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PTS technique to reduce PAPR at different IBO in SFBC MIMO OFDM system with reduced complexity

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ABSTRACT

OFDM with MIMO trans-receiver system has played a great role in today's communication world. It provides a large data rate but the drawback faced is Peak average to power ratio (PAPR).Combination of MIMO OFDM with SFBC gives good result in computation complexity and is suitable for fast fading channels .In this paper we have studiedpartial transmit sequence (PTS) techniques in terms of complexity , PAPR reduction, BER performance and effect of IBO on reliability of space frequency block coding (SFBC) diversity OFDM-MIMO system .We have considered Rayleigh channel. In receiver it has been used maximum likelihood detector (MLD) to study the effect of different IBO values on BER and PAPR performance of PTS technique. In one type of PTS scheme it has been calculated only selected signal PAPR value by taking decision on cost function of signal and in another type of PTS scheme signal is separated in such a way that only one signal can help to transmit lower PAPR signal. In this way studied PTS method is lower complexity Simulation result show that IBO play very important role in PAPR reduction technique performance of SFBC system in terms of BER and power amplifier efficiency.

Keywords: Input Backoff (IBO); Multiple input multiple output(MIMO); Orthogonal Frequency Division Multiplexing (OFDM) Peak to Average Power Ratio (PAPR); Partial transmit sequence (PTS); Space frequency block coding (SFBC); Maximum Likelihood Detector (MLD).

1. INTRODUCTION

To overcome problems of single carrier communication, Orthogonal Frequency Division Multiplexing (OFDM) multicarrier modulation is the most generally used technique; In requirement of High data rates wireless communication it has turned out to be extremely prominent with multiple input and multiple output (MIMO). MIMO with OFDM are ability of large capacity and robustness to multipath fading. Recently, Increasing requirement of reliability in fast fading environment different diversity technique has been used. Because of it's robust towards selective fading channels,MIMO-OFDM with diversity technique space frequency block code (SFBC) haspaying attention[1]. However, detriments from OFDM techniques are additionally acquired by SFBC MIMO signal is sensitivity to synchronization and also inherits high peak-to- average power ratio (PAPR). Many strategies are available for PAPR reduction but need to apply and verity performance for SFBC OFDM with MIMO SYSTEM.

In OFDM N symbols transmitted parallelly on same number of orthogonal subcarrier . These orthogonal subcarriers added using IFFT property may sprouts Peaks suddenly at the point when same phase subcarriers added, these peak may amplify in nonlinear region of amplifier and loss orthogonally of subcarriers mayleads bit error performance degradation. We may increase saturation region of amplifier that may leads to inefficient use of power amplifier [2]. Peak shoots measure in terms of PAPR if amplify in nonlinear region will effect

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on in-band and out of band distortion The Impact of PAPR with different modulation techniques is demonstrated by the Author in [3]. Different PAPR reduction technique are studied for OFDM SYSTEM for example clipping signal [4] which distort signal, partial transmit sequence (PTS) [5] [6] scrambling after IFFT, selected mapping (SLM) [7][8] before IFFTand various other methods are proposed to restrain the PAPR.Among many technique PTS can accomplish great PAPR reduction without signal distortion, So PTS is an alluring and effective techniqueamong these methods.

In this paper,review partial transmit method [9] of PAPR reduction technique in terms of complexity, reliability and effect of IBO on BER performance of SF block codewith MIMO-OFDM systems is studied. In this PTS technique modulated data symbols are partitioned into different subblock and generate signal of each subblock of same length of OFDM symbol by padding zeros. And calculate the cost of each signal and threshold for PAPR calculation. Estimate the PAPR of signal only when cost of each signal is greater than threshold. By utilizing the selected signal for peak power estimation the computational complexity is thus lessened. Also, to further reduce the computational complexity of evaluating the cost function and candidate signals, to develop algorithms the similarity of the time-domain signals from different antennas is utilized. Simulation results show that the performance of different IBO values on PAPR reduction and bit error rate (BER) is evaluated of SF block code with MIMO OFDM systems by PTS scheme but with much lower computational complexity.

The rest of the paper is systematized as follows. In Section II, the basic detail of SF block code diversity technique with OFDM systems is introduced. The basic idea behind the high power amplifier and IBO is described in Section III. The computational complexity of the proposed PTS schemes in Section IV. In Section V, Channel and detection technique used is described. In section VI simulation results are presented to compare the IBO effect on PAPR using PTS schemes with related works. Finally, a brief conclusion is drawn in Section VII.

2. SPACE FREQUENCY BLOCK CODING(SFBC)

High–mobility broadband wireless access is gained in this,where receiver experience both inter symbol interference and inter carrier interference as the channel is highly time as well as frequency selective .Coding across space and frequency is involved. Instead of time dimension, space time code is applied in frequency dimension. Low complexity decoding and suitability for fast fading channels are the results of SFBC OFDM. The transmission delay is also minimized by this. Fig. 1 shows two transmitter and one receiver SFBC system.

In SFBC-OFDM modulation, a block of N symbols modulates on N subcarriers f_n. (n = 0, 1, 2, … N-1) which is transmitted in parallel. Orthogonality is the property of the subcarriers, and fn = n Δ f, where T is the symbol period and Δ f = 1/T. The number of bits in symbols depends on value M of modulation array M-QAM used in technique i.e $log_2 M$. In system first data is converted into N symbols and modulates the symbols into complex data i.e. X_n. (n = 0, 1, 2, … N-1).

Then SFBC encode the complex data into orthogonal code. Fig. 1 show basic block diagram of SFBC OFDM system. In two transmitter system SFBC encoded a pair of symbols X_1 and X_2 with their orthogonal code $X_1^*,\ and -\ X_2^*$. The pair of symbols X_1 and X_2 are transmitted over a adjecent sub-carrier of first antenna and their orthogonal code $X_1^*,\ and -\ X_2^*$ transmitted on same adjacent subcarrier frequency but on second antenna. This shows thattwo antennas transmit each symbol over same sub-carriers instead of over next time symbol as in STBC.

In real achievement, in the transmitter Inverse Fast Fourier Transform (IFFT) is used to generate the transmission signal as shown following equation.

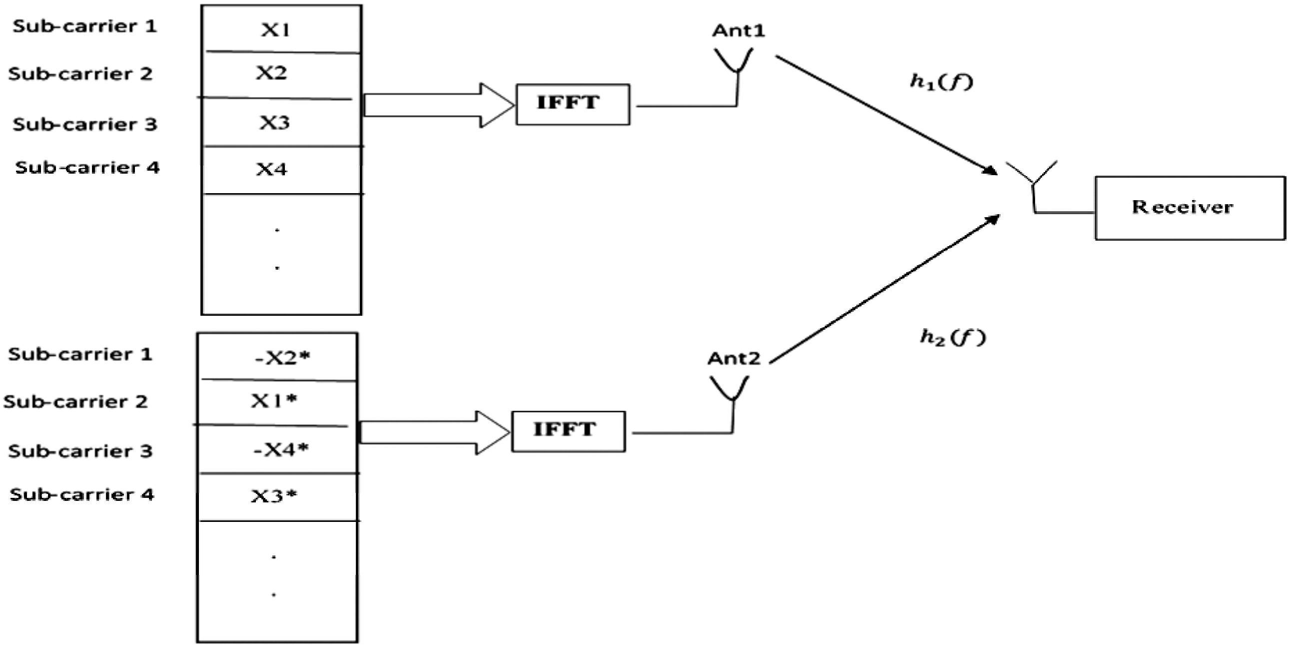

Figure 1: Block diagram of SFBC OFDM SYSTEM

$$x_n(k) = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} X_n e^{-j2\pi kn/N} \tag{1}$$

The PAPR of the OFDM signal can be defined as

$$PAPR\{x_n\} = \frac{\max |\{x_n\}|^2}{E\{|x_n|^2} \tag{2}$$

Expectation operation is denoted by E{.}. With the increase in number of subcarriers, PAPR also increases and high PAPR is often exhibited by OFDM signal due to which independent phases of subcarriers get aligned with each other. To distinguish the chances that PAPR of an OFDM signal crosses a given threshold (PAPR0). The complementary cumulative distribution function (CCDF) is often used.

Due to the high PAPR, large of dynamic range is required in Digital to Analog Converter (DAC) to contain the large peaks of the OFDM signals. It is very expensive Even though, high PAPR with low quantization noise is supported by a high precision DAC. alternatively quantization noise is more and cheaper in low precision DAC.

OFDM signals chase the Gaussian distribution for large number of OFDM sub-carrier. Average of the peak signal is rarely occured in such type of distribution and Analog to Digital Converter is uniformly quantized which is not desirable. In-band distortion and out-of-band expansion i.e adjacent channel interference will be occurred if clipping of the signal is done.

Conversely, over P neighbouring subcarriers, the channel desires to be around constant. In order to make the subcarrier spacing very confined, in case of channels with low frequency-selectivity this proves true or it can be fulfilled by means of a large number of subcarriers. The problem of fast time alterations is prevented by Space-Frequency Block Codes. However, in heavily frequency-selective channels, the performance will get minimized where the expectation of same channel coefficients over a space-frequency block code matrix is not legitimized. System having more than two-transmit antennas face this problem.

At the receiver Fig. 1 shows one antenna which receives two average signal from each transmitting antenna with corrupted by channel interference and additive noise as per following .

$$Y = HX + W \tag{3}$$

Where His channel coefficient and W is additive noise.

The estimation of X_1 and X_2 symbol as per following equation.

$$\widehat{X}_1 = H_{11}^{*}Y_{11} + H_{12}Y_{12}^{*} + H_{21}^{*}H_{21} + H_{22}Y_{22}^{*} + W1 \tag{4}$$

$$\widehat{X}_2 = H_{12}^{*}Y_{11} - H_{11}Y_{12}^{*} + H_{22}^{*}Y_{21} - Y_{22}^{*}H_{21} + W2 \tag{5}$$

Where Y_{ij} signal receiving ith subcarrier and jth antenna. And H_{ij} is a channel coefficients on ith subcarrier and jth antenna. Equation (4) and (5) is passed through the MLD detector to detect symbols X_1 and X_2.

3. EFFECT OF IBO ON RF AMPLIFIER

3.1. Input Back-Off

To categorize so that we can receive the desired output linearity and power, an evaluation of how extreme u must diminish the input power should be done in power amplifier. Stated differently, RF amplifiers input power level relative to the maximum output power produced by the input power.

High power amplifier (HPA) sets the operating pointas input Back-Off (IBO) and is defined as

$$IBO = 10\ log_{10}\ (\text{Pmax/Pavg}) \tag{6}$$

Pmax refers to the HPA’s saturation input power and Pavg is the input signals average power.

As the input to an amplifier is increased the output from the amplifier increases steadily also, the difference between these two is the gain of the amplifier.there comes a point when the amplifier can no longer supply any more output power with an increase in input signal and thus the gain of the amplifier drops with increasing input level. When the gain has dropped by 1dB the amplifier has reached its 1dB compression point as it is often called and distortion rises rapidly beyond this point.

The main objective is that the effect of IBO of HPA can be reflected automatically as when the PAPR reduces.As PAPR reduces their effect is also on the Input Back-Off (IBO) which in turn reduced the probability of occurring of the non-linear degradation of the OFDM signal by HPA. We have suggested the effect of IBO which is dependent on the amount of the PAPR. In general the IBO value if greater than PAPR value causes distortion of the OFDM signal and reduction in the PAPR value will benefit the OFDM transmitter system and also reduces the degradation of the OFDM signal.Also to avoid the non-linear distortion, the IBO must be larger than the PAPR of the signal. However, the magnification of the IBO can become the cause of the inefficiency in the HPA. So, an appropriate value of IBO is needed.

PAPR causes large variations in the amplitude of multi-carrier signal which further causes the problems for Digital to Analog Converter (DAC) and High Power Amplifier (HPA) . As the HPA has a linear range for receiving sufficient transmit power and when multi-carrier signal with high values of PAPR passes through it, gets distorted . To overcome from this problem, either the range of HPA is too increased or the PAPR has to be reduced. But this enlargement of HPA’s linear range will also cause some inefficiency. So, there is only one condition left to reduce PAPR to an extent so that it can easily pass through the HPA without any kind of degradation. Also, to avoid the non-linear distortion, the Input Back-Off (IBO) of HPA must be larger than PAPR but not much as power consumption of HPA increases with increase in IBO, as 41% of total power is wasted only by inefficient use of dynamic range of power amplifier.

4. PROPOSED TECHNIQUES

4.1. PTS Type-1 system

Fig. 2 shows PTS Type-1 system flowchart. In this system we are using two transmitting antennas. The data is first convert serial to parallel according to symbol length and convert into complex data by modulating the symbol. This modulating symbol convert into SFBC orthogonal code for two transmitting antenna. Then process of proposed technique is as per following algorithm.

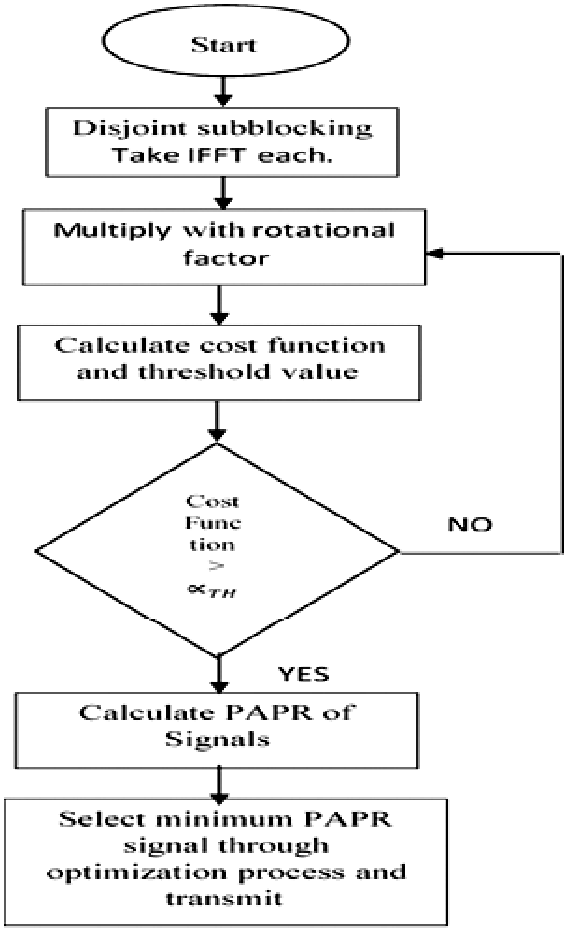

Figure 2: PTS Type-1 system flowchart

1. SFBC MIMO-OFDM systems every transmitting antenna in the type I PTS scheme, uses conventional PTS scheme. The new thing introduced in this scheme is that the data block x_i is divided into Mb disjoint sub blocks evenly, partition is done using interleaving sub blocking.

$$X_{i,m} = \left[X_{i,m,0},\ X_{i,m,1} \dots \dots \dots .\ X_{i,m,N-1} \right]^T \tag{7}$$

2. As the power distribution between the signals is not uniform we take IFFT of the signals and then multiply with rotation factors so that they get rotated by phase factor.

$$x_i^c = \sum_{m=1}^{M_b} b_{i,m}^c IFFT \left\{ X_{i,m} \right\} = b_{i,m}^c x_{i,m} \tag{8}$$

   $b_{i,m}^c$ is the rotation factor having values 1, -1, j, -j.

3. To find PAPR optimization is done at different phase factor. In optimization the signals of two antennas having maximum PAPR are compared and from that whichever has minimum PAPR is considered and transferred further.

$$\left[x_1^{c_{opt}}, x_2^{c_{opt}}\right] = \left\{\max\left\{PAPR\left(x_1^c\right), PAPR\left(x_2^c\right)\right\}\right\} \tag{9}$$

To reduce computational complexityof deriving the PAPR of all signals for optimization, we have introduced cost function and threshold value in this technique. For this after doing IFFT of all signals we have to find the cost function of all signals. In our case we have taken 64 subcarriers so for 1st antenna we will get 64 cost function and for 2nd we get 64 cost function.

$$\tilde{Q}_{i,n} = \sum_{m=1}^{M_b} \left|x_{i,m,n}\right|^2 \tag{10}$$

Where $n = 0, 1\ldots N - 1$.

We compare all these cost function with the predefined threshold value $\propto_{TH}$ and the signals with cost function greater than threshold value those signals are only used to calculate the PAPR. So the computational complexity is reduced.

$$\alpha_{TH} = \phi_N^{\gamma} / M_b \tag{11}$$

$$\phi_N^{\gamma} = -\sigma^2 \ln \frac{\left[\ln\left(1-\gamma\right)\right]}{\left[-n\left(\frac{\Pi}{3}\ln N\right)^{05}\right]} \tag{12}$$

The threshold value $\propto_{TH}$is depends on ϕ_N^{γ} the possible minimum peak power of N subcarrier. The ϕ_N^{γ} is depends on average power of OFDM symbol (σ^2) and γ possible lower value of occurrence of peak power equal to or greater than ϕ_N^{γ}.

4.2. Type II PTS scheme

The procedure of finding the PAPR is same as in the type I scheme but this scheme describes the reduction of computational complexity than the type I scheme. Fig. 3 shows type II PTS as per following algorithm.

1. The signal of first antenna is divided into odd and even part but the length of odd and even part is kept same as the original signal by appending zeros in between two symbols.

$$X_1^0 = \left[X_0, 0, X_2, \ldots \ldots X_{N-2}, 0\right]^T \tag{13}$$

$$X_1^1 = \left[0, -X_1^*, 0, \ldots - X_{N-1}^*\right]^T \tag{14}$$

2. Second antennas odd part is derived from 1st signals even part by shift left, negate and conjugate operations. even part is derived from 1st signals odd part by performing shift right and conjugate operation.

$$X_2^0 = \left[X_1, 0, X_3, \ \ldots \ldots X_{N-1}, 0\right]^T \tag{15}$$

$$X_2^1 = \left[0, X_0^*, 0, \ldots, 0, -X_{N-2}^*\right]^T \tag{16}$$

3. These above four signals are again divided into two parts eachso we get two signals of odd and even part each, $M = 2$.

   For 1st antenna:

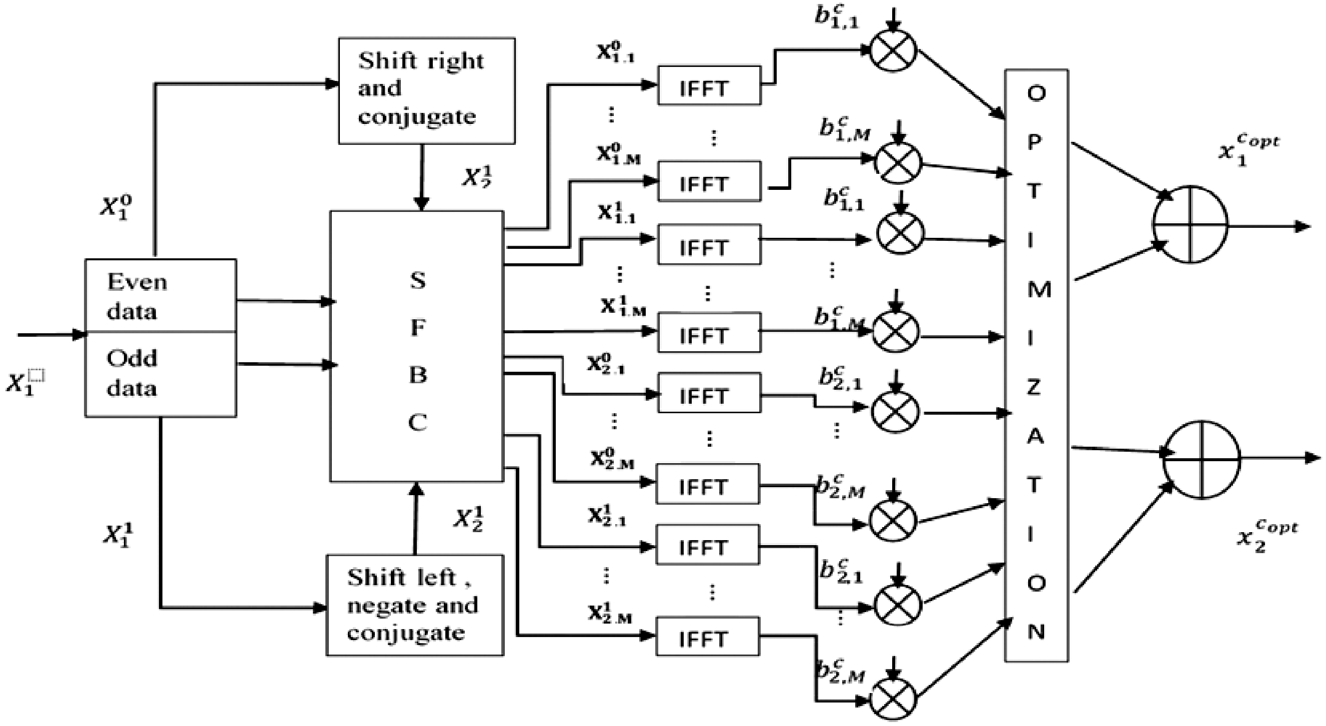

Figure 3: Type II PTS scheme with optimization method

$$X_{1,1}^{0} = \left[X_0,\ 0,\ \ldots\ \ldots,\ X_{N/2-2},\ 0,\ zeros\left(N/2\right)\right]^T \tag{17}$$

$$X_{1,2}^{0} = \left[zeros\left(N/2\right),\ X_{N/2},\ 0,\ldots\ \ldots\ .,X_{N-2},\ 0\right]^T \tag{18}$$

$$X_{1,1}^{1} = \left[0,-X_1^{*},\ldots,0,-X_{N/2-1}^{*},zeros\left(N/2\right)\right]^T \tag{19}$$

$$X_{1,2}^{1} = \left[zeros\left(N/2\right),0,-X_{N/2+1,}\ldots,0,-X_{N-1}^{*}\right]^T \tag{20}$$

For 2nd antenna:

$$X_{2,1}^{0} = \left[X_1,0,\ldots\ \ldots,X_{N/2-1},0,zeros\left(N/2\right)\right]^T \tag{21}$$

$$X_{2,2}^{0} = \left[zeros\left(N/2\right),X_{N/2},0,\ldots\ \ldots,X_{N-1},0\right]^T \tag{22}$$

$$X_{2,1}^{1} = \left[0,X_0^{*},\ldots,0,X_{N/2-2}^{*},zeros\left(N/2\right)\right]^T \tag{23}$$

$$X_{2,2}^{1} = \left[zeros\left(N/2\right),0,-X_{N/2+1}^{*},\ldots,0,X_{N-2}^{*}\right]^T \tag{24}$$

4. These signals are of 1st and 2nd antennas signals can be derived from equation (13) and (14). Then after taking IFFT we did optimization process same as in type I PTS scheme.
5. To reduce computational complexity we derived the cost function of half part of odd and even signal i.e only for N/2 signals because half part is same as first half part of 1st antenna. The cost function at nth sample can be calculated by:

$$Q_{i,n} = \sum_{m=1}^{M}\left(\left|x_{i,m,n}^{0}\right|^2 + \left|x_{i,m,n}^{1}\right|^2\right) \tag{25}$$

Where $n = 1, 2 \ldots\ldots N/2$ and $x^0_{i,m,n}$, $x^1_{i,m,n}$ are nth sample of $x^0_{i,m}$, $x^1_{i,m}$ respectively.

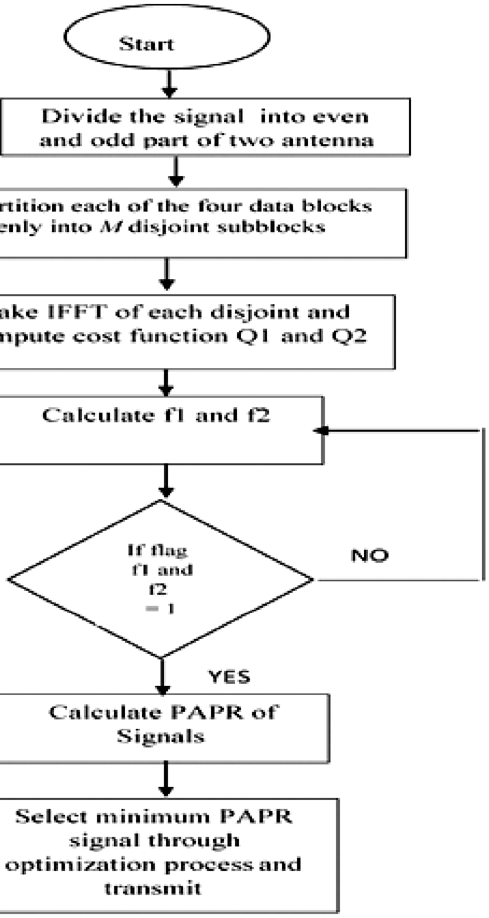

Figure 4: Flow chart of reduced complexity PTS system.

6. Cost function of second antenna signal is derived from first signals cost function by linearity and shift operation of FFT.

$$Q_2 = \begin{bmatrix} 1 & 0 & \ldots & 0 \\ 0 & 0 & & 1 \\ \vdots & & \ddots & \vdots \\ 0 & 1 & \cdots & 0 \end{bmatrix} Q_1 = JQ_1 \tag{26}$$

Therefore the overhead of generating the cost function is reduced.

7. Flag function is introduced to store the results of comparison of cost function and threshold value. If cost function of signal is greater than threshold flag will set one otherwise zero.

$$f_{i,n} = \begin{cases} 1 \; if \;\; Q_{i,n} \geq \alpha_{TH} \\ 0 \; if \;\; Q_{i,n} \leq \alpha_{TH} \end{cases} \tag{27}$$

Flag function for 2nd antenna is again derived from first using cyclic operation.

$$f2 = Jf1 \tag{28}$$

8. The signals having cost function greater than threshold value i.e. flag is one then that signal are used to calculate the PAPR. As there is relationship between the signals in type II the computational

complexity is reduced to one fourth that of the original OFDM signal.Fig. 4shows flow chart of reduced computational complexity partial transmit sequence.

5. SIMULATION RESULTS

In this paper, we investigate performance of the proposed PTS schemes in terms of PAPR reduction, BER for different input back off. For complexity reduction of proposed schemes threshold (α_{TH}) has been decided by $\lambda\phi_N^\gamma$, where The mean power $\sigma2 = 1$ and minimum value 4.204 is considered of peak power ϕ_N^γ, occurrence γ, lower value of peak value is 0.9999. and $\lambda \geq 1/Mb$. And Mb is number of disjoint sub block. In this section, computer simulations of PAPR reduction performance, the BER performance in SFBC MIMO-OFDM systems are shown. The system has N = 128 subcarriers with a 4-QAM constellation. 2 by 2 MIMO with Maximum likelihood detection with zero force estimation is used. Duringsimulations, the oversampling factor considered L = 4 is used to obtain the discrete-time signal. The input data blocks are partitioned into $M_b = 4$ subblocks. The rotation factor b value are taken as 1, -1, j, -j.

5.1. PAPR reduction performance

A shows the complementary cumulative distribution function (CCDF) of the PAPR analysis and BER analysis for PTS scheme in space frequency diversity MIMO-OFDM systems with 2trans receiving MIMO antennasfor different IBO is studied.

Fig. 5 to Fig. 8 shows PAPR and BER performance of type I, type II and ordinary SFBC system. PAPR in type I and II has negligible difference but type II gives slightly better result than type I in BER performance.

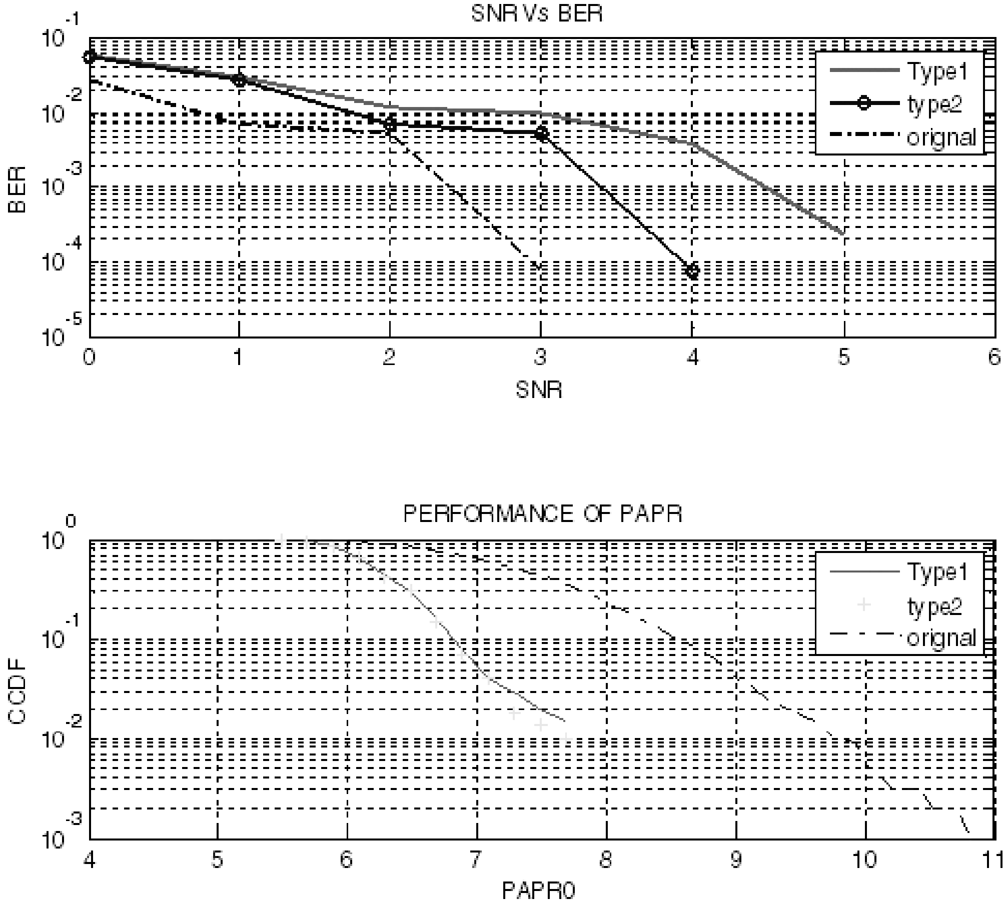

Figure 5: PAPR reduction and BER performance at 8QAM with IBO=17 dB

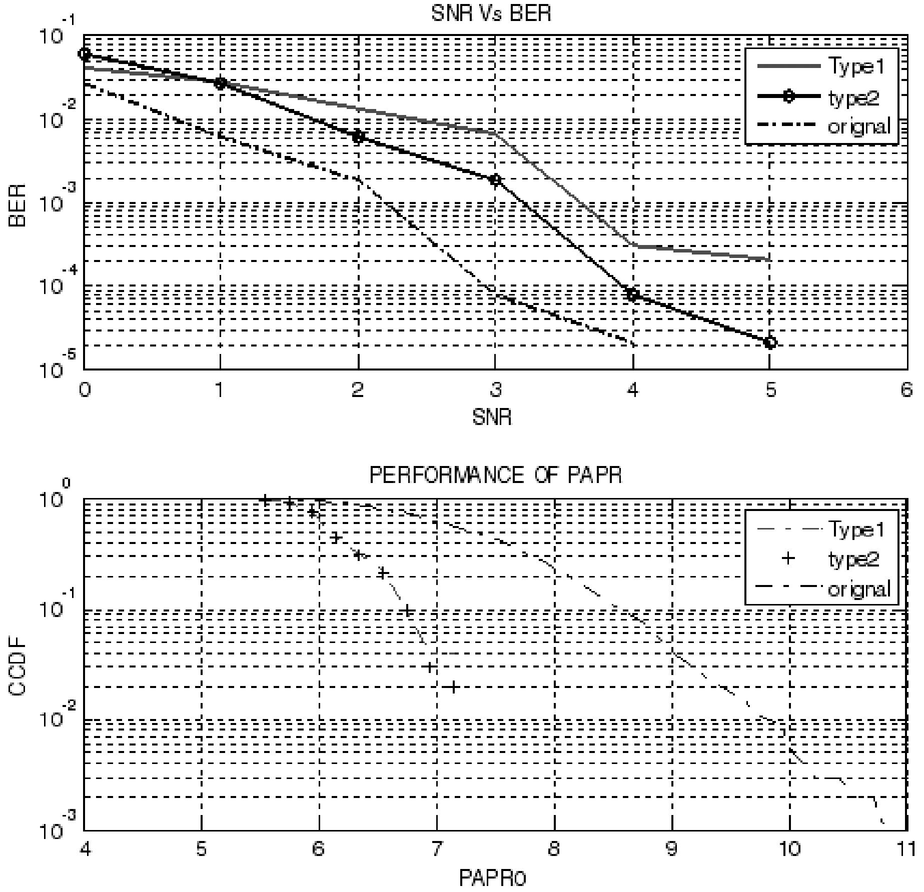

Figure 6: PAPR reduction and BER performance at 8QAM with IBO=10 dB

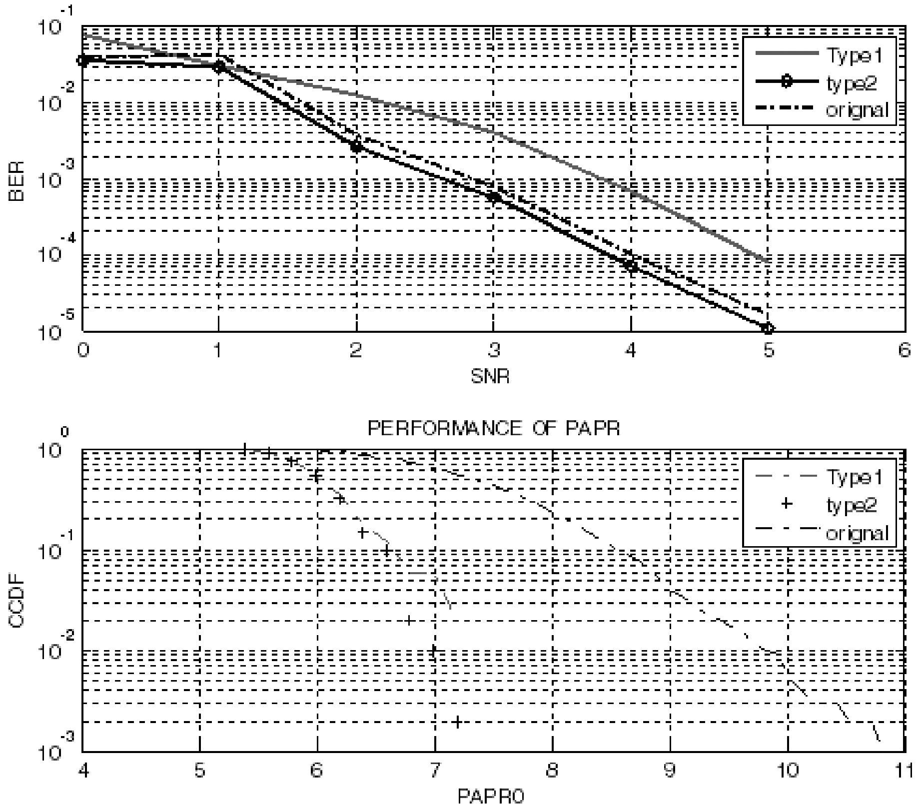

Figure 7: PAPR reduction and BER performance at IBO=3dB

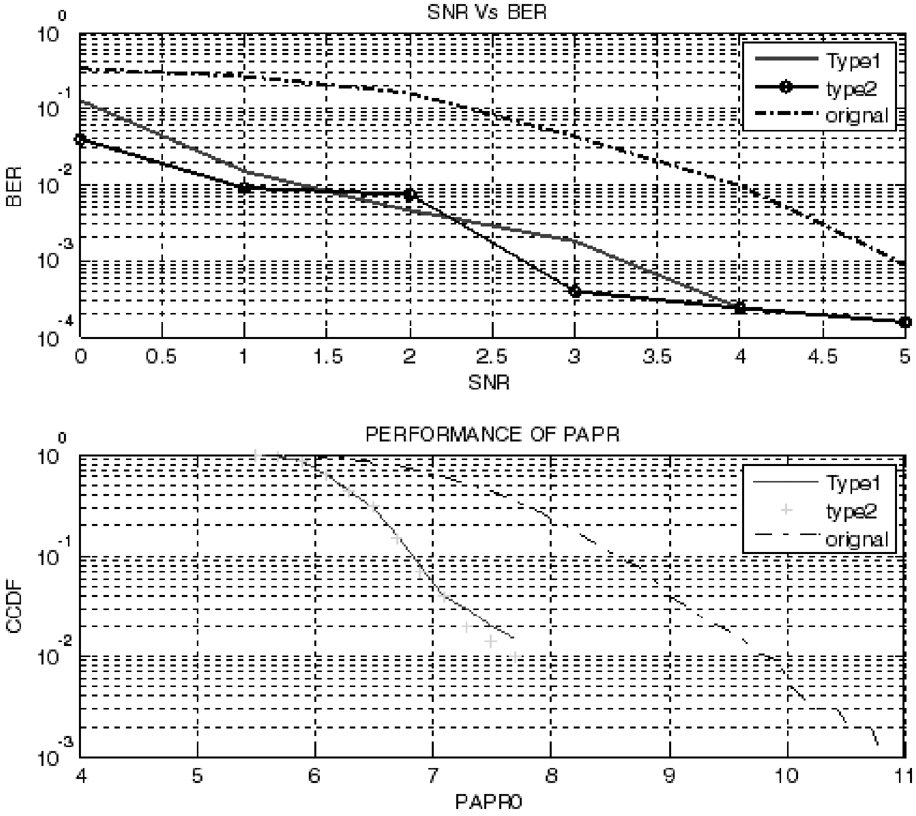

Figure 8: PAPR reduction and BER performance at IBO=0dB

Table 1
Gives the detail information of the values of PAPR and BER at different IBO.

Sr. No.	*PAPR reduction method*	*IBO (dB)*	*PAPR at CCDF*	*BER at 3 dB SNR*
1.	SFBC-OFDM without PAPR reduction.	0	10	10^{-13}
2.	TYPE I PTS	0	7.3	10^{-19}
3.	TYPE II PTS	0	7.3	$10^{-2.4}$
4.	SFBC-OFDM without PAPR reduction.	3	10	10^{-3}
5.	TYPE I PTS	3	7.2	$10^{-3.2}$
6.	TYPE II PTS	3	7	$10^{-3.3}$
7.	SFBC-OFDM without PAPR reduction.	10	10	10^{-4}
8.	TYPE I PTS	10	7.1	$10^{-2.3}$
9.	TYPE II PTS	10	7.2	$10^{-2.9}$
10.	SFBC-OFDM without PAPR reduction.	17	10	10^{-3}
11.	TYPE I	17	7.2	10^{-2}
12.	TYPE II	17	7.2	$10^{-2.4}$

And in terms of computational complexity also type II is better than type I because the complexity is reduced to one fourth of that original PAPR. These two type compared with SFBC OFDM system without PAPR reduction technique and graph shows that IBO increases BER performance of SFBC OFDM system without PAPR reduction technique will improve but PTS technique will effect nothing.Table shows power amplifier used with increasing input back off the severity of BER performance degradation reduces. And for increasing IBO decreases PAPR value. Table and graph shows that at large IBO considered in this result 17, 10 the BER of PTS technique of type I and II degrades than SFBC-OFDM without PAPR reduction. And at 3, 0 dB IBO the performance of SFBC-OFDM without PAPR reduction degrades than PTS I and II.

The PTS II is slightly improved performance than PTS I . The PAPR value reduction up to 4 dB at CCDF 10^{-2} than original SFBC system.

6. CONCLUSION

In this paper, we have studied PAPR reduction PTS technique with low-complexity of SFBC MIMO-OFDM systems. Compared the PAPR and BER at different IBO values. In this we have seen that as we increase the IBO, BER is reduced.Thus it is necessary to use the appropriate value of IBO so that there is no power loss and PAPR is also reduced.it should not be too much greater than HPA range and not too small such that the signal doesn't pass through it.it should be appropriate.

If we consider 100% computational complexity for deriving PAPR by normal PTS scheme then by PTS type II it gets reduced to 25 % because we don't need to derive all the calculations for 2nd antenna as it is interrelated to 1st so computational complexity is also reduced.

From our analysis it is found that irrespective of PAPR reduction technique being employed, the efficiency of power amplifier increases with decreasing peak power. It also help for given BER performance the necessity of Input-Back off (IBO) reduces with reduction in Peak to average power ratio.

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