Performance Comparison of DWT and FFT Based Multiuser MIMO-OFDM PAPR Reduction by Residue Number System

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Abstract

Multi-input multi-output (MIMO) orthogonal frequency division multiplexing (OFDM) system has been commonly authorized promising scheme for Wi-Fi communication systems. Nonetheless it suffers the high Peak-to-Average power ratio (PAPR), which is the primary drawback of OFDM-headquartered techniques. In this paper, a Residue Number System (RNS) founded PAPR reduction scheme in Discrete Wavelet based MIMO-OFDM systems is proposed. This scheme makes use of the houses of RNS to largely shrink the PAPR and the computational complexity as good. The RNS-headquartered DWT based MIMO-OFDM PAPR reduction scheme is most effective with a minimal, better PAPR reduction performance without restrict to modulation layout, but also low computational complexity without facet know-how. A performance comparison of RNS based DWT Multiuser (MU)-MIMO-OFDM and FFT based MU-MIMO-OFDM has been observed and found that the DWT based one is superior in performance.

Keywords: MIMO-OFDM, RNS, PAPR, DWT, FFT
I. INTRODUCTION

Probably the main challenges of OFDM-headquartered methods are the excessive Peak-to-Average power ratio (PAPR) of transmitted alerts, resulting in signal distortion. The mixture of MIMO and OFDM could take advantage of the spatial dimension capacity to strengthen the process potential through employing spatially separated antennas [1]. In MIMO-OFDM, unbiased OFDM alerts are transmitted from several transmit antennas. As a result, MIMO-OFDM systems nonetheless undergo an inherent challenge of high PAPR. There are some obstacles for lessee PAPR reduction technologies, comparable to clipping, height windowing, commanding change into, and many others [2], [3]. Nonlinear distortion and clipping of the transmitted signals lead to performance degradation. A couple of lossless PAPR reduction technologies have been proposed and investigated [4], [5], [6], [7], one amongst them, the partial transmit sequence (PTS) scheme, which is an efficient process and a lossless scheme for PAPR discount by way of optimally combining sign sub-blocks. Selective mapping (SLM) can also be a excellent procedure, in which some statistically impartial sequences are generated from the equal knowledge and the sequence with the lesser PAPR is transmitted. Both schemes provide elevated PAPR statistics at the cost of additional complexity and lack of the information cost, in view that they ought to enforce some further IFFT and iterations of section optimization and transmit the side know-how. In addition, SLM scheme results in a bigger computational complexity at the identical degree of PAPR reduction, because it operates on all carriers [8], [9].

Residue number system (RNS), a parallel number process, is founded on Chinese remainder theorem (CRT), which divides a massive integer into a number of impartial and parallel smaller ones with a unique modulus set. Due to the carry-free and parallel residences, RNS simplifies the computations through decomposing a problem into a suite of parallel, impartial residue computations [10]. Lately, extra awareness is also paid to RNS in parallel verbal exchange subject in view that of its parallel and fault-tolerant properties. An RNS-headquartered OFDM transmission was proposed, where focused on the method’s description and on the PAPR simulation results.

In DWT based MIMO-OFDM, a new style of PAPR discount scheme through RNS is offered in this paper. The parallel property of RNS to transform input alerts into smaller residue alerts is used, which are transmitted in a suite of parallel, unbiased residue sub-channels; and make use of the characteristic of RNS modular operation to without problems minimize the PAPR [1]. The efficiency in comparison with conventional MIMO-OFDM and PTS-MIMO-OFDM is reviewed. It's confirmed that the proposed scheme improves PAPR performance and generally reduces computational complexity.

This paper is organized as follows: section II gives an overview of PAPR and PTS in
DWT based MIMO-OFDM. The proposed PAPR reduction scheme is described in section III. Then we evaluate the efficiency of PAPR reduction and computational complexity in section IV, even as the conclusions are supplied in section V.

Computerized identification of the digital modulation form of a signal has found applications in lots of areas, including electronic battle, surveillance and hazard evaluation. This paper reports the use of wavelet change into QPSK signals. The process is to make use of the wavelet turn to extract the transient traits in a digital modulation signal, and observe the specific sample in wavelet and develop into domain for easy identification. The primary statistics for foremost threshold determination are derived underneath the situation that the noise considered is additive white Gaussian. The performance of the identification scheme is investigated by means of simulations.

II. SYSTEM MODEL

Considering the communication of impartial data streams, \( N_T \) transmit antennas are considered throughout the paper.

A. PAPR of MIMO-OFDM

At each antenna, the PAPR of output alert is defined as the ratio between the maximum peak power and the average power.

\[
PAPR_{n_t} = 10 \log \frac{\max \{|s_{n_t,k}|^2\}}{E{|s_{n_t,k}|^2}}
\]

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

In MIMO-OFDM, the PAPR of all \( N_T \) transmit signals should be simultaneously as small as possible, which is defined as

\[
PAPR = \max\{PAPR_1, PAPR_2, ... PAPR_{N_T}\}
\]

It is known that the CCDF (Complementary Cumulative Distribution Function) is commonly used to denote the probability that the PAPR exceeds a given threshold value \( z \) or not, for conventional OFDM as shown in (3).

\[
P\{PAPR > z\} = 1 - \{PAPR \leq z\} = 1 - (1 - e^{-z})^N
\]
Hence for $N_T$ number of antennas, the CCDF for MIMO-OFDM is presented as

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

It can be seen from (3) and (4) that the PAPR performance of MIMO-OFDM systems is even worse than that of Conventional OFDM.

B. Partial Transmit Sequence in MIMO-OFDM

The block diagram of partial transmit sequence (PTS) scheme in DWT based MIMO-OFDM is shown in Fig.1. In each antenna channel it is a single antenna PTS-OFDM. It partitions an input data block of $N$ symbols into $M$ disjoint sub-blocks as follows:

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

Then each partitioned sub-block is multiplied by a complex phase factor $b^\mu = e^{j\phi^\mu}$, $\mu=1,2,\ldots,M$ subsequently taking its Inverse DWT to yield,

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

![Fig.1 PTS scheme in DWT based MU-MIMO-OFDM](image-url)
After the PAPR comparisons among the user sequences, the most effective phase factor $\tilde{b}_\mu$ can be acquired. And the corresponding sign within the $n_t$ antenna with the lowest PAPR may also be shown as

$$\tilde{S}_{n_t,k} = \sum_{\mu=1}^{M} \tilde{b}_\mu x^\mu, 0 \leq k \leq N - 1, 1 \leq n_t \leq N_T$$

(7)

### III. RNS-BASED PAPR REDUCTION

An RNS is defined by the relative prime modulus set $m_v (v = 1, 2, \ldots, V)$. Any integer $R$ can be represented in RNS by way of residue sequence $\{r_1, r_2, \ldots, r_v\}$.

$$r_v \equiv R \pmod{m_v}$$

(8)

The quantity $r_v$ is claimed to be the residue of $R$ with appreciation to $m_v$, and expressed as $r_v = \langle R \rangle_{m_v}$. Hence, a big integer can be modified into smaller residues in RNS, and these residues are perpetually smaller than the corresponding modulus. The integers in the variety of $[0, M_I]$ can also be represented on this RNS uniquely and unambiguously. Where $M_I = \prod_{i=1}^{V} m_v$ is referred to as the information dynamic range, i.e., the legitimate range of the information symbol.

The knowledge symbols will also be uniquely recovered through residue sequence by means of CRT, which is among the predominant theorems of RNS. The relationship between the messaging symbols $R$ and its residues is as follows:

$$R = (\sum_{v}^{V} S_v \langle 1 | S_v \rangle_{m_v} r_v) \pmod{M_I}$$

(9)

where $\langle 1 | S_v \rangle_{m_v}$ called as multiplicative inverse of $S_v$, $S_v=M_I/m_v$ and $(S_v \langle 1 | S_v \rangle_{m_v}) \pmod{m_v}=1$.

The definition of signed quantity in RNS is similar to that in TCS (Two’s Complement process) [10], [13]. An integer $R$ in the legitimate range $[0, M_I]$ can be represented as a signed quantity, $\tilde{R}$. Then if $0 \leq R < \lceil M_I/2 \rceil$ or $\lceil M_I/2 \rceil \leq R < M_I$, $\tilde{R}$ is positive and negative respectively, where $\lceil x \rceil$ denotes the smallest integer larger than $x$.

The fundamental diagram of RNS-headquartered PAPR reduction scheme in DWT based MIMO-OFDM is given in Fig.2. The quantity of modulus $\{m_1, m_2, \ldots, m_v\}$ is $V$, and the inputs are changed into $V$ residues through the corresponding modulus set, and the quantity of transmit antennas equals the quantity of residue sub-channels.
These residue indicators are preformed OFDM modulation within the corresponding residue channels. Within the each and every of the $V$ parallel residue sub-channels, one Inverse DWT (DWT Demodulator) is employed. The function of mapping module, if the input is constructive, it can be sent into B/R (binary to residue) module directly; in any other case the input provides the legitimate $M_i$ earlier to B/R.

Through B/R conversion, according to (8), the serial data streams are divided into $V$ parallel residue sub-channels transmitting signals. In each residue sub-channel, the residue sequences $\{r_{m_0}, r_{m_1}, ..., r_{m_{(N-1)}}\}$ which correspond to the modulus residue sub-channel, are transmitted into IDWT module respectively. The output corresponding to the modulus $m_v$ residue sub-channel after IDWT is represented as follows:

$$s_{m_v,k} = s(kT/N) = \sum_{i=0}^{N-1} r_{m_v,i} \exp\left(j \frac{2\pi ik}{N}\right)$$  \hspace{1cm} (10)

$$0 \leq k \leq N - 1, 0 \leq i \leq N - 1$$

**A. PAPR of RNS-based scheme**

The true and imaginary components of OFDM signal have asymptotically Gaussian distributions for a huge number of subcarriers with the aid of the central limit theorem. Then the amplitude of the OFDM signals follows a Rayleigh distribution. The PAPR of RNS-based scheme in every sub-channel will be written as:
\[ PAPR_{nt} = 10 \log \frac{\max \left\{ \sum_{i=0}^{N-1} r_{mv,i} \exp \left( \frac{j2\pi ik}{N} \right) \right\}^2}{E \left\{ \left| \sum_{i=0}^{N-1} r_{mv,i} \exp \left( \frac{j2\pi ik}{N} \right) \right|^2 \right\}} \]

\[ = 10 \log \frac{\max \left\{ \sum_{i=0}^{N-1} r_{mv,i} \exp \left( \frac{j2\pi ik}{N} \right) \right\}^2}{2\sigma^2} \]

where \( \sigma \) is the variance of OFDM signals. In MIMO-OFDM, the PAPR performance is governed by the worst-case PAPR and presented as

\[ PAPR_{RNS-MIMO} = \max_{n_t = 1,2,...,N_T} PAPR_{nt} \]

\[ = 10 \log \frac{\max_{n_t} \left\{ \sum_{i=0}^{N-1} r_{mv,i} \exp \left( \frac{j2\pi ik}{N} \right) \right\}^2}{2\sigma^2} \]

In step with (8), the residue at all times smaller than the corresponding modulus, which may be chosen smaller than the fashioned quantity. Then the residue is smaller than the long-established quantity. After multiplying a rotation element and summing up all the \( N \) elements, it is nonetheless smaller than the sum of fashioned one. It may be seen that the proposed scheme has the abilities to give a boost to the PAPR reduction efficiency.

**B. Complexity**

In RNS, the addition and multiplication are modular operations. In theoretical evaluation, they can be designed for flexibility where in case the methodology allows for the design of adders for any modulus. The elemental adder for any modulo-\( m \) is outlined as (13)

\[ \langle A + B \rangle_m = \begin{cases} A + B & \text{if } A + B < m \\ A + B - m & \text{otherwise} \end{cases} \]

In probably the most easy implementation, probably the most problematic means, a normal modular requires 3 adders: one for the addition, one for the subtraction, and one for the assessment[13].

A modular multiplication of tricky signals can also be expressed as (14):
(A \times B)_m = (\langle a_1 a_2 \rangle_m - \langle b_1 b_2 \rangle_m + i \langle b_1 a_2 \rangle_m - \langle b_2 a_1 \rangle_m)_m

(14)

The modular multiplication of problematic signals wishes extra 6 modular operations than complex multiplier. In each modular operation, it wishes 2 adders (one for addition and one for comparison), which is analogous to the case of the modular adder. Based on the definition of RNS, the residue is smaller than its corresponding modulus.

Regardless of the number of additions and multiplications, the sum of residue indicators in every residue sub-channel is still smaller than its corresponding modulus. It may be obvious that this scheme effortlessly controls the dynamic range of the transmitted signals to enhance the PAPR reduction efficiency.

IV. SIMULATION RESULTS

The simulations are employed to demonstrate PAPR reduction efficiency and computational complexity evaluation between the proposed scheme and the common PTS scheme. The OFDM symbol of each antenna channel contains 2048 subcarriers, and for simplicity all N sub-carriers are counted to be lively.

A. Complexity Analysis

The overall computational complexity of RNS scheme in MIMO-OFDM will be discussed. A complex multiplication takes 4 real multiplications and 2 real additions, and a complex addition requires 2 real additions. Furthermore, it can be assumed that the complexity of a real multiplication equal the complexity of 4 real additions [8]. In the RNS scheme according to (10), it needs the number of modulus $V$ inverse DWT operations. Considered the input as the complex signal, a modular addition would take 6 real additions in the most complexity situation and a modular multiplication would take 30 real additions. Probably, a length N IDWT operation requires 2(N/2) logN tricky multiplications and a pair of N log N tricky additions.

B. PAPR Reduction

The number of antennas used for the scheme is three with identical number of subcarriers in each and every sub-channel. The entire performance of PAPR reduction is evaluated by CCDF. The parameter used for simulation is shown in the table below.
<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subcarrier number, N</td>
<td>2048</td>
</tr>
<tr>
<td>The number of input symbols</td>
<td>1000</td>
</tr>
<tr>
<td>Antenna number, 𝑁_𝑟</td>
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<tr>
<td>Moduli set of RNS</td>
<td>{128,127,63}</td>
</tr>
<tr>
<td>PTS Sub-block number, M</td>
<td>3/8</td>
</tr>
<tr>
<td>PTS phrase factor</td>
<td>{1, -1}</td>
</tr>
</tbody>
</table>

Figure 4 depicts PAPR reduction performance of RNS scheme for DWT based MIMO–OFDM for M=8 case. The conventional MIMO-OFDM is also considered for reference with M=3 & 8. This clearly expresses the low value of PAPR for M=8 case, where DWT is a predominant over its counterparts.

**Fig.4** PAPR reduction performance of RNS scheme in DWT based MU-MIMO-OFDM
Figure 5 expresses PAPR reduction performance of RNS and PTS schemes for DWT based OFDM for M=8 case. It clarifies that a low value of PAPR is achieved for RNS method over PTS method.

![Figure 5](image)

**Fig.5** PAPR reduction performance comparison of PTS and RNS techniques for DWT based OFDM system

![Figure 6](image)

**Fig.6** PAPR reduction performance of RNS scheme in FFT based MU-MIMO-OFDM
Figure 6 expresses PAPR reduction performance of RNS scheme for FFT based Multiuser MIMO-OFDM for M=8 case. This clearly expresses the low value of PAPR for M=8 case, over the conventional MIMO-OFDM. Figure 7 exhibits the comparison of DWT and FFT based MU-MIMO-OFDM systems for PTS Scheme. Though the main area of interest is in RNS scheme, a better low of PAPR in PTS scheme is also desirable and here dominated by DWT based system itself.

**Fig.7** PAPR reduction performance comparison of PTS scheme in FFT and DWT based MU-MIMO-OFDM

**Fig.8** PAPR reduction performance comparison of RNS scheme in FFT and DWT based MU-MIMO-OFDM
Fig. 8 compares the PAPR reduction efficiency of the proposed scheme, the PTS scheme and the conventional MIMO-OFDM. The curves labeled via “DWT M=3 64-QPSK”, “DWT M=3 4-QPSK” denote the PAPR performance of RNS-based scheme. The curves label by way of “PTS M=3 4/64 QPSK”, “PTS M=8 4/64 QPSK” denote the PAPR performance of the PTS scheme in MIMO-OFDM with $M = 3$ and $M = 8$ disjoint sub-blocks respectively. When $M = 3$, $W = \{−1, 1\}$, the RNS-based scheme is better than the PTS by about 5dB. When $M = 8$, the proposed scheme still outperform PTS. Meanwhile, the computational complexity of the proposed scheme reduces to just 6.1% of that of the PTS. About 6dB improvement of PAPR reduction is obtained by the proposed scheme, at the CCDF of $10^{-3}$.

CONCLUSION

An RNS-situated PAPR reduction scheme in DWT based MIMO-OFDM is provided in this paper, which utilize the residences of RNS and characteristic of RNS modular operation to readily cut back the PAPR without facet understanding. Theoretical analysis and simulation outcome show the proposed scheme outperforms the PTS scheme in the PAPR discount performance and the computational complexity and shows a superior performance of RNS in DWT over the FFT MU-MIMO-OFDM.

REFERENCES


