PAPR Reduction Method for OFDM based
Massive MIMO Systems

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Abstract

The problem of peak-to-average power ratio (PAPR) reduction in orthogonal frequency-division multiplexing (OFDM) based massive multiple-input multiple-output (MIMO) downlink systems is considered. OFDM consist of large number of independent subcarriers, as a result of which the amplitude of such a signal can have high peak values. The peak to average power ratio of a transmitted signal is one of main challenges in OFDM or MIMO-OFDM. Understanding the effects of PAPR on OFDM and MIMO-OFDM systems is critical when determining what techniques to use improve system performance. Selective-Mapping (SLM) scheme which does not require the transmission of side information and can reduce the PAPR in OFDM system is proposed. SLM is a distortion less technique that can reduce PAPR efficiently without increase in power requirement and incurring data rate loss. Simulation results show that the system can achieve significant reduction in PAPR and satisfactory bit error rate performance over AWGN channels.

Keywords: PAPR, OFDM, SLM, AWGN

I. INTRODUCTION

Massive multiple-input multiple-output also known as large-scale or very-large MIMO, is a promising technology to meet the ever growing demands for higher throughput and better quality-of-service of next-generation wireless communication systems. MIMO is a method for multiplying the capacity of a radio link using multiple transmit and receive antennas to exploit multipath propagation. MIMO is fundamentally different from smart antenna techniques developed to enhance the performance of a single data signal, such as beamforming and diversity. Massive MIMO systems are those that are equipped with a large number of antennas at the base station simultaneously serving a much smaller number of single-antenna users sharing the same time-frequency bandwidth. In addition to higher throughput, massive MIMO systems also have the potential to improve the energy efficiency and enable the use of inexpensive, low-power components. Hence, it is expected that massive MIMO will bring radical changes to future wireless communication systems. In practice, broadband wireless communications may suffer from frequency-selective fading. Orthogonal frequency division multiplexing (OFDM), a scheme of encoding digital data on multiple carrier frequencies, has been widely used to deal with frequency-selective fading. 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. However, a major problem associated with the OFDM is that it is subject to a high peak-to-average power ratio owing to the independent phases of the sub-carriers. To avoid out-of-band radiation and signal distortion, handling this high PAPR requires a high-resolution digital-to-analog converter and a linear power amplifier (PA) at the transmitter, which is not only expensive but also power-inefficient. The situation deteriorates when the number of antennas is large leaving such systems impractical. Therefore, it is of crucial importance to reduce the PAPR of massive MIMO-OFDM systems to facilitate low-cost and power-efficient hardware implementations. Many techniques have been developed for PAPR reduction in single-input single-output (SISO) OFDM wireless systems. The most prominent are clipping, tone reservation (TR), active constellation extension (ACE), partial transmission sequence (PTS) and others.

Although these PAPR-reduction schemes can be extended to point-to-point MIMO systems easily, extension to the multi-user (MU) MIMO downlink is not straightforward, mainly because joint receiver-side signal processing is almost impossible in practice as the users are distributed. Recently, a new PAPR reduction method was developed for massive MIMO-OFDM systems. The scheme utilizes the redundant degrees-of-freedom (DoFs) resulting from the large number of antennas at the BS to achieve joint multiuser interference (MUI) cancelation and PAPR reduction. Specifically, the problem was formulated as a linear constrained $\ell_0$ optimization problem and a fast iterative truncation algorithm (FITRA) was developed. However, the FITRA algorithm shows
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to have a fairly low convergence rate. Also, the algorithm employs a regularization parameter to achieve balance between the PAPR reduction and the MUI cancelation (i.e. data fitting error). The choice of the regularization parameter may be tricky in practice. On the other hand, the regularization parameter may be seen instead as an additional degree of freedom that allows to regulate the operation of the algorithm. A peak signal clipping scheme was employed to reduce the PAPR and some of the antennas at the BS are reserved to compensate for peak-clipping signals. This method has a lower computational complexity. But it achieves only a mild PAPR reduction and those antennas reserved for compensation may incur large PAPRs. This paper follows with some literature paper works and limitations leading to a new system design. Also this paper covers and concluded with a new design.

II. LITERATURE SURVEY

A. PAPR Reduction Techniques for OFDM Signals

As an attractive technology for wireless communications, Orthogonal Frequency Division Multiplexing which is one of multi-carrier modulation techniques, offers a considerable high spectral efficiency, multipath delay spread tolerance, immunity to the frequency selective fading channels and power efficiency. One of the challenging issues for Orthogonal Frequency Division Multiplexing system is its high Peak-to-Average Power Ratio. In this paper, it reviews and analysis different OFDM PAPR reduction techniques, based on computational complexity, bandwidth expansion, spectral spillage and performance. They are clipping, filtering, coding schemes and partial transmit sequences.

The simplest and most widely used technique of PAPR reduction is to basically clip the parts of the signals that are outside the allowed region. Generally, clipping is performed at the transmitter. However the receiver need to estimate the clipping that has occurred and to compensate the received OFDM symbol accordingly. Therefore, clipping method introduces both in band distortion and out of band radiation into OFDM signals, which degrades the system performance including BER and spectral efficiency. Filtering can reduce out of band radiation after clipping although it cannot reduce in-band distortion. However, clipping may cause some peak regrowth so that the signal after clipping and filtering will exceed the clipping level at some points. A simple block coding scheme was introduced and its basic idea is that mapping 3 bits data into 4 bits codeword by adding a Simple Odd Parity Code at the last bit across the channels. The main disadvantage of SOBC method is that it can reduce PAPR for a 4-bit codeword. Later, Wulich applied the Cyclic Coding to reduce the PAPR Fragiacomo proposed an efficient Simple Block Code to reduce the PAPR of OFDM signals. However, it is concluded that SBC is not effective when the frame size is large. In a typical OFDM system with PTS approach to reduce the PAPR, the input data block in is partitioned into disjoint subblocks. In general, for PTS scheme, the known subblock partitioning methods can be classified into three categories: adjacent partition, interleaved partition and pseudo random partition. Then, the subblocks are transformed into time-domain partial transmit sequences. The objective is to optimally combine the subblocks to obtain the time domain OFDM signals with the lowest PAPR.

Fig. 1: Block diagram of PTS technique

B. Antenna Reservation Scheme

An OFDM based MU-MIMO system is considered. The problem of high Peak-to-Average Ratio in OFDM based systems is well known and the large number of antennas (RF-chains) at the Base Station in massive MIMO systems aggravates this further, since large numbers of these Power Amplifiers are used. High PAR necessitates linear PAs, which have a high hardware cost and are typically power inefficient. In this paper we propose a low-complex approach to tackle the issue. The idea is to deliberately clip signals sent to one set of antennas, while compensating for this by transmitting correction signals on a set of reserved antennas (antenna-reservation). massive MIMO there is inherently a large degree-of-freedom (due to the large number of antennas at the BS), that can be utilized to reduce the PAR. In contrast, here propose an approach which does not deliver the same amount of PAR reduction, but is of much lower complexity and hardware cost. The idea is to reserve antennas ("antenna reservation" analogy to
"tone-reservation"), which will be used to compensate for a (deliberate) clipping of the signals on the remaining antennas. In terms of signal processing, an advantage is that even though there is a quite large number of antennas to be handled at the BS, most of the processing can be performed using simple linear methods. For example, low-complex pre-coding can be deployed which reduces the overall digital (signal processing) hardware cost. It is also important to look at the RF chains where, considering the large number of instances, it is very important to reduce both hardware cost and power consumption. It relies on reserving bandwidth (around 20% for 10 dB reduction in PAR), which, in-turn, reduces the spectral-efficiency significantly since it has a linear (pre-log-factor) relation to capacity. In massive MIMO there is inherently a large degree-of-freedom (due to the large number of antennas at the BS), that can be utilized to reduce the PAR. The proposed antenna-reservation method has a low complexity overhead and can be implemented with existing hardware blocks, namely a DFT and a matrix inversion (pre-coder).

C. Active Constellation Extension

The high peak-to-average power ratio in Orthogonal Frequency Division Multiplexing modulation systems can significantly reduce power efficiency and performance. Methods exist which alter or introduce new signal constellations to combat large signal peaks. Here present a new PAR-reduction method that dynamically extends outer constellation points in active (data-carrying) channels, within margin-preserving constraints, in order to minimize the peak magnitude. This scheme simultaneously decreases the bit error rate slightly while substantially reducing the peak magnitude of an OFDM transmit block. Furthermore, there is no loss in data rate and unlike other methods, no side information is required. PAR reduction for an approximated analog signal is considered, Large PARs occur when symbol phases in the sub-channels line up in a fashion that results in constructively forming a peak in the time-domain signal. One class of methods reduce peak power by inserting signals in unused subchannels that partially cancel the time-domain peaks. Since the subchannels are orthogonal, these additional signals cause no distortion of the data-bearing subchannels. In the case of DMT in wireline systems, there are typically subchannels with SNRs too low for sending any information, so these subchannels must go unused and are available for PAR reduction. In wireless systems, however, there is typically no fast, reliable channel-state feedback to dictate whether some subchannels should go unused. Instead, a set of subchannels must be reserved regardless of the received SNRs, resulting in a bandwidth sacrifice. This may not be appropriate for some wireless systems. Here, a new nonbijective constellation technique called active constellation extension is introduced along with practical algorithms that show promising results for commercial use in OFDM systems.

III. Proposed system

System model of the proposed system is explained using fig.2 and fig.3. For the transmitting and receiving systems respectively. The data from the input source are error corrected using block codes. Then modulation is done using BPSK modulation technique. The modulated signals are converted to 2×2 or 4×4 sub-blocks using Space Time Block Codes (STBC). After that IFFT is done in OFDM modulation that converts frequency domain signal to time domain signals. After that PAPR reduction is to be done. Here, Selective mapping is proposed for PAPR reduction. It is a simple PAPR suppression method for OFDM signals. At the receiver side, FFT is performed. The sub-blocks are reconverted using MIMO combiner. RLS algorithm is used in the adaptive filter. The received signal then undergoes for demodulation, decoding and given to destination.

SLM PAPR reduction technique can be employed for larger number of sub-carriers with moderate complexity. The technique contains codes only for PAPR reduction and does not include error correction. The need for transfer of side information to the receiver without any margin for transmission errors is very crucial under the fading channels. The SLM technique is developed from the idea of symbol scrambling. SLM is distortion less peak-to-average power ratio reduction schemes that has been proposed for orthogonal frequency division multiplexing. This is an effective and distortion less technique used for the PAPR reduction in OFDM. Here the phase vector is applied to reduce the PAPR. This phase vector is multiplied by the subcarrier of OFDM for reduction the peak. Transmitter and receiver know the phase vector. The phase vector circularly rotates. The rotation which has minimum peak is selected and send rotation number as side information. The benefit of this SLM scheme is that there is very less side information is used for reducing PAPR in OFDM systems.

![Fig. 2: Block diagram of transmitter section](image)

![Fig. 3: Block diagram of receiver section](image)
IV. SIMULATION RESULTS

The simulation results are based on MATLAB code and it is observed. MATLAB is used as the simulation tool for implementing this project as, it is a high performance language for technical computing. It integrates computation, visualization, and programming in an easy to use environment where problems and solutions are expressed in familiar mathematical notation. Typical uses include, math and computation, algorithm development, modeling, simulation and prototyping, data analysis, exploration, and visualization.

The complementary cumulative distribution function (CCDF) is used to evaluate the PAPR reduction performance. The CCDF denotes the probability that the PAPR of the estimated signal exceeds a given threshold PAPR0. To better evaluate the PAPR reduction performance, the CCDF of the PAPR in normal case and when using SLM scheme is shown in Fig.4 and 5. The BER performance of the SLM technique is shown in Fig.6. The SER performance of the SLM technique is shown in Fig.7. The convergence rates of the proposed method and the FITRA algorithm is examined. PAPR, MUI and OBR vs. the number of iterations are shown in Fig.8, Fig.9 and Fig.10. The PAPR-reduction performance under different number of transmit antennas is also examined. PAPR, MUI and OBR vs. the number of transmit antennas are shown in Fig.11, Fig.12 and Fig.13.
V. CONCLUSION

The problem of PAPR reduction in OFDM based massive MIMO downlink systems is considered. As compared to traditional single carrier modulation system the multicarrier modulation system offers better transmission. OFDM system suffers from serious problem of high PAPR. PAPR in OFDM occurs when multiple carrier collectively define a larger peak value then the average peak value of a signal. To increase the linearity in the signal and to reduce the error rate, it is required to reduce the PAPR from the signal. Selective mapping technique improve the performance of OFDM system with respective PAPR, it can produce independent multiple frequency OFDM signals. From the simulation results it can be concluded that the PAPR performance of SLM technique is better than other techniques. As number of sub-blocks increases the performance of selective mapping scheme is continuously improved. The obtained results shows the effectiveness of the work in terms of high PAPR reduction and lesser BER in the system.

REFERENCES


