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Trade-off among the different PAPR Reduction Techniques for OFDM Signals used in Wireless Communication

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ABSTRACT: Irrespective of the good performance of the OFDM systems the main problem associated with the OFDM transmitter and receiver is the Peak-to-Average Power ratio of the modulated signal. The higher values of PAPR degrades the signal to noise ratio of the DAC in the transmitter and the ADC in the receiver, therefore the overall performance or efficiency of the system decreases. In this paper, the performance of the different PAPR reduction techniques for the OFDM signal i.e. Partial Transmit Sequence, Selective Mapping Techniques etc. has been evaluated in terms of Signal to Noise Ratio and Bit Error Rate, system complexity and Channel interference

KEYWORDS: Orthogonal Frequency Division Multiplexing (OFDM), Selective Mapping Techniques(SLM), Partial Transmit Sequence (PTS), Complementary Cummulative Distribution Function (CCDF), High Power Amplifier (HPA), signal to noise ratio (SNR), Bit Error Rate (BER).

I. INTRODUCTION

Irrespective of the good performance of the OFDM systems the main problem associated with the OFDM transmitter and receiver is the Peak-to-Average Power ratio (PAPR) [1]. Practically during the transmission the systems shows certain nonlinearities due to a particular limit of the maximum power. Due to the operation of the system in the non-linear region, the power spectrum of the signal expands and that causes out-of-band distortions [2]. In audio transmission there is a huge difference in the frequency of the radio signal and the transmitted signal that causes adjacent channel interference. The higher values of PAPR also degrades the signal to noise ratio (SNR) of the DAC in the transmitter and the ADC in the receiver, therefore the overall performance or efficiency of the system decreases. This problem is very sensitive in the case of uplink of the data using a mobile phone as the battery power is very small [3]. The higher values of the PAPR introduce distortion in the OFDM signal because the signal operates in the non-linear region of the high power amplifier [4]. Hence it will degrades the bit error rate of the of the OFDM system. The overall performance of the OFDM system depends mainly on the signal to noise ratio and bit error rate, if the distortion or noise increases the SNR of the system decreases, similarly if the number of bits transmitted and received have more errors then the BER degrades.

II. PAPR REDUCTION TECHNIQUES

There are various PAPR reduction techniques used for reducing the PAPR of the OFDM signal. In this paper we compare the following techniques:

- Modified Clipping and Filtering Technique with Interleaving
- Partial Transmit Sequence with Convolutional Codes
- Selective Mapping Techniques with Convolutional codes and Companding.

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All these techniques have been used to reduce the PAPR of the OFDM signal but at the cost of BER, Intersymbol Interference, Out- of - band radiations, increase in system complexity, bandwidth expansion etc.

III. CLIPPING AND FILTERING TECHNIQUE

Several techniques has been proposed by different authors, according to Hideki Ochiai [5] the effect of the clipping and adaptive symbol selection under the strictly band-limited condition has been evaluated in terms of the PAPR reduction capability and the BER performance degradation. It has been shown that with moderate increment of complexity, the significant PAPR reduction can be achieved by combination of the deliberate clipping and adaptive symbol selection. The out-of-band problem can be removed by modifying the properties of the rectangular window function. A rectangular window with Gaussian distribution shape in the frequency domain has been proposed by L.Wangel [6].

The out-of-band radiations can be minimized if a narrow band window filter is used. Guosen Yue [7] has been proposed a hybrid PAPR reduction scheme that provides 5.5dB PAPR reduction in an OFDM system with 128 subcarriers, 4-bit selection and 3dB clipping. Besides the significant PAPR reduction, the scheme also enjoys other advantages such as small overhead, low complexity, no side information transmission, and little performance loss. Due to the simplest way for PAPR reduction, clipping techniques are frequently used in practice for OFDM PAPR reduction. Desire Guel has been performed Classical-Clipping (CC), Heavyside-Clipping (HC), Deep-Clipping (DC) and Smooth-Clipping (SC) for reducing the PAPR of an OFDM system [8]. Another technique combines two basic PAPR reduction techniques i.e. Interleaving with Repeated clipping and filtering [9]. The main idea is to use a combination of data interleaving with clipping and filtering by choosing the optimum value of the clipping ratio.

IV. PARTIAL TRANSMIT SEQUENCE TECHNIQUE :

Partial transmit sequence (PTS) is one of the distortionless technique for reducing the Peak-to-Average Power Ratio (PAPR) of an Orthogonal Frequency Division Multiplexing (OFDM) transmitted signal. In PTS technique, the data blocks to be transmitted are partitioned into disjoint subblocks and the subblocks are combined using phase factors to minimize the PAPR of the OFDM signal. Several modified PTS techniques has been proposed to reduce the computational complexity requires for an exhaustive search over all combinations of allowed phase factors. The channel coding can be use with PTS technique for further reducing the PAPR of the OFDM signal and also improving the system performance in terms of bit error rate.

Several methods have been proposed by different authors to improve the performance of the OFDM signal using PTS technique for PAPR reduction. Seung Hee Han has proposed a PTS technique with reduced complexity for reducing the PAPR of the OFDM system [10]. The phase factors have been searched using the gradient search method. This technique reduces the PAPR of the OFDM signal with reduced search complexity at the cost of small performance degradation of the system. Another PAPR reduction technique with less complexity has been proposed by Chih-Chun Feng using error correcting codes [11]. OFDM modulation of the coded side information and that of data are performed separately, giving the benefit of considerably reduced complexity.

An efficient algorithm for computing the optimal PTS weights that has lower complexity than exhaustive search has been proposed by Ali Alavi [12]. The phase vectors that provide PAPR reduction are only search by the proposed algorithm. The PAPR has been reduced effectively by with reduced complexity in comparison with the exhaustive search approach. A novel Reduced Complexity PTS (RC-PTS) technique has been proposed by L.Yang to reduce the computational complexity [13]. In this technique the sub-optimal PTS has been combined with a preset threshold and the proposed technique reduces the computational complexity. The numerical results have shown that the proposed approach can achieve better performance with lower computational complexity. Another method that can reduce peak-to-average power ratio while maintaining performance improvement by linear precoding for the eigenmode MIMO-OFDM transmission has been proposed by Satoshi Suryama [14]. In the eigenmode MIMO-OFDM system, a transmitter performs linear precoding using Channel State Information (CSI), and thus excellent transmission performance can be achieved.

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A Quantum-Inspired Evolutionary Algorithm (QEA) - based method has been proposed by Jung-Chieh Chen to obtain the optimal phase factor for the PTS technique to reduce computational complexity and improve PAPR performance. The phase factor search has been formulated for of the PTS technique as a global optimization problem with nonlinear constraints. The QEA has been used to search the optimal phase factor for reducing the PAPR of the OFDM signal with less complexity [15]. Another technique has been proposed by A. Ghassemi in which Error-Correcting Codes (ECCs) are employed in the subblocking for the PTS radix FFT for the reduction of PAPR of the OFDM signal. This technique reduces the computational complexity of the OFDM system for reducing the PAPR [16]. Another PAPR reduction technique [17] with less complexity has been proposed by Seema Verma using Convolutional codes.

V. SELECTIVE MAPPING TECHNIQUE

Selective Mapping Technique (SLM) is one of the distortion less technique which does not affect the adjacent channel interference and inter channel interference. This technique is not affected by any interference or noise. To further reduce the PAPR of the OFDM signal, SLM technique can be modified to improve the performance of the system. Several modified SLM techniques has been proposed by different authors, Marco Breiling has been proposed an extension of Selected Mapping technique (SLM) for PAPR reduction in which the system employs scrambling and refrains from the use of explicit side information in the receiver [18]. Some additional complexity and nearly vanishing redundancy is introduced to achieve markedly improved transmit signal statistics. It has been shown by Naoto Ohkubo and Tomoaki Ohtsuk that SLM technique has much better and more effective than PTS technique for reducing the PAPR of Multicarrier Code Division multiple Access technique (MC-CDMA) [19].

A Simplified Scrambler Selected mapping technique has been proposed by Athinarayanan Vallavaraj. There are two advantages of this technique first, no explicite side information is required and second the simplified scrambler helps to avoid the problem of shift register error propagation in the receiver descrambler [20]. The Simplified Scrambler SLM-OFDM approach is investigated in terms of PAPR reduction, Power Spectral Density (PSD) and Bit-Error Rate (BER) performance. It has been shown that the Simplified Scrambler SLM-OFDM technique exhibits the same PSD and BER as general OFDM as well as improving the BER performance over SLM shift-register scrambler techniques. A Recursive Selected mapping technique (RSLM) has been proposed by Lingyin Wang in which by the use of different phase factor set in each stage, the correlation of candidate signals from different stages is reduced and the better PAPR reduction performance is obtained [21].

In Selective Mapping Technique (SLM) with convolutional codes, the PAPR of the OFDM signal has been reduced. In this technique the input data sequence has been scrambled before transmission of the OFDM signal [22]. The OFDM symbols with minimum power have been selected for transmission so that the probability of maximum PAPR will be reduced. The PAPR of the OFDM signal has been reduced by 1.4 dB (approximately).This technique does not affect by any interference or noise. When the number of sub-carriers increases, the bandwidth efficiency reduces and the complexity of the system also increases.

Selective Mapping Technique with Companding has been combined to reduce PAPR. However, Companding Technique is a distortion technique that increases its BER at a particular SNR. This problem has been rectified by combining convolutional code with companding technique resulting in improvement of BER performance of the OFDM system [23]. It also removes the disadvantage of SLM technique of extra side information i.e. this technique does not require any side information unlike in conventional SLM. By considering the example of OFDM with BPSK modulation, it has been shown in simulation results that the proposed scheme performs well in both reducing PAPR and improving BER performance without the need of any side information. It has been calculated that PAPR of OFDM signal has been reduced by 5dB over the original system with the proposed scheme.

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VI. SIMULATION RESULTS

The various PAPR reduction techniques of the OFDM signal used in this work are Clipping and Filtering, Selective Mapping Techniques and the Partial Transmit Sequences. All these techniques have been used to reduce the PAPR of the OFDM signal and their effect on BER, system complexity and bandwidth expansion has been observed. The PAPR and the BER of the OFDM signal after clipping and filtering with Interleaving has been shown in figures 1 and figure 2. The performance of the system has been evaluated in AWGN channel using CCDF for the PAPR reduction and BER curve. This technique has been used in most of the commercial applications because of easy to implement and cost effective. But the main disadvantage of this technique is In-band and out-of-band radiations that degrade the performance of the system in terms of BER. Therefore this technique cannot be used in systems which require high precision and accuracy.

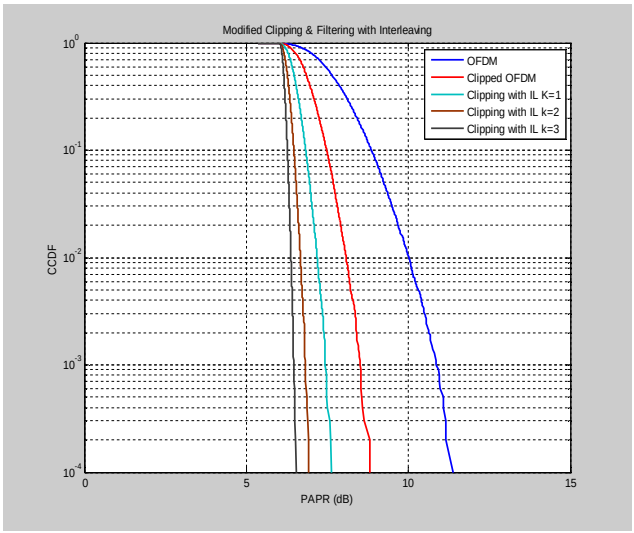

Figure 1: PAPR of modified clipping and filtering

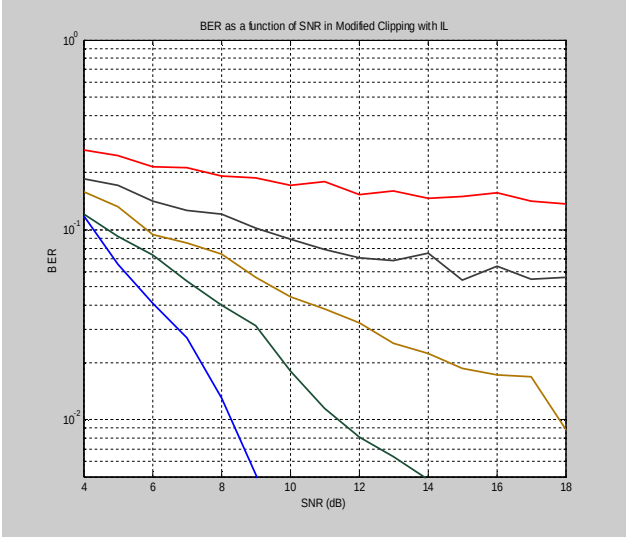

Figure 2: BER as a function of SNR for Modified C&F

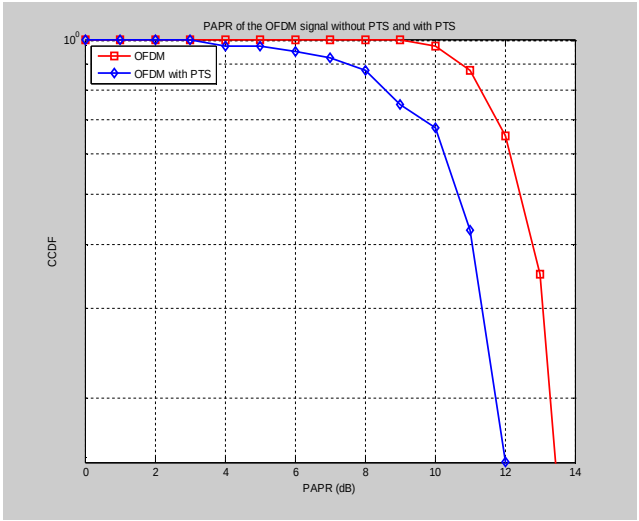

Figure 3: CCDF of PAPR without PTS and with PTS

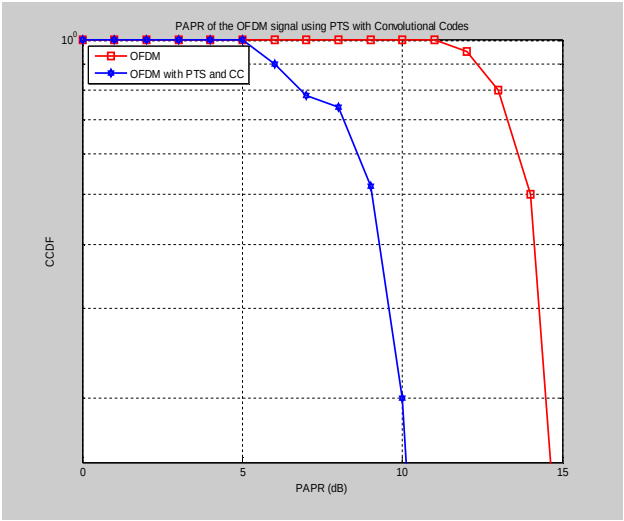

Figure 4: CCDF of PAPR using PTS with CC

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The simulation results of the evaluated PAPR of the OFDM signal without using PTS technique and with conventional PTS technique has been shown in figure 3. From the results it is seen that the performance of the OFDM system with PTS technique is much better than the conventional OFDM system. The PAPR has been further improved approximately by 1.8 dB. In figure 4 the performance of the PAPR of the OFDM signal is compared using the PTS with convolutional codes. The proposed technique using convolutional codes with PTS further reduces the PAPR of the OFDM signal by 3dB approximately.

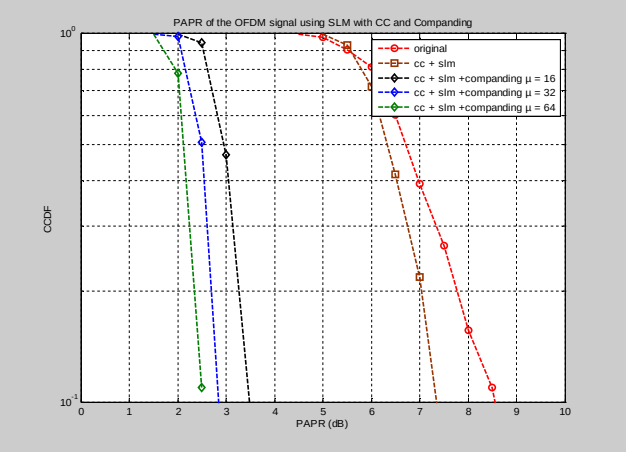

Figure 5: PAPR of the OFDM signal using SLM

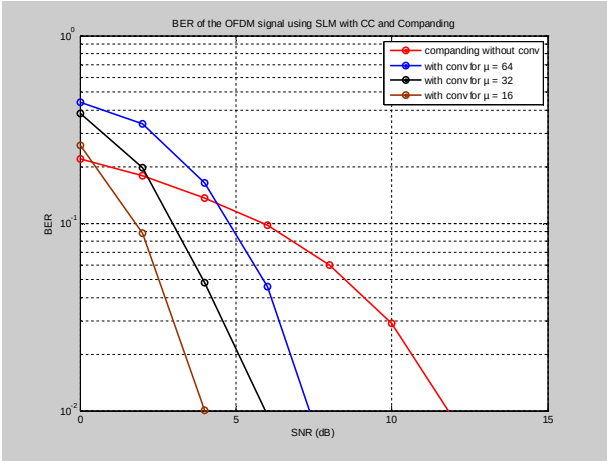

Figure 6: BER of the OFDM signal using SLM

The PAPR reduction of the OFDM signal and the Performance of the system in terms of BER have been evaluated using Selective Mapping Technique with Convolutional codes. The PAPR of the OFDM signal has been reduced by 3 dB with this technique as shown in figure 5.Companding technique has been used with convolutionally coded OFDM signal and SLM technique for further PAPR reduction. This technique reduces the PAPR by 5 dB as compared with the convolutionally coded signals with SLM. The Bit Error Rate of the signal has been studied as shown in figure 6, by taking different values of the companding parameter $\boldsymbol{\mu}$. It has been observed that the Bit Error Rate of the system degrades sharply with increased values of $\boldsymbol{\mu}$. Therefore, a trade-off between the PAPR and BER of the OFDM signal has to be considered.

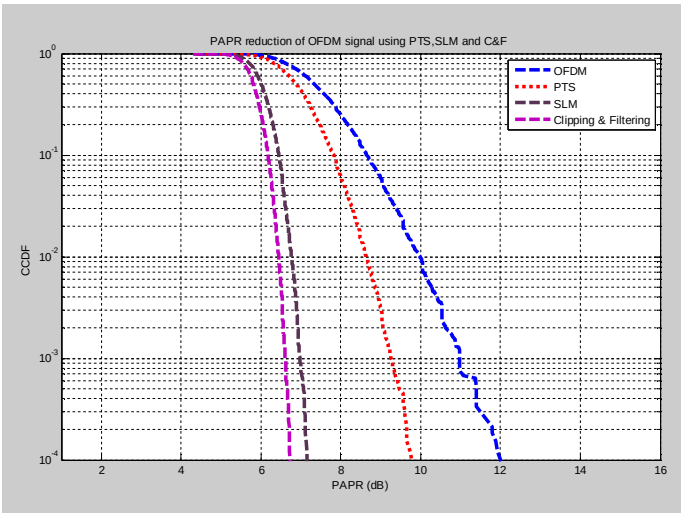

Figure 7: PAPR reduction of OFDM signal using PTS, SLM and C&F

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The different PAPR reduction techniques used for reducing the PAPR of the OFDM signal have been compared in figure 7.

VII. CONCLUSION AND FUTURE WORK

The performance of the OFDM system has been evaluated in terms of Bit Error Rate (BER) and Peak-to-Average power Ratio (PAPR). The convolutional codes have been used with Selective Mapping Technique (SLM) and Partial transmit Sequence (PTS) for PAPR reduction with improved system performance. The PAPR can be further reduced by using other error correction and detection coding techniques. New techniques can be developed for reducing the PAPR with improved system performance because OFDM is a potential candidate for the 5^{th} generation of wireless communication systems.

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