Reduction of PAPR in OFDM Using Partial Transmit Sequence (PTS) With Space Time Block Codes (STBC)

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Abstract

Nowadays, orthogonal frequency division multiplexing (OFDM) is widely used in the wireless communication system due to its high data transmission rate, resilient to inter symbol interference (ISI) and narrow-band effects, and resistant to selective fading. Yet, during the transmission, the OFDM suffers from a major challenge that is the high peak-to-average-power ratio (PAPR). To limit this issue, from the past few years several methods are deployed. However, still, it is a challenging issue in the OFDM system. Therefore, to address the mentioned problem, in this work, we introduced a partial transmit sequence (PTS) with space-time block codes (STBC) and an interleaving approach. From the experimental outcomes, we observed that the proposed system attained good PAPR reduction when compared to the conventional OFDM system. Keywords: Orthogonal frequency division multiplexing (OFDM), peak-to-average-power ratio (PAPR), and partial transmit sequence (PTS), and space-time block codes (STBC).

I. Introduction

With the ever-growing demand of this generation, the need for high-speed communication has become an utmost priority. Various multicarrier modulation techniques have evolved to meet these demands, few notable among them being Code Division Multiple Access (CDMA) and Orthogonal Frequency Division Multiplexing (OFDM). Orthogonal Frequency Division Multiplexing is a Frequency – Division Multiplexing (FDM) scheme utilized as a digital multi-carrier modulation method. A large number of closely-spaced orthogonal subcarriers is used to carry data. The data is divided into several parallel streams of channels, one for each subcarrier. Each subcarrier is modulated with a conventional modulation scheme (such as QPSK) at a low symbol rate, maintaining total data rates similar to the conventional single-carrier modulation schemes in the same bandwidth. Orthogonal frequency division multiplexing (OFDM) is a widely adopted modulation technique for broadband communication systems. Orthogonal Frequency Division Multiplexing is a special form of multicarrier modulation which is particularly suited for transmission over a dispersive channel.

Here the different carriers are orthogonal to each other, that is, they are independent of one another. This is achieved by placing the carrier exactly at the nulls in the modulation spectra of each other. OFDM communications systems can more effectively utilize the frequency spectrum through overlapping sub-carriers. These sub-carriers can partially overlap without interfering with adjacent sub-carriers because the maximum power of each sub-carrier corresponds directly with the minimum power of each adjacent channel. In below Figure 1, we illustrate the frequency domain of an OFDM system graphically. As you can see from the figure, each sub-carrier is represented by a different peak. Also, the peak of each sub-carrier corresponds directly with the zero crossings of all channels. OFDM channels are different from band-limited FDM channels how they apply a pulse-shaping filter. With FDM systems, a sinc-shaped pulse is applied in the time domain to shape each symbol and prevent ISI.

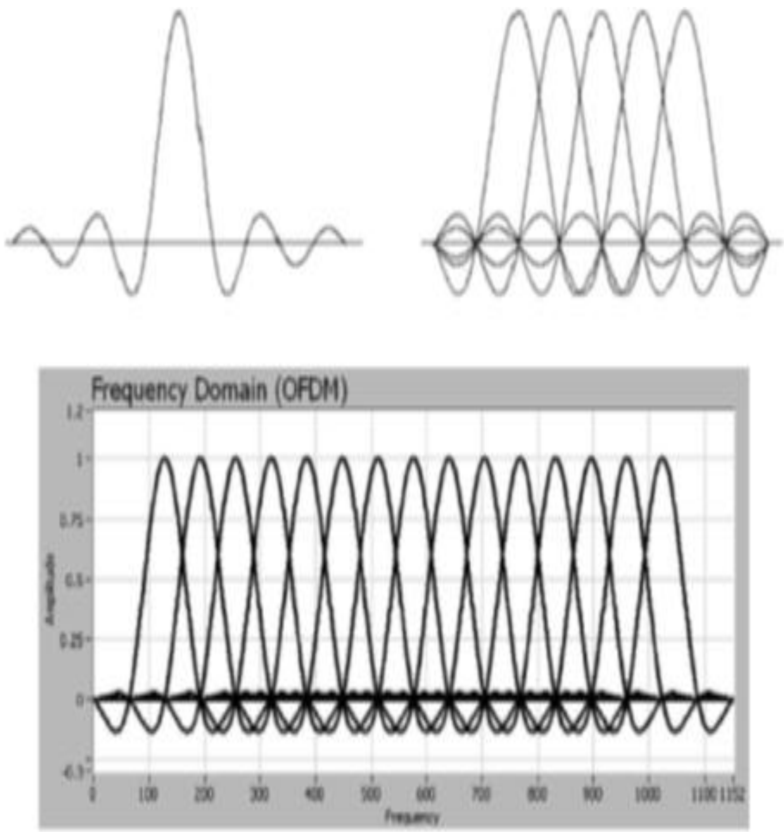

Figure 1: Orthogonality of Sub-channel carriers

II. Related Work

L.J. Cimini et al [1] say new technologies and thereby new applications are emerging not just in a wired environment but also in the wireless arena. The next-generation mobile systems are expected to provide a substantially high data rate to meet the requirements of future high-performance multimedia applications. The minimum target data rate for the 4G system is expected to be at 10-20 Mbps and at least 2 Mbps in the moving vehicles. To provide such a high data rate with high spectral efficiency, a new modulation scheme is to be used. A promising modulation technique that is increasingly being considered for adoption by the 4G community is OFDM. In recent years OFDM has emerged as the standard of choice in several important high data applications numerous Wireless Local Area Networks (e.g. IEEE 802.11a operating at 5 GHz) [2]. The paper, by Muller and Hubber, [3] proposes an effective and flexible peak power reduction scheme for an OFDM system by combining Partial Transmit Sequences (PTS) in 1997. The main idea behind the scheme is that the data block is partitioned into non-overlapping sub-blocks and each sub-block is rotated with a statistically independent rotation factor.

The rotation factor, which generates the time domain data with the lowest peak amplitude, is also transmitted to the receiver as side information. The paper, by Baumlet.al. in 1996 [4] proposes a method for the reduction of peak to transmit power of multicarrier modulation systems with selected mapping in 1996. In selected mapping (SLM) method a whole set of candidate signals is generated representing the same information, and then the most favorable signal as regards PAPR is chosen and transmitted. The side information about this choice needs to be explicitly transmitted along with the chosen candidate signal. The paper, by May and Holing, [5] proposes the method of PAPR reduction by manipulating the OFDM signal with a suitable additive correcting function. In this approach, the amplitude peaks are corrected (or signal is modified) in such a way that a given amplitude threshold of the signal is not exceeded after the correction. The paper by Son, C.H. Nam & H.S. Lee,[6] proposes an approach for PAPR Reduction based on Tone Reservation Method. In TR, the objective is to find the time domain signal to be added to the original time domain to reduce the PAPR. The PAPR reduction gain is defined by subtracting PAPR with PAPR reduction from PAPR without PAPR reduction. The GPAPR means the amount of peak reduction in dB.

III. Preliminaries

This section will discuss the OFDM system, PAPR problem, Altamonte STBC, and the traditional PTS based OFDM system.

3.1. OFDM System and PAPR Problem

To generate OFDM successfully the relationship between all the carriers must be carefully controlled to maintain the Orthogonality of the carriers. For this reason, OFDM is generated by firstly choosing the spectrum required based on the input data, and modulation scheme used. Each carrier to be produced is assigned the same data to transmit. The required amplitude and phase of them are calculated based on the modulation scheme. The required spectrum is then converted back to its time-domain signal using an Inverse Fourier Transform (IFT). In most applications, an Inverse Fast Fourier Transform (IFFT) is used. The IFFT performs the transformation very efficiently and provides a simple way of ensuring the carrier signals produced are orthogonal. The Fast Fourier Transform (FFT) transforms the acyclic time-domain signal into its equivalent frequency spectrum. This is done by finding the equivalent waveform, generated by a sum of orthogonal sinusoidal components. The amplitude and phase of the sinusoidal components represent the frequency spectrum of the time domain signal. The IFFT performs the reverse process, transforming a spectrum (amplitude and phase of each component) into a time-domain signal. The following Figure 2 represents the block diagram of the OFDM system.

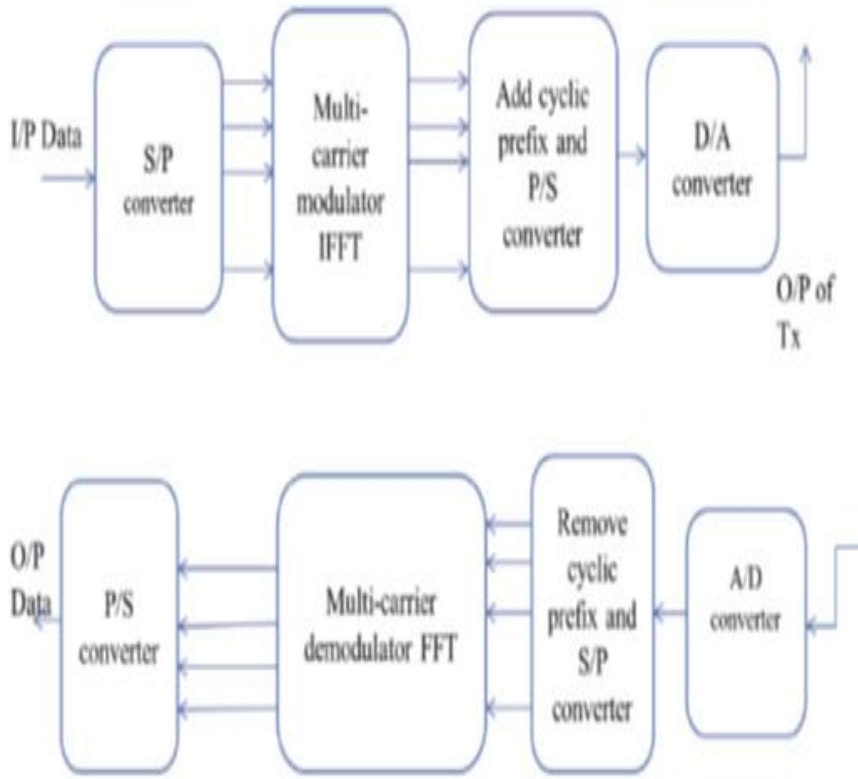

Figure 2: Block diagram of the OFDM system

OFDM is one of the many multicarrier modulation techniques, which provides high spectral efficiency, low implementation complexity, less vulnerability to echoes, and non – linear distortion. Due to these advantages of the OFDM system, it is vastly used in various communication systems. But the major problem one faces while implementing this system is the high peak – to – average power ratio of this system. The Peak-to-Average Power Ratio (PAPR) is given by the equation.

$$C = \frac{|X|_{peak}}{X_{rms}} \qquad (1)$$

Where C – Peak-to-Average Power Ratio.

$|X|_{peak}$ Peak Amplitude of the Waveform.

X_{rms}– RMS Value of the Waveform RMS x.

The Peak-to-Average Power Ratio (PAPR) is also named as the Peak-to-Average Power (PAR) or the Crest Factor. The PAPR of the original OFDM signals is approximately equal to 12 dB.

1.1.Partial Transmit Sequence (PTS) Technique

Partial Transmit Sequence (PTS) [7] is one of the techniques used to reduce PAPR in OFDM system which is implemented in this paper. The main idea of PTS is data blocks are divided into non-overlapping sub-block with independent rotation factors. This rotation factor generates time-domain data with the lowest amplitude. The fundamental idea of this technique is sub-dividing the original OFDM symbol data into sub-data which is transmitted through the sub-blocks which are then multiplied by the weighing value which were differed by the phase rotation factor until choosing the optimum value which has low PAPR.

The block diagram for the PTS technique implementation is shown in figure 3. The data sequence X in the frequency domain is sub-divided into v sub-sequence which were transmitted in sub-blocks without overlapping and having equal size of N which contains N/V non-zero values in each sub-blocks. Thus Peak to average power ratio has been reduced in OFDM using partial transmit sequence. The main drawbacks of this technique are searching complexity increases exponentially with the number of sub-blocks.

In PTS approach, the frequency domain sequence which is represented by vectors X_m, m= 1, 2,3,….., M is partitioned into M disjoint sub-block of equal size in X input data block., which can be represented as

$$X = \sum_{m=1}^{M} X_m \qquad (2)$$

Where all the subcarrier positions presented by another block are is set to zero, so that the sum of all the sub-blocks constitutes the original signal. Then, the sub-blocks X are transformed into time-domain partial transmit sequence by used Inverse Discrete Fourier Transform operation, which can be expressed as

$$\mathrm{X}_{m}= \sum_{m=1}^{M} IDFT\ \{X_m\} \qquad (3)$$

Each sub-block x is multiplied by phase factors and combined to create a set of candidates. The candidate with the lowest PAPR is chosen for transmission. After combination, the time domain signal is given by

$$x = \sum_{m=1}^{M} b_m x_m \quad (4)$$

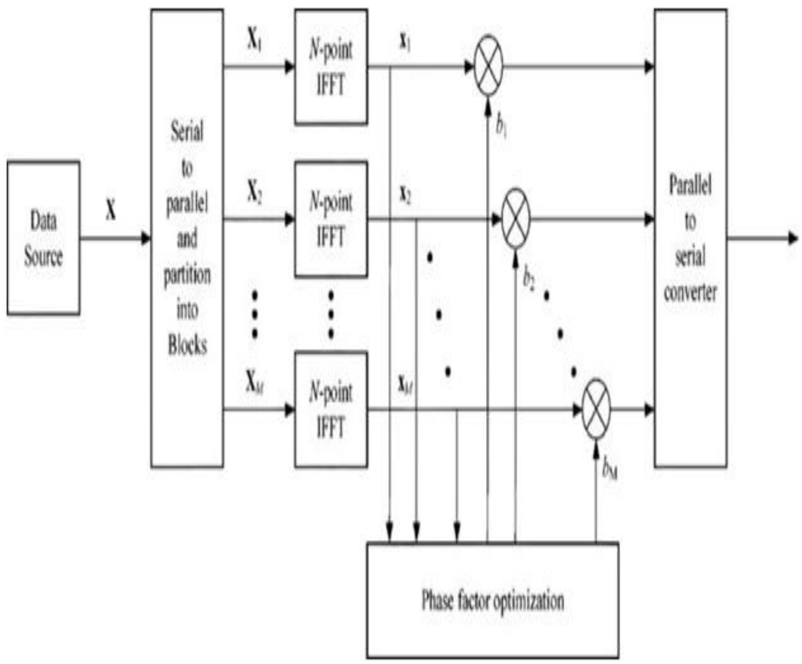

Figure 3. PTS scheme for PAPR reduction in OFDM Systems

1.2.Alamouti STBC

Alamouti in the year 1998 paper [8] offers a simple method for achieving spatial diversity with two transmit antennas and known as spatial time block codes (STBC). The scheme is as follows:

1. Let us consider we have a transmission sequence say $\{X_1, X_2, X_3, \ldots\ldots\ldots, X_m\}$
2. Typically during the transmission, we will be sending X_1 in the first time slot, X_2in the second time slot, X_3, and so on.
3. However, Alamouti suggested that we group the symbols into groups of two. In the first time slot, send X_1 and X_2 from the first and second antenna. In the second time slot send -X_2^* and X_1^* from the first and second antenna. In the third time slot send X_3 and X_4 from

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the first and second antenna. In the fourth time slot, send $-X_4^*$ and X_3^* from the first and second antenna and so on.

4. Notice that though we are grouping two symbols, we still need two-time slots to send two symbols. Hence, there is no change in the data rate.

5. This forms the simple explanation of the transmission scheme with Alamouti Space Time Block coding.

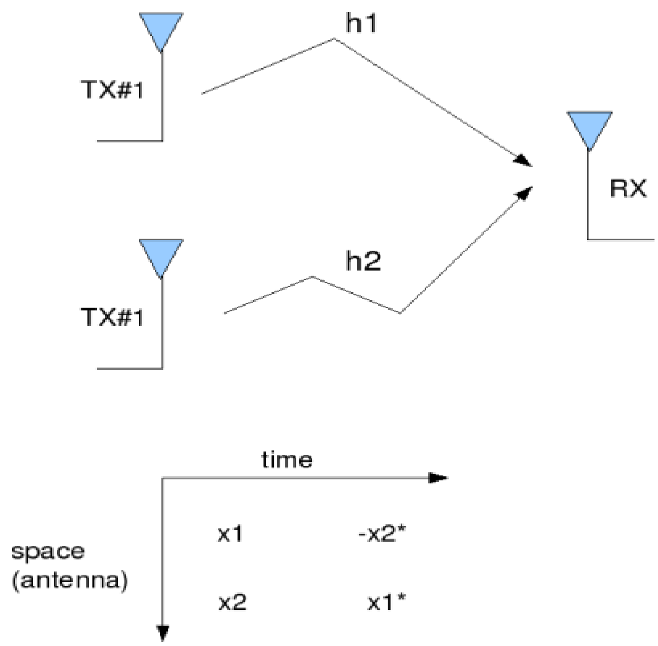

Figure 4: 2-Transmit, 1-Receive Alamouti STBC coding

II. Proposed PAPR Reduction System

Highly correlated data frames of OFDM signals have large PAPRs, which could be reduced if the long correlation patterns are broken down. A set of fixed permutations (interleaving) is used in OFDM to break these correlation patterns. Some of the existing single-antenna PAPR reduction based modified PTS with interleaving technique is extended to MIMO-OFDM systems. Interleaving is used to produce permuted data blocks from the same data block. The PAPR of (K-1) permuted data blocks and that of the original data block with the lowest PAPR is then chosen for MIMO-OFDM transmission. The uniqueness of the corresponding interleaver is also sent to the receiver as side information. Hence the interleaving method is simple to implement and reduces the transmitter complexity when compared with the PTS scheme. If all the K, PAPR computations are done simultaneously and the lowest PAPR sequence is selected in one step, the processing delay at the transmitter is significantly reduced. Therefore, it can also be used with high-speed data transmissions.

Interleaved MIMO-OFDM is also feasible for spectrum monitoring. Since subcarriers of one sub block are equally spaced, their frequency locations can be determined by capturing one subcarrier with the knowledge of system parameters. Users can monitor the radioactivity on one sub block by sensing only one or two subcarriers of the sub block instead of all the subcarriers across the whole frequency band. Interleaving can be used to combat the effect of noise bursts and fading in error correction systems. By interleaving a data frame, the peaks in the associated OFDM signal can be compressed. The entire process of proposed PAPR reduction system is depicted in Figure 5.

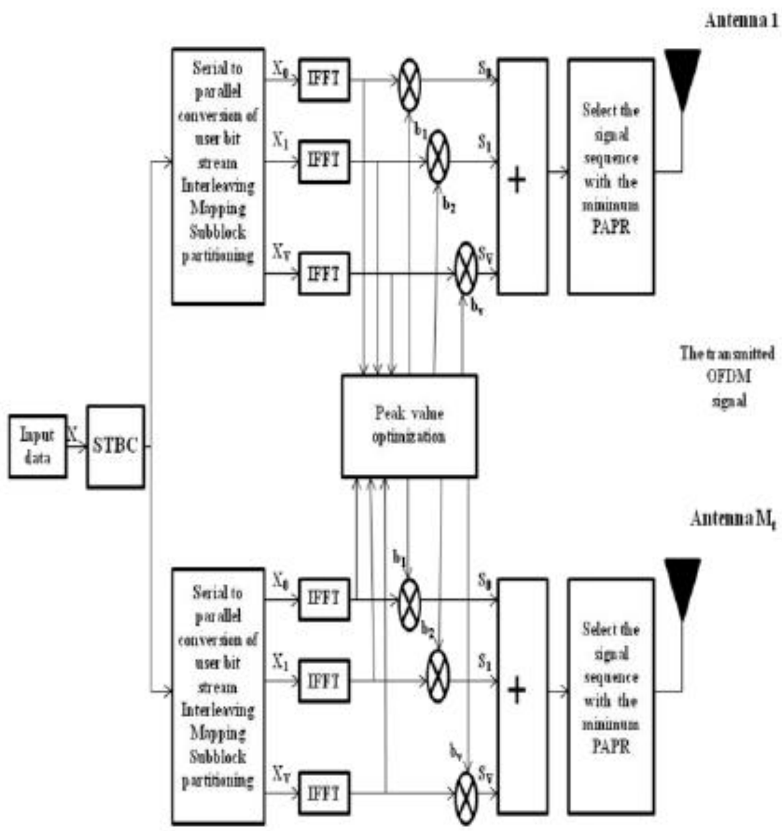

Figure 5: Block diagram of the proposed PTS with STBC and interleaved scheme

III. Experimental Results

In this section, we are assessing the PAPR performance of the proposed PAPR reduction technique. Table 1 represents the simulation parameters.

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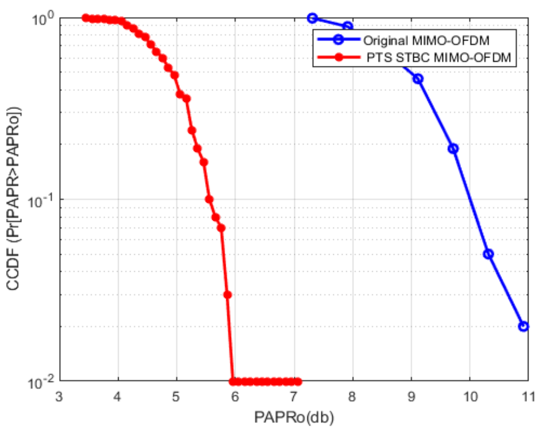
System Metrics	Value
Number of subcarriers (N)	64, 128, 256, 512,1024
Modulation type	QPSK
Phase rotations	(1, j, -1, -j)
Overlapping Factor (OF)	2,4
Subblock partition scheme	Interleaving
Number of subblocks	2,4,8,16
Number of transmitting antennas	2



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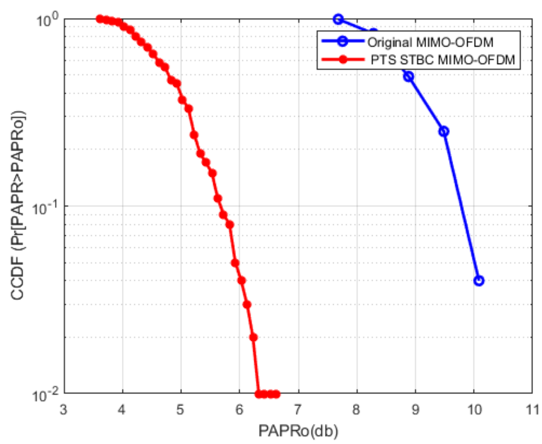

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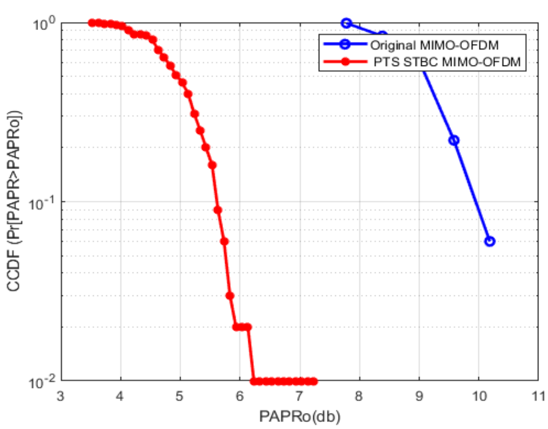

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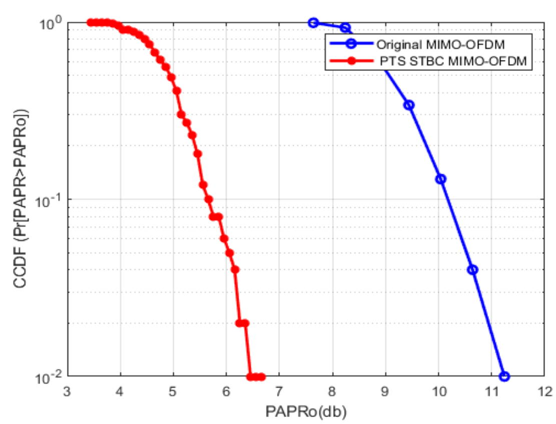

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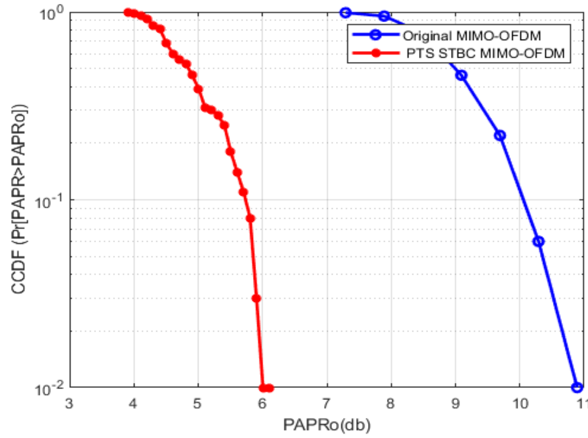
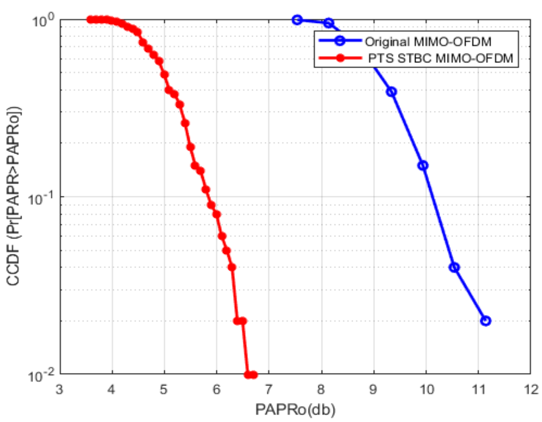


(e)

Figure 6: PTS-OFDM, and PTS-STBC based OFDM PAPR performance : (a) N=64, OF=2; (b) N=128, OF=2; (c) N=256, OF=2; (d) N=512, OF=2; (e) N=1024, OF=2



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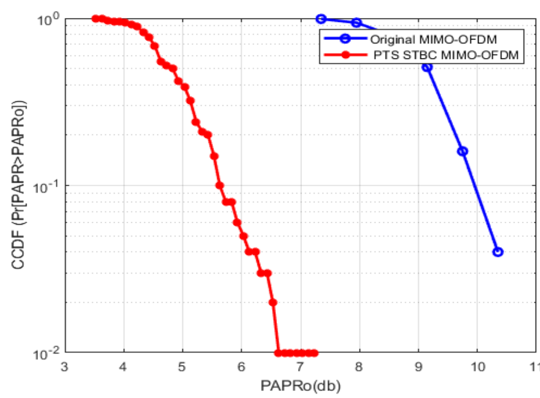

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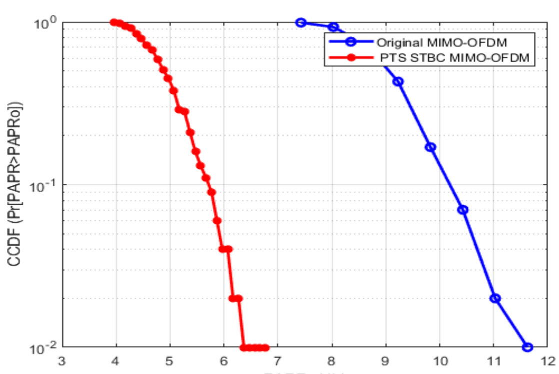

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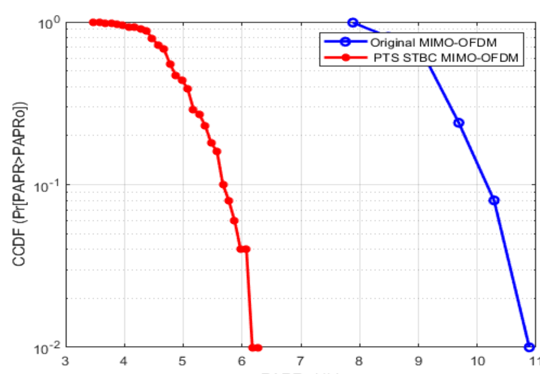

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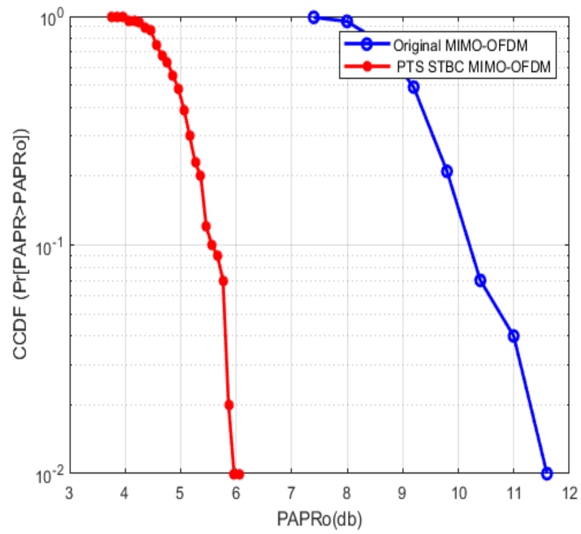
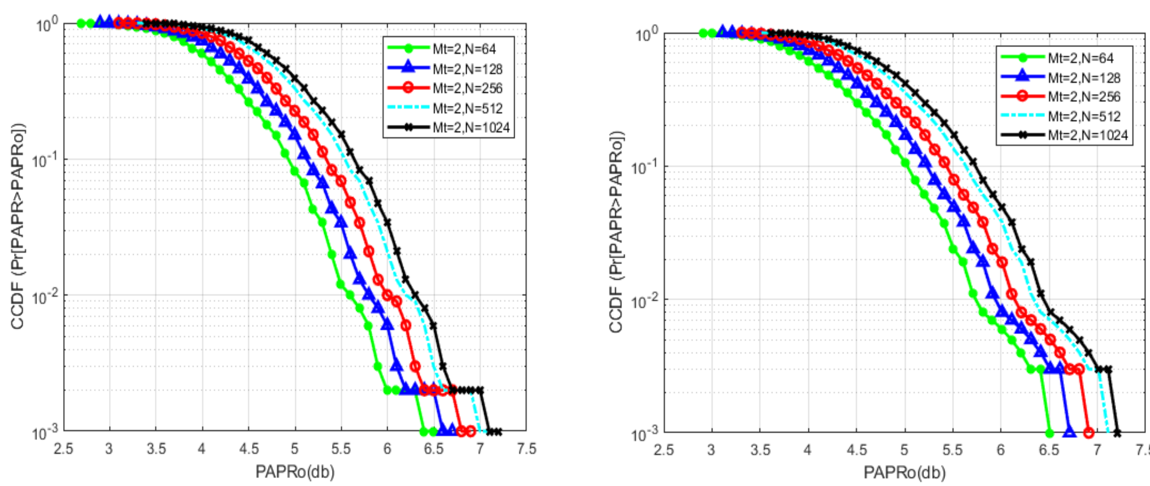


(e)

Figure 7: PTS-OFDM and PTS-STBC based OFDM PAPR performance: (a) N=64, OF=4; (b) N=128, OF=4; (c) N=256, OF=4; (d) N=512, OF=4; (e) N=1024, OF=4



(a) (b)

Figure 8: PAPR reduction performance for different number of subcarriers N= 64, 128, 256, 512, and 1024 when (a)OF=2 and Mt=2 ; (b) OF=4and Mt=2

The PAPR Reduction performance of the suggested PTS based STBC and interleaving technique is compared with the conventional PTS based OFDM system in Figures 6 and 7 with N= 64, 128, 256, 512 and 1024 with OF =2, and 4. These results represent that PTS with STBC and interleaver is given superior performance than traditional PTS based OFDM.

IV. Conclusion

This work suggested a PTS with interleaving and STBC method to minimize the peak-to-average power ratio for MIMO-OFDM system. The technique avoids the use of any extra Inverse Fast Fourier Transformations (IFFTs) as was done in PAPR reduction by ordinary PTS technique but instead is based on a proper selection of the different subcarriers and sub blocks. The performance of the suggested PTS with interleaving and STBC and was compared with the traditional PTS based OFDM systems. From the simulation analysis, we observed that the suggested approach is performed well when compared to the classicalPTS based OFDM system.

References

[1] L.J.Cimini, Jr, "Analysis and Simulation of a Digital Mobile Channel using OFDM", IEEETrans. On Communications, vol.Com-33, no.7, pp.665-675, July 1985.

[2] R.V.Paiement, "Evaluation of Single Carrier and Multicarrier Modulation Techniques for Digital ATV Terrestrial Broadcasting CRC Rep", Ottawa, ON, Canada, CRC-RP-004, 1994.

[3] T.de.Couasnon, et al, "OFDM for Digital TV Broadcasting", Signal Processing, vol.39, pp.1-32, 1994.

[4] X. Li and L. J. Cimini, Jr., "Effects of clipping and filtering on the performance of OFDM," IEEE Commun. Lett. vol. 2, no. 5, pp. 131–133, May 1998.

[5] X. B. Wang, T. T. Tjhung, and C. S. Ng, "Reduction of peak-to-average power ratio of OFDM system using a companding technique," IEEETrans. Broadcast. vol. 45, no. 3, pp. 303–307, Sep. 1999.

[6] C. P. Li, S. H. Wang, and C. L. Wang, "Novel low-complexity SLM schemes for PAPR reduction in OFDM systems," IEEE Trans. Signal Process., vol. 58, no. 5, pp. 2916–2921, May 2010.

[7] Chen, Jung-Chieh. "Partial transmits sequences for peak-to-average power ratio reduction of OFDM signals with the cross-entropy method." *IEEE signal processing Letters* 16.6 (2009): 545-548.

[8] Alamouti, Siavash M. "A simple transmit diversity technique for wireless communications." *IEEE Journal on selected areas in communications* 16.8 (1998): 1451-1458.