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PERFORMANCE ANALYSIS OF MIMO-OFDM RECEIVER USING MODIFIED PTS TECHNIQUE

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ABSTRACT

Partial Transmit Sequence is one of the distortionless methods to reduce the peak-to-average power ratio (PAPR) in Orthogonal Frequency Division Multiplexing (OFDM) systems. It is an attractive method since it provides PAPR reduction without any degradation in bit error rate (BER) performance. PTS has high computational complexity which increases exponentially with increase in subblocks. But modified PTS technique of PAPR reduction has decreased this computational complexity by using a neighbourhood search algorithm for finding the optimum set of phase factors required for independent phase rotation of the symbols in each subblock. The potential capability of the modified PTS technique is explored in MIMO-OFDM systems for PAPR reduction and its performance is evaluated. In this paper, the performance of MIMO-OFDM system employing modified PTS technique is investigated by using Least Square (LS) and Minimum Mean Square Error (MMSE) channel estimation methods. The performance of the system is evaluated in terms of mean square error (MSE) and bit error rate (BER) for different subblock sizes and different subcarriers. The simulation results depict improved BER performance with PAPR reduction by increasing the subblocks. The results also show that there is a slight degradation in BER with increase in number of subcarriers.

Keywords: *Channel Estimation, Modified PTS, Multiple-Input Multiple-Output Orthogonal Frequency Division Multiplexing, Peak-to-Average Power Ratio, Bit Error Rate*

1. INTRODUCTION

Present day wireless communications demand highly reliable wireless systems with high spectral efficiency. For this, Orthogonal Frequency Division Multiplexing (OFDM) is a promising candidate for transmission of digital signals over wireless channels [1]. It is a multicarrier modulation technique offering many advantages such as immunity against multipath fading effects, flexible management against inter-symbol interference (ISI), high spectral efficiency etc. So, it is adopted in many broadband communication systems supporting high data rates such as digital subscriber lines, wireless LANs and digital video broadcasting [2]. It is implemented by transmitting N information symbols in parallel over N subcarriers [3]. Accordingly, the time duration of one OFDM symbol is N times larger than that of a single carrier system. OFDM is achieved by performing inverse fast Fourier transform (IFFT) operation on a block of N information symbols. After IFFT operation, analog-to-digital conversion (ADC) is performed on each block of N symbols, usually preceded by cyclic prefix (CP) of G symbols. The effect of inter-symbol interference is mitigated by using CP whose length should be at least equal to the channel length. Multiple-Input Multiple-Output Orthogonal Frequency Division Multiplexing (MIMO-OFDM) has gained widespread attention in wireless communication system because of its ability in providing efficient, high data rate communication over a hostile multipath wireless transmission medium. Since the MIMO configuration increases the capacity with acceptable BER performance, OFDM is combined with MIMO technology to increase diversity gain and system capacity. But MIMO-OFDM system suffer from high peak-to-average power ratio (PAPR) when the signals of all sub-carriers are added constructively and its peak power is N times the average power. The high PAPR causes the power amplifier to work beyond its linear region resulting in non-linear distortion in the transmitted signal. Therefore, many PAPR reduction techniques have been proposed [4]-[11]. PTS technique is one of a distortionless and effective

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method of PAPR reduction, because of improved PAPR statistics and easier implementation. In this technique, the input data block is partitioned into V disjoint subblocks. Then, each subblock is multiplied with a phase factor for optimum shift in phase. IFFT operation is performed on each subblock and resulting sub-sequences are then added to result in an OFDM signal with low PAPR. This technique suffers from a disadvantage of exponential increase in computational complexity with increase in subblocks. To address the issue of high computational complexity, modified PTS technique has been proposed [12]. Modified PTS technique adopts a neighbourhood search algorithm to find the optimum set of phase factor by assuming a threshold PAPR. In this paper, the performance of the 2X2 MIMO-OFDM system is investigated by employing modified PTS technique for different subblocks and subcarriers. The simulation results are compared with conventional PTS technique. The performance of 2X2 MIMO-OFDM system employing the above techniques of PAPR reduction is analysed with LS and MMSE channel estimation methods. The performance of the system under consideration is measured with MSE and BER.

The paper is organized as follows: Section 2 describes briefly PAPR reduction using modified PTS technique and the system model. A brief overview of LS and MMSE channel estimation is given in section 3. Simulation results, discussions and comparisons of PAPR reduction performance and receiver performance is presented in Section 4. Section 5 concludes the paper.

2. MODIFIED PTS TECHNIQUE

Consider the MIMO-OFDM spatial multiplexing system shown in figure 1 and 2, with N subcarriers, two transmit antennas $(N_t = 2)$ and two receiver antennas $(N_r = 2)$.

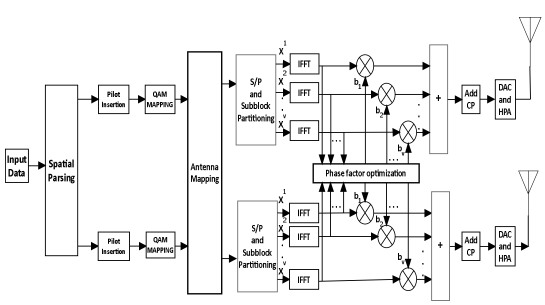

Figure 1: Block Diagram Of 2X2 MIMO-OFDM Transmitter Using Modified PTS Technique

Each antenna transmits a stream of IFFT modulated symbols after PAPR reduction. A cyclic prefix of G symbols is added at the beginning of each OFDM symbol before transmission and removed at the receiver to avoid inter-symbol interference (ISI). Let the data symbols transmitted by the system using spatial multiplexing be,

$$X_d[k] = [X_d(0), X_d(1), ..., X_d(k)]^T,\ 0 \le k \le N-1 \quad (1)$$

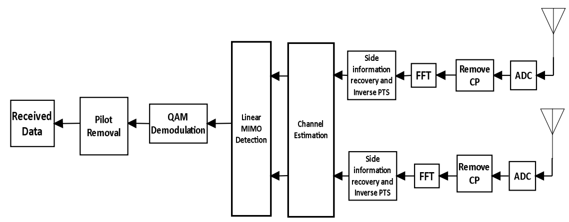

Figure 2: Block Diagram Of 2X2 MIMO-OFDM Receiver Using Modified PTS technique

The alternate symbols in the vector are fed to the two transmit antennas. The symbols fed to the transmit antenna T_1 is given by,

$$X_{T_1}[k] = [X_d(0), X_d(2), ..., X_d((N-1)/2)]^T \quad (2)$$

where $k = 0, 2, 4, ..., ((N-1)/2)$. Similarly, the symbols fed to the transmit antenna T_2 is given by,

$$X_{T_2}[k] = [X_d(1), X_d(3), ..., X_d(N-1)]^T \quad (3)$$

where $k = 1, 3, 5, ..., (N-1)$. Each symbol in the vector $X_{T_1}[k]$ will modulate one of the $(N/2)$ orthogonal carriers using IFFT and get transmitted through antenna T_1. Likewise, each symbol in the vector $X_{T_2}[k]$ will modulate one of the $(N/2)$ orthogonal subcarriers and get transmitted through antenna T_2. In each transmit antenna, the OFDM signal is obtained in time domain by using IFFT operation and it is the superimposition of all the modulated orthogonal subcarriers. The time domain signal at the output of the antenna is,

$$x_{T_1}(n) = \frac{1}{\sqrt{N/2}} \sum_{k=0}^{(N-1)/2} X_{T_1}(k) e^{\frac{j2\pi kn}{N/2}},\ 0 \le n, k \le (N-1)/2 \quad (4)$$

$$x_{T_2}(n) = \frac{1}{\sqrt{N/2}} \sum_{k=0}^{(N-1)/2} X_{T_2}(k) e^{\frac{j2\pi kn}{N/2}},\ 0 \le n, k \le (N-1)/2 \quad (5)$$

The PAPR of the OFDM signal at transmit antenna T_1 is defined as the ratio of the maximum to average power of the OFDM signal and it is given by,

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$$PAPR(x_{T_2}(n)) = 10\log_{10}\frac{\max_{0\le n\le (N-1)/2}\left|x_{T_2}(n)^2\right|}{E\left[\left|x_{T_2}(n)\right|^2\right]} \quad (6)$$

Similarly, the PAPR of the OFDM signal at the transmit antenna T_2 is given by,

$$PAPR(x_{T_2}(n)) = 10\log_{10}\frac{\max_{0\le n\le (N-1)/2}\left|x_{T_2}(n)^2\right|}{E\left[\left|x_{T_2}(n)\right|^2\right]} \quad (7)$$

In equations (6) and (7), $E[.]$ is the expected value. Assuming N as sufficiently large and based on central limit theorem, the time domain samples $x_{T_1}(n)$ and $x_{T_2}(n)$ are zero mean complex Gaussian distributed. So the performance of PAPR reduction method is analysed by using the complementary cumulative distribution function (CCDF). The CCDF of PAPR for a given PAPR level $PAPR_0$ is defined as the probability of the generated OFDM signal exceeding the given threshold value $PAPR_0$. It is given by,

$$CCDF(PAPR(x(n))) = \Pr(PAPR(x(n)) > PAPR_0) \quad (8)$$

The analysis of PAPR performance is similar to the case of Single-Input Single-output (SISO) OFDM system. Since the transmitted time-domain signals of all antennas are correlated, the PAPR of the MIMO-OFDM system is defined as [11],

$$PAPR\{\mathrm{x}\} = \arg\max_{1\le j\le N_t}\left(PAPR\{\mathrm{x(n)}_j\}\right) \quad (9)$$

The high PAPR of OFDM signal is due to the addition of many narrowband in-phase subcarriers in time domain. The high PAPR forces the HPA at the transmitter to operate with a large backoff. This results in reduced power efficiency of the HPA. In the design of HPA, the efficiency of the amplifier is an essential parameter. So for better efficiency, the PAPR of the OFDM signal is reduced by using conventional PTS technique and Modified PTS technique with adjacent subblock partitioning.

In PTS technique of PAPR reduction, the data block of each antenna with $N/2$ symbols is divided into V disjoint subblocks of equal size, represented as $X_{T_1}^v = [X_{T_1}^1, X_{T_1}^2, .., X_{T_1}^v]^T$ and $X_{T_2}^v = [X_{T_2}^1, X_{T_2}^2, .., X_{T_2}^v]^T$. Each subblock is multiplied with a phase factor $b_v = e^{j\varphi v}$ where $v = 1, 2, ..., V$, for independent phase rotation of the symbols in the subblocks. After phase rotation, the OFDM signal in time domain at transmit antenna T_1 is given by,

$$\mathbf{x}_{T_1} = IFFT\left\{\sum_{v=1}^{V} b_v X_{T_1}^v\right\} = \sum_{v=1}^{V} b_v \mathrm{x}_{T_1}^v \quad (10)$$

The OFDM signal at transmit antenna T_2 is given by,

$$\mathbf{x}_{T_2} = IFFT\left\{\sum_{v=1}^{V} b_v X_{T_2}^v\right\} = \sum_{v=1}^{V} b_v \mathrm{x}_{T_2}^v \quad (11)$$

where $\mathrm{x}_{T_1}^v$ and $\mathrm{x}_{T_2}^v$ are the partial transmit sequences and b_v is the optimal phase factor chosen from an allowed set $b_v = \{+1, -1, +j, -j\}$ [12]. The optimal phase factor for each transmitting antenna is independently searched. The OFDM signal with low PAPR in time domain signal at T_1 is,

$$\tilde{\mathrm{x}}_{T_1} = \sum_{v=1}^{V} b_v \mathrm{x}_{T_2}^v \quad (12)$$

Similarly, the OFDM signal at the transmit antenna T_2 is given by,

$$\tilde{\mathrm{x}}_{T_2} = \sum_{v=1}^{V} b_v \mathrm{x}_{T_2}^v \quad (13)$$

PTS technique of PAPR reduction suffers from a disadvantage of exponential increase in computational complexity with increase in subblocks. So, modified PTS technique which employs a neighbourhood search algorithm is used to find the optimum set of phase factors. In this technique, a neighbourhood region is defined as a function of the current PAPR and a threshold PAPR value $PAPR_0$. In the neighbourhood of the threshold PAPR, a new phase factor set is obtained and PAPR of the OFDM signal is calculated. If this PAPR value is less than $PAPR_0$ then the threshold value is replaced with the new value. This process of determining the optimum phase factor set containing V phase factors to yield an OFDM signal with less PAPR is repeated. After finite number of search, if the calculated PAPR is not below the threshold value, the current set of V phase factors is taken as the optimum solution. This set of V phase factor is used to determine the OFDM signal with optimal PAPR value. Because of neighbourhood search algorithm and adjacent subblock partitioning method, the modified PTS

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technique offers a better PAPR reduction performance at reduced computational complexity.

OFDM systems without PAPR reduction technique, demand a highly linear HPA with a larger dynamic range. A HPA with a larger dynamic range is costlier. So, the high PAPR reduces the efficiency of the amplifier which is defined as the ratio of RF output power to DC input power [13] and it is expressed as,

$$\eta = \frac{P_{out}}{P_{in}} \tag{14}$$

The DC input power consumed by the amplifier for amplification of OFDM signal with PAPR reduction is less and accordingly the power efficiency is improved. The amount by which the input power is decreased is the difference between the DC input power consumed for amplification without PAPR reduction and with PAPR reduction. If P_{PAPR} and P are DC input powers with PAPR and without PAPR reduction, respectively, then the decrease in input power consumed is proportional to (P_{PAPR} / P). Thus, there is an increase in the efficiency of the amplifier by a factor of (P / P_{PAPR}). Accordingly, there is an increase in effective signal-to-noise ratio which is given by $SNR = (P_{out} / N_0)$, where N_0 is the noise spectral density. Thus, with PAPR reduction, there is increase in efficiency of the amplifier and effective SNR. The increase in effective SNR is realized as improvement in BER performance. The effective SNR which affects the BER of the OFDM system is proportional to $(P_{out} / PAPR / N_0)$ [14].

3. LEAST SQUARE (LS) AND MINIMUM MEAN SQUARE ERROR (MMSE) CHANNEL ESTIMATION

In the OFDM system, the signal after PAPR reduction undergoes distortion while travelling through the wireless channel. To improve the performance of MIMO-OFDM system with PTS and modified PTS techniques the effects of the channel are estimated and compensated with LS and MMSE channel estimation methods. In 2X2 spatial multiplexing MIMO-OFDM system each transmit antenna transmits statistically independent data symbols from different antennas. The bandwidth of the transmitted signal is narrower and so the frequency response of the channel can be considered flat. For MIMO-OFDM system with two transmit and two receive antennas, the channel matrix H is a $N_r x N_t$ complex matrix, where $N_t = 2$ and $N_r = 2$. The elements of the channel matrix h_{ji} are the fading coefficients from $j-th$ transmit antenna to the $i-th$ receive antenna. Accordingly, the channel matrix H is given by,

$$H = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \tag{15}$$

The received signal at the receive antenna R_1 is given by,

$$Y_1 = h_{11}\tilde{x}_{T_1} + h_{12}\tilde{x}_{T_2} + n_2 = [h_{11}\ h_{12}] \begin{bmatrix} \tilde{x}_{T_1} \\ \tilde{x}_{T_2} \end{bmatrix} + n_2 \tag{16}$$

The received signal at the receive antenna R_2 is given by,

$$Y_2 = h_{21}\tilde{x}_{T_1} + h_{22}\tilde{x}_{T_2} + n_1 = [h_{21}\ h_{22}] \begin{bmatrix} \tilde{x}_{T_1} \\ \tilde{x}_{T_2} \end{bmatrix} + n_1 \tag{17}$$

where n_1 and n_2 are the white Gaussian noise at the respective receive antenna. The channel coefficients are estimated by using LS and MMSE channel estimations methods. Accordingly, the estimated channel matrix using LS channel estimation is given by,

$$\hat{H}_{LS} = \begin{bmatrix} \hat{h}_{LS11} & \hat{h}_{LS12} \\ \hat{h}_{LS21} & \hat{h}_{LS22} \end{bmatrix} \tag{18}$$

The channel coefficient $\hat{h}_{LSji}$ is given by, $\hat{h}_{LSji} = \frac{y_{ji}}{\tilde{x}_{Tj}}$, where $j = 1,\ldots,N_r$ and $i = 1,\ldots,N_t$.

Similarly, by using MMSE channel estimation the channel matrix is given by,

$$\hat{H}_{MMSE} = \begin{bmatrix} \hat{h}_{MMSE11} & \hat{h}_{MMSE12} \\ \hat{h}_{MMSE21} & \hat{h}_{MMSE22} \end{bmatrix} \tag{19}$$

The channel coefficient $\hat{h}_{MMSEji}$ is given by, $\hat{h}_{MMSEji} = \frac{y_{ji}}{\tilde{x}_{Tj}}$, where $j = 1,\ldots,N_r$ and $i = 1,\ldots,N_r$.

The estimated LS channel coefficients $\hat{H}_{LS}(k)$ at pilot locations are interpolated to evaluate the channel coefficients $\hat{H}_{LS\_d}(k)$ at the locations of the data. Accordingly, the estimated data symbol

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$\hat{X}_{LS\_d}(k)$ with LS channel estimation is given by [15],

$$\hat{X}_{LS\_d}(k) = \frac{Y(k)}{\hat{H}_{LS\_d}(k)} \tag{20}$$

In MMSE channel estimation method, the average mean square error (MSE) between the transmitted symbol and its estimate is minimized [16-17]. The channel coefficients are given by,

$$\hat{H}_{MMSE} = R_{HH}\left[R_{HH} + \frac{I}{SNR}\right]^{-1}\hat{H}_{LS}(k) \tag{21}$$

where R_{HH} is the covariance matrix of the channel, SNR is the signal-to-noise ratio and I is the identity matrix. The channel coefficients at data locations $\hat{H}_{d\_MMSE}(k)$ is used to estimate the data symbol by using,

$$\hat{X}_{MMSE\_d}(k) = \frac{Y(k)}{\hat{H}_{MMSE\_d}(k)} \tag{22}$$

In frequency domain, the performance of the channel estimation is measured by using Mean Square error (MSE). The MSE of LS channel estimation is defined as,

$$MSE_{LS} = E\left[\left|H(k) - \hat{H}_{LS}(k)\right|^2\right] \tag{23}$$

The MSE for MMSE channel estimation is given by,

$$MSE_{MMSE} = E\left[\left|H(k) - \hat{H}_{MMSE}(k)\right|^2\right] \tag{24}$$

The performance of LS and MMSE channel estimation methods are also evaluated by using BER.

4. RESULTS AND DISCUSSION

The performance of the 2X2 MIMO-OFDM system with PTS and modified PTS techniques is analyzed with LS and MMSE channel estimation methods by using MATLAB^{TM}7.10. The parameters listed in table 1 are used to evaluate the performance of the system in terms of MSE and BER.

4.1 MIMO-OFDM System Performance With PTS Technique Employing LS Channel Estimation For N=256 And Different Subblocks

The PAPR performance of the MIMO-OFDM system employing PTS technique is evaluated in terms of CCDF and is illustrated in figure 3. It is observed that PAPR reduction increases with increase in subblock. With increase in subblocks, the symbols in each subblock undergo independent phase rotations resulting in better PAPR performance. The percentage of decrease in PAPR at CCDF of 10^{-3}, is about 11.66%, 19.73%, 29.15% and 35.43% for subblock sizes V=2, 4, 8 and 16 respectively, compared to MIMO-OFDM system without PTS technique.

Table 1: Simulation Parameters

Simulation parameters	Type value	
	PTS	Modified PTS
Number of Transmitting Antennas N_t	2	2
Number of Transmitting Antennas N_r	2	2
Number of subcarriers N	256	256
Number of subblocks V	2,4,8 and 16	2,4,8 and 16
Guard band	N/8	N/8
Modulation scheme	16 QAM	16 QAM
Phase factors	+1,-1	+1,-1,+j,-j

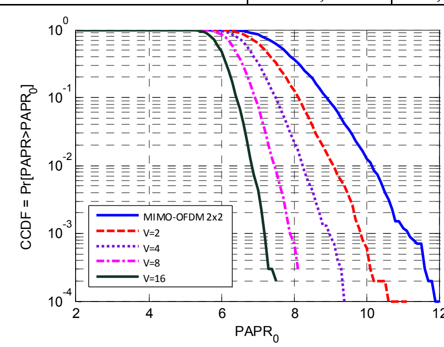

Figure 3: PAPR Performance Of 2X2 MIMO-OFDM System With PTS Technique

The performance of MIMO-OFDM system with PTS technique is evaluated in terms of MSE of the channel coefficients using LS channel estimation and it is portrayed in figure 4. It is observed that rate of decrease in MSE increases with increase in subblocks due to increase in effective SNR. At SNR of 15dB, the average MSE of the channel coefficients decreases by 16.14%, 27.39%, 38.21%

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and 48.43% for subblocks of V=2,4,8and 16, respectively when compared to the system without PAPR reduction.

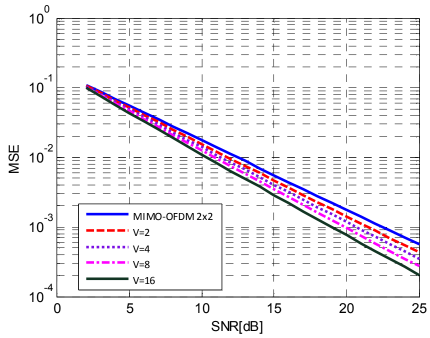

Figure 4: MSE Performance Of MIMO-OFDM Receiver With PTS Technique Employing LS Channel Estimation

Figure 5 shows the BER performance of MIMO-OFDM system with PTS technique. LS channel estimation is employed to evaluate the BER performance. From the results, it can be concluded that BER decreases due to increased PAPR reduction. The decrease in BER with increase in subblocks is due to improvement in efficiency of the HPA. The reduced power consumption of the HPA amplifier improves the efficiency of the power amplifier. At SNR=15dB, BER decreases by about 10.75%, 23.76%, 35.95% and 47.09% for V=2, 4, 8 and 16 respectively with respect to MIMO-OFDM system without PAPR reduction.

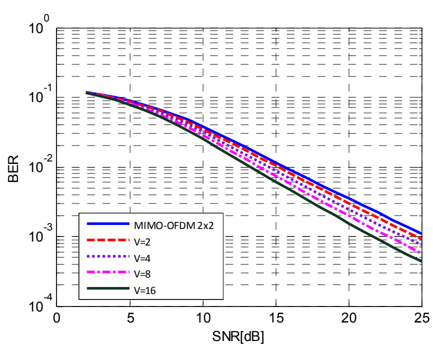

Figure 5: BER Performance Of MIMO-OFDM Receiver With PTS Technique Employing LS Channel Estimation

4.2 MIMO-OFDM System Performance With Modified PTS Technique Employing LS Channel Estimation For N=256 And Different Subblocks

The performance of MIMO-OFDM system with modified PTS technique is analysed by using simulation parameters enumerated in table 1. The PAPR performance of modified PTS technique is shown in figure 6. It is found from simulation results that better PAPR performance is achieved by using modified PTS technique with adjacent subblock partitioning. When compared to MIMO-OFDM system without PAPR reduction and at CCDF of 10^{-3}, the reduction of PAPR is about 19.28%, 36.32%, 47.53% and 51.12% for V=2, 4, 8 and 16 respectively.

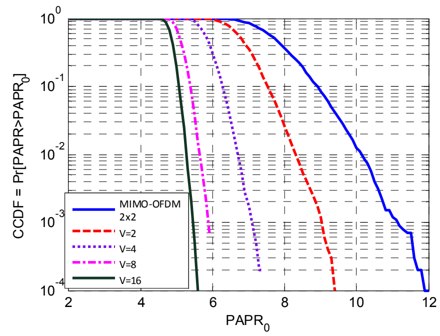

Figure 6: PAPR Performance Of 2X2 MIMO-OFDM System With Modified PTS Technique

The performance of 2X2 MIMO-OFDM system with modified PTS technique and LS channel estimation is evaluated in terms of MSE of the channel is depicted in figure 7. It is observed that the MSE decreases with increase in PAPR reduction. With reference to the system without PAPR reduction and at SNR of 15dB, the MSE decreases by 27.36%, 51.31%, 66.05% and 70.14% for V=2, 4, 8 and 16, respectively. The decrease in MSE is due to reduced power consumption and increased efficiency of the power amplifier.

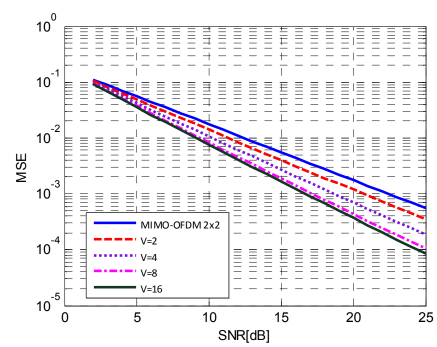

Figure 7: MSE Performance Of MIMO-OFDM Receiver With Modified PTS Technique Employing LS Channel Estimation

The BER performance of 2X2 MIMO-OFDM system with modified PTS technique and LS channel estimation is shown in figure 8. For SNR=15dB, the decrease in BER is about 23.56%, 49.61%, 65.81% and 69.29% for V=2, 4, 8 and 16, respectively, when compared to MIMO-OFDM system without PAPR reduction. The decrease in

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BER is attributed to decrease in PAPR and reduced power consumption by the power amplifier.

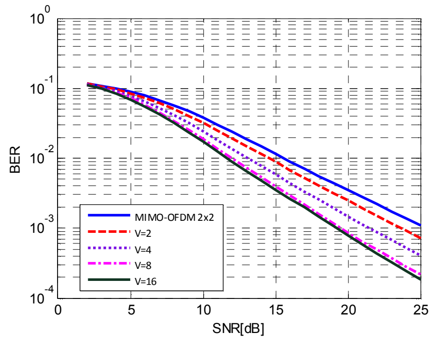

Figure 8: BER Performance Of MIMO-OFDM Receiver With Modified PTS Technique Employing LS Channel Estimation

4.3 Comparison Of The Performance Of MIMO-OFDM Receiver With PTS And Modified PTS Techniques For Different Subcarriers N= 256 And 512 Employing LS Channel Estimation

The PAPR reduction performance of PTS and modified PTS technique is evaluated and compared with help of simulation parameters listed in table 1 for a subblock size V=16 and different subcarriers N = 256 and 512. The receiver performance is evaluated and compared by computing the MSE and BER using LS channel estimation.

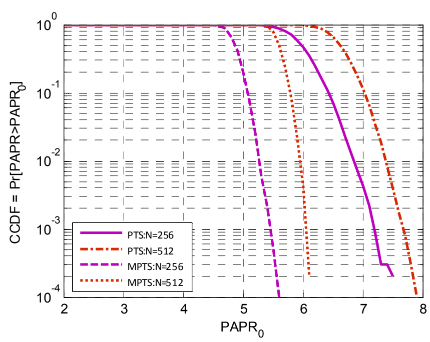

Figure 9: PAPR Performance Of 2X2 MIMO-OFDM System With PTS And Modified PTS Techniques For Different Subcarriers

The PAPR reduction performance with PTS and modified PTS techniques for different subcarriers sizes N=256, 512 and subblock V=16 is illustrated in figure 9. The performance of modified PTS technique is better because of adjacent subblock partitioning compared to the ordinary PTS technique. The PAPR reduction performance is better and it is achieved at reduced computational complexity because of the implementation of neighbourhood search algorithm. For CCDF of 10^{-3} and N=256, the improvement of PAPR reduction performance is about 1.75dB. Likewise, for N=512, the performance improves by 1.6dB.

Figure 10 depicts the comparison of MSE performance with LS channel estimation for different subcarriers N=256 and 512. It is observed that there is slight degradation in MSE performance with increase in subcarriers due to increase in error between the actual and estimated values of channel coefficients. The probability of occurrence of high peaks with increase in subcarrier size is less. So there is no less change in effective SNR with increase in subcarrier size. The MSE of the channel with LS channel estimation and PTS technique is 0.0028 for N=256 and it increases by about 2.687% for N=512. Also, with modified PTS technique the MSE is 0.0016 for N=256 and it increases by 9.95%, for N = 512.

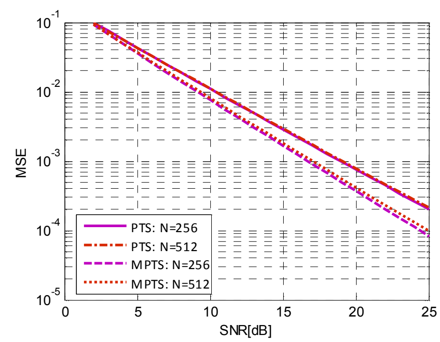

Figure 10: Comparison Of MSE Performance Of MIMO-OFDM Receiver With LS Channel Estimation For Different Subcarriers

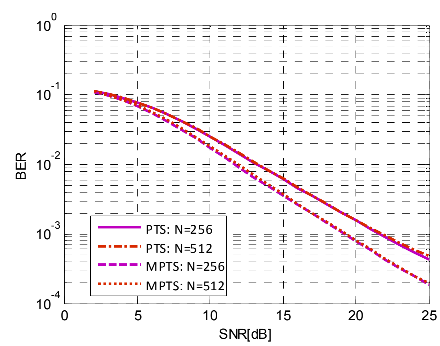

Figure 11: Comparison Of BER Performance Of MIMO-OFDM Receiver With LS Channel Estimation For Different Subcarriers

Figure 11 shows the comparison of BER of 2X2 MIMO-OFDM system employing PTS and modified PTS techniques for different subcarriers N=256 and 512. The BER is calculated with help of LS channel estimation. At higher SNR values, the BER of the receiver slightly degrades with increase in subcarriers from N=256 to 512. For PTS

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technique, at SNR of 15dB and N=256, the BER of MIMO-OFDM receiver is about 0.0061 and increases by 2.08% for N=512. Likewise for modified PTS technique, at SNR of 15dB and N=256, the BER is about 0.0035 and it degrades by 5.02% with increase in subcarriers to 512.

4.4 MIMO-OFDM System Performance With PTS Technique Employing MMSE Channel Estimation For N=256 And Different Subblocks

The performance of MIMO-OFDM system employing PTS technique is evaluated with help of MMSE channel estimation by using the simulation parameters listed in table 1.

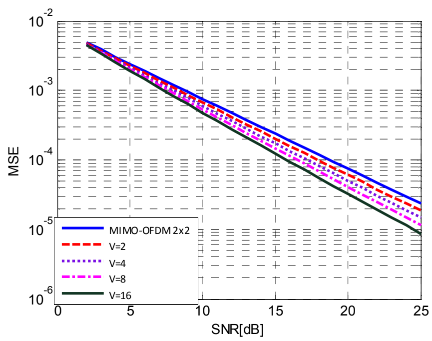

Figure 12: MSE Performance Of MIMO-OFDM Receiver With PTS Technique Employing MMSE Channel Estimation

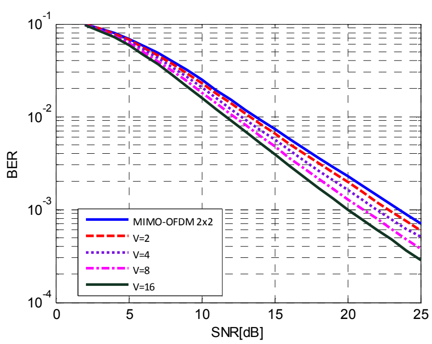

Figure 13: BER Performance Of MIMO-OFDM Receiver With PTS Technique Employing MMSE Channel Estimation

The MSE performance of the MIMO-OFDM system with PTS technique for N=256 and different subblocks is evaluated. Figure 12 shows the performance of MSE obtained by using MMSE channel estimation. It is concluded that MSE decreases with increase in PAPR reduction due decrease in power consumption and increase in efficiency of the power amplifier. From the simulation results, it is observed that for SNR of 15dB, the MSE decreases by 15.28%, 27.45%, 37.89% and 48.08% when compared to the system without PTS technique.

Figure 13 shows the BER performance of the 2X2 MIMO-OFDM system with PTS technique evaluated by using MMSE channel estimation. It is found that due to increase in efficiency of the power amplifier and effective SNR, the BER decreases by 9.87%, 22.89%, 34.92% and 46.32% with respect to the MIMO-OFDM system without PAPR reduction.

4.5 OFDM Receiver Performance With Modified PTS Technique Using MMSE Channel Estimation For N=256 And Different Subblocks

The performance of the system under consideration employing modified PTS technique is evaluated with MMSE channel estimation by using the simulation parameters listed in table 1.

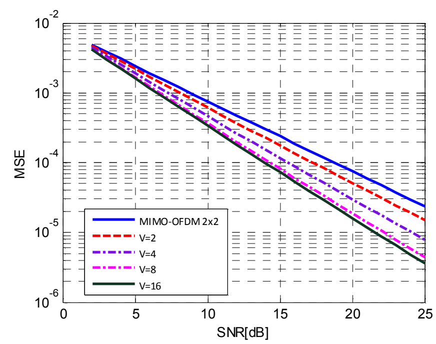

Figure 14: MSE Performance Of MIMO-OFDM Receiver With Modified PTS Technique Employing MMSE Channel Estimation

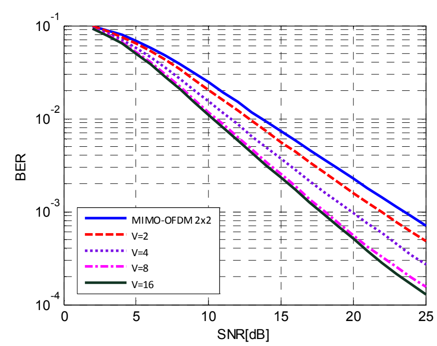

Figure 15: BER Performance Of MIMO-OFDM Receiver With Modified PTS Technique Employing MMSE Channel Estimation

Figure 14 portrays the MSE performance of the system. It is found that the MSE decreases with increase in V. For SNR = 15dB, the decrease in MSE is about 26.06%, 51.07%, 65.60% and 69.56% respectively for V=2, 4, 8 and 16 respectively, when compared to MIMO-OFDM

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system without PAPR reduction. The MSE decreases because of increased efficiency of the power amplifier due to PAPR reduction.

Figure 15 illustrates the performance of BER performance of the system with modified PTS technique. The observation is that the BER decreases with increase in size of subblocks. Due to PAPR reduction, the power amplifier consumes less power leading to increased efficiency. The increase in efficiency will result in increased effective SNR. The BER decreases by about 22.88%, 48.86%, 65.46% and 68.14% for V=2,4,8 and 16, when compared to MIMO-OFDM system without PAPR reduction.

4.6 Comparison Of The Performance Of MIMO-OFDM Receiver With PTS And Modified PTS Techniques For Different Subcarriers N= 256 And 512 Employing LS Channel Estimation

The MIMO-OFDM system performance with PTS and modified PTS technique is analysed by employing MMSE channel estimation. The simulation parameters listed in table 1 are used in the analysis of with different subcarriers N=256, 512 and V = 16.

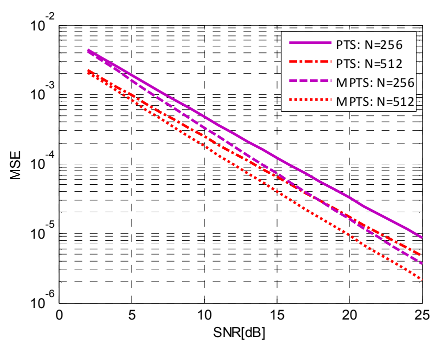

Figure 16: Comparison Of MSE Performance Of MIMO-OFDM Receiver With PTS And Modified PTS Techniques Using MMSE Channel Estimation For N=256 And 512

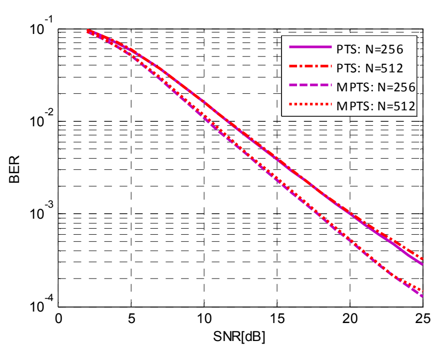

Figure 17: Comparison Of BER Performance Of MIMO-OFDM Receiver With PTS And Modified PTS Techniques With MMSE Channel Estimation For N=256 And 512

Figure 16 shows the MSE of the channel obtained with MMSE channel estimation for different subcarriers N=256 and 512. The MSE of the channel is evaluated for PTS and modified PTS techniques. The inference is that the MSE increases slightly with increase in subcarriers for a particular method of PAPR reduction. The MSE performance of MMSE channel estimation is better for modified PTS technique. For SNR=15dB, V=16 and N=256, the value of MSE of the channel with PTS technique is 0.00012 and modified PTS technique is 0.00007. The decrease in MSE is about 41.33%. With N=512, by using modified PTS technique the decrease in MSE is about 37.57%.

Figure 17 shows the comparison of BER performance of MIMO-OFDM receiver with PTS and modified PTS technique employing MMSE channel estimation for N=256 and 512. The BER of MIMO-OFDM system with modified PTS technique is better than the system with PTS technique. For SNR=15dB and N=256, the BER of the MIMO-OFDM system with modified PTS technique is about 40.66% less when compared to PTS technique. Likewise for N=512, the decrease in BER of the system employing modified PTS is about 38.88%. The reason for the decrease in BER is because of increases in PAPR reduction, efficiency of the power amplifier and effective SNR. With increase in subcarrier size there is a slight degradation in BER in both techniques of PAPR reduction.

5. CONCLUSION

In this paper, the performance of 2X2 MIMO-OFDM receiver is analyzed using PTS and modified PTS techniques by employing LS and MMSE channel estimation methods. In both methods of PAPR reduction, the performance of the receiver is evaluated in terms of MSE and BER. The performance of the receiver improves with increase in PAPR reduction due to increase in subblock sizes. The decrease in MSE and BER of the receiver is due to increase in effective SNR and improvement in PAPR reduction with increase in subblocks. The increase in PAPR reduction results in reduced power consumption and increase in efficiency of the power amplifier. This increase in efficiency is realized as increase in effective SNR. The PAPR performance of modified PTS is better than PTS technique, due to adjacent channel partitioning at reduced computational complexity. So, the performance of MIMO-OFDM receiver using modified PTS technique is better when compared with PTS technique of PAPR reduction.

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Also, the performance of MIMO-OFDM receiver with MMSE channel estimation is better when compared with LS channel estimation method. With increase in subcarriers, there is a slight degradation in MSE and BER of the MIMO-OFDM receiver at higher SNR values, due to increased data transfer rate.

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