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CRITERIA FOR SELECTION OF PAPR REDUCTION TECHNIQUES IN OFDM SYSTEM

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***Abstract*— Orthogonal Frequency Division Multiplexing is the revolutionary multicarrier modulation technique in the modern communication world. In the present communication generation, it mainly focuses towards OFDM systems for wireless communications for high speed data transmission. The OFDM is a special concept of multi-carrier transmission technique that divides the communication channel into several frequency bands. The high Peak to Average Power Ratio, PAPR, is the major drawback in the OFDM systems. This high PAPR value results in the irregular symbol injection into the channel. The cost for reduction of PAPR is unnecessarily too high in terms of loss of information and power. The paper shows the major categories of techniques for PAPR reduction and their types are also listed and compared using the different criteria.**

***Index Terms*— Communication generation, OFDM, PAPR, Symbol Injection.**

I. INTRODUCTION

The secured way of communication is tended towards the fast way and high data transmission with low power consumption and low memory utilization. It should be noted that the high speed is possible when calculated time for symbol is high. Orthogonal Frequency Division Multiplexing, OFDM is an efficient method of data transmission or high speed communication systems. Rayleigh type distribution of the amplitude in the OFDM signal exhibits strong fluctuation which results in a high Peak to Average Power Ratio. In the least case, PAPR of an OFDM system with n sub-channels may reach up to a value of n. High PAPR value has some disadvantages for practical implementations and needs to be reduced to an acceptable level. Hence the main drawback of OFDM system is that, it exhibits high Peak to Average Power Ratio of the transmitted signals as mentioned before. Generally PAPR reduction in OFDM system is an area of prim importance for the OFDM system to perform better and not to cause any undesirable events like irregular symbol injection in the channel. This is studied at several stages of Communication Generation. Different ways of PAPR reduction are available; the main categories of PAPR reduction are based on the action how algorithm performs.

The basic two categories are

- Signal distorting techniques,
- Signal non-distorting techniques

These techniques reduce the amplitude of samples whose power exceeds a certain threshold by non-linearly distorting the OFDM signal at or around the peaks. These are categories based on the techniques used will deteriorate the original message signal and if it happens to have some loss in symbols then it is called as signal distorting technique. If there is no loss in the original signal then the technique is categorised into signal non-distorting technique.

II. OFDM SYSTEM

OFDM is a digital multicarrier modulation scheme uses a number of closely spaced orthogonal sub-carriers. A single stream of data is split into parallel streams of each coded and modulated onto a subcarrier with a conventional modulation scheme at low symbol rate. The basic principle of OFDM is to split a high rate input data stream into a number of lower rate streams that are transmitted simultaneously over a number of subcarriers. The guard interval at the beginning of each OFDM symbol so that Inter Symbol Interference, ISI, is eliminated almost completely. The empty guard time interval is filled with a cyclically extended version of the OFDM symbol. This method is used to avoid Inter Carrier Interference, ICI. OFDM is a special case of Multi-Carrier-Modulation, MCM, input data stream is divided into lower rate sub-streams, and these sub-streams are used to modulate several subcarriers.

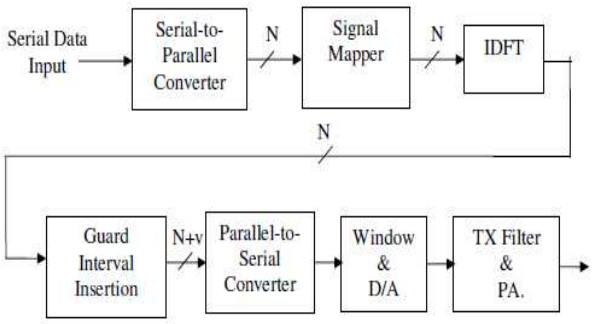

Fig. 1: Block Diagram for OFDM Transmitter

An OFDM symbol in baseband is defined as,

$$x(t) = \sum_{k=(n/2)}^{\left(\frac{n}{2}\right)-1} \left(a_{k+\left(\frac{n}{2}\right)} \exp\left(\frac{j2\pi kt}{T}\right) \right) s(t) \qquad \ldots (1)$$

where, $a_{k+n/2}$ denotes the complex symbol modulating the k-th carrier, s(t) is the time window function defined in the interval [0,T], n is the number of subcarriers, and T is the OFDM symbol period. Subcarriers are spaced Δf=1/T apart, which is the minimum sub carrier spacing.

III. PAPR REDUCTION

In presence of large number of independently modulated sub-carriers in OFDM systems, the peak value of the some signals can be very high as compared to the average of the whole system. The complex envelope of an OFDM signal is an overlap of N complex oscillations with different frequencies, phases and amplitudes. As a result, we get a time domain signal with high Peak to Average Power Ratio. These peaks may cause signal clipping at high levels and may force the amplifier in the transmitter side to work in the non linear region, thereby producing frequency components in addition to the original and results in out of band radiation. The ratio of the peak to average power value is termed as Peak-to-Average Power Ratio. Mathematically PAPR can be given as:

$$PAPR = \frac{\max |x(t)*x'(t)|}{E[|x(t)*x'(t)|]} \quad \text{... (2)}$$

Where, max $|x(t)|^2$ is the peak signal power and $E[|x(t)^2|]$ is the average signal power. The average power is calculated using the equation 3.,

$$Average\ power = \frac{sum\ of\ magnitude\ of\ all\ the\ symbols}{no.of\ symbols} \quad \text{... (3)}$$

The Complementary Cumulative Distribution Function (CCDF) of the PAPR is one of the most frequently used methods to check how often the PAPR exceed the threshold values. Graph is plotted among threshold and CCDF values. The CCDF can be calculated by the relation,

P (PAPR>X)=1-P(PAPR<X) ...(4)

The fixation of threshold value ranges from zero to maximum value. To calculate the threshold value the equation 5 is used,

$$Threshold = \frac{0:(Max.PAPR-Min\ PAPR)}{Max\ PAPR\cdot Min\ PAPR} \quad \text{... (5)}$$

Threshold value is updated regularly and a CCDF curve is drawn.

IV. PAPR REDUCTION TECHNIQUE

PAPR reduction is very crucial in present networking scenario. There are different methods are proposed to reduce the PAPR value. They are basically classified into two types.

- Signal Distortion Techniques,
- Signal Non-Distorting Techniques

These are categories based on the techniques used will deteriorate the original signal; if it happens to have some loss in power then it is called as signal distorting technique. If no loss in power is found it is called a Signal Non-Distorting Technique.

- Clipping
- Peak windowing
- Peak cancellation
- Selected mapping(SLM)
- Partial Transmit Sequences(PTS)
- Channel Coding Technique

A. Clipping Technique

One simplest approach of reducing the PAPR is to *clip* the amplitude of the signal to a fixed level.

$$y = \begin{cases} -A, & (x < -A) \\ x, & (-A \le x \le A) \\ A, & (x > A) \end{cases} \quad \text{... (6)}$$

Equation 2 represents the clipping process of the signal, where x denotes the signal before clipping and y denotes the signal after clipping. The pseudo-maximum amplitude in this approach is referred to as the clipping level and denoted by *A*. Clipping technique introduces two major problems; first problem is the introduction of self interference which degrades the Bit Error Rate, BER performance. Second, nonlinear distortion of OFDM signal increases the out-of-band radiation. Clipping is the primitive method but of everlasting importance till date. The clipping circuits are used in OFDM systems because of their circuit simplicity and low memory occupying capability. Although the clipping technique is used in PAPR reduction there is a considerable amount of loss in the symbol or data to be transmitted. Hence, this is a Signal Distortion Techniques. The effect of out-of-band radiation problem can be reduced by clipping the signal; another method is to multiply large signal peaks with a non-rectangular window, on the other hand, the window should not be too long in the time domain, because that implies many samples are affected, which increases the BER.

B. Scrambling Techniques

The basic idea of symbol scrambling is that, for each OFDM symbol, the input sequence is scrambled by a certain number of scrambling sequences. The output signal with the smallest PAPR is transmitted. For uncorrelated scrambling sequences, the resulting OFDM signals and corresponding PAPR values will be uncorrelated, so if the PAPR for one OFDM symbol has a probability *q* of exceeding a certain level without scrambling, the probability is decreased to q^i by using *i* scrambling codes. Hence, symbol scrambling does not guarantee a PAPR below some low level; rather, it decreases the probability that high PAPR values occur. Two basic types of scrambling techniques are well known. They are,

- Selected Mapping (SLM),
- Partial Transmit Sequences (PTS)

These SLM and PTS methods improve the PAPR statistics by introducing little redundancy and also solve the problem signal distortion techniques which may cause in-band distortion and out-of-band noise.

C. Channel Coding Technique

Only a small fraction of all possible OFDM symbols have a high PAPR value. This statement suggests another solution to the high PAPR problem based on coding. The PAPR value can be reduced by using a code that only produces OFDM symbols for which the PAPR value is below some threshold.

Several techniques for modulation are followed. Coding is very important in the digital communication. Although coding a signal seems to pay less cost for peak to average power ratio, it needs considerable attention. One of the most frequently used coding methods is the block coding scheme. Low

Density Parity Check codes are a type of linear block codes. The PAPR value can be reduced by using a code that only produces OFDM symbols for which the PAPR value is below some threshold. By avoiding the transmission of codeword having higher PAPR, reduction in PAPR can be achieved. This can be done by block coding the data such that a 3 bit data word is mapped on to a 4 bit code word, the set of permissible words does not contain those that result in excessive PAPR. Codes with error correcting capabilities has been proposed by M.J. Golay to achieve more lower PAPR for OFDM signals by determining the relationship of the cosets of Reed-Muller codes to M.J. Golay complementary sequences. While these block codes reduce PAPR, they also reduce the transmission rate, significantly for OFDM systems with large number of subcarriers. An adaptive coding technique has been proposed by Zafar et al., for reducing PAPR in COFDM to achieve reduction in PAPR as well as error correction capability. The adaptive approach has been adopted in order to reduce hardware for a slight increase in complexity.

Table I: Criteria Selection of PAPR Reduction Technique

METHOD	CLIPPING	SLM	PTS	CODING
PAPR reduction capabilities	High	Medium	Medium	High
Rate hit	Low	Low –high	Low-high	High
Side information	No	Yes	Yes	No
Complexity	Low	Low-high	Low-high	High
Power Inc	No	No	No	No
BER degradation	Medium	High	High	Low
Distortion	Yes	No	No	No

V. Criteria for Selection of PAPR Reduction Technique

A number of factors must be considered while selecting a specific technique for PAPR reduction. These factors include PAPR reduction capability, signal distortion, rate hit, side information, complexity, power increase in the transmit signal, BER increase at the receiver, computation complexity increase and so on.

The criteria are interdependent. Each criterion is a proportional value. PAPR reduction capabilities of different techniques and each criterion are related and shown in the table I.

All these criteria vary with the type of technique selected for PAPR reduction.

- PAPR reduction capabilities
- Rate hit
- Side Information, SI
- Bit Error Rate Degradation
- Distortion
- Complexity

Distortion is high in clipping technique compared to the channel coding and scrambling techniques, Selective Mapping, SLM and Partial Transmit Sequences, PTS.

VI. Discussion for Clipping And Channel Coding Results

The results for Matlab code are shown. They are obtained for the clipping and Channel coding technique using the Low Density Parity Check Codes. The following results are obtained for the clipping technique,

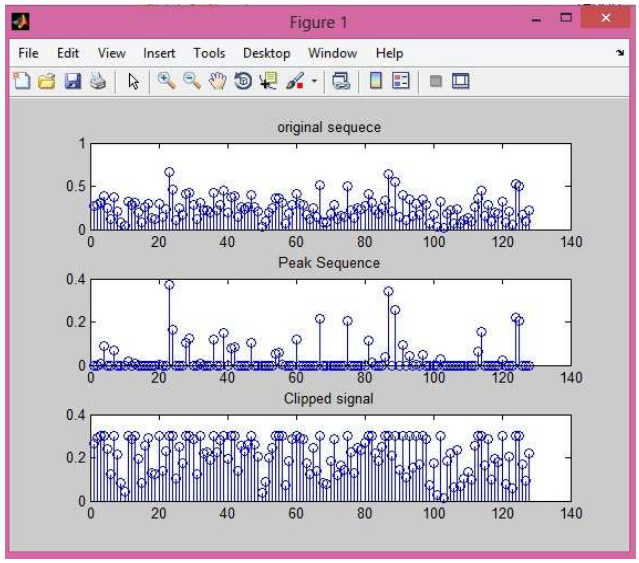

Fig.2: Clipping Technique

The figure 2 clearly shows the high variation. The high amplitude in the signal makes the third part shows the amount of clipped off signal from the original signal.

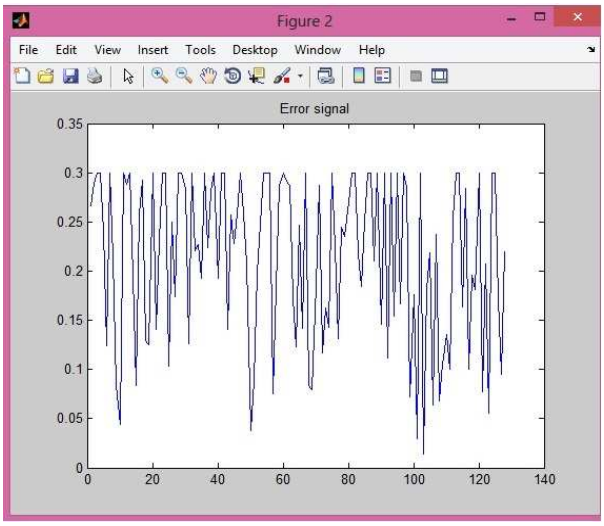

Fig 3: Signal after Clipping Action

The figure 3 shows the signal after the clipping of signal using clipping technique for PAPR reduction in OFDM systems. On simulating the clipping technique program PAPR of original signal is found to be 20.6920dB and PAPR of clipped sequence 5.6330dB.

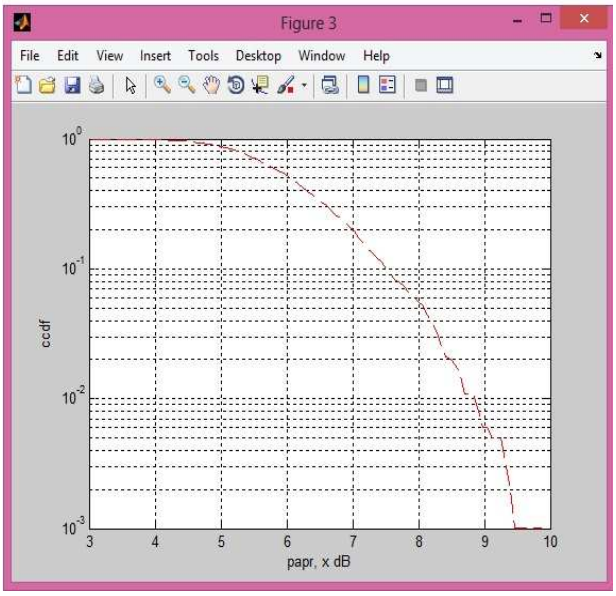

Fig. 4:CCDF of Uncoded signal

The above figure 4 shows the CCDF of the uncoded signal.

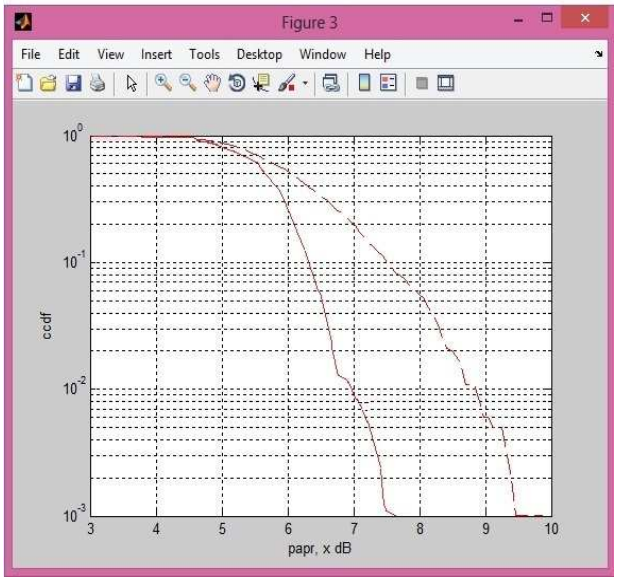

Fig. 5: CCDF of Uncoded Vs. LDPC Coded Signal

Different techniques are used for reduction of PAPR value of the OFDM systems. In that clipping is the primitive and simplest technique. The advantage of clipping technique is its simplicity; it is easy to implement using electronic components. The greatest disadvantage of clipping technique is that is reduces the peak amplitude signals hence the peak amplitudes above a threshold or value gets clipped off. Hence the average of the run signal also gets deteriorated. It disturbs the PAPR value of the OFDM system.

The coding technique is very efficient and it never disturbs the signals but only reduces the signal PAPR value. Here in LDPC coding technique the PAPR value is reduced by 2.042dB.The PAPR value is reduced by approximately 2dB in each simulation. This is desirable for reducing the PAPR value. The signal loss is comparatively little for coding technique on comparing to the clipping technique.

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