Project	**IEEE 802.16 Broadband Wireless Access Working Group** <http://ieee802.org/16>
Title	**Channel Feedback for CL-MIMO in the DL**
Date Submitted	**2008-05-06**
Source(s)	Ron Porat, Wee Peng Goh, Lei Wang Nextwave Wireless Voice: E-mail: rporat@nextwave.com; *<http://standards.ieee.org/faqs/affiliationFAQ.html>
Re:	The IEEE 802.16 Working Group's *Task Group m* (TGm) 's Call for Contributions on Project 802.16m System Description Document (SDD), IEEE 802.16m-08/016r1 – Downlink-MIMO Schemes
Abstract	This document describes a proposal for 802.16m channel feedback for enabling DL-MIMO
Purpose	To be discussed and adopted by 802.16m SDD.
Notice	
Release	
Patent Policy	

Channel Feedback for CL-MIMO in the DL

Ron Porat, Wee Peng Goh, Lei Wang

Nextwave Wireless

1. Introduction

Channel feedback from a MS to the BS is required in order to enable optimal CL-MIMO in FDD and to some extent in TDD.

There are two main approaches:

1) BS centric approach – an MS estimates the MIMO channel and feeds back the un-quantized values of the channel. This is done by modulating the OFDM subcarriers by the actual complex channel values (hence the name analog feedback). It is also possible to feed back the actual precoder (in an analog fashion) to reduce feedback.
    a. Typically, one value is fed back for a certain band, say 800KHz, and while feeding back the channel value for the center of this band is possible, feeding back the 'average' channel for that band performs better.
    b. In this document we simulated feeding back the average covariance.
2) MS centric approach – here the MS uses vector quantization (codebook) to quantize only the precoder and feeds back the rank and precoder index (RI and PMI). This is a digital approach.

2. Key Considerations

1) Complexity –
    a. Approach 1 is simpler at the MS as there is no codebook search.
    b. Approach 2 - in this contribution we propose a simple QPSK based codebook to simplify the search at the MS which vastly improves upon the current 802.16e codebook.
2) UL feedback mechanism – given the digital nature of option 2, a general UL feedback mechanism can feed back the RI and PMI whereas approach 1 requires a separate feedback mechanism.
3) UL feedback overhead –
    a. Approach 1 – feeding back the average covariance matrix for 4 BS antennas requires 8 complex values. Feeding back the precoder only, requires 3 complex values for rank 1 and 5 for rank 2.
    b. Approach 2 - here we propose 4bit codebook for 4 antennas which require 5bits per one PMI+RI feedback.
4) DL SU-MIMO performance - for single user MIMO, there is a dB loss due to precoder error. As the following simulation results show, different antenna configurations require different codebooks for optimal performance whereas analog feedback doesn't.
5) DL MU-MIMO performance – In this case there is a much higher spatial multiplexing loss due to the

fact that multiple users are being served on the same resource block. In this case the required feedback accuracy is proportional to SNR and one codebook design is insufficient. In addition the number of bits required is much higher.

a. Analog feedback has an inherent property that the feedback quality improves with UL SINR and is hence more suitable.
b. In addition, full channel feedback enables better MU-MIMO schemes as the BS can reduce interference to the MS via MMSE or non-liner schemes like THP.

3. Proposal:

This document describes a QPSK based 4 bit codebook for 4 transmit antenna and shows SU-MIMO simulation results for this codebook as compared to analog feedback and optimal waterfilling per subcarrier.

We recommend including both analog and codebook based options in 16m SDD.

4. Simulation Results:

Here we show 10% outage capacity results using 3GPP SCM spatial channel model and assuming the Urban Macro scenario.

The BS has 4 antennas and the MS 2. Rank 1 or 2 was used for the codebook approach.

We show results for three typical antenna configurations:

1. 4 closely spaced antennas with 0.5 lambda spacing
2. 2 closely spaced cross polarized antennas with 0.5 lambda spacing
3. 2 widely spaced cross polarized antennas with 4 lambda spacing

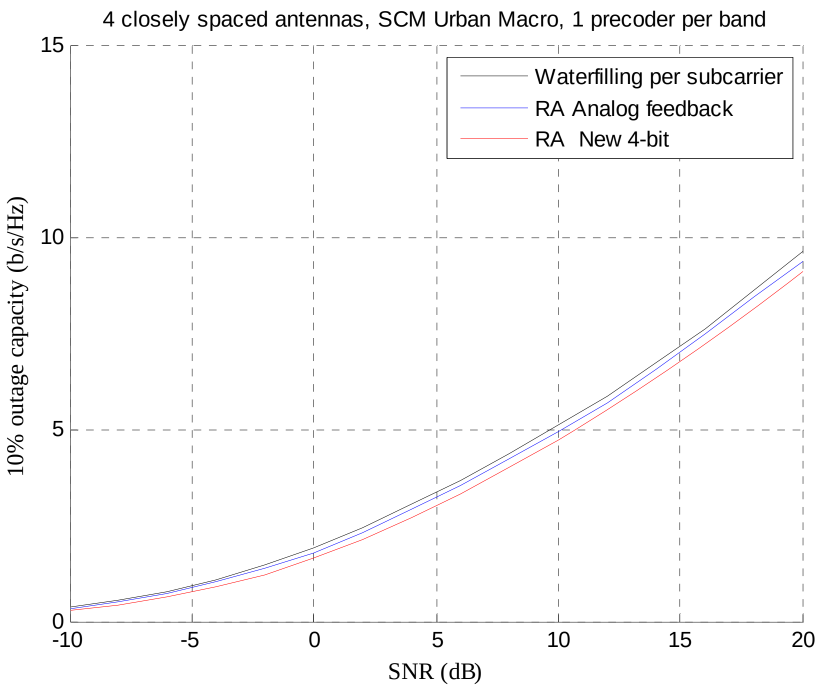
All plots show the following 3 graphs:

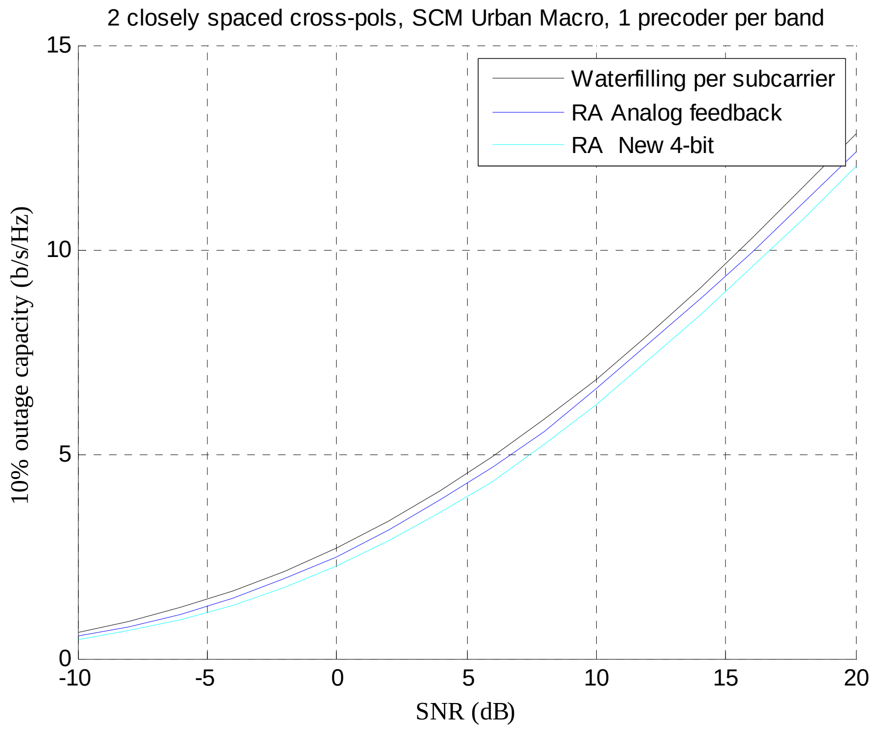
1. Optimal precoding (waterfilling) per subcarrier
2. Analog feedback based on average covariance matrix per band (800KHz)
3. Rank adaptation per band using the 4 bit codebooks

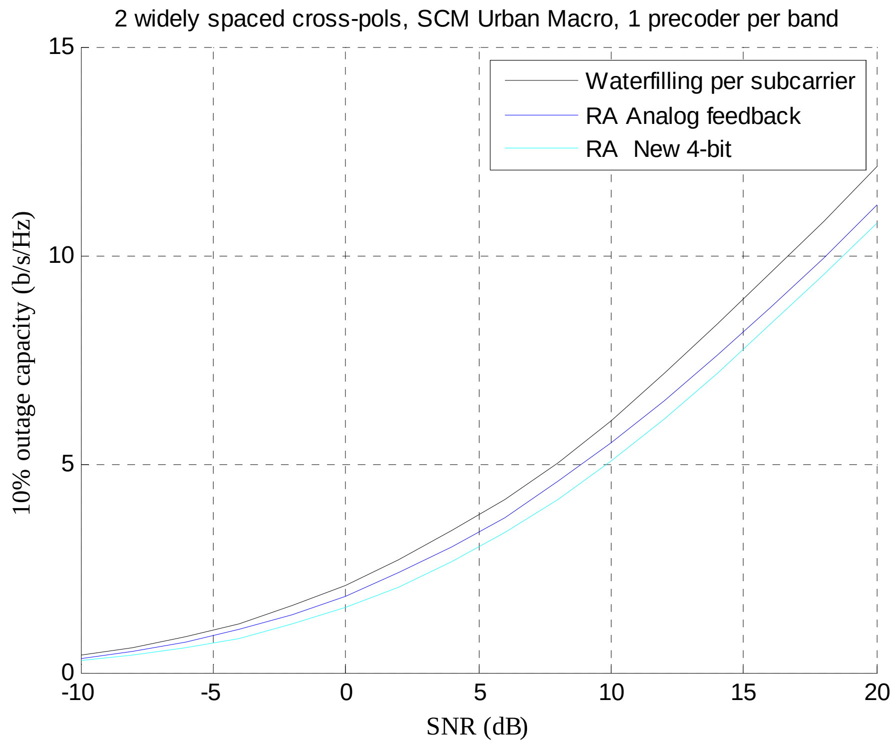
The results are summarized in this table that shows the loss in dB relative to an optimum precoding per subcarrier (10KHz)

	Analog Feedback	4bit Codebook

4 closely spaced verticals	0.3	0.9
2 closely spaced cross-pols	0.5	1.25
2 widely spaced cross-pols	1.4	2.1




2 closely spaced cross-pols, SCM Urban Macro, 1 precoder per band
Waterfilling per subcarrier
RA Analog feedback
RA New 4-bit
10% outage capacity (b/s/Hz)
SNR (dB)
0
5
10
15
-10
-5
0
5
10
15
20


2 widely spaced cross-pols, SCM Urban Macro, 1 precoder per band
Waterfilling per subcarrier
RA Analog feedback
RA New 4-bit
10% outage capacity (b/s/Hz)
SNR (dB)
0
5
10
15
-10
-5
0
5
10
15
20

5. Codebook description

We use $j = \sqrt{-1}$:

For rank 2 the description [V0 V1] means that the precoder has two columns – rank-1 column 0 and rank-1 column 1. Similarly for rank 3.

Rank-2 matrices should be further divided by $\sqrt{2}$ to normalize power.
Rank-3 matrices should be further divided by $\sqrt{3}$ to normalize power.

4-Bit 4-Tx Codebook for Close Loop MIMO

Codebook Index	Rank 1	Rank 2	Rank 3
0	$\frac{1}{2}\begin{bmatrix} -j \\ 1 \\ -j \\ -1 \end{bmatrix}$	[V0 V1]	[V1 V2 V3]
1	$\frac{1}{2}\begin{bmatrix} -j \\ -1 \\ -j \\ 1 \end{bmatrix}$	[V1 V3]	[V0 V2 V3]
2	$\frac{1}{2}\begin{bmatrix} -j \\ 1 \\ j \\ 1 \end{bmatrix}$	[V2 V3]	[V0 V1 V3]
3	$\frac{1}{2}\begin{bmatrix} -j \\ -1 \\ j \\ -j \end{bmatrix}$	[V0 V2]	[V0 V1 V2]

4	$\frac{1}{2}\begin{bmatrix}-1\\-j\\-j\\1\end{bmatrix}$	[V4 V5]	[V5 V6 V7]
5	$\frac{1}{2}\begin{bmatrix}-1\\-j\\j\\-1\end{bmatrix}$	[V5 V7]	[V4 V6 V7]
6	$\frac{1}{2}\begin{bmatrix}-j\\-1\\-1\\j\end{bmatrix}$	[V6 V7]	[V4 V5 V7]
7	$\frac{1}{2}\begin{bmatrix}j\\1\\-1\\j\end{bmatrix}$	[V4 V6]	[V4 V5 V6]
8	$\frac{1}{2}\begin{bmatrix}-1\\-1\\j\\-j\end{bmatrix}$	[V8 V9]	[V9 V10 V11]
9	$\frac{1}{2}\begin{bmatrix}j\\j\\-1\\1\end{bmatrix}$	[V9 V11]	[V8 V10 V11]
10	$\frac{1}{2}\begin{bmatrix}j\\-j\\-1\\-1\end{bmatrix}$	[V10 V11]	[V8 V9 V11]
11	$\frac{1}{2}\begin{bmatrix}1\\-1\\-j\\-j\end{bmatrix}$	[V8 V10]	[V8 V9 V10]

12	$\frac{1}{2}\begin{bmatrix} j \\ j \\ j \\ j \end{bmatrix}$	[V12 V13]	[V13 V14 V15]
13	$\frac{1}{2}\begin{bmatrix} 1 \\ -1 \\ 1 \\ -1 \end{bmatrix}$	[V13 V15]	[V12 V14 V15]
14	$\frac{1}{2}\begin{bmatrix} j \\ j \\ -j \\ -j \end{bmatrix}$	[V14 V15]	[V12 V13 V15]
15	$\frac{1}{2}\begin{bmatrix} -1 \\ 1 \\ 1 \\ -1 \end{bmatrix}$	[V12 V14]	[V12 V13 V14]