Comparison Analysis of PAPR Reduction in OFDM by using Different Techniques

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Abstract - One of the most important multi-carrier transmission techniques used in the latest wireless communication aspects is known as Orthogonal Frequency Division Multiplexing (OFDM). It has several characteristics such as providing greater immunity to multipath fading & impulse noise, eliminating Inter Symbol Interference (ISI) & Inter Carrier Interference (ICI) using a guard interval known as Cyclic Prefix (CP). In this paper, we are using different techniques for reducing Peak to Average Power Ratio (PAPR). The performance of an orthogonal frequency division multiplexing (OFDM) system is degraded if the peak-to average power ratio (PAPR) is high. A regular difficulty of OFDM signal is high peak to average power ratio (PAPR) which is defined as the ratio of the peak power to the average power of OFDM Signal. This paper includes different PAPR reduction techniques and concludes an overall comparison analysis of these techniques.

Keywords - Orthogonal Frequency Division Multiplexing (OFDM), Peak-to-Average Power Ratio (PAPR), Complementary Cumulative Distribution Function (CCDF), Bit Error rate (BER), Long Term Evolution (LTE), and Selected Mapping (SLM).

I. INTRODUCTION

Recently, Orthogonal Frequency Division Multiplexing has been used widely in digital transmission. OFDM has been adopted in several communication systems such as wireless local area networks (WLAN), wireless metropolitan area network (WMAN), digital audio broadcasting (DAB), digital video broadcasting (DVB). OFDM is a potential candidate for the 4th generation mobile wireless systems. OFDM is an attractive modulation technique in wireless applications because OFDM system divides frequency selective channel into several frequencies flat sub channels so that OFDM can get more immunity to multipath fading.

OFDM is one of the multicarrier modulation techniques. This is attractive technique for high speed data transmission. OFDM communication systems do not rely on increased symbol rates in order to achieve higher data rates. OFDM is a multicarrier digital modulation scheme. In OFDM carrier spacing is carefully selected so that each carrier is orthogonal to the other sub carrier. Two signals are orthogonal if their dot product is '0'. OFDM systems break the available bandwidth into many narrower sub-carriers and transmit the data in parallel streams. Each sub-carrier is modulated using varying levels of QAM modulation, e.g. QPSK, QAM, 64QAM or possibly higher orders depending on signal quality. Each OFDM symbol is a linear combination of the instantaneous signals on each of the sub-carriers in the channel .This facilitates efficient use of bandwidth and reduced Inter Symbol Interference (ISI).

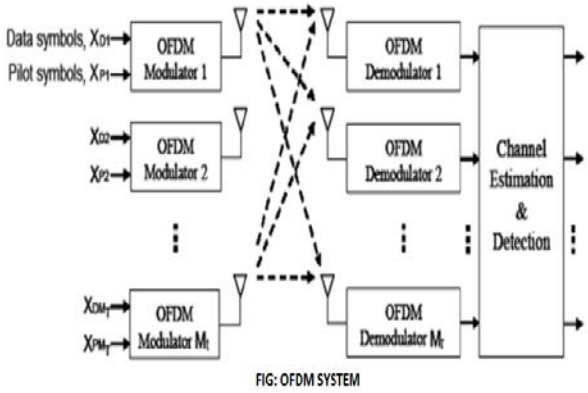

FIG: OFDM SYSTEM

1) Advantages:

i. Reduction in delay spread.

ii. Addition of guard band, it removes the ISI and ICI in the system.

iii. In narrowly spaced orthogonal sub – carriers, presents frequency selective fading.

iv. In High spectral efficiency, It can be implemented using IFFT.

2) Disadvantages:

i. This is highly sensitive to Doppler shifts which affect the carrier frequency offsets, resulting in ICI.

ii. Presence of a large number of sub – carriers with varying amplitude results in a hig0h Peak to Average Power Ratio (PAPR) of the system.

3) Limitations of OFDM technique:

A number of approaches have been proposed and implemented to reduce PAPR with increase transmit signal power, bit error rate (BER), computational complexity and data rate loss etc. So, a system trade-off is required. These reduction techniques are basically divided into three types of classes such as signal distortion, multiple signaling and probabilistic and coding. In this paper, amplitude clipping and filtering based design (signal distortion) is used to reduce PAPR. The objective of this paper is to analyze the comparative performance of different higher order modulation techniques.

II. PEAK TO AVERAGE POWER RATIO (PAPR)

PAPR is used to evaluate variation of the output envelope. It is also an important factor in the design of both high power amplifier (PA) and digital-to-analog (D/A) converter, for generating error-free (minimum errors) transmitted OFDM symbols. As, there are large number of independently modulated sub-carriers in an OFDM system, the peak value of the system can be very large as compared to the average value of the whole system. So, the PAPR is defined as the ratio of peak power to average power is known as PAPR.

Hence,

$$\text{PAPR} = \frac{\text{PEAK POWER}}{\text{AVEARGE POWER}}$$

The major disadvantages of a high PAPR are-

i. Increased complexity in the analog to digital and digital to analog converter.

ii. Reduction is efficiency of RF amplifiers.

Cumulative Distribution Function:

The Cumulative Distribution Function (CDF) is one of the most regularly used parameters, which is used to measure the efficiency of any PAPR technique. Normally, the Complementary CDF (CCDF) is used instead of CDF, which helps us to measure the probability that the PAPR of a certain data block exceeds the given threshold. By implementing the Central Limit Theorem for a multi – carrier signal with a large number of sub-carriers, the real and imaginary part of the time – domain signals have a mean of zero and a variance of 0.5 and follow a Gaussian distribution. So Rayleigh distribution is followed for the amplitude of the multi – carrier signal, where as a central chi-square distribution with two degrees of freedom is followed for the power distribution of the system.

The CDF of the amplitude of a signal sample is given by-

$$F(Z) = 1-\exp(z)$$

The CCDF of the PAPR of the data block is desired is our case to compare outputs of various reduction techniques. This is given by-

$$P(\text{PAPR}>z) = 1-P(\text{PAPR}\leq Z)$$

$$= 1-F(Z)^{N}$$

$$= 1-(1-\exp(-Z))^{N}$$

III. PAPR REDUCTION TECHNIQUES

Several PAPR reduction techniques have been explained in this literature. These techniques are divided into two groups which are -

a) Signal scrambling techniques-

i. Block Coding Techniques

ii. Selected mapping (SLM)

iii. Partial Transmit Sequence (PTS)

iv. Interleaving Technique

v. Tone Reservation (TR)

vi. Tone Injection (TI).

b) Signal distortion techniques

i. Peak Windowing

ii. Envelope scaling

iii. Peak Reduction Carrier

iv. Clipping and Filtering.

IV. SIGNAL SCRAMBLING TECHNIQUES

A. Block Coding Techniques:

An objective of this technique is to reduce PAPR using different block coding and 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.

B. Interleaving Technique:

An adaptive interleaving is to set up an initial terminating threshold. PAPR value goes below the threshold rather than seeking each interleaved sequences. The minimal threshold will compel the adaptive interleaving (AL) to look for all the interleaved sequences. The main important of the scheme is that it is less complex than the PTS technique but obtains comparable result.

C. Tone Reservation (TR):

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.

D. Tone Injection (TI):

By using this method, we achieve PAPR reduction of multicarrier signal without any data rate loss [3]. This method used 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 and this extra point freedom can be easily used to reduce the PAPR. These additional amounts of freedom can be utilized for PAPR reduction. The drawback of this method is the requirement of IFFT operation which is much more complex.

E. Selected Mapping Algorithm (SLM):

Selected mapping (SLM) is a promising PAPR reduction technique. Although SLM is also a scrambling technique, SLM is quite different from PTS. It selects the most favorable signal from a set of phase rotated candidate data blocks generated by transmitter, which all represent the same information as the original data block.

SLM generates several OFDM symbols as candidates and then select one with the lowest PAPR for the actual transmission. Conventionally, the transmission of side information is needed so that the receiver can use the side information to determine which candidate is selected in the transmission and then recover the information. SLM technique has introduced some additional complexity, but with loss in efficiency.

F. Partial Transmit Sequence (PTS):

Partial transmit sequence is also one of the Probabilistic based. In this PTS, 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 is more effective in reducing PAPR for OFDM.

V. SIGNAL DISTORTION TECHNIQUES

A. Peak Windowing:

This method is possible to remove large peaks at the cost of a slight amount of self interference when large peaks arise infrequently [5]. Peak windowing reduces PAPRs at the cost of increasing the BER and out-of-band radiation. The technique of peak windowing offers better PAPR reduction with better spectral properties. In peak windowing method we multiply large signal peak with a specific window, for example; Gaussian shaped window, cosine, Kaiser and Hamming window. The OFDM signal is multiplied with several of these windows; consequential spectrum is a convolution of the original OFDM spectrum with the spectrum of the applied window. Thus, the window should be as narrow band as possible, conversely the window should not be too long in the time domain because various signal samples are affected, which results an increase in bit error rate (BER). By using this technique, PAPR can be reducing to 4 dB of each subcarrier.SNR is limited to 3db due to signal distortion.

B. Envelope Scaling:

The Envelope Scaling technique is to reduce PAPR by scaling the input envelope for some subcarriers before they are sent to IFFT [6]. They used 256 subcarriers with QPSK modulation technique, so that envelopes of all the subcarriers are equal. Method is that the input envelope in some sub carrier is scaled to achieve the smallest amount of PAPR at the output of the IFFT. This method is appropriate for QPSK modulation. The envelopes of all subcarriers are equal. Then resulting in PAPR can be reduced significantly at around 4 dB.

C. Peak Reduction Carrier:

The technique is to reduce the effective PAPR in the OFDM system [7]. It includes the use of a higher order modulation scheme to represent a lower order modulation symbol. This method is suitable for PSK modulation, where the envelopes of all subcarriers are the equals. When the QAM modulation scheme will be implemented in the OFDM system, the carrier envelope scaling will result in the serious BER degradation.

D. Clipping and Filtering:

One of the simple and effective PAPR reduction techniques is clipping, which cancels the signal components that exceed some unchanging amplitude called clip level. However, clipping yields distortion power, which called clipping noise, and expands the transmitted signal spectrum, which causes interfering [8].

Clipping and filtering techniques is mostly effective techniques to reduce the high PAPR in OFDM system. Clipping is the nonlinear process in which increase the band noise distortion, also increase in the bit error rate also decrease the spectral efficiency [4]. Filtering after clipping will reduce out of band radiation. This technique will reduce the PAPR without spectrum expansion. 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. In this scheme, each signal must be over sampled by factor of four. This scheme is more compatible with the PSK modulation.

VI.COMPARISON OF SIMULATION RESULTS FOR PAPR REDUCTION TECHNIQUES IN OFDM SYSTEM:

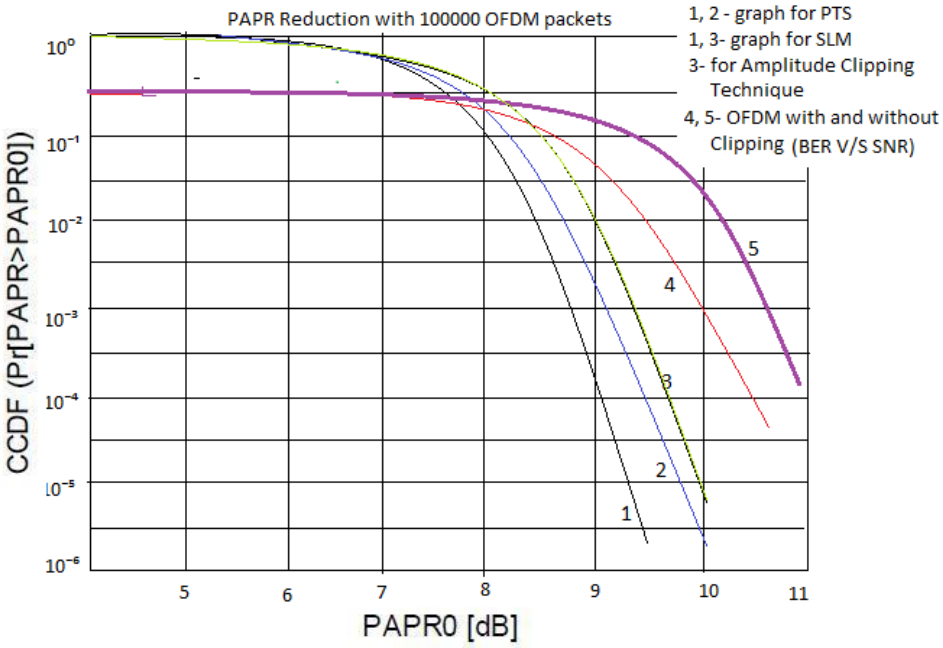

FIG: COMPARISON OF PAPR TECHNIQUES - SLM, PTS, CLIPPING AND FILTERING

VII. OVERALL ANALYSIS OF DIFFERENT TECHNIQUES

Table -1: Comparison of all PAPR Reduction Techniques

PAPR Technique	Clipping and Filtering	Selective Mapping (SLM)	Block Coding	Partial Transmit	Interleaving	Tone Reservation (TR)	Tone Injection(TI)
Decrease distortion	No	Yes	Yes	Yes	Yes	Yes	Yes
Power Raise	No	No	No	No	No	Yes	Yes
Defeat data rate	No	Yes	Yes	Yes	Yes	Yes	No
BER improved	No	Yes	Yes	Yes	No	No	Yes

VIII. CONCLUSION

In this paper, some PAPR reduction techniques for multicarrier transmission have been discussed. Many techniques to reduce the PAPR have been proposed of these potential to provide substantial reduction in PAPR at the cost of loss in data rate, transmit signal power increase, BER increase, computational complexity increase and so on. In SLM technique, it provides the best solution for PAPR reduction in OFDM performance. The selected technique provides us with a good range in performance to reduce PAPR problem.

In fact, the simplified SLM does not change the orthogonality of space frequency codes. In this method, the same phase sequence is concurrently applied to the frequency-domain signals for both antennas, and the signal with minimum PAPR has been found and transmitted. So inorder to avoid the drawbacks in SLM we have used a simple approach based on Clipping and

Differential Scaling to reduce the PAPR of OFDM signals. We have used Clipping along with three different scaling methods, namely up scaling, down scaling and up-down scaling. Simulations results show the values of thresholds for clipping and parameters for scaling with a view to reduce PAPR without degradation in BER.

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