering is done repeatedly to avoid out-of-band noise.Figure2 is the block diagram of C&F technique that explains the concept of filtering which is being done repeatedly so that peak re-growth can be avoided in the OFDM signal.

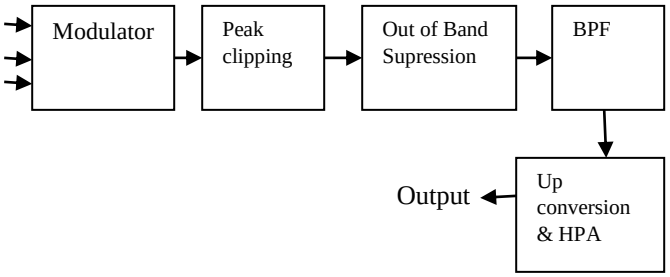

Figure 2 Block Diagram of C&F Technique [21]

3.2. Selective Mapping(SLM)

One of the most promising techniques for the reduction of PAPR is Selective Mapping as there is no distortion and performance of the system is well maintained. In this, data blocks are present which are being converted into a number of independent blocks and the one with least PAPR value is

selected. The block with low PAPR value is sent where converting process is having data sequences which are multiplied to random phase sequences generated. The index that is selected is known as side-information index (SI Index). This SI Index is transmitted so that data block can be recovered at the receivers end. Data rate is reduced in SLM. Recovering the side information is a complex issue in SLM.

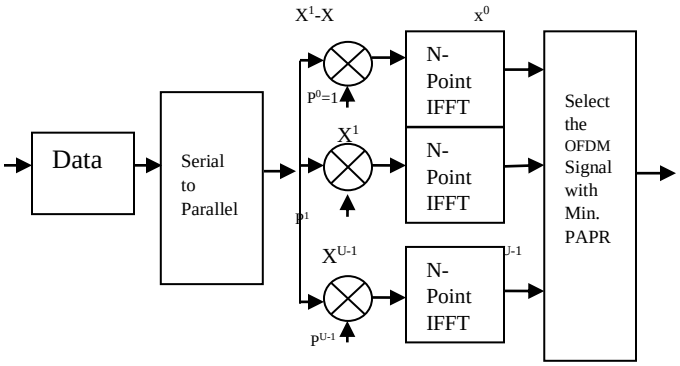

Figure 3 Block Diagram of SLM Technique [20]

3.3. Interleaving

Interleaving is also known as Adaptive Symbol Selection Method. Sequences are given as input which will produce multiple symbols in OFDM that are created by bit Interleaving.

In this, one with the least PAPR is selected if we are having a W number of interleaving ways. If the receiver want to recover the signals, then the information about particular interleave to be used is needed.

3.4. Companding

In OFDM, there are two types of companding one is linear and other is non-linear. If we want to expand small signals, then linear companding is used. Nonlinear companding focuses on expanding small signals and compressing the large signals so that uniform distribution of signals is there. Thereby increasing the average power and reducing the PAPR of OFDM systems. Due to these, efficiency of power amplifiers can be increased.

3.5. Coding Techniques

In coding techniques, FEC codes are used so as to reduce the signal degradation. OFDM is also known as COFDM. In this, basic concept is to add N signals in a phase which is further added to the signal power. These arrangements are used with coding techniques like Simple Odd Parity Code, Cyclic coding, Simple Block Code, Modified Compliment Block Coding.

3.6. Partial Transmit Sequence(PTS)

The idea behind PTS technique is to divide an Input data block of N symbols into many sub sequences and after this signal is being transmitted. These sub sequences are combined to reduce the PAPR. There are three types of sub sequences portioning schemes which are Interleaved, Adjacent and Pseudo Random Partitioning. PTS technique works with any modulation scheme. Its main advantage is to work with multiple sub carriers. Original OFDM sequence is being divided in PTS.

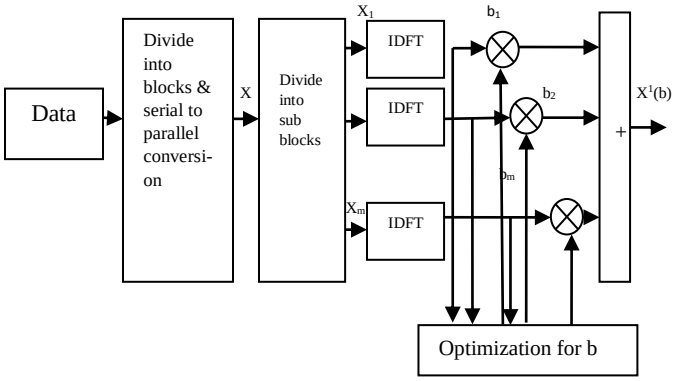

Figure 4 Block Diagram of PTS [18]

3.7. Active Constellation Extension(ACE)

It is a technique in which outside the signal constellation we extend the constellation points which are further used for the cancellation of time domain peaks. Its main advantages are:

- No degradation in the performance of the system
- No data loss
- Reduction of bit error rate

3.8. Tone Reservation and Tone Injection

In this, some set of tones are present which are being reserved and these reserved set of tones are known as Peak Reduction Carriers. In data signal these tones are added which isolates energy to cancel the peaks that are large. The Tone Injection technique is used for the reduction of PAPR which will further reduce the data rate.

4. PROBLEM FORMULATION

As the reduction of PAPR is the main problem in OFDM System. Many techniques like Selective Mapping, Clipping, Interleaving, Companding, Tone Reservation and Tone Injection are being used to reduce PAPR with simple implementation cost. The problem occurs in low pass filtering of clipped OFDM signal samples which results in re growth of peak power but the degradation in Bit Error Performance reduces to certain amount. There is no any efficient technique present for the reduction of PAPR and Bit Error Rate. There is a need for the technique in which the PAPR, Bit Error Rate as well as complexity of the OFDM system should be reduced.

5. CONCLUSION

In this paper, several techniques have been discussed which are used to reduce the PAPR and Complexity of the system. To increase the efficiency of the system there should be a new hybrid method which will reduce the parameters like PAPR and BER. This hybrid method can be the new area of research which will increase the performance of the system by reducing the large peaks of different frequencies.

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