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| Source(s)      | Yang Tang, Young Hoon Kwon, Zhigang Rong, Jianmin Lu<br><br>Huawei   | Email: <a href="mailto:ytang@huawei.com">ytang@huawei.com</a> |
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| Abstract       | To clarify the concerns on non-unitary precoding.  |   |
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# On PAPR, CQI mismatch and inter-cell interference of non-unitary precoding

*Yang Tang, Young Hoon Kwon, Zhigang Rong, Jianmin Lu*

*Huawei*

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

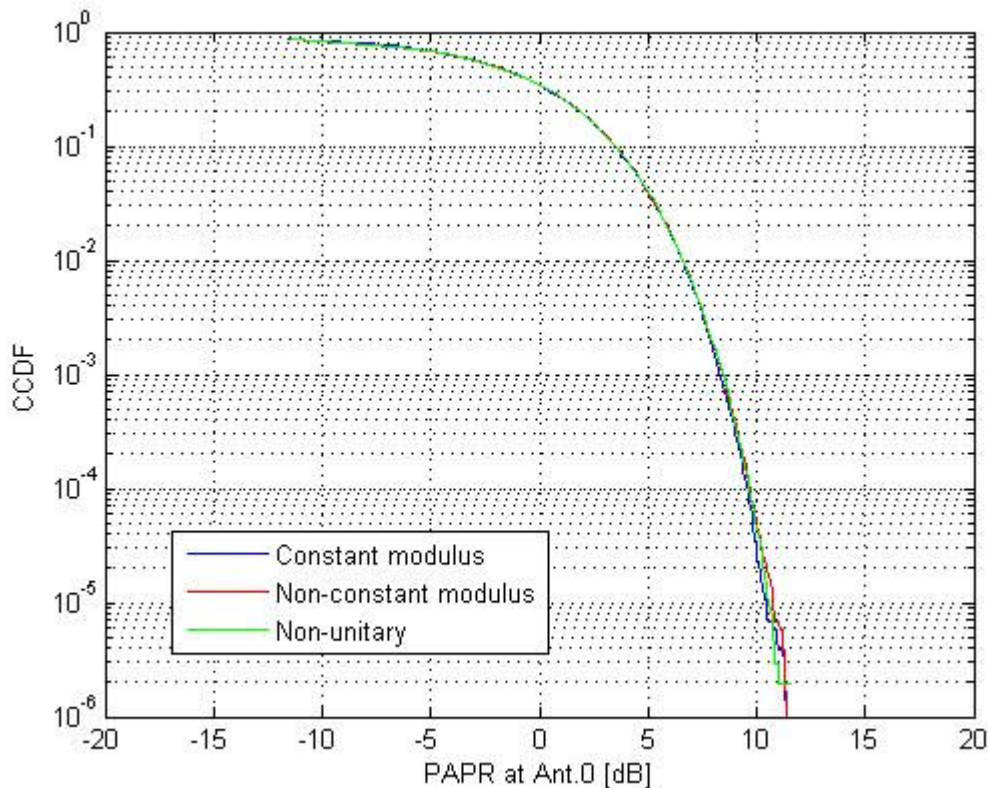


Figure 1: PAPR comparison

| 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<br>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  $\sigma^2$  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.

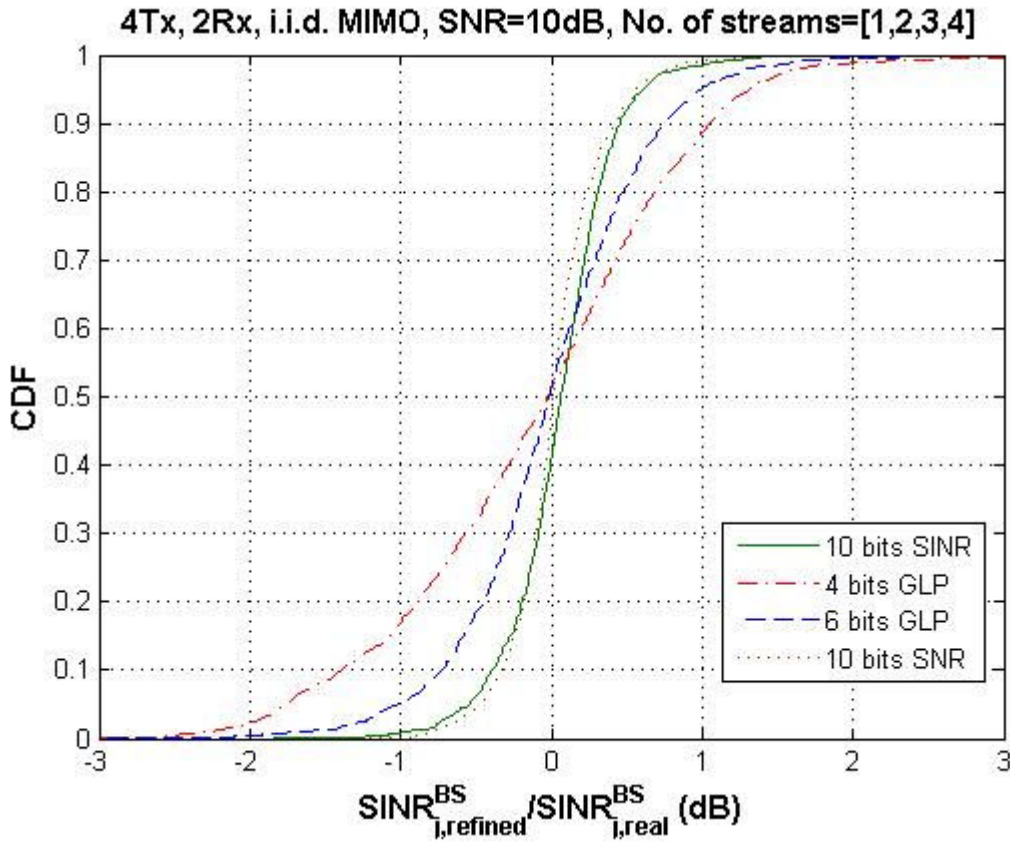
An alternative way is that MS feeds back SNR denoted by  $SINR_j^{MS}$ , given by

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

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

$$1 \quad SINR_{j,refined}^{BS} = \frac{N_t}{K} |\hat{h}w_j^*|^2 SINR_j^{MS} = \frac{\cos^2 \theta |\hat{h}w_j^*|^2}{\frac{\sigma^2 K}{P|h|^2} + \frac{K}{N_t} \sin^2 \theta}$$

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



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

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

### 10 3. Inter-cell interference

11 The inter-cell interference is defined as

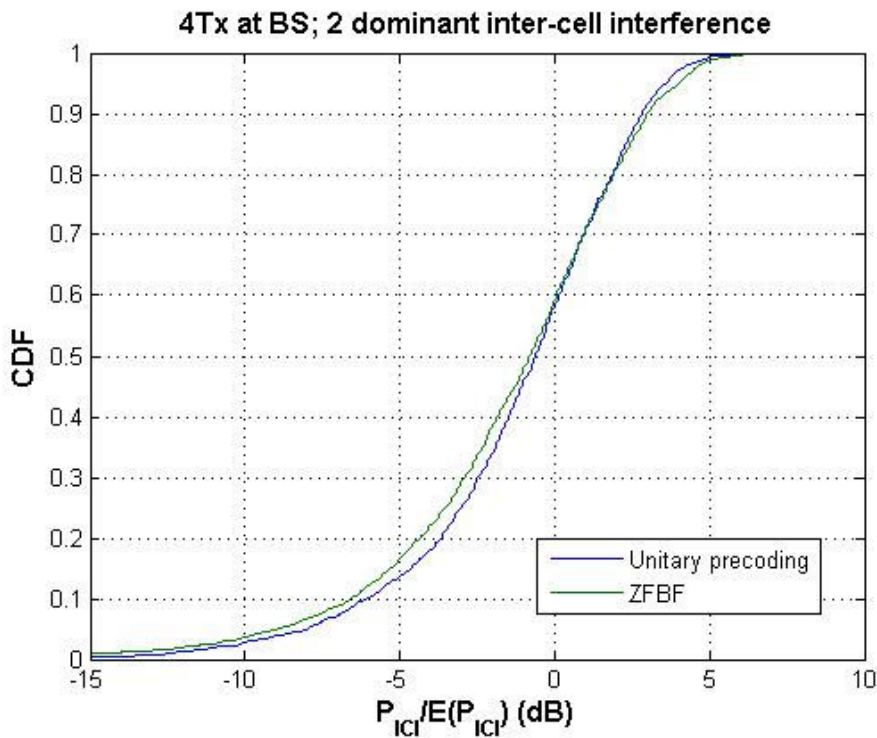
$$12 \quad P_{ICI} = \sum_{i=1}^N u \left( \sum_{j=1}^M H_i v_{i,j} \right)$$

13 where  $N$  is the number of dominant sources,  $u$  is a combining vector at MS,  $H_i$  represents the channel matrix  
 14 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  
 15 interference BS.

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| 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<br>Unbalanced amplitude: 3bit GLP(2Tx) 6 bit GLP(4Tx) |

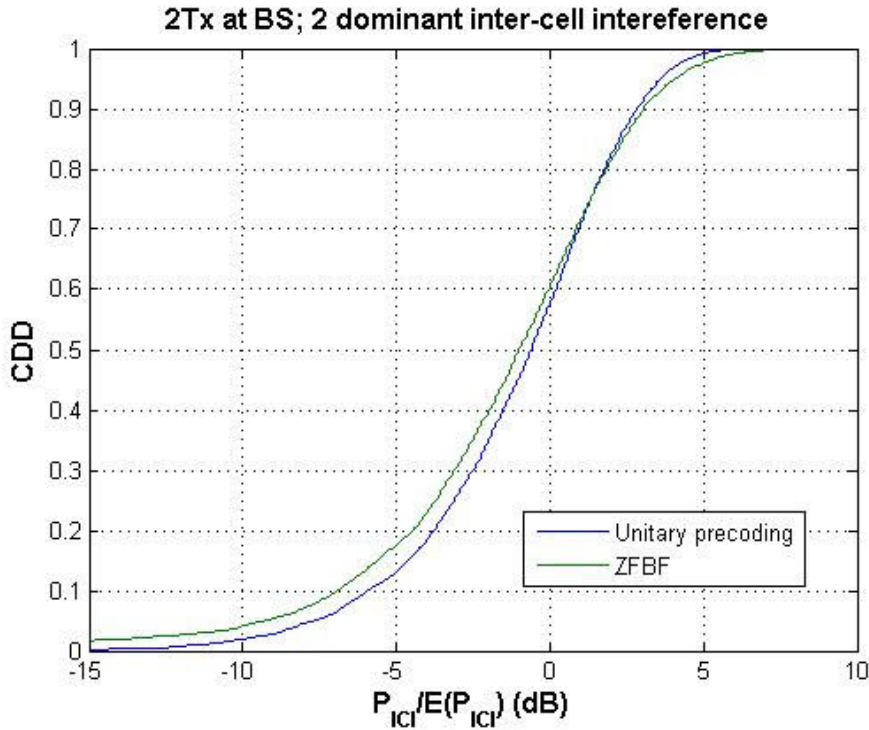
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Figure 3 Inter-cell interference comparison (4Tx) based on various precoding schemes.



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

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

5

6 **Conclusions:**

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

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14 References:

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- 16 [1] Philip R1-062483 "Comparison between MU-MIMO codebook-based channel reporting techniques for  
17 LTE downlink" 3GPP TSG RAN WG1 Seoul, South Korea, 9<sup>th</sup> October – 13<sup>th</sup> October 2006

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