Reduction of PAPR Loss in Orthoganal Frequency Division Multiplexing using Compression Sensing and Reconstruction Algorithm

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***Abstract*-This paper presents a technique to handle the problem of high peak-to-average power ratio (PAPR) in orthogonal frequency-division multiplexing (OFDM) systems. The presented scheme is a combination of two well-known techniques, namely selected mapping (SLM) and clipping. In contrast to other hybrid schemes, where the mentioned techniques are performed consecutively, we integrate the clipping procedure in the SLM algorithm. This yields an additional PAPR reduction compared to the serial combination. Further, the clipping strategies are considered with focus on receiver side peak reconstruction using methods provided by the theory of Compressed Sensing and reconstruction algorithm. Simulation results verify the performance using MATLAB.**

Key words:* *Orthogonal Frequency Division Multiplexing (OFDM), Peak to Average Power Ratio (PAPR), Selected mapping (SLM), Compressed Sensing theory, Reconstruction.

1. BASICS OF OFDM

Orthogonal Frequency Division Multiplexing (OFDM) is a digital multi-carrier modulation scheme that extends the concept of single subcarrier modulation by using multiple subcarriers within the same single channel. Rather than transmit a high-rate stream of data with a single subcarrier, OFDM makes use of a large number of closely spaced orthogonal subcarriers that are transmitted in parallel. Each subcarrier is modulated with a conventional digital modulation scheme (such as QPSK, 16QAM, etc.) at low symbol rate. However, the combination of many subcarriers enables data rates similar to conventional single-carrier modulation schemes within equivalent bandwidths. OFDM is based on the well-known technique of Frequency Division Multiplexing (FDM). In FDM different streams of information are mapped onto separate parallel frequency channels. Each FDM channel is separated from the others by a frequency guard band to reduce interference between adjacent channels, but it is suffer from the peak to average ratio.

OFDM is a form of multicarrier modulation. An OFDM signal consists of a number of closely spaced modulated carriers. When modulation of any form - voice, data, etc. is applied to a carrier, then sidebands spread out either side. It is necessary for a receiver to be able to receive the whole signal to be able to successfully demodulate the data. As a result, when signals are transmitted close to one another they must be spaced so that the receiver can separate them using a filter and there must be a guard band between them. This is not the case with OFDM. Although the sidebands from each carrier overlap, they can still be received without the interference that might be expected because they are orthogonal to each another. This is achieved by having the carrier spacing equal to the reciprocal of the symbol period.

The major advantage of OFDM is its robustness against multi path propagation. Thus, it is suitable to be implemented in wireless environments. The introduction of cyclic prefix made OFDM system resistance to time dispersion. OFDM symbol rate is low since a data stream is divided into several parallel streams before transmission. This make the fading is slow enough for the channel to be considered as constant during one OFDM symbol interval.

OFDM communications systems are able to more effectively utilize the frequency spectrum through overlapping sub-carriers. These sub-carriers are able to partially overlap without interfering with adjacent sub-carriers because the maximum power of each sub-carrier corresponds directly with the minimum power of each adjacent channel. Below, we illustrate the frequency domain of an OFDM system graphically. As you can see from the figure, each sub-carrier is represented by a different peak. In addition, the peak of each sub-carrier corresponds directly with the zero crossing of all channels.

But inspite of these benefits there are some obstacles in using OFDM: (i) OFDM signal exhibits very high Peak to Average Power Ratio (PAPR) (ii) Very sensitive to frequency errors (Tx. & Rx. offset) (iii) Inter carrier Interference (ICI) between the subcarriers.

In this paper we will discuss the problem of high PAPR associated in OFDM. We will discuss what is PAPR, how it causes problem in existing OFDM & its effect and give a review of several techniques for sorting out this problem.

2. PEAK TO AVERAGE POWER RATIO

The peak to average power ratio (PAPR) of a transmitted signal is one of main challenges in wideband multi-carrier systems that use orthogonal frequency division multiplexing (OFDM) or multiple-input multiple-output (MIMO) OFDM. Understanding the effects of PAPR on OFDM and MIMO-OFDM systems is critical when determining what techniques to use improve system performance. For the purposes of this blog post, we can use the terms OFDM and MIMO-OFDM interchangeably without affecting the meaning of PAPR. The use of a large number of subcarriers introduces a high PAPR in OFDM systems. PAPR can be defined as the relationship between the maximum power of a sample in a transmit OFDM symbol and its average power.

$$\text{PAPR} = 10 \log_{10} \frac{P\ peak}{P\ average}\ \text{dB}$$

Where P_{peak} and $P_{average}$ are the peak power and average power of a given OFDM symbol. The same definition of PAPR is applied to MIMO-OFDM systems. A high PAPR appears when a number of subcarriers of a given OFDM symbol are out of phase with each other. Figure 1 shows the time domain representation of the 3 subcarriers of an OFDM symbol. The right column indicates that the subcarriers are out of phase, which causes an increase in PAPR of about 2.5 dB compared to the subcarriers in the left column.

3. PAPR REDUCTION SCHEME IN TRANSMITTER SIDE

There are different techniques to reduce PAPR of OFDM.

1. Clipping
2. selected mapping method (SLM)
3. Hybrid method (SLM and clipping)

A. Clipping

Clipping is the simplest technique that is used to reduce PAPR in OFDM system. The basic idea of this technique is to clip the parts of the signals that have high peak outside of the allowed region.

B. Selected Mapping

In SLM, from the original data block several candidate data blocks are generated and the one with lowest PAPR is transmitted. At the receiver the reverse operation is performed to recover the original data block.

C. Hybrid Method

The above two methods (clipping and SLM) are integrated and the performance is improved further more. but due to clipping loss there occurs signal loss. To overcome this distortion, the signal is reconstructed at the receiver side using the compression sensing theory.

To improve the PAPR performance, this paper combines both techniques. The clipped SLM is more efficient in both PAPR performance and overall transmit power reduction.

4. COMPRESSION SENSING THEROY USED IN RECEIVER SIDE

Compressed sensing (also known as compressive sensing, compressive sampling, or sparse sampling) is a signal processing technique for efficiently acquiring and reconstructing a signal, by finding solutions to underdetermined linear systems. There are two conditions under which recovery is possible. The first one is sparsity which requires the signal to be sparse in some domain. The second one is incoherence which is applied through the isometric property which is sufficient for sparse signals. Compressed sensing takes advantage of the redundancy in many interesting signals they are not pure noise. In particular, many signals are sparse, that is, they contain many coefficients close to or equal to zero, when represented in some domain. This is the same insight used in many forms of lossy compression.

To avoid losses in system performance due to clipping, it is necessary to estimate the clipping signal at the receiver. Compressed Sensing theory is a signal processing technique for acquiring and reconstructing a signal.

In Compressed sensing theory we prefer noisy measurement model and the formula used here is,

$y = \Omega x + n$

where,

Ω=matrix

x=non zero elemen

n=noise vector

5. RECONSTRUCTION ALGORITHM

To further reduce the loss, reconstruction algorithm is used in this paper. The reconstruction algorithm is compared with the compressed sensing theory. In clipping reconstruction, I have used curve fitting.

Curve fitting

Curve fitting is the process of constructing a curve that has the best fit to a series of data point. Curve fitting can involve either interpolation, where an exact fit to the data is required, or smoothing, in which a "smooth" function is constructed that approximately fits the data. In his paper used the interpolation process in curve fitting. Interpolation is a method of constructing new data points within the range of a discrete set of known data points.

Mean square error

The mean square error is difference between original signal and the reconstructed signal.

In statistics, the mean squared error (MSE) or mean squared deviation (MSD) of an estimator measures the average of the squares of the errors or deviations, that is, the difference between the estimator and what is estimated. MSE is a risk function, corresponding to the expected value of the squared error loss or quadratic loss. The mean square error is here comparing to compression sensing theory and reconstruction algorithm. Mean square error is derived from the formula that is,

$\text{MSE} = \text{Mean}(X_1 - X_2)^2$

where,

X_1- input signal (or) original signal

X_2- output signal (or) reconstructed signal.

6. EXPERIMENTAL ANALYSIS AND RESULT

The technique of a hybrid PAPR reduction scheme for multicarrier accentuation using SLM with cutting at the transmitter, and sparse reconstruction at the Receiver using Mat lab R2014a. Mat lab is appropriate software for analysis the work done evaluation of results for multicarrier accentuation.

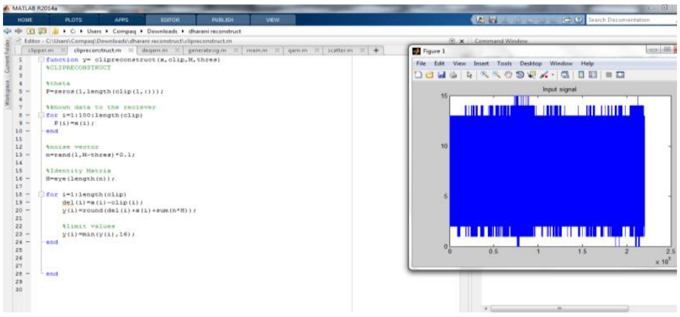

Fig 1: Original Signal

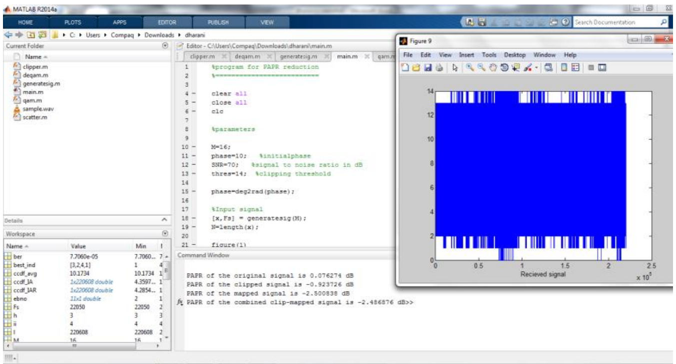

Fig2: Reconstructed Signal (Compression Sensing Theory)

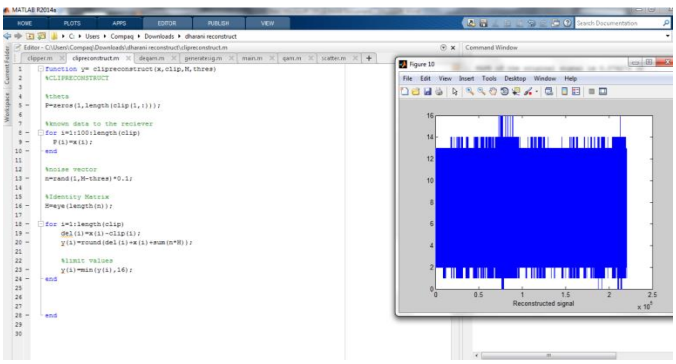

Fig.3.Reconstruction Algorithm

This tabulation results shows the reducing the peak to average power ratio and loss using the compression sensing theory and reconstructed algorithm. The reconstructed algorithm gives the good performance compare to compression sensing theory.

S.NO	Compression Sensing theory	Reconstruction algorithm
1	0.0278	0.00234
2	0.927	0.978

7. CONCLUSION

The hybrid method proposed in this paper significantly reduces the PAPR in OFDM transmission systems using clipping and selected mapping method in transmitter side. Due to clipping loss using the compressed sensing theory and reconstruction algorithm to detect and correct clipping distortion signal. Finally reduce the loss occurred due to clipping technique.

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