Project	**IEEE 802.16 Broadband Wireless Access Working Group** <http://ieee802.org/16>	
Title	**On PAPR, CQI mismatch and inter-cell interference of non-unitary precoding**	
Date Submitted	**2008-07-10**	
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Re:	DL MIMO Rapporteur Group Discussions	
Abstract	To clarify the concerns on non-unitary precoding.	
Purpose	For review and discussion in the Project 802.16m DL MIMO Rapporteur Group	
Notice		
Release		
Patent Policy		

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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.

1. 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 $PAPR = 10\log_{10}\left(\frac{s_m}{E\{S_n\}}\right)$.

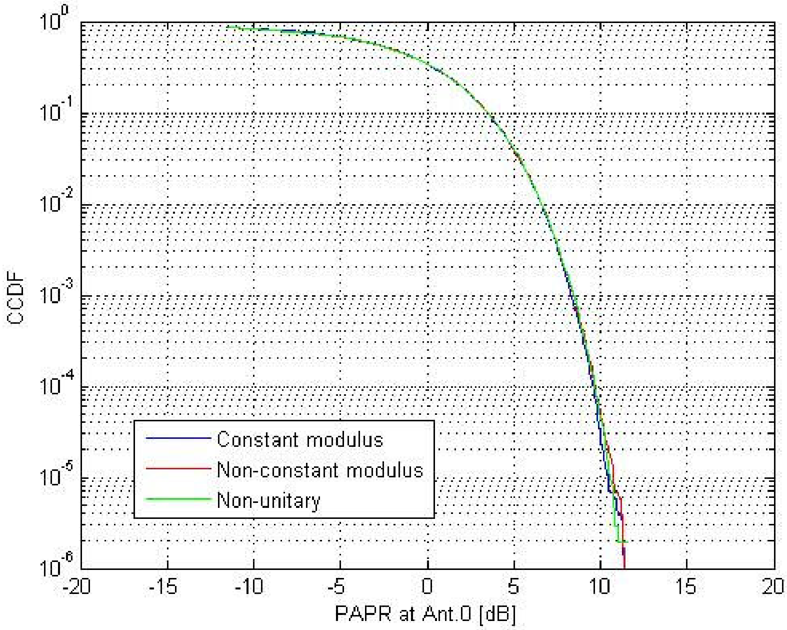

Figure 1: PAPR comparison

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 $SNR_{j,real}^{BS}$, given as

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

, in which $h = U^*(:,1)H$, where $H = U\Sigma V^*$ is channel matrix of MS j, K is the number streams and $w_i, i \in [1,..,K]$, 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 $\cos\theta = \frac{\left|h\hat{h}^*\right|}{|h|}$ 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

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

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

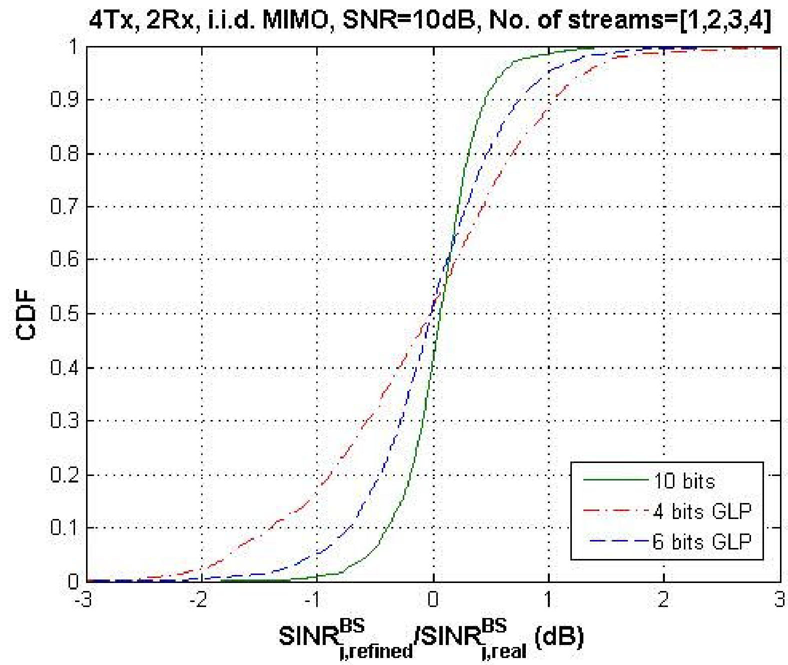

Figure 2: CQI mismatch of ZFBF with various size of codebook

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

3. **Inter-cell interference**

The inter-cell interference is defined as

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

where N is the number of dominant sources, u is a combining vector at MS, H_i represents the channel matrix 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 interference BS.

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)

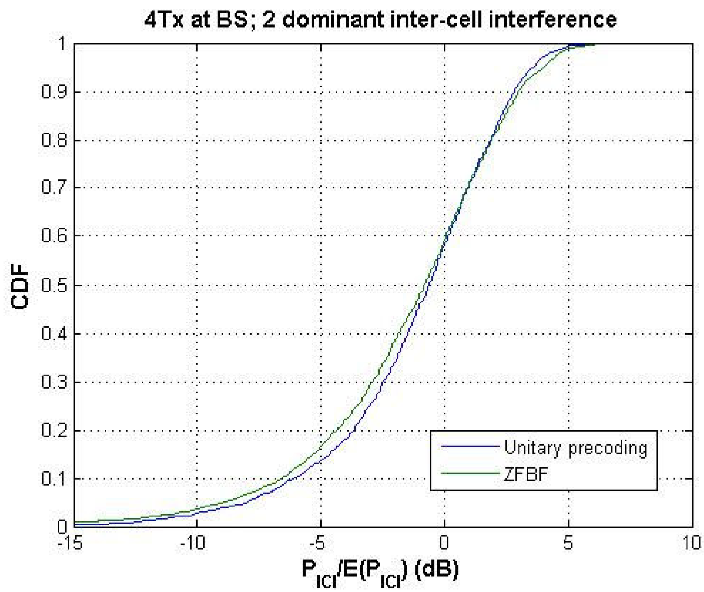

Figure 3 Inter-cell interference comparison (4Tx) based on various precoding schemes.

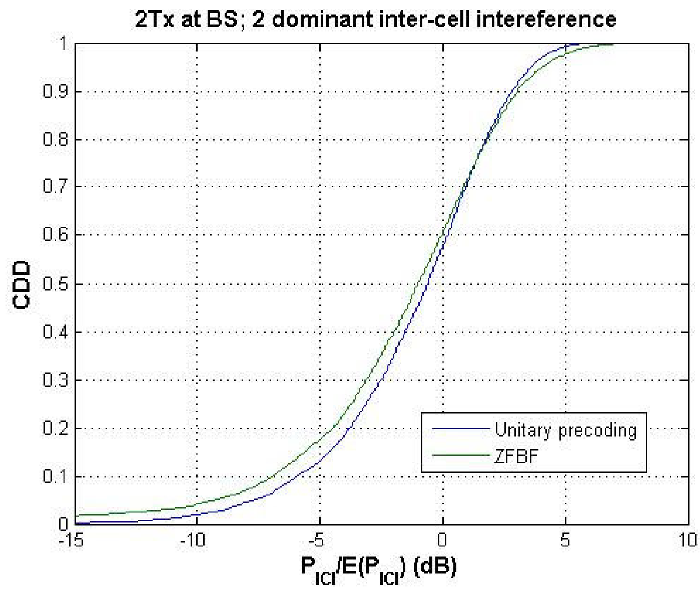

Figure 4 Inter-cell interference comparison (2Tx) based on various precoding schemes.

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