Survey Paper: on Peak-to-Average Power Ratio Reduction Techniques for MIMO-OFDM Signal

Sony Kumari[1], Prof. Ankit Tripathi[2] , Prof. Bharti Chourasia[3]

M Tech. Scholar[1], Prof. [2],Head of Dept[3]

Dept. of Electronics and communication, Scope college of Engineering, Bhopal

Abstract- In Digital communication systems, High Peak to average power ratio (PAPR) reduction techniques are the challenging problem for multiple input multiple output orthogonal frequency division multiplexing (MIMO-OFDM). In this paper, we review and analysis different reduction technique for MIMO OFDM PAPR, based on the criteria of bandwidth expansion, computational complexity, spectral spillage and performance.

Keyword: peak to average power ratio (PAPR), partial transmit sequence (PTS), Selective mapping (SLM), Residue number system (RNS), Complementary Cumulative Distribution Function (CCDF).

I. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) is a modified form of frequency Division Modulation (FDM). Modulation and Multiplexing both concept are used in OFDM. Modulation is a technique through which we change the one or more properties of carrier signal according to message signal or modulating signal, which contains information to be transmitted. Modulation occurs in the form of phase, amplitude, frequency or its combination. Multiplexing is a technique through which, we integrate the multiple signals, which are generated from different source into a single transmitted signal over shared medium. Multiplexing can be done in the term of time division and so it is known as Time Division Multiplexing (TDM) and when this is done in term of frequency, it is known as Frequency Division Multiplexing (FDM). OFDM enables reliable broadband communications by distributing user data across a number of closely spaced, narrowband sub channels. This arrangement makes it possible to eliminate the biggest obstacle to reliable broadband communications, intersymbol interference (ISI). ISI occurs when the overlap between consecutive symbols is large compared to the symbols' duration. Normally, high data rates require shorter duration symbols, increasing the risk of ISI. By dividing a high-rate data stream into numerous low-rate data streams, OFDM enables longer duration symbols. A cyclic prefix (CP) may be inserted to create a (time) guard interval that prevents ISI entirely. If the guard interval is longer than the delay spread—the difference in delays experienced by symbols transmitted over the channel—then there will be no overlap between adjacent symbols and consequently no intersymbol interference. Though the CP slightly reduces spectral capacity by consuming a small percentage of the available bandwidth, the elimination of ISI makes it an exceedingly worthwhile tradeoff [10]

To increases the capacity of OFDM system we take multiple input multiple output (MIMO) antenna system. MIMO is effectively a radio antenna technology as it uses multiple antennas at the transmitter and receiver to enable a variety of signal paths to carry the data, choosing separate paths for each antenna to enable multiple signal paths to be used.

MIMO-OFDM is the foundation for most advanced wireless local area network and mobile broadband network standards because it achieves the greatest spectral efficiency and, therefore, delivers the highest capacity and data throughput. Greg Raleigh invented MIMO in 1996 when he showed that different data streams could be transmitted at the same time on the same frequency by taking advantage of the fact that signals transmitted through space bounce off objects (such as the ground) and take multiple paths to the receiver. That is, by using multiple antennas and precoding the data, different data streams could be sent over different paths. Raleigh suggested and later proved that the processing required by MIMO at higher speeds would be most manageable using OFDM modulation, because OFDM converts a high-speed data channel into a number of parallel, lower-speed channels partially overlap in frequency. MIMO-OFDM is a particularly powerful combination because MIMO does not attempt to mitigate multipath propagation and OFDM avoids the need for signal equalization. MIMO-OFDM can achieve very high spectral efficiency even when the transmitter does not possess channel state information (CSI). When the transmitter does possess CSI (which can be obtained through the use of training sequences), it is possible to approach the theoretical channel capacity. CSI may be used, for example, to allocate different size signal constellations to the individual subcarriers, making optimal use of the communications channel at any given moment of time. The MIMO Applications are-

- MIMO provides high speed wireless communication link to support wide range of applications without the expansion of the available bandwidth or increase of transmitted power.
- Narrowband Applications where limited bandwidth and lower data rate, higher performance required (since space-time block coding (STBC) is attractive).Pager, text messaging applications such as blackberry
- Communication network applications such as broadcasting network, cellular network, satellite communication.

Major advantages of MIMO is-

- Higher capacity.
- Increase data rate.
- Lower bit error rate.
- Increased coverage.
- Improved position estimation

And the disadvantage of MIMO is-

- Computational complexity.
- Channel modeling complexion.
- High peak to average power ratio

Despite of all advantageous feature of MIMO OFDM, there is still a major limitation to it use in terms of high peak to average power ratio, which needed to be addressed before considering it use. This reduces the performances of high power amplifier.

PEAK TO AVERAGE POWER RATIO (PAPR)

The PAPR is the relation between the maximum powers of a sample in a given OFDM transmit symbol divided by the average power of that OFDM symbol. PAPR occurs when in a multicarrier system the different sub-carriers are out of phase with each other. At each instant they are different with respect to each other at different phase values. When all the points achieve the maximum value simultaneously; this will cause the output envelope to suddenly shoot up which causes a 'peak' in the output envelope. Due to presence of large number of independently modulated subcarriers in an OFDM system, the peak value of the system can be very high as compared to the average of the whole system. This ratio of the peak to average power value is termed as Peak-to Average Power Ratio. An OFDM signal consists of a number of independently modulated sub-carriers which can give a large PAPR when added up coherently. When N signals are added with the same phase they produce a peak power that is N times the average power of the signal. So OFDM signal has a very large PAPR, which is very sensitive to nonlinearity of the high power amplifier.

PAPR represents the relationship between the maximum power of transmitted OFDM signal and its average power is[5].

$$PAPR = 10log_{10}\frac{P_{peak}}{P_{average}}(dB)$$

As we know that large number of subcarriers are generated in MIMO-OFDM technique. When these subcarriers are out of phase with each other, a significant PAPR appears which causes power amplification of transmitter, run within nonlinear operating region, which causes signal distortion at output of power amplifier. In MIMO OFDM system PAPR is calculated by complementary cumulative disibution function (CCDF).

CCDF (complementary cumulative distribution function) it compute the power from a time domain signal. The CCDF curve shows the amount of time a signal spends above the average power level of the measured signal, or equivalently, the probability that the signal power will be above the average power level. The full CCDF is 1-CDF, which estimates the probability of a sample having an instantaneous power value greater than the maximum power in a given bin.The CCDF measurement only displays the portion of the CCDF for power values greater than the average power of the histogrammed samples (any samples discarded because they are outside the threshold range are not included in the average power calculation.) The y-axis values displayed are the probabilities that a sample's instantaneous power will be greater than or equal to the power that is the x-axis value from the average power.[VSS Measurement Catalog NI AWR Design Environment v13 Edition].

The CCDF curve is generated by first computing the probability density function (PDF) using a histogram of the measured signal

$$\text{CCDF [bin]}= \sum_{i}^{bin} PDF[i]$$

The CCDF is commonly used to evaluate the performance of PAPR reduction techniques. The CCDF of the PAPR denotes the probability that the PAPR of an OFDM symbol exceeds a threshold $PAPR_0$.

$$CCDF = P\ (PAPR > PAPR_0\ )$$

Effect of PAPR

PAPR Problem One of the new problems emerging in OFDM systems is the so-called Peak to Average Power Ratio (PAPR) problem. The input symbol stream of the IFFT should possess a uniform power spectrum, but the output of the IFFT may result in a non uniform or spiky power spectrum. Most of transmission energy would be allocated for a few instead of the majority subcarriers. This problem can be quantified as the PAPR measure. It causes many problems in the OFDM system at the transmitting end. There are some obstacles in using OFDM in transmission system in contrast to its advantages due to exhibits a very high Peak to Average Power Ratio (PAPR).

(i) RF power amplifiers should be operated in a very large linear region. Otherwise, the signal peaks get into non-linear region of the power amplifier causing signal distortion. This signal distortion introduces inter modulation among the subcarriers and out of band radiation. Thus, the power amplifiers should be operated with large power back-offs. On the other hand, this leads to very inefficient amplification and expensive transmitters. Thus, it is highly desirable to reduce the PAPR.

(ii) These large peaks cause saturation in power amplifiers, leading to inter modulation products among the subcarriers and disturbing out of band energy. Therefore, it is desirable to reduce the PAPR.

(iii) To reduce the PAPR, several techniques have been proposed such as clipping, coding, peak windowing, Tone Reservation and Tone Injection. But, most of these methods are unable to achieve simultaneously a large reduction in PAPR with low complexity, with low coding overhead, without performance degradation and without transmitter receiver symbol handshake.

(iv) Complexity is increased in the analog to digital and digital to analog converter.

Criteria for PAPR Reduction Method Selection

The criteria of the PAPR reduction is to find the approach that it can reduce PAPR largely and at the same time it can keep the good performance in terms of the following

i) The high capability of PAPR reduction: it is a primary factor to be considered in selecting the PAPR reduction technique with as few harmful side effects such as in-band distortion and out-of band radiation.

ii) Low average power: Although it also can reduce PAPR through average power of the original signals increase, it requires a larger linear operation factors as possible. The following criteria should be considered in using the techniques: Region in HPA and thus resulting in the degradation of BER performance.

iii) Low implementation complexity: Generally, complexity techniques exhibit better ability of PAPR reduction. However, in practice, both time and hardware requirements for the PAPR reduction should be minimal.

iv) No bandwidth expansion: The bandwidth expansion directly results in the data code rate loss due to side information Moreover, when the side information are received in error unless some ways of protection such as channel coding employed. Therefore, when channel coding is used, the loss in data rate is increased further due to side information. Therefore, the loss in bandwidth due to side information should be avoided or at least be kept minimal.

v) No BER performance degradation: The aim of PAPR reduction is to obtain better system performance including BER than that of the original OFDM system. Therefore, all the methods, which have an increase in BER at the receiver, should be paid more attention in practice.

vi) Without additional power needed: The design of a wireless system should always take into consideration the efficiency of power.

PAPR Reduction Techniques Many methods have been suggested to reduce PAPR over the years [8][15][16][18][19]. PAPR reduction techniques vary according to the requirement of the system and are dependent on various factors such as PAPR Spectral efficiency, reduction capacity, increase in transmit signal power, loss in data rate, complexity of computation and increase in the bit-error rate(BER) at the receiver end are various factors which are taken into account before adopting.

PAPR reduction technique of the system.

Many techniques have been suggested for PAPR reduction, with different levels of success and complexity. A lots of techniques presents for the reduction of this PAPR [20][21].These techniques are divided into two groups - signal scrambling techniques and signal distortion techniques which are given below:

(i) Signal Scrambling Techniques

- Block Coding Technique
- Block Coding Scheme with Error Correction
- Selected Mapping (SLM)
- Partial Transmit Sequence (PTS) •

Interleaving Technique

- Tone Reservation (TR)
- Tone Injection (TI)

(ii) Signal Distortion Techniques

- Peak Windowing
- Envelope Scaling
- Peak Reduction Carrier
- Clipping and Filtering

Whereas residue number system (RNS) are based upon mathematical computation. They are neither in Signal Scrambling Techniques nor in Signal Distortion Techniques.

II. LITRETURE REVIEW

Ji Zhou Yaojun Qiao [2] "Low-PAPR Asymmetrically Clipped Optical OFDM for Intensity-Modulation/Direct-Detection Systems" In this paper a DHT-spread technique for PAPR reduction in DHT-based ACO OFDM system. The proposed scheme has better transmission performance than the conventional scheme due to its effective equalization and low PAPR .Proposed scheme is attractive to IM/DD systems due to its low PAPR and excellent transmission performance.

Chirag V Trivedi et al. [3], " PTS Technique for MIMO-OFDM Paper Reduction" in this paper PTS technique for PAPR reduction OFDM technology, simulation of theoretical Complementary Cumulative Distributive Function (CCDF) of MIMO-OFDM technology is given. This paper analyzed theoretical PAPR for MIMO-OFDM system with and without oversampling. Theoretical results show that MIMO system in conjunction with OFDM system possesses Problem of PAPR on multiple paths and hence it is critical to solve this issue. To reduce Complexity we use Rows of Riemann Matrix as a phase factors and To reduce PAPR we use autocorrelation property of DCT combination of both technique can give reduced PAPR with reduced complexity

Yu Zhang1, Wei Tang2 [4] In this paper, propose a PAPR reduction methods of clipping and ACE (active constellation extension) to compensate for the nonlinear distortion. Then, the amount of required IBO is lowered so that power efficiency is improved than the only pre distortion case. Based on the memory less solid state power amplifier (SSPA) of Rapp model, computer simulations and analysis in this paper demonstrates that, especially when the HPA is working near or in the saturation region, a predistorter will cease to be in effect. In such cases, PAPR reduction techniques may be resorted to help to improve the HPA efficiency

Yi Yao, Jianhao Hu [5], "MIMO-OFDM PAPR Reduction by Residue Number System"In this paper, proposed a residue number system (RNS) based PAPR reduction scheme in MIMO-OFDM systems, the properties of RNS to greatly reduce the PAPR and the computational complexity as well. Compared with the partial transmit sequence (PTS) scheme, the RNS-based PAPR reduction scheme has not only much better PAPR reduction performance without restriction to modulation format, but also low computational complexity without side information.

Beena R. Ballal et al. [6], "Orthogonal Frequency Division Multiplexing and its Applications" in this paper discussed about benefit of OFDM over single-carrier schemes is its ability to cope with severe channel conditions without complex equalization filters. It has improved the quality of long-distance communication by eliminating Inter Symbol Interference (ISI) and improving Signal-to-Noise ratio (SNR). The main drawbacks of OFDM are its high peak to average power ratio and its sensitivity to phase noise and frequency offset. This paper gives an overview of OFDM, its applications in various systems such as IEEE 802.11a, Digital Audio Broadcasting (DAB) and Digital Broadcast Services to Handheld Devices (DVB-H) along with its advantages and disadvantages

Alok Joshi et al. [7] In this paper Modified Selective mapping (SLM), Partial Transmit sequence (PTS) and Discrete Hartley Transform (DHT) precoding schemes are proposed for PAPR reduction, where SLM, PTS and DHT precoding schemes are used in conjunction with post clipping and filtering processes. However clipping can degrade the BER performance but the degradation in performance can be compensated by using OFDM with channel coding; here we have

used Reed Solomon (RS) codes along with convolution codes (CC) used as serial concatenation and TURBO codes as parallel concatenation code for channel coding purpose. The BER performances are simulated for Additive white Gaussian (AWGN), Rayleigh, Rician and Nakagami (m=3) channels and Complementary cumulative distribution functions (CCDF) curves are simulated for modified as well as ordinary SLM, PTS and DHT precoding techniques.

Alaa jalal mohammed et al. [8] "DHT-BASED PRE-CODING FOR PAPR REDUCTION IN

MULTICARRIER M-QAMOFDM SYSTEMS" In this paper a pre-coding based PAPR reduction is proposed using discrete Hartley transform (DHT).A comparative analysis is done with the proposed method against Walsh Hadamard transform (WHT) and discrete Fourier transform (DFT), and selective mapping method(SLM).Experimental analysis shown that the proposed method outperforms when compared against WHT and SLM. DHT Precoded OFDM system does not require any power increase, complex optimization and side information to be sent for the receiver.

Haidar N. Al-Anbagi et al. [9] " in this paper, two schemes, SLM and PTS were proposed as distortion less PAPR reduction algorithms. for comparing performance of both scheme this paper uses a new PAPR reduction efficiency parameter which will be applied on the complementary cumulative distribution function (CCDF) of each technique to compare the results. This paper show as well how the performance of the system reacts when increasing the probability of getting high PAPR values. Using the proposed efficiency formula, here it will be cleared that PTS system performance improves when increasing the probability, whereas the SLM system performance gets impaired when increasing the probability within the same range format but also low computational complexity without side information..

Manushree Bhardwaj et al. [10] "A Review on OFDM: Concept, Scope & its Applications" this paper discussed about the basic idea behind the ofdm, the most emerging technology of this era. Here we take a review on its concept, its properties in terms of its advantages and disadvantages, its limitations and also its applications in different fields. This paper has explored the role of OFDM in the wireless communication and its advantages over single carrier transmission. In wireless communication, concept of parallel transmission of symbols is used to achieve high throughput and better transmission quality. Orthogonal Frequency Division Multiplexing (OFDM) is one of the techniques for parallel transmission. The idea of OFDM is to split the total transmission bandwidth into a number of orthogonal subcarriers in order to transmit the symbols using these subcarriers in parallel.

Tao Jiang [11], this paper, we propose a novel alternative multisequence (AMS) scheme for the peak-to-average power ratio (PAPR) reduction in multiple-input–multiple-output orthogonal frequency-division multiplexing (MIMO-OFDM) systems with space–frequency block coding (SFBC). The key idea of the proposed scheme is keeping the advantage of the SFBC structure to generate some AMSs via combining the signals at different transmit antennas. Specifically, when the proposed scheme is employed in SFBC MIMO OFDM systems with quadrature-amplitude modulation (QAM), one of the big advantages is that the side information (SI) does not need to be sent to the receiver. Theoretical analysis and simulation results validate that the proposed scheme has the ability to provide large PAPR reduction, a low bit error rate, and low computational complexity without SI in SFBC MIMO-OFDM systems.

Michela Svaluto Moreolo [12], this paper demonstrate that optical OFDM (O-OFDM) based on discrete Hartley transform (DHT) can be used with large-size constellations, furnishing alternative simplified schemes suitable for intensity-modulated direct-detection (IM/DD) systems. Both DC-biased and power-efficient asymmetrically clipped

(AC) solutions are analyzed for real constellations from BPSK (binary-phase-shift keying) to 32 PAM (pulse-amplitude modulation). The performance is compared to standard O-OFDM based on fast Fourier transform (FFT) using constellations from 4 QAM(quadrature-amplitude modulation) to 1024 QAM, showing perfect agreement. The analysis of clipping effect evidences the suitability of the proposed AC scheme for adaptive systems.

Sonal Sharma et al. [13], This paper presents a high level implementation of a high performance FFT for OFDM Modulator and Demodulator. In this paper we analyzes several aspects of discrete Hartley transform (DHT) as an alternative to replace the conventional complex valued and mature discrete Fourier transform (DFT) as OFDM .The random binary data was generated and transmitted via the dispersive channel with using additive white Gaussian noise (AWGN) channel model. We also analyze several aspects on the performance of the system was which valuated by calculating the number of bit errors for several value of signal to noise ratio (SNR).As compared to the conventional method we also compare so that we can improve the power of the system.

Nikhil Arora et al. [14], In this paper PTS SUB-BLOCKS PAPR reduction techniques have been proposed and analyzed. OFDM Suffers as the no of Subcarriers operating in the large dynamic range operates in the non-linear region of amplifier due to OFDM suffer the PAPR problem Application of high power amplifiers results in increased component cost. In general, there has been a trade-off between PAPR reduction and computational complexity in partial transmits sequence (PTS) OFDM. The complexity reduction of PTS

PAPR reduction scheme in OFDM systems by reducing the complexity of the IFFT architecture is investigated in this paper. In the IFFT architecture of PTS OFDM scheme, there are a lot of additions and multiplications with zero, which are obviously unnecessary. We can efficiently reduce the computational complexity without changing the resulting signal or degrading the performance of PAPR reduction by eliminating the additions and multiplications with zero from the architecture.

L. Wang et al. [15], this paper demonstrate Partial transmit sequence (PTS) provides attractive peak-to-average power ratio (PAPR) reduction performance in OFDM or MIMO OFDM. However, it leads to prohibitively large computational complexity. A cooperative PTS (co-PTS) is proposed. In co-PTS, alternate optimization and spatial subblock circular permutation are employed. Simulation results show that co-PTS can reduce computational complexity dramatically and achieve better PAPR reduction performance compared to ordinary PTS.

Yao Yi et al. [16], In this paper, the residue number system (RNS) based OFDM transmission scheme is proposed to reduce the PAPR, which uses the features of RNS to control the dynamic range of the transmitted signals and avoid the nonlinear distortion for the PAPR reduction. Experimental results show that at least 5dB of PAPR performance is improved with the proposed method, compared with the original OFDM.

Shang Ma et al. [17], this paper show scaling in Residue Number System (RNS) plays an important role in the application of RNS for Digital Signal Processing (DSP) systems. However, the scaling in RNS has been still regarded as a complex and time-consuming procedure. In this paper, we propose an efficient 2/1 scaling algorithm for RNS along with two relative propositions and their certifications based on Division Remainder Zero Theorem (DRZT). The 2/1 scaling is performed in only one step with the *n* LSBs of RNS integers. The VLSI implementation results show that the proposed scalar can obtain high performances in area, delay, and power consumption.

Damien Roque et al. [18], In this paper, we present a weighted cyclic prefix orthogonal frequency-division multiplexing (WCP-OFDM) transceiver as a generalization of traditional cyclic prefix (CP)-OFDM. In time-variant channels, this multicarrier transmission scheme may mitigate inter-channel interference (ICI) thanks to the use of non-rectangular pulse shapes. A precoding step may be required in order to reduce the peak-to-average power ratio (PAPR) at the transmitter output. For instance, a discrete Fourier transform (DFT) precoder leads to a single carrier transmission scheme with frequency domain equalization. We analyze the consequences of such a precoding, in terms of performances, in the context of a time-frequency selective channel.

Qingsong Wen et al. [19], this paper, explored the correlation among the multiple candidate signals of PTS and proposed a modified scheme with lower complexity. The main idea is based on selecting a subset from the whole set of candidate signals by analyzing the correlation of candidate signals. Simulation results show that the performance of the modified scheme is close to the theoretical lower bound and outperforms selected mapping (SLM) scheme with the same computational complexity.

Tao Jiang et al. [20], In this paper, we review and analysis different OFDM PAPR reduction techniques, based on computational complexity, bandwidth expansion, spectral spillage and performance. We also discuss some methods of PAPR reduction for multiuser OFDM broadband communication systems.

Robert F.H. Fischer et al. [21], this paper describe Peak-to-average power ratio (PAR) reduction in OFDM using antenna arrays (MIMO OFDM) is considered. In particular, generalizations of selected mapping (SLM) recently proposed in literature, are studied, and a new version, we call it directed SLM (dSLM), is introduced. It is shown that, in contrast to the other schemes, dSLM utilizes the potential offered by MIMO transmission—the complementary distribution function of the PAR exhibits a steeper (increased by a factor equal to the number of transmit antennas) decay.

III. SYSTEM MODEL

In OFDM technique, firstly data converted from serial sequence into parallel sequence of data, these parallel sequence of data separately converted into the digital modulation format by BPSK, QAM, QPSK constellation mapped method, after that these signals are to be superimposed on required orthogonal subcarrier for transmission modulate data.

The basic block diagram of OFDM transmission is shown in figure below

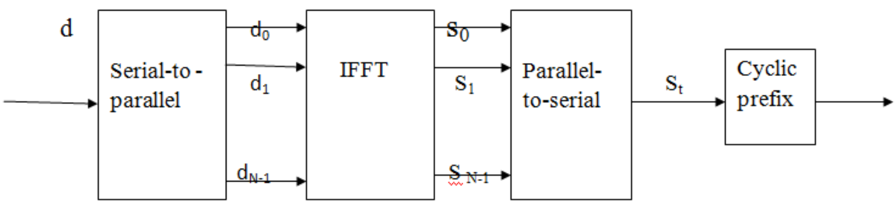

Figure 1.5 Block diagram of OFDM

A key advantage of OFDM is that fast Fourier transforms (FFTs) may be used to simplify implementation. Fourier transforms convert signals back and forth between the time domain and frequency domain. Consequently, Fourier transforms can exploit the fact that any complex waveform may be decomposed into a series of simple sinusoids. In signal processing applications, discrete Fourier transforms (DFTs) are used to operate on real-time signal samples. DFTs may be applied to composite OFDM signals, avoiding the need for the banks of oscillators and demodulators associated with individual subcarriers. Fast Fourier transforms are numerical algorithms used by computers to perform DFT calculations[10].FFTs also enable OFDM to make efficient use of bandwidth. The sub channels must be spaced apart in frequency just enough to ensure that their time-domain waveforms are orthogonal to each other. In practice, this means that the sub channels are allowed to partially overlap in frequency.

The block diagram showing a simplified configuration for an OFDM transmitter and receiver is given below:-

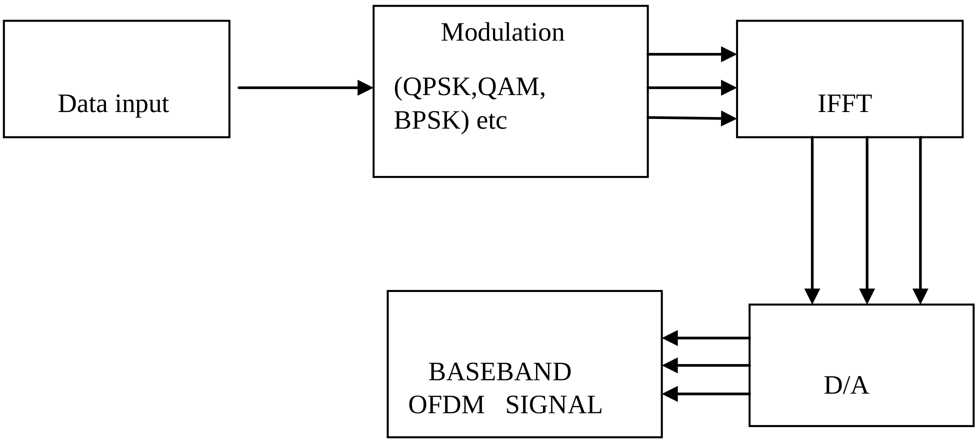

Fig.1.6: Transmitter

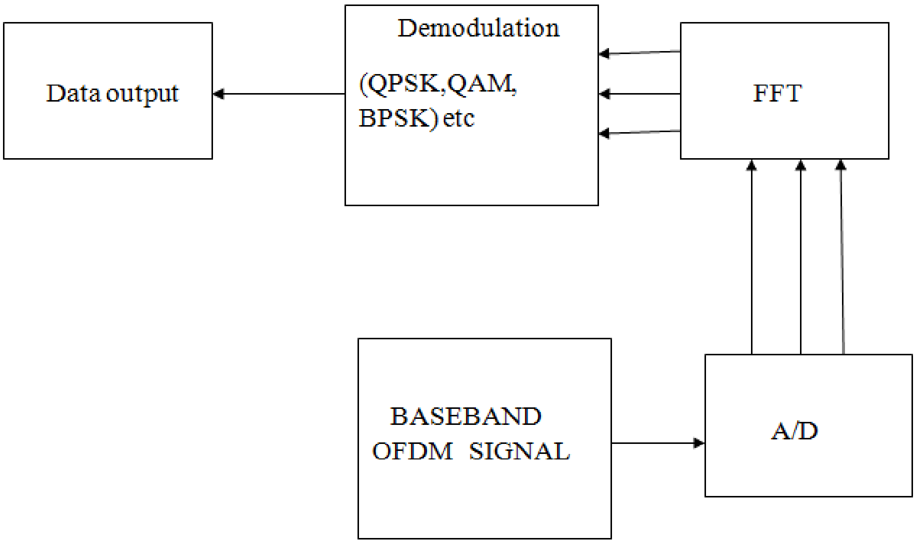

Fig.2: Receiver

IV. MEHODOLOGY

Here we describing the concept of implementation algorithm of reduction of PAPR using partial transmit sequence, Residue number system.

A. Analysis of PAPR for MIMO-OFDM

As definition, the PAPR is the ratio between the maximum peak power and the average power for output signals at each antenna.

$$PAPR_{n_t} = 10\,log\frac{\max\left\{\left|S_{n_t,k}\right|^2\right\}}{E\left\{\left|S_{n_t,k}\right|^2\right\}}(dB)$$

$$(n_t = 1, 2........N_T;\ k = 0, 1, 2..........N-1) \quad (1)$$

When we consider for MIMO-OFDM, the PAPR of every N_T transmit signals should be as small as possible at the same time and this is described as-

$$PAPR = \max\{PAPR_1, PAPR_2............PAPR_{N_T}\} \quad (2)$$

We know about the Complementary Cumulative Distribution Function (CCDF), which is generally used to notify the probability criteria. For conventional OFDM as shown in equation (3), the PAPR exceeds a given value z.

$$P\{PAPR > z\} = 1 - \{PAPR \le z\} = 1 - (1 - e^{-z})^N \quad (3)$$

For MIMO-OFDM, the CCDF is presented for N_T number of antennas as-

$$P\{PAPR > z\} = 1 - \{PAPR \le z\} = 1 - (1 - e^{-z})^{N_T N} \quad (4)$$

In case of MIMO-OFDM, from equation (3) & (4), we can observe that the PAPR performance is very poor in comparison to OFDM systems.

B. Analysis of Partial Transmit Sequence (PTS) in MIMO-OFDM[3]

From figure 1, each antenna channel is a single antenna PTS-OFDM and there are partitions of input data block of N symbols into M separated sub-blocks which is given as-

$$X = [X^0, X^1 \dots\dots\dots\dots X^{M-1}]^T \quad (5)$$

Then each separated sub-block is integrated by a complex phase factor $b^\mu = e^{j\varphi\mu}$, $\mu = 1, 2 \dots\dots\dots M$, taking its IFFT to found-

$$x = IFFT\{\textstyle\sum_{\mu=1}^{M} b^\mu X^\mu\} = \sum_{\mu=1}^{M} b^\mu x^\mu \quad (6)$$

The optimal phase factor b^μ can be found after the PAPR comparisons among the sequences. For lower PAPR in the n_t antenna, the corresponding signal can be denoted as-

$$S_{n_t,k}^{\sim} = \textstyle\sum_{\mu=1}^{M} b^\mu, 0 \le k \le N-1, 1 \le n_t \le N_T \quad (7)$$

Here x^μ is known as partial transmit sequence. The PAPR vector is selected such that PAPR can be minimized.

For μ sub block and W phase factors $w^{\mu-1}$sets of phase factors needs to be searched to find optimum phase factor which reduces PAPR.

In PTS technique we are also transmitting side information as phase sequence which minimizes the PAPR .therefore search complexity increases with more number of sub blocks.

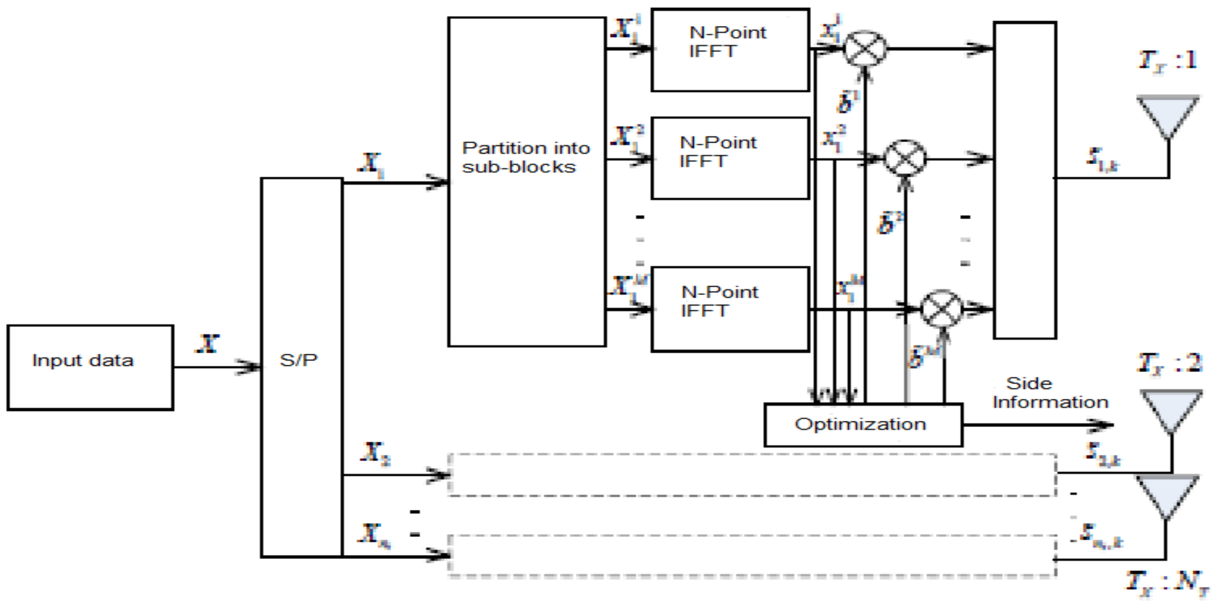

Figure1: The block diagram of PTS scheme in MIMO-OFDM.

C. Analysis of Residue number system (RNS) [5]

The residue number system is always described by relative prime modulus set $m_v(v = 1,2 \ldots \ldots \ldots V)$. In RNS, any integer R can be expressed by residue sequence $\{r_1, r_2 \ldots \ldots \ldots r_v\}$ and-

$$r_v \equiv R(mod\ m_v) \tag{8}$$

The number r_v is stated as residue of R with respect to m_v and generally it is denoted by $r_v = \langle R \rangle_{m_v}$. By this idea, a large integer can be divided into the small residues and so the resulted residues are always smaller than the corresponding modulus. The integers in this residue number system are in the range of [0, M_I] and this should be denoted separately and clearly. Here,$M_I = \prod_{i=1}^{V} m_v$, It indicates dynamic range or legitimate range of the numbers and symbols (information symbols). The information symbols can be easily and uniquely collected with the help of residue sequence and CRT, which is one of the basic theorems of residue number system. The information symbols R and its residues are related as-

$$R = \left(\sum_v^V S_v \left|\langle 1/S_v \rangle_{m_v}\right| r_v\right) mod\ M_I \tag{9}$$

Here $\langle 1/S_v \rangle_{m_v}$ is multiplic ative inverse of S_v

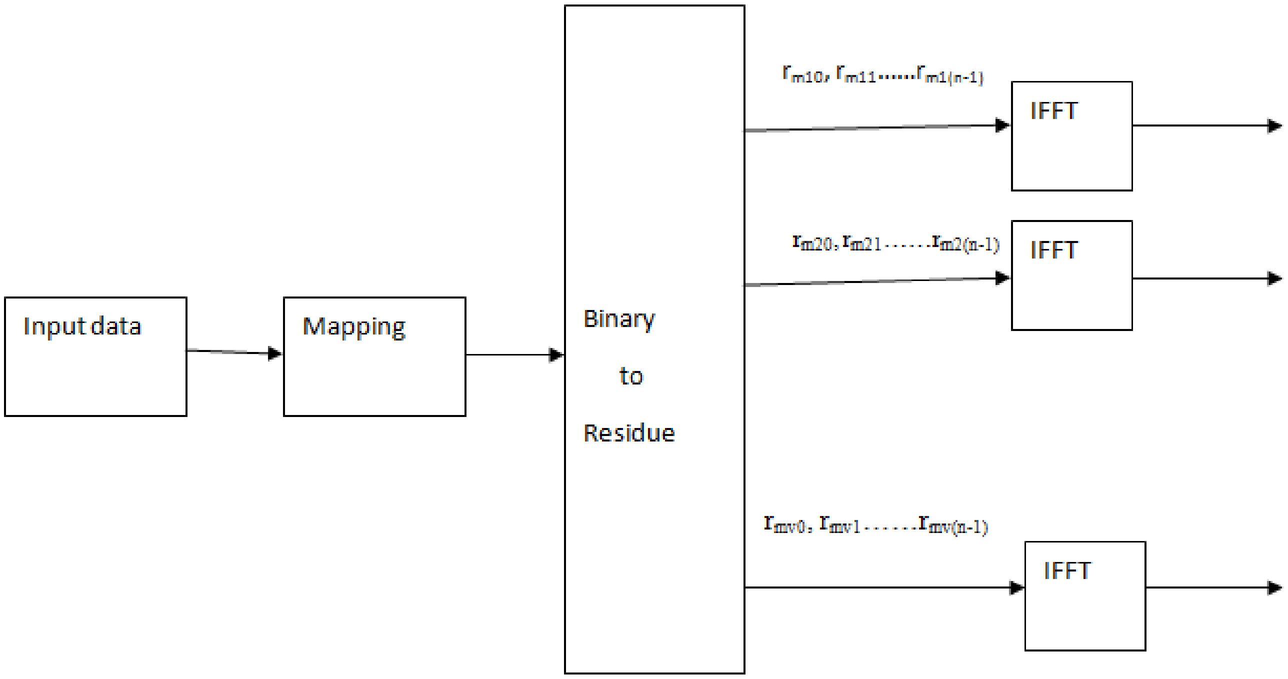

Figure 5.2: Block diagram of RNS-based scheme in MIMO-OFDM.

For MIMO-OFDM, the block diagram of RNS-based peak to average power ratio reduction scheme is given in figure 2. Here the number of modulus $\{m_1, m_2 \ldots \ldots \ldots m_v\}$ is V and the inputs data are transformed into V residues through corresponding modulus set. The numbers of residue sub-channels are according to the number of transmit antennas. The OFDM modulation is performed by these residue signals in the corresponding residue channels. Single IFFT of length N is applied in every of the V number parallel residue sub channels.

The detail function of mapping module is, when the input is positive, this is send into binary to residue (B/R) module directly and in another case the input adds the legitimate M_I before binary to residue module. The serial data signals are break into V number parallel residue sub channels transmitting signals by binary to residue conversion, which is stated in equation (8).

The residue sequences $\{r_{m_v 0}, r_{m_v 1} \ldots \ldots \ldots r_{m_v (N-1)}\}$, which is related to the modulus m_v residue sub channel in every residue sub channel, are transmitted into IFFT module. The output of modulus m_v residue sub channel is expressed as following equation after IFFT.

$$S_{m_v,k} = S(kT/N) = \sum_{i=0}^{N-1} r_{m_v,i} \exp(j \frac{2\pi ik}{N})$$

$$(0 \le k \le N-1, 0 \le i \le N-1) \tag{10}$$

According to central limit theorem, for big subcarriers, both parts real and imaginary of OFDM signals have asymptotically Gaussian distribution. In each sub channel, the peak to average power ratio can be written as follows for RNS based scheme.

$$PAPR_{n_t} = 10log \frac{\max\left\{\left|\sum_{i=0}^{N-1} r_{m_v,i} \exp\left(j\frac{2\pi ik}{N}\right)\right|^2\right\}}{E\left\{\left|\sum_{i=0}^{N-1} r_{m_v,i} \exp\left(j\frac{2\pi ik}{N}\right)\right|^2\right\}}$$

$$= 10log \frac{\max\left\{\left|\sum_{i=0}^{N-1} r_{m_v,i} \exp\left(j\frac{2\pi ik}{N}\right)\right|^2\right\}}{2\sigma^2}(dB) \qquad (11)$$

Here σ is the variance of signal.

When we consider about MIMO-OFDM, the PAPR performance is worst and it can be seen by-

$$PAPR_{rns-mimo} = \max PAPR_{n_t}$$

Where n_t=1, 2……..N_T

$$= 10log \frac{max_{\,n_t}\left\{\left|\sum_{i=0}^{N-1} r_{m_v,i} \exp\left(j\frac{2\pi ik}{N}\right)\right|^2\right\}}{2\sigma^2}(dB) \qquad (12)$$

We have seen in equation (8) that the residue is always smaller with respect to corresponding modulus and it may be selected smaller in comparison to original number. In this case the residue becomes smaller than the original number. After processing through a rotation factor and adding all N elements, the residue still smaller than the sum of original one. So using RNS based reduction technique, we can reduce the PAPR and improve the overall performance of MIMO-OFDM systems.

V. CONCLUSION

OFDM is a very effective technique for wireless communications due to its spectrum efficiency and channel robustness. One of the major drawbacks of in OFDM systems is that very high PAPR when the input sequences are highly correlated. In this paper,we described several important aspects, as well as provide a mathematical analysis, including the distribution of the PAPR, in MIMO OFDM systems. Two latest techniques to reduce PAPR have been analyzed, all of which have the potential to provide substantial reduction in PAPR at the cost of loss in data rate, transmit signal power increase, BER performance degradation, computational complexity increase, and so on. But here we concluded that PTS technique having some side information transmission issue.

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