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Reduction of PAPR and Efficient detection ordering scheme for MIMO Transmission Systems Using Power Control

V.Sreevani[1], K.Suma[2]
Department of Electronics and communications Engineering. G.I.E.T
Department of Digital Electronics Engineering, G.I.E.T

Abstract
The technical challenges for communication engineers is the development of best performance wireless networks with negligible amount of distortions. We have to consider multipath propagation attenuation and radio spectrum inefficiency. Now a days, In MIMO (Multi Input Multi Output) systems there is a huge demand for the networks with the high transmission rates and better quality of service which are having low PAPR ratio. Instead of OFDMA, filter banks are used in massive MIMO to reduce the complexity. But they are error prone to noise. This base paper discusses about PAPR reduction in MIMO systems using different precoding based OFDM systems. Mainly, minimization of multi-antenna systems by controlling the transmission power and reduction of PAPR using ZC (Zadoff-Chu) matrix transform.
Keywords: OFDM, Peak-to-average power ratio

I. Introduction

Filter banks used in massive MIMO to reduce the complexity are error prone to noise [1].MIMO can be implemented efficiently using OFDM [2].

Due to the robustness against narrowband interference, good spectral efficiency, improved sevice quality and frequency selective fading, OFDM became the technology of choice in wired and wireless digital communication systems for the next generation [4]. OFDM stands for Orthogonal Frequency Division Multiplexing. It is a multicarrier transmission scheme. By using a Cyclic Prefix (CP), a Guard interval (GI) is inserted so that OFDM can withstand to Inter symbol interference. Using a simple equalizer OFDM moderates the frequency selectivity of the multipath channel [5]. Asymmetric digital subscriber line (ADSL) uses OFDM technology. In various communication standards like DVB (Digital Video Broadcasting), DAD (Digital Audio Broadcasting) and even in the networks beyond 3G

The biggest disadvantage in Orthogonal Frequency Division Multiplexed signal is the peak-to-average power ratio[3]. In the literature many number of reduction techniques for PAPR have been proposed. [7]- [12]. However, precoding techniques are simple linear techniqus because they does not require any additional information. This paper consists the presentatation of a PAPR reduction using the ZCT-ROFDM (Zadoff-Chumatrix Transform Row-wise precoder based OFDM) system with RRC(Root Raised Cosine) pulse shaping and comparision with other precoding based OFDM systems. The efficient detection ordering scheme for multi input- multi output transmission systems using

power control is proposed and verified using Matlab and the results are analyzed.

The remaining portions of this paper are categorized as follows: the description of section II is basics of OFDM, PAR or PAPR, and ZCT method. System model, ZCT precoded OFDM (ZCT-OFDM) system[11] and ordering scheme are presented in section III and simulation results are presented in section IV and conclusion of the paper is presented in section V.

II. OFDM & ZCT

Because of their great potential of enhancing the system's performance, the utilization of MIMO (multiple-input multiple-output) systems became an active area of research as well as practical transceiver implementations for.
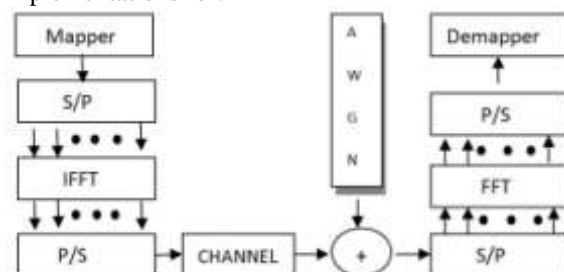

Fig 1: A conventional OFDM system

The block diagram of conventional OFDM system is showned in fig (1).The input to the serial to parallel converter is the baseband modulated symbols from mapper. It generates a complex vector of size N.It is written as $X=[X_0,X_1,X_2,.......X_{N-1}]^T$ .Then it is passed through IFFFT block to generate complex

baseband OFDM signal which has N subcarriers.It is given by

$$X_n = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X_{k.} \, e^{j2\pi\frac{n}{N}k} \qquad \text{...} \qquad \text{Eq(1)}$$

Where n=0,1,2…..N-1
The PAPR for the above system can be defined as follows

$$\text{PAPR} = \frac{\max[|x_n|^2]}{E[|x_n|^2]} \qquad\qquad \text{Eq-(2)}$$

Where E [.] indicates the expectation.
It helps in band radiation.

By filling ZCT kernel row-wise or alternatively column wise, the ZCTs are obtained from ZC(Zadoff-Chu) sequences . Column wise filling give rise 7.8 dB at clip rate of 10-3 while Row-wise filling gives rise to CE-OFDM (Constant Envelope OFDM) system with 0 dB PAPR, with system subcarriers for QPSK modulation or any modulation depending upon the type of communication.

Constant Envelope OFDM (orthogonal frequency division multiplexing) systems helps to keep in band radiation with the help of pulse shaping and the PAPR are not a constant zero db .In this paper we show PAPR analysis of several pre-coding based OFDM techniques with the popular Rout Raised Cosine(RRC) pulse shaping. The simulation results shows that ZCT row wise pre-coder OFDM(ZCT-R-OFDM) system has lowered PAPR then the ZCT Column-wise pre-coder based OFDM (ZCT-C-OFDM)system, the hardward transform pre-coder based OFDM (WHT-OFDM) systems and the conventional OFDM systems.

We can derive the ordering of the system from the convexity of the function. From the ordering of the system we can get converge to the geometric mean. The use of the geometric mean is to maintain the constant threshold, and also ordering of the algorithm is derived from the geometric mean. For this modified scheme of employing adaptive threshold technique is developed by correlation among the ordering result. The simultaneous results are obtained by the theoretical analysis. QR-decomposition not only require reduced computational complexity when we compared to the conventional scheme. Due to this error performance is improved in result.

III. SYSTEM MODEL
A.ZC Sequences and ZCT (Zadoff-chu Matrix Transform)

ZC (Zadoff-Chu) sequences have optimum correlation properties. They are class of poly phase sequences. ZC sequences have constant magnitude and an ideal periodic auto-correlation. According to [13], ZC sequences of length N can be defined as

$$a_n = \begin{cases} e^{\frac{j2\pi r}{N}\left(\frac{k(k+1)}{2}+qk\right)} & for\ N\ Odd \\ e^{\frac{j2\pi r}{N}\left(\frac{k^2}{2}+qk\right)} & for\ N\ Even \end{cases} \qquad \text{…3}$$

where $k = 0, 1, 2… N$-1, q is any integer, r is any integer relatively prime to N and $j=\sqrt{-1}$.
The kernel of the ZCT is defined in eqn(4),is obtained by reshaping the ZC sequence by k=mL+l as hereunder.

$$A = \begin{bmatrix} a_{00} & a_{01}.. & .a_{0L-1} \\ a_{10} & a_{11}.. & .a_{1L-1} \\ \vdots & & \vdots \\ a_{(L-1)0} & a_{(L-1)1}.. & a_{(L-1)(L-1)} \end{bmatrix} \qquad \text{...4}$$

Here l is the column variable and m is the row variable.In other words $N=L^2$ point long ZC sequence fills the kernel of the matrix rowwise.In this case PAPR reduces to 0dB[10].However the PAPR reduces to 7.8dB,it does not reduces to 0dB,if the kernel is filled columnwise[7].

B.OFDM system with ZCT precoding:

ZCT precoded OFDM system is showned in fig(2).Here,The ZCT kernel acts as a rowwise precoding matrix of A of dimensions N=L×L and it is applied to each symbol to reduce PAPR.The baseband modulated data is passed through S/P converter in the ZCT precoded OFDM system which generates a complex vector of size L. The complex vector can be written as
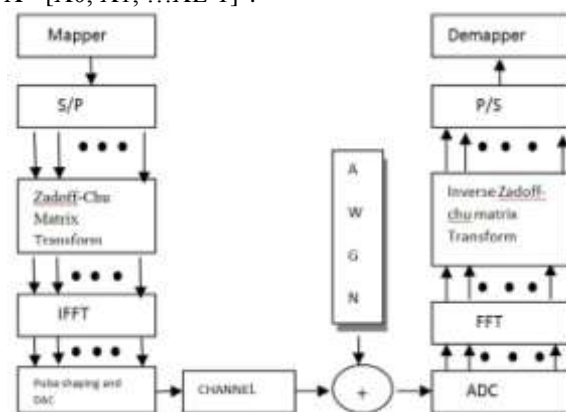X= [X0, X1, …XL-1]^T.

Fig 2: A ZCT precoded OFDM System

After that Zadoff Chu matrix transform precoding is applied to complex vector X.This precoding technique transforms the complex vector into a new vector with same length L.The new vector obtained by ZCT precoding with lenth L can be written as
Y=AX=[Y_0,Y_1,Y_2,.......Y_{L-1}]^T
Where A is a precoder matrix of size L× L
and y_m can be written as

$$Y_m = \sum_{l=0}^{L-1} a_{m,l}.X_l \quad , m = 0,1,..L-1 \qquad \text{......(5)}$$

Here $a_{m,l}$ indicates m[th] row and l[th] column.
The ZCT-R-OFDM complex baseband signal with L subcarriers is defined as

$$x_n = \frac{1}{\sqrt{L}} \sum_{m=0}^{L-1} Y_m.e^{j2\pi\frac{n}{L}m}, \qquad \text{................(6)}$$

where $n = 0,1,.....L$-1

After RRC(Root Raised Cosine)pulse shaping and D/A of n Samples ,the complex passband transmit signal x(t) of ZCT-R-OFDM can be written as

$$x(t) = e^{j w_c t} \sum_{n=0}^{L-1} x_n . r(t - n\breve{T}) \qquad \text{......(7)}$$

Here ω_c is the carrier frequency,r(t) is the baseband pulse and $\breve{T}$=after IFFT ,compressed symbol duration in seconds.
The definition of Root Raised Cosine filter is

$$r(t) = \frac{\sin(\frac{\pi t}{T}(1-\alpha)) + 4\alpha \frac{t}{T}\cos(\frac{\pi t}{T}(1+\alpha))}{\frac{\pi t}{T}(1 - \frac{16\alpha^2 t^2}{T^2})} \qquad \text{....(8)}$$

With pulse shaping the PAPR of the ZCT-R-OFDM is defined as

$$PAPR = \frac{\max_{0 \le t \le NT}[|x(t)|^2]}{\frac{1}{NT}\int_0^{NT}[|x(t)|^2]dt} \qquad \text{.........(9)}$$

without pulse shaping PAPR of ZCT-R-OFDM can be defined as

$$PAPR = \frac{\max_{n=0,1...,N-1}[|x_n|^2]}{\frac{1}{M}\sum_{n=0}^{N-1}[|x_n|^2]} \qquad \text{......(10)}$$

Assume that the number of transmit antennas isN_t and the number of receiving antennas is N_r in MIMO system. The $N_r X N_T$ matrix H with the element h_{ji} represents flat-fading MIMO channel. h_{ji} represents the channel gain from i^{th} transmit antenna to j^{th} receive antenna. The $N_r X1$ signal vector received $Y = [y1, ..., y_{Nr}]^T$ is written as

$$y = \sqrt{\frac{E_s}{N_t}} HP_x + n \qquad \text{----- (11)}$$

Where $X = [x1 ..., x_{Nr}]^T$ denotes $N_t X1$ the transmitted signal vector, and $n = [n1, ..., n_{N_r}]^T$ is the one–dimensional noise vector. In noise vector the elements follow complex zero mean Gaussian distribution with variance of σ_n^2. E_s is the total transmitted signal energy on transmit antennas and P = $\sqrt{N_t}$,diag($P_1, P_2, ...P N_t$) denotes the diagonal PA precoding matrix.

An$(N_r + N_t)X N_t$augmented channel matrix $\overline{H}$,$(N_r + N_t)X 1$ an extended receive vector $\overline{y}$ and$N_t X 1$ an zero matrix$0_{N_{t,1}}$,to express the signal model for the MMSE-QR detector, is given by

$$\overline{H} = \begin{bmatrix} H \\ \sigma_n I_{N_t} \end{bmatrix} \xrightarrow{ordering} \overline{Q} \, \overline{R} \text{ and } \overline{y} = \begin{bmatrix} y \\ 0_{N_t,1} \end{bmatrix} \text{ --}$$
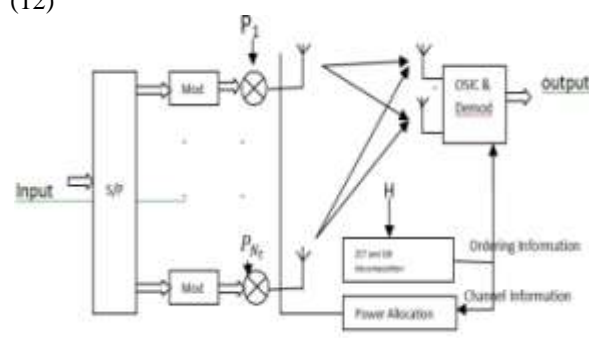(12)

Fig 3: MIMO Transmission model with QR OSIC and ZCT Decoder

The detection-order defines the upper triangular matrix$\overline{R}$ differently which determines the post detection SINR ρ_k and SNR of the data stream is given as

$$\rho_k = \frac{E_s}{\sigma_n^2} P_k^2 \overline{R_{k,k}^2} - 1, \quad k = 1,2,.....,N_t \text{ ....(13)}$$

Using the architecture shown in Fig.3 ,The BER-minimized PA transmission using QR-decomposition based ZCT-OSIC detection can be performed. Transmission power P_k is assigned to each data stream based on the feedback information of the diagonal elements$\overline{R}_{k,k}$.Through a diagonal PA matrix, the independently encoded symbols are processed and then they are transmitted from N_t data streams. According to the designated detection-order, The QR-OSIC receiver detects the transmit symbols sequentially.

TABLE 1:
**Proposed Detection Ordering Algorithm**

| Step	Operation for each step
1.	$\overline{R} \equiv 0_{N_t}, \overline{Q} \equiv \overline{H}$,k={1,2,3....N_t) , $\mu_1 = \mu$
2.	For i=1,2,3…N_t
3.	$\tau_i = \left\| \overline{Q}_{:,i} \right\|^2$
4.	End
5.	For l=1,2,3…N_t
6.	$K_l = \arg \min_\omega \left| \sqrt{\tau_\omega} - \mu_l \right|$
7.	Fixed : $\mu_{l+1} = \mu_l$, Adaptive: $\mu_{l+1} = \frac{\frac{N_{t-l+1}}{N_{t-l}}}{\sqrt{\frac{\mu_l}{\overline{R}_{l,l}^{N_{t-l+1}}}}}$
8.	$\overline{R}_{(:,l)} \longleftrightarrow \overline{R}_{(:,k_t)}, \tau_l \longleftrightarrow \tau_{k,l}$ K(l) $\longleftrightarrow$ k(k_l), $\overline{Q}_{(1:N_r - l+1,t)}$ $\longleftrightarrow$ $\overline{Q}_{(1:N_r - l+1,k_l)}$
9.	$\overline{R}_{(l,l)} = \sqrt{\tau_l}$
10.	$\overline{Q}_{(:,l)} = \frac{\overline{Q}_{(:,l)}}{\overline{R}_{(l,l)}}$
11	For m= l+1,…..N_t
12.	$\overline{R}_{(l,m)} = \overline{Q}_{(:,l)}^H . \overline{Q}_{(:,m)}$
13.	$\overline{Q}_{(:,m)} = \overline{Q}_{(:,m)} - \overline{R}_{(l,m)} . \overline{Q}_{(:,l)}$
14.	$\tau_m = \tau_m - \overline{R}_{(l,m)}^2$
15.	End
16.	End

IV. Simulation Results

In order to show the simulation results for PAPR analysis using ZCT-R-OFDM with RRC pulse shaping,input is randomly generated and then modulated by Quadrature phase shift keying(QPSK).All the simulation results are performed based on 10^5 random OFDM blocks. parameters of system:

1. system subcarriers:64,512
2. precoding techniques:WHT,ZCT
3. modulation technique:QPSK
4. Pulse shaping:RRC
5. Rolloff factor α for RRC:$\alpha = 0.22$
6. Oversampling factor=4

PAPR is evaluated stastically using complementary cumulative distributive function.The probability of PAPR exceeding the given threshold is CCDF=Prob(PAPR>$PAPR_O$)
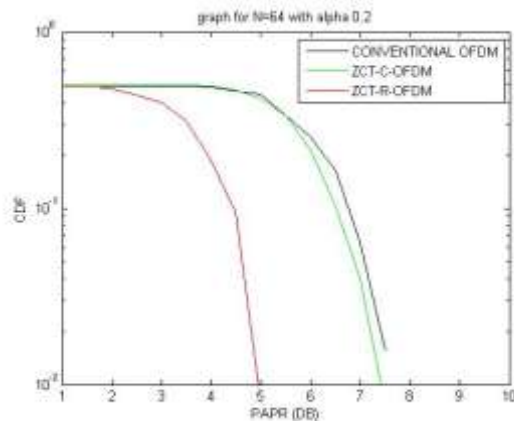
Result of ZCT over other conventional PAPR techniques with N=64,512 with alpha 0.2
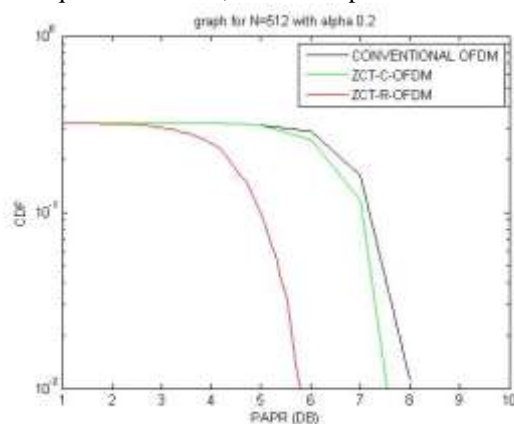
It is clear from the simulation results that the PAPR value of ZCT-R-OFDM is less when compared to other PAPR techniques even when the N value is increased/Decreased.

V. CONCLUSION

In this paper, we present a PAPR reduction using the ZCT-R-OFDM system for MIMO transmission with Root raised cosine pulse shaping. From the results and series of experiments conducted, we conclude that ZCT proves to be a better model among the other pre-coding techniques like WHT etc. in terms of PAPR. Another noticable fact is that, pulse shaping increases the PAPR of the ZCT-R-OFDM from 0dB to 5dB. Any power increase and complex optimization is not required in ZCT-R-OFDM system

and no need to send any additional information to the receiver. In addition, this system offer substantial performance gain in fading multipath channels.It is sufficient to confirm the superiority of the proposed design because the ordering algorithm of previous studies comply with the stategy of the B-OSIC (Ordered Successive Inerference Cancellation) [14]-[16].It also take advantage of the frequency variations of the communication channel and Performing ZCT-QR decomposition based OSIC detection made it more eligible for transmission.

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