An Approach for PAPR Reduction with Discrete Hartley Transform in MIMO-OFDM

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Abstract - In wireless communication systems, multi input multi output orthogonal frequency division multiplexing (MIMO-OFDM) systems plays an important role. Orthogonal Frequency Division Multiplexing (OFDM) is an efficient modulation technique that splits a single wideband signal into various narrowband independent signals. It is used in digital audio and video broadcasting, wireless LAN/MAN standards, and Wi MAX standards. However, one of the serious problems of OFDM is the high Peak to Average Power Ratio (PAPR), which causes a signal distortion at the High Power Amplifier (HPA) of a transmitter. MIMO-OFDM system have peak to average power ratio (PAPR). Which is a major challenges for multicarrier transmissions i.e. OFDM based systems. To reduce the nonlinear distortion, the power efficiency of the HPA has to be significantly decreased. In this paper, the proposed scheme reduces the PAPR by the use of Discrete Hartley Transform (DHT) based PAPR reduction technique in MIMO-OFDM system. The Discrete Hartley transform allow a function to be broke into two independent sets of sinusoidal components; these sets are represented in terms of positive and negative frequency components, respectively. This verifies the use of the properties of the DHT cas operation to effective and efficient reduction of PAPR. The proposed DHT based PAPR reduction scheme in MIMO-OFDM, is compared with the partial transmit sequence (PTS), and Residue number system (RNS) for PAPR reduction and is verified by MATLAB simulation.

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

I. INTRODUCTION

In advance communications technology, the demand for higher data rate services such as multimedia, voice, and data over both wired and wireless links is also increased. Ever-increasing demands in communication industry towards wireless, challenges are - to improve spectral efficiency, efficient bandwidth utilization, economical Signal Processing algorithms and high speed processing. So there is need to introduce new modulation scheme to transfer the large amount of data with higher data rate. The new modulation schemes must be able to provide high data rate, allowable Bit Error Rate (BER), and maximum delay. Multiple input multiple output Orthogonal Frequency Division Multiplexing (MIMO-OFDM) is one of them new modulation schemes. Orthogonal Frequency Division Multiplexing (OFDM) is a digital transmission method, developed to meet the increasing demand for higher data rates in communications which can be used in both wired and wireless environments [10]. MIMO makes antennas work smarter by enabling them to combine data streams arriving from different paths and at different times to effectively increase receiver signal-capturing power. OFDM can be applied for various systems such as HDTV, Wireless LAN Networks, HIPERLAN/2, DAB IEEE 802.11g. Despite of all advantageous feature of OFDM, there is still a major limitation to it use in terms of high peak to average power ratio (PAPR), which needed to be addressed before considering it use. PAPR reduces the performances of high power amplifiers. Recently many errorless technologies of PAPR reduction have been invented and described. Some of them are Partial Transmit Sequence (PTS) scheme [3] and Residue number system (RNS) [5]. Partial Transmit Sequence (PTS) scheme, which proves an efficient approach and an errorless scheme for PAPR reduction by efficiently combining signal sub-blocks. But PTS need some extra IFFT and iterations of phase optimization and transmit the side information. For minimizing the computational complexity of above PTS scheme, a new scheme has been proposed Residue number system (RNS) [5]. Residue number system is a parallel number system and it uses the properties of Chinese remainder theorem (CRT). This paper presents a new PAPR reduction scheme for MIMO OFDM. This scheme uses Discrete Hartley Transform (DHT) for generating OFDM signal in system. Hartley transform permits a function to be decomposed into two independent sets of sinusoidal components; these sets are represented in terms of positive and negative frequency components, respectively. This is in contrast to the complex exponential, exp ($j\omega x$), used in classical Fourier analysis. For periodic power signals, various mathematical forms of the familiar Fourier series come to mind. For aperiodic energy and power signals of either finite or infinite duration, the Fourier integral can be used. In either case, signal and systems analysis and design in the frequency domain using the Hartley transform may be deserving of increased awareness due necessarily to the existence of a fast algorithm that can substantially lessen the computational burden when compared to the classical complex-valued Fast Fourier Transform (FFT) and so Discrete Hartley transform (DHT) can be used in reduction of PAPR in OFDM systems.

II. SYSTEM MODEL

The DHT based MIMO OFDM system model was illustrated in Fig. 1. The inverse (forward) Fast Hartley transform (FHT) implements the OFDM modulation (demodulation). Since the DHT is a real transform, if a real constellation is used for the input data mapping, the discrete OFDM signal

$H_k=\sum_{n=0}^{n-1} x_n \left[\cos(\frac{2\pi}{N}nk)+\sin(\frac{2\pi}{N}nk)\right]$

k= 0………N-1

$H(w) = \frac{1}{2\pi}\int_{-\infty}^{\infty} s(t).cas(wt)dt$

$Cas(t) = \cos(t)+\sin(t) =+\sqrt{2}\cos(t-\frac{\pi}{4}) +\sqrt{2}\sin(t+\frac{\pi}{4})$

is real; $x(n)$ is the n-th element of the N-length vector of constellation symbols at the input of the IFHT and N is the transform order.

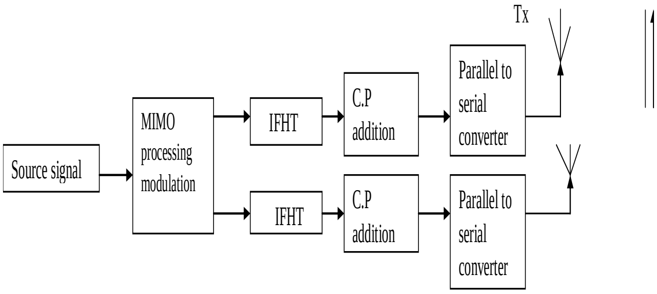

Figure 1 Block diagram of DHT based Transmitter of MIMO OFDM system

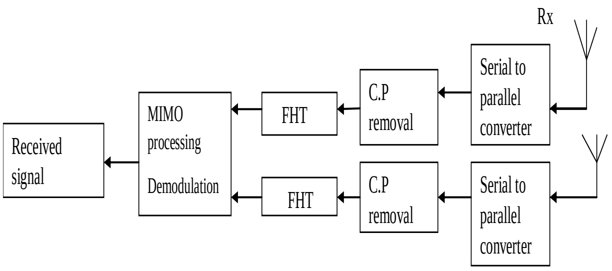

Figure 2 Block diagram of DHT based Receiver of MIMO OFDM system

III. PREVIOUS WORK

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

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

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

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

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 3, 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-

$X = [X^0, X^1 ………… X^{M-1}]^T$ (5)

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

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

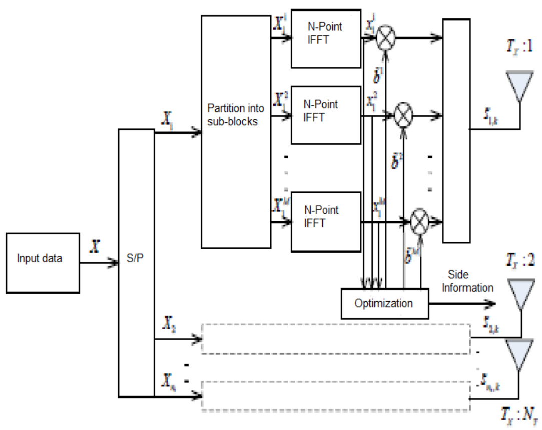

Figure3: The block diagram of PTS scheme in MIMO-OFDM

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-

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

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.

C. Analysis of Residue Number System (RNS) in MIMP-OFDM [5]

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

$$r_v \equiv R(mod\ m_v) \quad (8)$$

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-

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

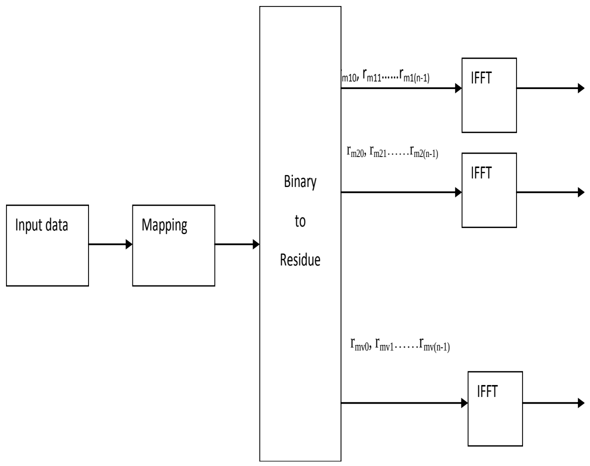

Figure.4: Block diagram of RNS-based scheme in MIMO-OFDM

For MIMO-OFDM, the block diagram of RNS-based peak to average power ratio reduction scheme is given in figure 4. Here the number of modulus $\{m_1, m_2 \dots\dots\dots m_v\}$ 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 $\{r_{m_v 0}, r_{m_v 1} \dots\dots\dots r_{m_v (N-1)}\}$, 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.

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

$$(0 \le k \le N-1, 0 \le i \le N-1)$$

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.

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

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

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

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

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.

IV. PROPOSED METHODOLOGY

Analysis of DHT based scheme

A multicarrier OFDM signal is the addition of many independent non constant envelope signals modulated onto sub channels of equal bandwidth. The data symbols *Xn*, is denoted as a vector X = [X_0, X_1, ... , X_{N-1}]T that will be data block. The complex representation of a multicarrier signal consisting of N subcarriers is given by

$$X(t)=\frac{1}{\sqrt{N}}\sum_{n=0}^{N-1} X_n\, e^{j2\pi n\Delta f t}\ ,0\leq t\leq NT \qquad (13)$$

Where, Δf represents sub channel spacing.

The Complementary Cumulative Distribution Function (CCDF) is the most frequently used performance metric for PAPR reduction techniques. The CCDF of the PAPR indicates the probability that the PAPR of an OFDM signal exceeds a given PAPR threshold.

The CCDF of the PAPR of a data block is derived as

$$\begin{aligned}\Pr(\text{PAPR} > Z) &= 1 - \Pr(\text{PAPR} \leq Z)\\ &= 1 - F(Z)N\\ &= 1 - (1 - \exp(-Z))N \qquad (14)\end{aligned}$$

Where, Z is the PAPR threshold. Thus by using DHT scheme we can reduce PAPR of OFDM systems efficiently.

V. SIMULATION RESULT

Here PAPR reduction performance is shown by simulations result of proposed scheme and conventional scheme together with simulated result of RNS and PTS scheme bringing out for PAPR results. Here OFDM symbol contains 64 subcarriers for each antenna channel and it is expected that all N subcarriers to be active for simplicity. The performance of PAPR reduction is evaluated by CCDF. To compare the PAPR reduction performance of proposed scheme with conventional scheme and with RNS- PTS scheme in MIMO-OFDM, it is assumed that antenna number of all schemes and the subcarrier number in each sub-channel are the same. Each OFDM symbol contains *N* = 64 subcarriers throughout, where the number of input symbols are 1024, 2048, 4096. The parameter used for simulation is shown in Table 1.

TABLE 1 Parameters used for simulation of PAPR.

Parameters	value
The number of input symbol, S	1024,2048,4096
Subcarrier number, N	64
Antenna number, N_t	3
Modulations format, M	64QAM/4QAM
Moduli number of RNS, V	1
Moduli Set of RNS	{127}
PTS sub block number C	3/8
PTS phase factor	{1, −1}

For the comparison of PAPR reduction performance of the RNS, the PTS scheme and the conventional MIMO-OFDM, where the modulation formats are taken as 64QAM and 4QAM. The curves labeled by “RNS -64-QAM” and “RNS -4-QAM” denote the PAPR performance of RNS-based scheme at M=64 and M =4 respectively. The curves labeled by “PTS -3-4-QAM”, and “PTS-8-64QAM” denote the PAPR performance of the PTS scheme in MIMO-OFDM with C = 3 and C = 8 disjoint sub-blocks respectively. Whereas the curves labeled by “Orig-64-QAM and Orig-4-QAM” denote the conventional MIMO-OFDM PAPR performance at M=64QAM and M=4QAM modulation format respectively [5].

There are six simulation results graph. In which figure 5, 6, 7 shows that RNS based PAPR reduction performance scheme is better than PTS scheme and conventional scheme for MIMO-OFDM at different number of input symbols. The RNS based scheme outperforms the PTS scheme and conventional scheme in the PAPR reduction performance was mentioned in **[5].**

Figure 8, 9, 10 shows that comparative simulation result graph of proposed scheme with conventional scheme, RNS scheme and PTS scheme at different number of input symbol. Figure 8, and 9 clearly show that proposed scheme DHT based PAPR reduction performance is better than conventional scheme, RNS and PTS schemes.

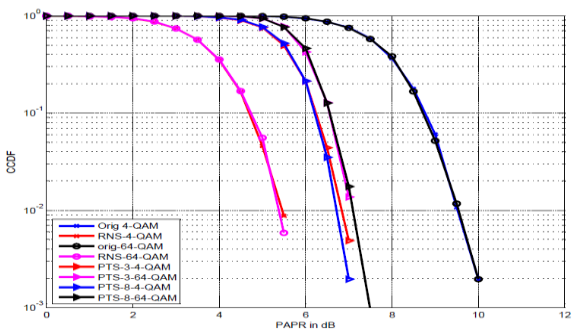

Figure 5 Simulation results of PAPR reduction performance of the RNS, PTS scheme and the

conventional MIMO-OFDM at **S=1024,** N=64, M=4QAM/64QAM, V=1, P= {-1, 1}, C=3/8.

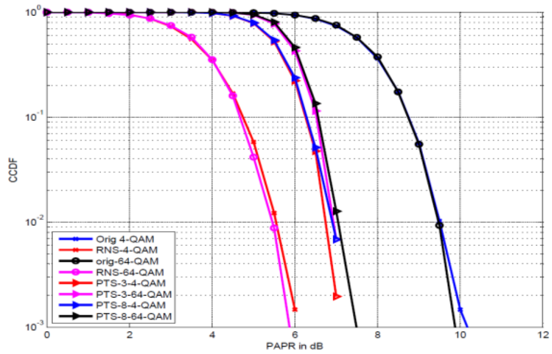

Figure 6 Simulation results of PAPR reduction performance of the RNS, PTS scheme and the conventional MIMO-OFDM at **S=2048**,N=64, M=4QAM/64QAM, V=1, P= {-1, 1}, C=3/8.

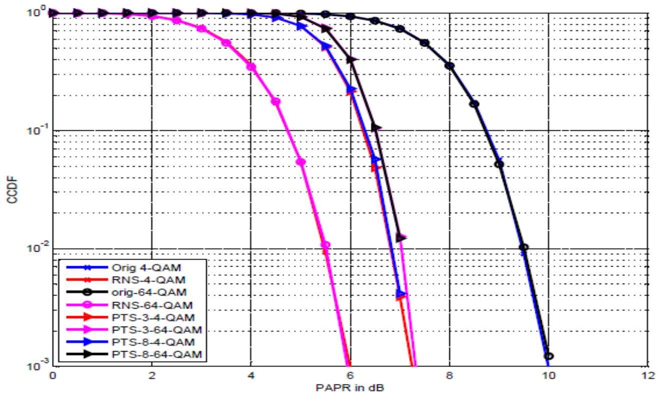

Figure 7 Simulation results of PAPR reduction performance of the RNS, PTS scheme and the conventional MIMO-OFDM at **S=4096** N=64, M=4QAM/64QAM, V=1, P= {-1, 1}, C=3/8.

Figure 5, 6, 7 shows that PAPR value of all three schemes conventional, PTS, and RNS has not noticeable change with changing the value of number of input symbol. The reason behind this fact is 'average power' of all three schemes is depend upon number of FFT (Fast Fourier transform) taken not upon the input number of symbol. Hence Average Power does not change with varying the number of input symbols. PAPR is the ratio of peak to average power. Here peak power and average power do not depend upon number of input symbol. Hence it seems to be almost same even number of input symbol varies. Another notable point is comes out from the table 2, 3, and 4 is nearly no differences between the CCDF for 4QAM, 64QAM. All the three schemes are not restricted to modulation format. So for further comparison of proposed schemes DHT based with other scheme one modulation format is consider that is 4QAM and number of disjoint sub block for PTS is 3.

Simulations are performed for different number of input symbols by different PAPR reduction schemes such as DHT based, RNS based, PTS based and conventional MIMO OFDM. The results are evaluated under the following table taken as: S=1024, 2048, 4096, N=64, M=4QAM, V=1, P= {-1, 1}, C=3

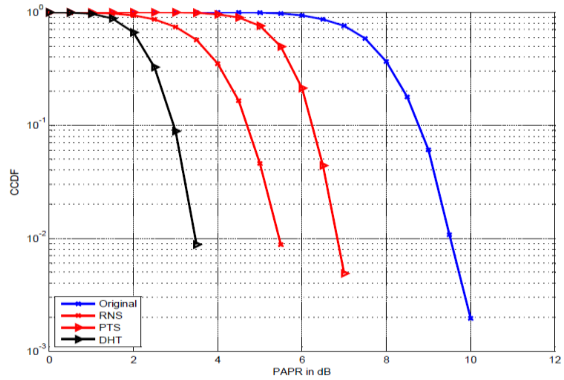

Figure 8 Simulation results of PAPR reduction performance of the proposed scheme, PTS scheme, RNS scheme and the conventional MIMO-OFDM at S=1024 N=64, M=4QAM, V=1, P= {-1, 1}, C=3

TABLE 2: PAPR and CCDF calculated from figure 8

CCDF	**PAPR in db**			
	Conv	**PTS**	**RNS**	**DHT**
0.9	6.3	4.5	2.25	1.4
0.1	8.767	6.24	4.7	2.995
0.01	9.5	7	5.5	3.472

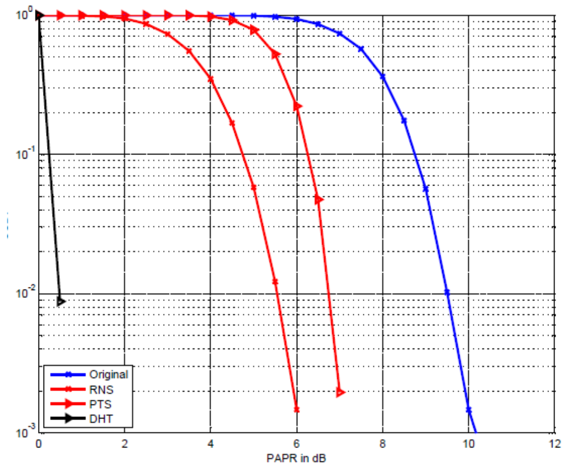

Figure 9 Simulation results of PAPR reduction performance of the proposed scheme, PTS scheme, RNS scheme and the conventional MIMO-OFDM at S=2048 N=64, M=4QAM, V=1, P= {-1, 1}, C=3

TABLE 3: PAPR and CCDF calculated from figure 9

CCDF	PAPR in db			
	Conv.	PTS	RNS	DHT
0.9	6.3	4.5	2.25	0.02
0.1	8.767	6.24	4.7	0.25
0.01	9.5	6.74	5.55	0.5

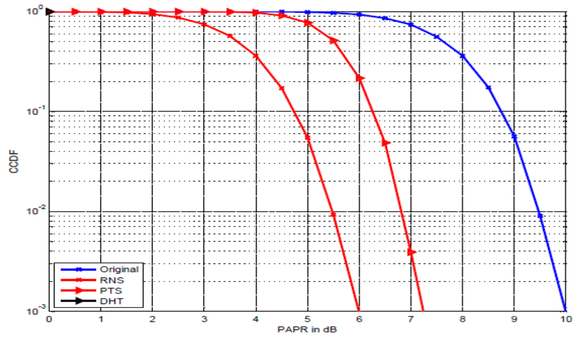

Figure 10 Simulation results of PAPR reduction performance of the proposed scheme, PTS scheme, RNS scheme and the conventional MIMO-OFDM at S=4096 N=64, M=4QAM, V=1, P= {-1, 1}, C=3.

VII. CONCLUSION

If PAPR reduction performances are measured at the number of symbol is 1024 and the CCDF is 0.01, conventional scheme has 9.5dB, PTS based scheme has 7dB, RNS based scheme has 5.5dB and proposed scheme that is DHT based scheme has lowest PAPR is 3.472dB. When number of symbol is 2048 and CCDF is 0.01, conventional scheme has 9.5dB, PTS based scheme has 6.74dB, RNS based scheme has 5.5dB and proposed scheme that is DHT based scheme has lowest PAPR is 0.5dB. According to theoretical analysis and simulation results, DHT based PAPR reduction scheme in MIMO-OFDM is effectively reduces the PAPR.

From figure 5,When number of input symbol is increased, taken as 4096 then PAPR of DHT based scheme has 0db, which is not a valid value because PAPR is the ratio of two powers which cannot be zero. So DHT based scheme does not give proper response at S=4096.

At 0.01 CCDF, DHT based scheme is 50.23 % better than conventional scheme at S=1024, and 75% better than conventional scheme at S=2048 but no proper response at s=4096. According to theoretical analysis and simulation results, DHT based PAPR reduction scheme in MIMO-OFDM is effectively reduces the PAPR.

VII. FUTURE SCOPES

In this paper, PAPR (peak to average ratio reduction) problem of OFDM system have been considered and suitable solution in term of DHT (Discrete Hartley Transform) based MIMO OFDM have been provided. As it is an established fact, that research is never ending process, a new beginning is always waiting. Therefore, following are the works that may be considered as a future scope in this direction.

- An efficient technique can be implemented with low implementation complexity which has the potential of compensating both PAPR and BER problems significantly without affecting spectral efficiency of the system.
- Hybrid technique can be proposed to improve the percentage of PAPR reduction.
- DHT based PAPR reduction scheme can be extended for number of input symbol more than 2048.

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