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Optimization of PAPR in Orthogonal Frequency Division Multiplexing

P. Raga Lavima[1], Routhula. Tulasi[2], Ravi Jeevan[3], Gunji Gopinadh[4], Deverapalli Sudheer Babu[5]

[1]Electronics and Communication Engineering, L I M A T, Vijayawada, Andhra Pradesh, India.
[2]Electronics and Communication Engineering, L I M A T, Pedana, Andhra Pradesh, India.
[3]Electronics and Communication Engineering, L I M A T, Nuzvid, Andhra Pradesh, India.
[4]Electronics and Communication Engineering, L I M A T, Tenali, Andhra Pradesh, India.
[5]Electronics and Communication Engineering, L I M A T, Vuyyuru, Andhra Pradesh, India.

ABSTRACT

This paper briefs about Peak-to-Average Power Ratio Reduction of OFDM Signals, PAPR reduction efficiency of this method in comparison with Companding and Clipping and some merits and demerits of using various methods of PAPR reduction. Based on the above survey the criteria for the selection of PAPR reduction is given and proposed scheme of combining PTS approach and clipping is also shown along with comparative graphs

Keywords: *OFDM, Partial Transmit Sequence, Companding, in band radiation, out of band distortion, BER, Signal power, Complexity*

1. INTRODUCTION

With the ever growing demand of this generation, need for high speed communication has become an utmost priority. OFDM has been used to meet these demands where a large number of closely spaced orthogonal subcarriers are used to carry data. When RF bandwidth is allocated for OFDM signal, the subcarriers frequencies are chosen to be distributed around centre frequency of the band. One of the major drawbacks of OFDM is high Peak to Average Power Ratio (PAPR) since high PAPR makes the power amplifier at the transmitter side to have a large backoff in order to ensure linear amplification of the signal. PAPR increases approximately linearly with number of subcarriers. It is always desirable to have large number of subcarrier in order to get high data rate but this is at the cost of high PAPR. The block diagram for OFDM transmitter is as shown in Fig 1.

There are many proposed techniques to reduce the PAPR of OFDM system. The easy distortion technique to reduce PAPR is the clipping method. The transmitted signal higher than given threshold is clipped. Clipping is the easy method, but problem persists in in-band distortion and out-of-band radiation and results in bit error rate (BER) performance degradation. An improvement of clipping method is clipping and filtering to remove the out-of-band radiation.

Coding is also one of the effective method can reduce PAPR and coded signal has constant envelope. But, coding method is useful only if number of sub-carriers are less and low order of constellation. Phase rotation techniques such as partial transmit sequence (PTS) and selected mapping (SLM) is efficient techniques to reduce PAPR. Both techniques require multiple inverse fast Fourier transform (IFFT) processors. In order to overcome this drawback of PTS and SLM, sub-block phase weighting can be used.

The low complexity phase weighting method works as efficiently as PTS and SLM but decrease the IFFT processors number to one.

Fig 1:Block diagram of OFDM Transmitter

2. PAPR IN OFDM:

Let X=[X_0,X1,X_2,…..X_M] is data coming out of S/P. OFDM is represented in time domain by

$$X(t)=\frac{1}{\sqrt{N}}\sum_{k=0}^{N-1} Xke^{j2\pi k\delta f t} \quad , 0\leq t \leq T$$

Where δf =1/T is frequency spacing between subcarriers. T is

OFDM symbol duration. The basic PAPR formula is given by

PAPR=[Max|x(t)|^2]/pav ,0<=t<=NT

Where Pav=E [|X(t)|^2] is average power.

3. PAPR REDUCTION TECHNIQUES

3.1. PAPR reduction in OFDM by Partial Transmit Sequence (PTS)

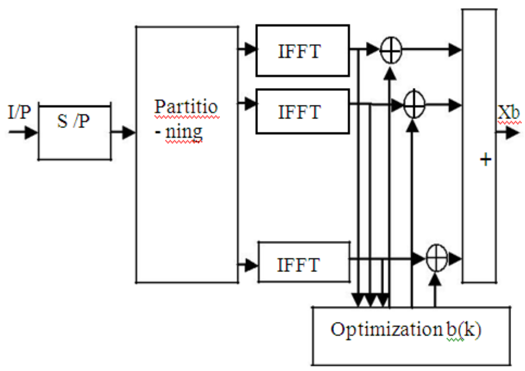

Fig 2: Block diagram for PTS approach

The input signal after S/P is partitioned into M sub blocks in any one of the schemes like adjacent, interleaved, pseudorandom partitioning. Pseudorandom portioning is the best way to get better PAPR reduction.

It is then processed by IFFT processor to get $X=[x^0,x^1....,x^M]$ and combined with the phase factor $b=[b^0,b^1,....,b^M]^T$ .b takes values exp(j2πl/W) where l=0,1,2..W-1. W being the number of allowed phase factors. The combined signal is given by as shown in Fig.2 Selection of phase factor is the need of optimization. As W increases complexity increases. Heung et al., (2005) stated that his proposed low complexity phase shifting makes use of T- matrix for computation where $T=Q^{-1}BQ$. Where B is the diagonal matrix of weighting factor $b=[b_1,b_2,...b_M]$ where M is the number of sub blocks and bi={ l 0,1,2..W-1}. The output $X^b=Tx$. T- matrix has only M nonzero elements and others are zero.

3.2. Companding

At the transmitter side after the IFFT process Companding is done then quantized and D/A conversion. And at the receiver side, A/D conversion and then expanded. µ-Law companding is the robust quantization where signals with high peaks are quantized into less number of steps i.e., less resolution therefore BER performance degrades.

3.3. Clipping

Peak signals in OFDM are clipped by setting threshold this is as simple as multiplying OFDM signal to a window. This causes in band radiation and out of band distortion. Li & Cimini(1998) introduces a post filtering. Though Post filtering reduces spectral growth, time domain peaks still persists

Table 1. Comparison of different approaches

Scheme	PTS	Companding	Clipping
MERITS	1.No side information bit is needed if differential modulation is used. 2. Distortion less. 3.No power loss issue.	1. Spectral regrowth is minimum. 2. Better than clipping in PAPR reduction performance.	1.No power increase. 2.No data rate loss.
DEMERITS	1. If side information is having error then entire block may be lost & increase BER. 2. More complexity. 3. Data rate loss.	1. Degrades BER performance. 2. Increase transmitter signal power but noise power remains constant.	1. In band distortion & out of band radiation. 2. ICF reduces out of band distortion but with complexity.

4. SELECTION CRITERIA

There are many factors that should be considered before a specific, PAPR reduction technique is chosen as shown in table. These factors include PAPR reduction capability, power increase in the transmit signal, BER increase at the receiver, loss in data rate, computation complexity increase and so on

5. PROPOSED SCHEME

As clipping is the easiest scheme to achieve PAPR reduction in time domain it can be used with any other time domain reduction method. Here we are combining PTS approach with the clipping method to achieve better PAPR reduction. Choosing of threshold value in clipping method is dependent on number of message data samples that are taken into analysis it may vary from 0.1 to 100 in random. In our analysis as the peak value rises to nearly 130, we have taken average or threshold value to 100 and the results are depicted as below Fig 5. OFDM is done by first partially transmitting the data signal with optimization and it is clipped by setting the threshold value to around 100. As this is being an easiest approach for better PAPR reduction, the main drawbacks inherent with the clipping method is the loss of data and Out-of-band distortion but not the data rate loss and cost paid for clipping is in its design which is complex. But loss of data can be decreased by setting a suitable threshold which involves keen observation of absolute squared values after the PTS block. Block diagram for the overall scheme is shown in Fig 3. Xb signal obtained from optimization block can be written as sum of X2 signals where,

$$X2(1,:) = X2(1,:) + b(k) * iz(k,:)$$

Where iz(k,:) is the IFFT processors output signals and are being optimized by b(k) by taking +1 and -1 values for each b(k) and selecting the least PAPR signal among iterations performed. It is then clipped by setting suitable threshold and which can be sent to Out-of band filter after converting back to time domain by using FFT processor. Iterative clipping and filtering can be used to reduce out-of-band distortion.

The Figures 4, 5, 6 and 7 shows comparative study on using PTS approach alone, Clipping alone, PTS v/s Clipping and PTS combined with clipping methods. Here we have used 128 bit QAM technique with carrier frequency 1000Hz and randomly generated [1,-1,3,-3] values as data signal. Over sampling is done converting 128 bit data to 512 bit and this oversampled data are taken for every analysis for better study. PTS approach is done by partitioning over sampled data signal in 8 blocks so that each block is of 512 bit with 64 bit raw data samples in varying positions between every block.

Future work will be the combination of positive features of Companding and PTS approach or with the clipping and considering the better result obtained in time domain at transmitter side.

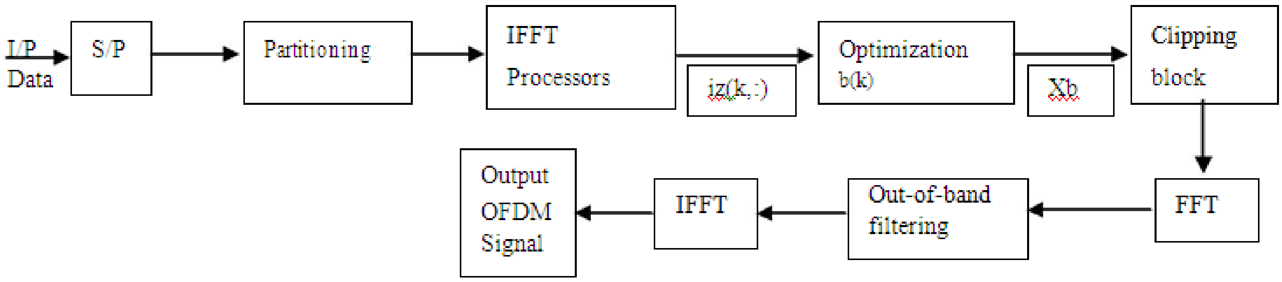

Fig.3 Proposed scheme

6. RESULTS

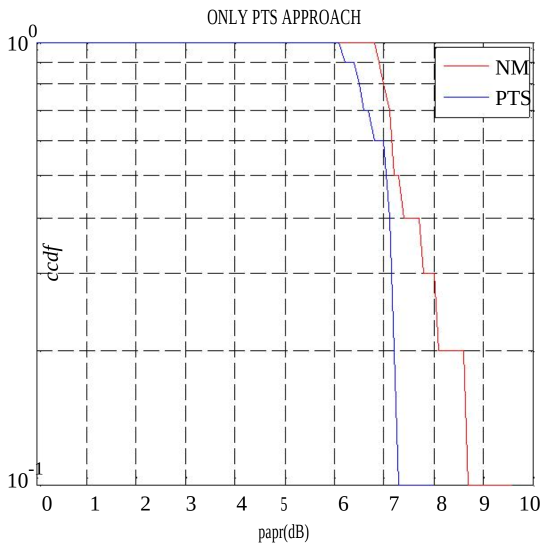

Fig 4: No Method (NM) v/s PTS approach

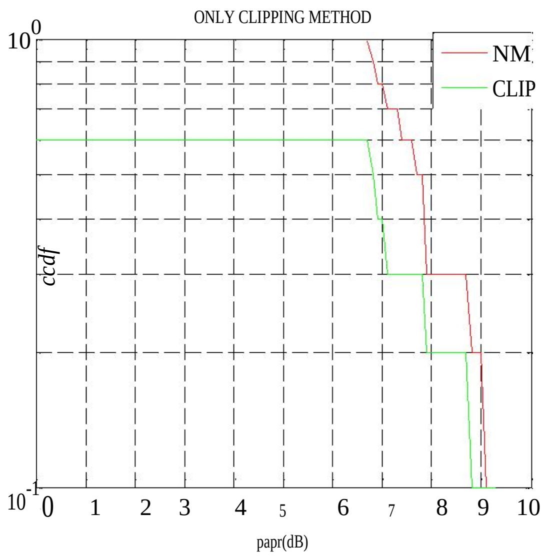

Fig 5: No Method (NM) v/s Clipping.

Individual comparisons are done with No Method reduction techniques used. The above two graphs assisted PTS scheme. Comparison with PTS and clipping and proposed scheme of combining PTS scheme and clipping are shown in below graphs

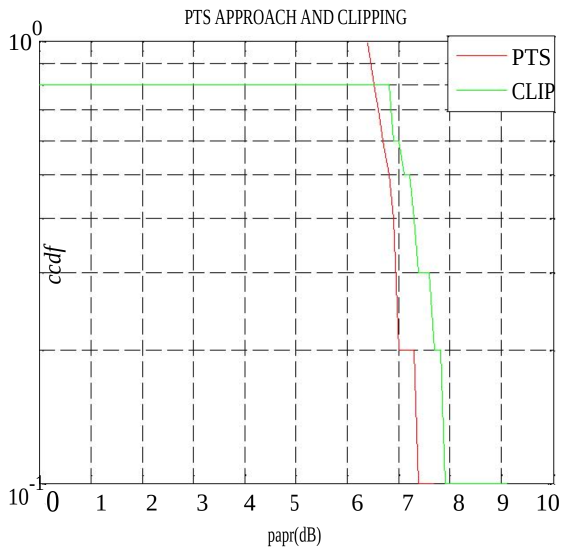

Fig 6: PTS Scheme v/s Clipping

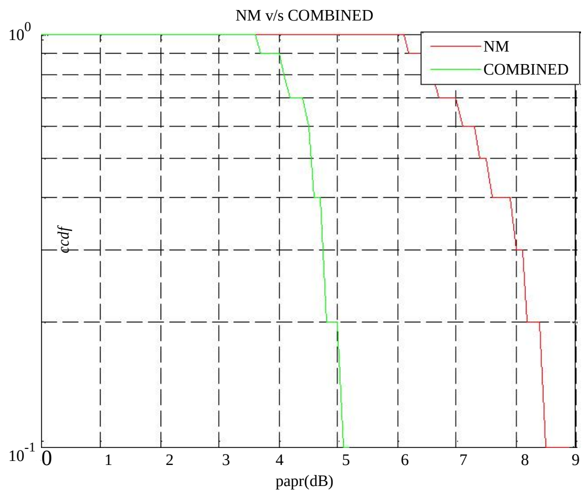

Fig 7: No Method (NM) v/s combined PTS and clipping

Fig 7 clearly reveals the PAPR reduced around to 5 db when compared to 7.8 db for No Method used. In general, The CCDF (Complementary Cumulative Distribution function) object measures the probability of a signal's instantaneous power to be a specified level above its average power.

7. CONCLUSION

Orthogonal frequency division multiplexing is a form of multi carrier modulation technique with high spectral efficiency, robustness to channel fading, uniform average spectral density capacity of handling very strong echoes and less non linear distortion. It has recently been used for both wireless and wired high rate digital data communications. Despite of its many advantages, like: high peak to average power ratio (PAPR) and frequency offset. High PAPR causes saturation in power amplifiers. Therefore, it is desirable to reduce the PAPR. Several techniques have been proposed such as clipping, tone reservation, tone injection, windowing, coding, pulse shaping, companding etc. But most of these techniques are unable to achieve simultaneously a large reduction in PAPR with low complexity, with low coding overhead, without performance degradation and Basic requirement of practical PAPR reduction techniques include the compatibility with the family of existing modulation schemes, high spectral efficiency and low complexity. There are many factors to be considered before a specific PAPR reduction technique is chosen. These factors include PAPR reduction capacity, BER increase at the receiver, loss in data rate, computational complexity increase, Power increase and so on [5]. No specific PAPR reduction technique is the best solution for all multi carrier transmission.

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First Author P. Raga Lavima, completed B Tech at Nova College of Engineering and Technology for Women, in Department of Electronics and Communication Engineering in year 2012. Now Pursuing M. Tech in LIMAT Vijayawada rural.

Second Author Routhula. Tulasi completed B. Tech at Gudlavaleru Engineering College in Department of Electronics and Communication Engineering in year 2011. Now Pursuing M. Tech in LIMAT Vijayawada rural.

Third Author Ravi Jeevan completed B. Tech at Sri Sarathi Institute of Engineering and Technology College of Department Electronics and Communication Engineering in year 2013. Now Pursuing M. Tech in LIMAT Vijayawada (rural).

Fourth Author Gunji Gopinadh completed B. Tech at V N R College of Engineering of Department Electronics and Communication Engineering in year 2012. Now Pursuing M. Tech in LIMAT Vijayawada(rural).

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Fifth Author Deverapalli Sudheer Babu completed B. Tech at Gudlavaleru Engineering College in Department of Electronics and Communication Engineering in year 2012. Now Pursuing M. Tech in LIMAT Vijayawada rural