PAPR Reduction in MIMO OFDM System Using ZCT Technique

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Abstract: ***An Arrangement of using OFDM system with space time block coded - multiple input multiple output (STBC-MIMO) System provides excellent performance against Multi-path effects and frequency selective fading. However, one of the major drawback of MIMO-OFDM have high peak-to-average power ratio (PAPR) in order to the signals transmittted on different antennas. In this paper, we propose Zadoff-Chu matrix Transform (ZCT) technique to reduce the peak-to-average power ratio (PAPR) with precoding and postcoding Alamouti STBC MIMO-OFDM system. To reduce the high PAPR, BPSK modulation techniques is used for different values of N(64,128,256) .Our proposed work shows that ZCT POSTCODED based STBC MIMO-OFDM SYSTEM has the lowest PAPR performance compared to ZCT PRECODED based STBC MIMO-OFDM SYSTEM. MATLAB simulation shows that the performance of the proposed algorithm significantly improves the PAPR reduction.***

Keywords: MIMO, OFDM, PAPR, STBC, ZCT

1. Introduction

MIMO-OFDM improves the data rate (bits per second) and quality of signals so that the better quality of service can be achieved. In multicarrier system, there are different subcarriers that may be out of phase with each other and that subcarrier may be having extreme amplitude that passes through the transmitted signal. Due to multicarrier system, the peak value of system can be as high as compare to average value of whole system. This ratio of peak to average power value is called as Peak to average power ratio (PAPR). There are many techniques used to reduce the PAPR of MIMO-OFDM system that are Clipping and filtering , Selected mapping(SLM), Zadoff-Chu transform (ZCT). Zadoff-Chu sequence provides constant amplitude output signal with optimum correlation properties and reducing the cost and complexity of output signal [2]. In this paper, we propose to use the property of space-time block coded (STBC) in Alamouti MIMO-OFDM system. The main idea of Alamouti STBC MIMO-OFDM system is that the conjugate symbols transmitted on two antennas that have same property[8]. In this paper,ZCT Precoded technique is used for PAPR reduction in Alamouti STBC MIMO OFDM system and we compare our result with ZCT Postcoded Alamouti STBC MIMO OFDM.

2. MIMO OFDM System and PAPR

2.1 ALAMOUTI STBC MIMO-OFDM SYSTEM

Fig.1 illustrates the basic block diagram of a Alamouti STBC MIMO-OFDM system. The input data is passed through Mapper which modulates the signal. Modulated baseband symbols are passed through serial-to-parallel (S/P) converter which generates complex vector of size N and can be expressed as $S_k = [S_1, S_1, \dots, S_N]^T$.The Complex vector S_k is then passed through the space time block code encoder which generates two sequences for 1st and 2nd antenna respectively:

$$S_1 = [s_1, -s_2^*, s_3, -s_4^*, \dots\dots\dots, s_{N-1}, -s_N^*]$$
$$S_2 = [s_2, s_1^*, s_4, s_3^*, \dots\dots\dots, s_N, s_{N-1}^*]$$

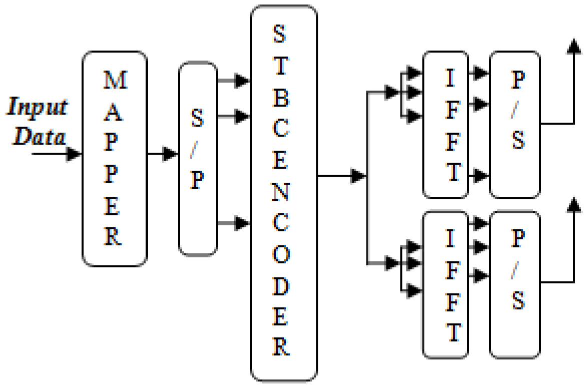

Figure 1: Block diagram of Alamouti STBC MIMO- OFDM system

Where S_k be the transmitted modulated MIMO OFDM symbol of the i^{th} transmitting antenna at the k^{th}subcarrier. Both of these sequences are then passed through each IFFT block for antenna 1 and antenna 2 respectively which convert the frequency domain signal in to time domain signal which is converted into parallel form by using S/P Converter, then we will perform its IFFT. The Output of IFFT gives the time domain MIMO-OFDM symbols, which are converted into serial data streams through P/S converter. The Cyclic Prefix (CP) or Guard Interval is a periodic extension of the last part of an OFDM symbol that is added to the front of the symbol in the transmitter. Finally the output of CP is passes through the transmitter with different transmission period.Alamouti MIMO OFDM signal for antenna i can be written as:

$$s_i(t) = \frac{1}{\sqrt{N}} \sum_{k=1}^{N} S_m(k) e^{j2\pi f_n t} \quad (1)$$

Where $f_n = n\Delta f, n = 1,2,\dots,N$, where $\Delta f = \frac{1}{NT}$, T is the symbol period and $k = 1,2,\dots,N, i = 1,2$ and $j = \sqrt{-1}$ above Eq. becomes:

$$s_i(t) = \frac{1}{\sqrt{N}} \sum_{k=1}^{N} S_i(k) e^{j2\pi n \frac{k}{NT} t} \quad (2)$$

The PAPR of the signal $s_i(t)$ is defined as the ratio of the peak instantaneous power to average power of an OFDM symbol is
written as:

$$PAPR = \frac{\max_{0 \le t \le NT} |s_i(t)|^2}{E[|s_i(t)^2|]} \quad (3)$$

Where E[·] is the expectation operator. Complementary Cumulative Distribution Function (CCDF), calculate the probability of PAPR of an OFDM signal exceeds a given threshold. In MIMO OFDM, the probability of MN-OFDM symbol over all M transmit antenna as:

$$CCDF = Prob[PAPR > PAPR_0] = 1 - (1 - e^{-PAPR_0})^{MN} \quad (4)$$

2.2 Zadoff-Chu Sequences And Zadoff-Chu Transform (ZCT)

Zadoff-Chu sequences are class complex-valued sequence and having optimum correlation properties. Zadoff-Chu sequences have constant magnitude and an ideal periodic autocorrelation [2, 10] .Mathematically, Zadoff–Chu sequences can be defined for a sequence of length L as:

$$a_n = \begin{cases} e^{\frac{j2\pi r}{N}\left(\frac{k^2}{2}+qk\right)} & for\ N\ even \\ e^{\frac{j2\pi r}{N}\left(\frac{k(k+1)}{2}+qk\right)} & for\ N\ odd \end{cases} \quad (5)$$

Where $k = 0,1,\dots,N-1$, q is any integer, r is any integer relatively prime to N and j=$\sqrt{-1}$. Zadoff-Chu matrix transform (A) is of size $N = L\times L$ is obtained by reshaping the ZC sequence with $k = m + lL$ as written below:

$$A = \begin{bmatrix} a_{00} & a_{01} & \cdots & a_{0(L-1)} \\ a_{10} & a_{11} & \cdots & a_{1(L-1)} \\ \vdots & \vdots & \ddots & \vdots \\ a_{(L-1)0} & a_{(L-1)1} & \cdots & a_{(L-1)(L-1)} \end{bmatrix} \quad (6)$$

Here,
m = row variable and l = column Variable.

3. Proposed Model

3.1 ZCT BASED PRECODED ALAMOUTI STBC MIMO OFDM (ZCT-MIMO-OFDM) SYSTEM

Fig.2 shows the block diagram of ZCT based Precoded Alamouti STBC MIMO OFDM system. In the ZCT based Precoded Alamouti STBC MIMO-OFDM system, the modulated data is passed through the S/P converter which generates a complex vector of size N that can be written as $S_k = [S_1, S_2, \dots, S_L]^T$. The complex vector S_k is passed through STBC encoder which generates two sequences (S_1 and S_2), for antenna 1and 2.

$$S_1 = [s_1, -s_2^*, s_3, -s_4^*, \dots, s_{L-1}, -s_L^*]$$

$$S_2 - [s_2, s_1^*, s_4, s_3^*, \dots, s_L, s_{L-1}^*]$$

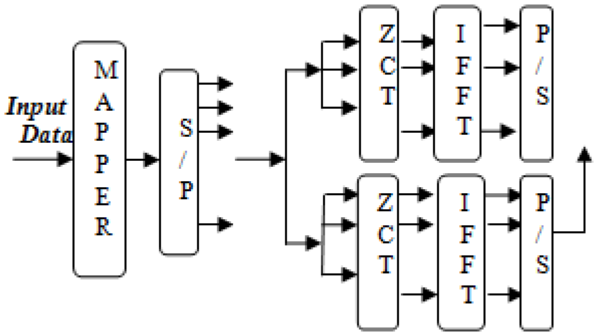

Figure 2: Block diagram of ZCT Precoded based Alamouti STBC MIMO- OFDM system

These two generated sequences are then applied to the Zadoff- Chu Transform in this system, A matrix of dimension $N = A \times A$ is applied to the symbols after the STBC encoding then IFFT is used to reduce the PAPR. Subsequently, ZCT matrix is applied to this complex vector which transforms this complex vector into a new vector of length L that can be written as, $Y = AS_i = [Y_0, Y_1, \dots, Y_{L-1}]^T$, where A is ZCT matrix of size $N = L \times L$ and $Y_{m,i}$ can be written as:-

$$Y_{i,m} = \sum_{l=1}^{L} a_{m,l} \cdot S_{i,l}, \quad m = 1,2,\dots,L \ and\ i = 1,2 \quad (7)$$

$a_{m,l}$ means m^{th} row and l^{th} column of precoder matrix. Expanding Eq.(26), using row wise sequence $k = mL + l$ and putting $q = 0$ and $r = 1$ in Eq.(5) we get:

$$Y_{i,m} = \sum_{l=1}^{L} \left(e^{j\frac{\pi(mL+l)^2}{L^2}} \right) \cdot S_{i,l}, \quad m = 1,2,\dots,L \ and\ i = 1,2 \quad (8)$$

The complex baseband ZCMT Alamouti MIMO OFDM signal for antenna I with N subcarriers can be written as:

$$s_{i,n} = \frac{1}{\sqrt{L}} \sum_{m=1}^{L} Y_{i,m}\, e^{j2\pi \frac{n}{L} m}, \quad n = 1,2 \dots, L \quad (9)$$

The PAPR of ZCT OFDM signal can be written as:

$$PAPR = \frac{\max[|s_{i,n}|^2]}{E[|s_{i,n}|^2]} \quad (10)$$

3.2 ZCT BASED POSTCODED ALAMOUTI STBC MIMO OFDM (ZCT-MIMO-OFDM) SYSTEM

Fig.3 shows the block diagram of ZCT based Postcoded Alamouti STBC MIMO OFDM system. In the ZCT based Postcoded Alamouti STBC MIMO-OFDM system, the modulated data is passed through the S/P converter which generates a complex vector of size N that can be written as $S_k = [S_1, S_2, \dots, S_L]^T$.
Then S_k is passed through STBC encoder which creates two sequences, for antenna 1and 2.

$$S_1 = [s_1, -s_2^*, s_3, -s_4^*, \dots, s_{L-1}, -s_L^*]$$

$$S_2 = [s_2, s_1^*, s_4, s_3^*, \dots, s_L, s_{L-1}^*]$$

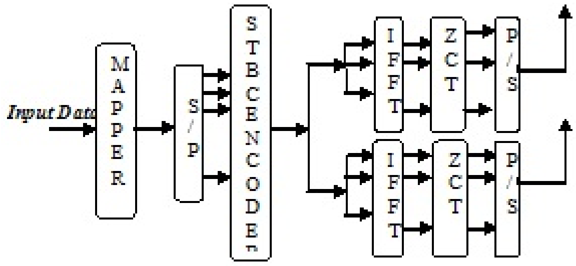

Figure 3: Block diagram of ZCT Postcoded based Alamouti STBC MIMO- OFDM system

These two generated sequences are then applied to the IFFT then Zadoff- Chu Transform in this system, which is A matrix of dimension $N = A \times A$ i.e. applied to the symbols after the STBC encoding and IFFT then it reduces the PAPR. Subsequently, ZCT matrix transforms this complex vector into a new vector that can be can be written as:-

$$X_{i,m} = \frac{1}{\sqrt{L}} \sum_{l=1}^{L} S_{i,l} \cdot e^{j2\pi \frac{n}{L} m}, m = 1,2 \ldots N, n = 1,2, \ldots N \text{ and } i = 1,2 \quad (11)$$

$a_{m,l}$ means m^{th} row and l^{th} column of matrix Expanding Eq.(11), using row wise sequence $k = mL + l$ and putting $q = 0$ and $r = 1$ in Eq.(5).The complex baseband ZCMT Alamouti MIMO OFDM signal for antenna I with N subcarriers can be written as:

$$S_{i,m} = \frac{1}{\sqrt{L}} \sum_{l=1}^{L} \sum_{m=1}^{L} e^{j\pi \frac{(mL+l)^2}{L^2}} \cdot e^{j2\pi \frac{n}{L} m} \cdot S_{i,l} \quad (12)$$

The PAPR value of ZCT postcoded based signal can be written as:

$$PAPR = \frac{MAX[|s_{i,m}|^2]}{E[|s_{i,m}|^2]} \quad (13)$$

4. Result

In this section, we presents the simulation result of OFDM and STBC MIMO-OFDM System with Zadoff chu transform.To show the PAPR analysis of the proposed system, we randomly generates the data which is modulated by BPSK Modulation Technique and we take different number of subcarriers (N). We evaluate the PAPR statistically by using complementary cumulative distribution function (CCDF). Figure 4,5,6 shows the CCDF comparison of PAPR of ZCT based precoded MIMO-OFDM system with ZCT based postcoded MIMO-OFDM system for N = 64,128,256.

Table 1: System Parameters

SYSTEM	PAPR OF ZCT POSTCODING BASED STBC MIMO–OFDM SYSTEM (DB)	PAPR OF ZCT PRECODING BASED STBC MIMO–OFDM SYSTEM (DB)
N = 64	5.2	7.4
N = 128	5.4	7.7
N = 256	5.7	8.0

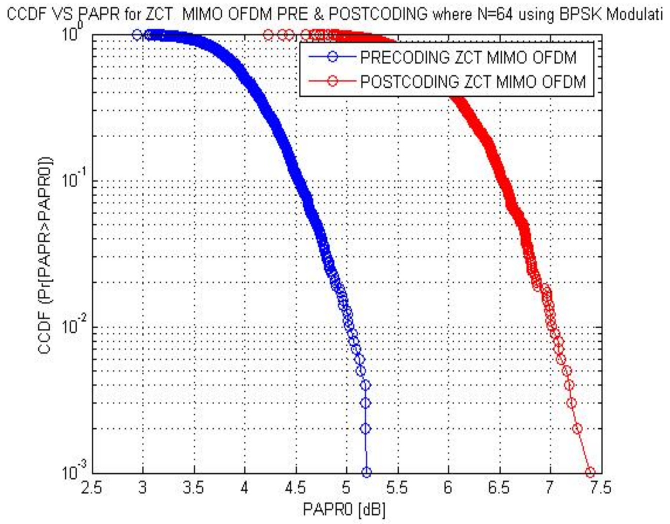

Figure 4: CCDF versus PAPR for N =64

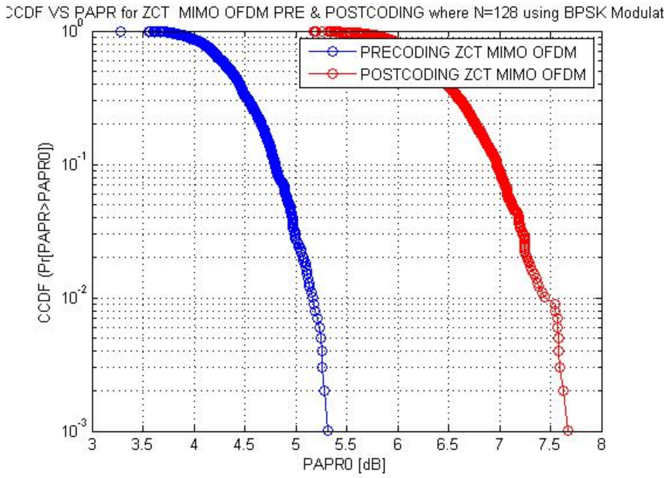

Figure 5: CCDF versus PAPR for N= 128

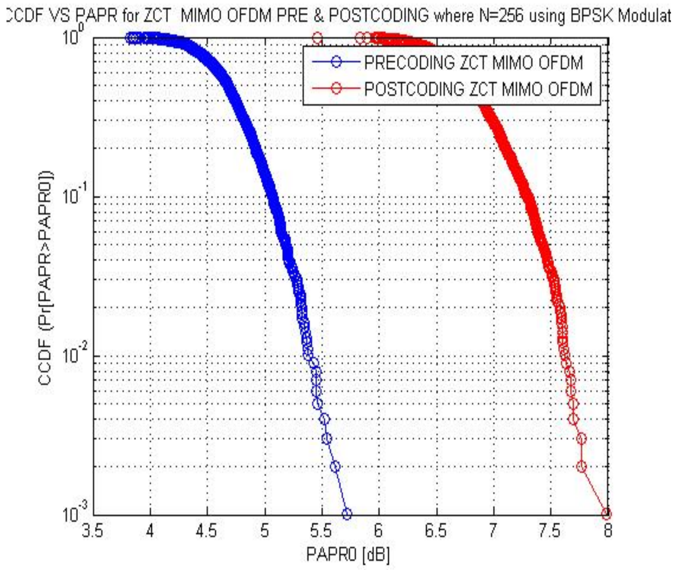

Figure 6: CCDF versus PAPR for N=256

5. Conclusion

In this paper, we present an analysis of the PAPR for the ZCT Precoded based Alamouti STBC MIMO OFDM system and compare this with ZCT Postcoded Alamouti STBC MIMO OFDM.Simulation results have shown that the ZCT Postcoded Alamouti STBC MIMO OFDM system has lower PAPR then ZCT Precoded Alamouti STBC MIMO OFDM. Hence, it can be concluded that the ZCT Postcoded based STBC MIMO-OFDM system is more favourable. The ZCT MIMO-OFDM system does not require any complex optimization and side information to be sent for the receiver. Additionally, this system also takes advantage of the frequency variations of the communication channel and provides substantial performance in fading multipath channels.

6. Future Scope

One of the major drawback of MIMO-OFDM have high peak-to-average power ratio (PAPR) in order to the signals transmittted on different antennas. Here we use ZCT based Alamouti STBC MIMO OFDM system that reduces the PAPR similarly we can be designed MIMO-OFDM by using 2X2, 3X3 transmitting and receiving system respectively and analyze the PAPR performance.

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