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On PAPR and CQI mismatch of non-unitary precoding

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Abstract: To clarify some concerns on non-unitary precoding regarding PAPR, CQI mismatch and variance of inter-cell interference, corresponding simulations are included. Firstly, it is shown that the non-unitary precoding and amplitude uniformity of the precoding vector (matrix) has no impact on PAPR. In other words, PAPR should not be an issue to differentiate between unitary and non-unitary precoding. Secondly, it is shown that the CQI mismatch of non-unitary precoding is rather trivial. With a proper codebook design, existing CQI estimation of non-unitary precoding is sound. Thirdly, the variances of inter-cell interference (ICI) associated with unitary and non-unitary precoding are investigated. Simulations show that the variances of ICI corresponding to unitary and non-unitary precoding are almost identical.

I. PAPR

The peak value s_m is defined such that the probability of the signal power greater than s_m equals to p_0 .

$$\Pr\{S_n \geq s_m\} = p_0$$

As a result, PAPR is defined by $PAPR = 10 \log_{10} \left(\frac{s_m}{E\{S_n\}} \right)$.

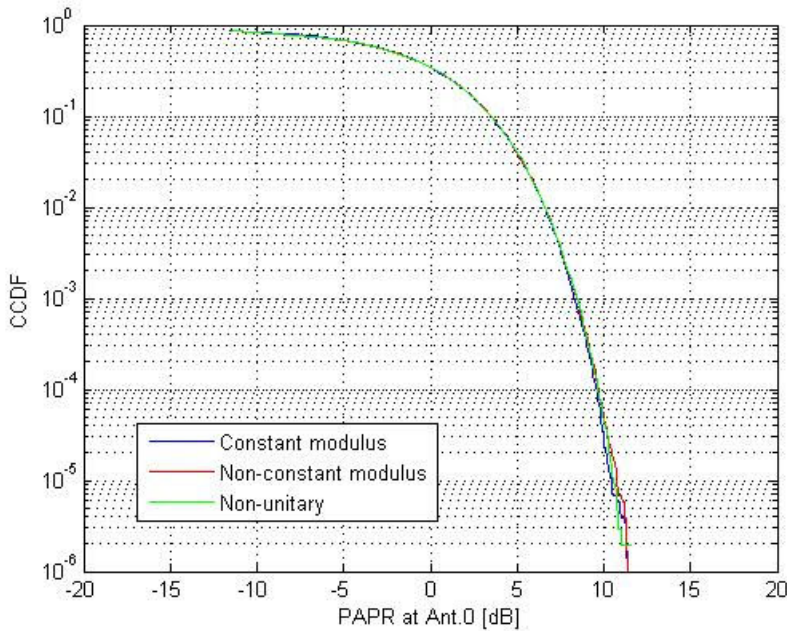


Figure 1: PAPR comparison

Simulation Parameters	
Number of transmit antenna	4
FFT size	1024
RB size	1 precoding vector per 72 subcarriers
Modulation	QPSK
Codebook	Uniform amplitude: 4 bits LTE Unbalanced amplitude: V(4,1,6) in Wimax

It is clearly shown in Fig. 1 that the amplitude uniformity of precoding vector (matrix) has very little impact of PAPR. As a result, PAPR should not be a factor to differentiate between unitary and non-unitary precoding.

2. CQI mismatch (without inter-cell interference)

The real and instantaneous SINR of MS j is denoted by $SINR_{j,real}^{BS}$, given as

$$SINR_{j,real}^{BS} = \frac{|hw_j^*|^2}{\frac{\sigma^2 K}{P} + \sum_{\substack{i=1 \\ i \neq j}}^K |hw_i^*|}$$

, in which $h = U^*(:,1)H$, where $H = U\Sigma V^*$ is channel matrix of MS j , K is the number streams and $w_i, i \in [1, \dots, K]$, is the precoding vector associated with the i -th stream, P is total transmit power and σ^2 is the power spectrum density of additive noise.

The estimated SINR denoted by $SINR_j^{MS}$ is obtained by the MS and fed back to the BS. $SINR_j^{MS}$ is given by [1]

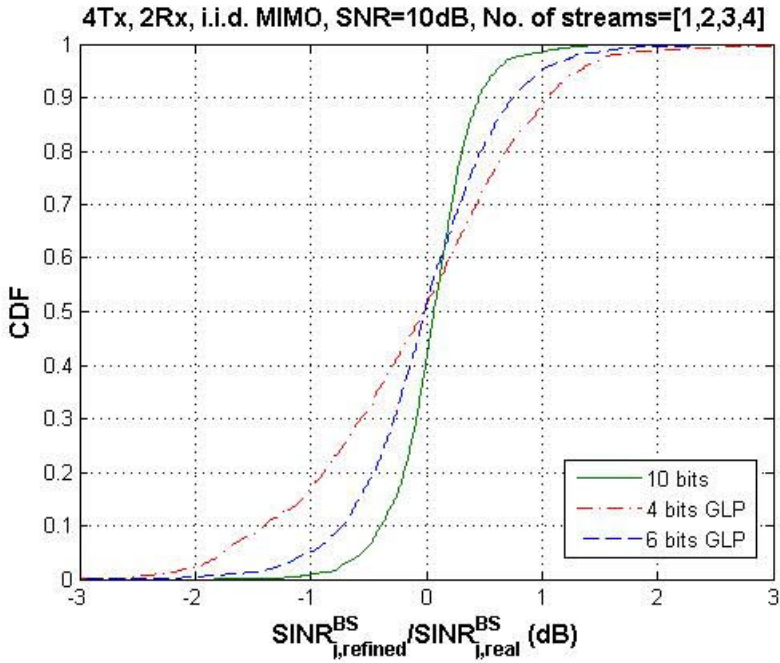
$$SINR_j^{MS} = \frac{\cos^2 \theta}{\frac{\sigma^2 N_t}{P|h|^2} + \sin^2 \theta}$$

Where $\cos \theta = \frac{|h\hat{h}^*|}{|h|}$ denotes the quantization error between h and \hat{h} , where \hat{h} is the quantized h based on a predefined codebook, N_t represents the number of transmit antenna at BS.

At the BS, based on user grouping information, $SINR_j^{MS}$ is refined to $SINR_{j,refined}^{BS}$. As a result, $SINR_{j,refined}^{BS}$ is obtained as

$$SINR_{j,refined}^{BS} = \frac{N_t}{K} SINR_j^{MS} |\hat{h}w_j^*|^2 = \frac{\cos^2 \theta |\hat{h}w_j^*|^2}{\frac{\sigma^2 K}{P|h|^2} + \frac{K}{N_t} \sin^2 \theta}$$

1 The CQI mismatch is denoted by $10 \log_{10} \left(\frac{SINR_{j,refined}^{BS}}{SINR_{j,real}^{BS}} \right)$



2
3 Figure 2: CQI mismatch of ZFBF with various size of codebook

4 It is shown in Fig. 2 that when the codebook is properly selected (for example the selected 10 bits codebook),
5 the CQI mismatch of non-unitary precoding is very limited. This can be illustrated by the near vertical CDF in
6 Fig. 2. Moreover, if the channel is correlated, a smaller space needs to be quantized. As a result, an even smaller
7 codebook can also achieve very sound CQI estimation.

3. Inter-cell interference

8
9 The inter-cell interference is defined as

$$10 \quad P_{ICI} = \sum_{i=1}^N u \left(\sum_{j=1}^M H_i v_{i,j} \right)$$

11 where N is the number of dominant sources, u is a combining vector at MS, H_i represents the channel matrix
12 between MS and the i -th interference BS and $v_{i,j}$ denotes the precoding vector of the j -th layer at the i -th
13 interference BS.
14
15

Simulation Parameters

Number of transmit antenna	2, 4
Number of dominant interference	2
Resource allocation	Same dedicated MU-MIMO zone for all BSs.

Scheduler	Independent scheduling of each BS
Precoding Scheme	Same precoding scheme for all BSs
Codebook	Unitary: 4 bits randomized unitary codebook Unbalanced amplitude: 3bit GLP(2Tx) 6 bit GLP(4Tx)

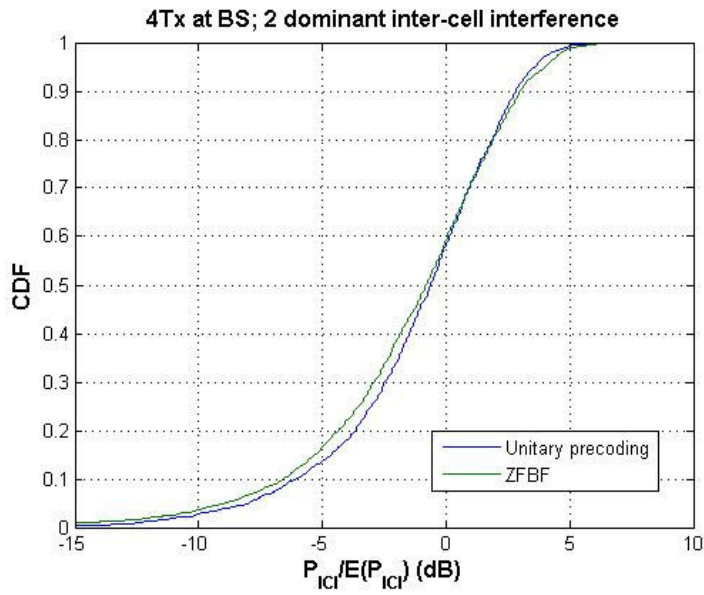


Figure 3 Inter-cell interference comparison (4Tx) based on various precoding schemes.

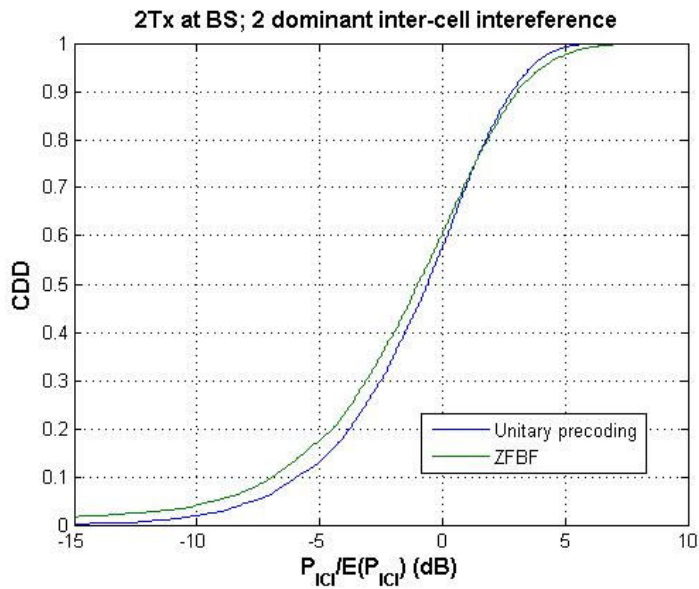


Figure 4 Inter-cell interference comparison (2Tx) based on various precoding schemes.

It has been shown in Figure 3 and 4 that the variance of the inter-cell interference is almost identical for both unitary precoding and ZFBF.

Conclusions:

- (1) The impact of amplitude uniformity of precoding vector (matrix) is rather trivial. As a result, PAPR should not be a factor to differentiate between unitary and non-unitary precoding.
- (2) The performance of current existing CQI estimation scheme for non-unitary precoding is sound. With proper codebook selection, CQI mismatch is not an issue for non-unitary precoding.
- (3) Compared to the unitary precoding, non-unitary precoding (e.g. ZFBF) does not result in a bigger variance of inter-cell interference.

References:

- [1] Philip R1-062483 "Comparison between MU-MIMO codebook-based channel reporting techniques for LTE downlink" 3GPP TSG RAN WG1 Seoul, South Korea, 9th October – 13th October 2006