Project	**IEEE 802.16 Broadband Wireless Access Working Group** <http://ieee802.org/16>	
Title	**Analog vs. Codebook Feedback – Performance Comparison**	
Date Submitted	**2008-07-07**	
Source(s)	Ron Porat, Maryam Shanechi Nextwave Wireless	Voice: E-mail: rporat@nextwave.com; *<http://standards.ieee.org/faqs/affiliationFAQ.html>
Re:	Contribution to support a Comment on the DL-MIMO Rapporteur group final draft: C802.16m-08/657r2.	
Abstract	This document describes a proposal for 802.16m DL or UL CL-MIMO feedback	
Purpose	To be discussed and adopted by 802.16m SDD.	
Notice	*This document does not represent the agreed views of the IEEE 802.16 Working Group or any of its subgroups.* It represents only the views of the participants listed in the "Source(s)" field above. It is offered as a basis for discussion. It is not binding on the contributor(s), who reserve(s) the right to add, amend or withdraw material contained herein.	
Release	The contributor grants a free, irrevocable license to the IEEE to incorporate material contained in this contribution, and any modifications thereof, in the creation of an IEEE Standards publication; to copyright in the IEEE's name any IEEE Standards publication even though it may include portions of this contribution; and at the IEEE's sole discretion to permit others to reproduce in whole or in part the resulting IEEE Standards publication. The contributor also acknowledges and accepts that this contribution may be made public by IEEE 802.16.	
Patent Policy	The contributor is familiar with the IEEE-SA Patent Policy and Procedures: <http://standards.ieee.org/guides/bylaws/sect6-7.html#6> and <http://standards.ieee.org/guides/opman/sect6.html#6.3>. Further information is located at <http://standards.ieee.org/board/pat/pat-material.html> and <http://standards.ieee.org/board/pat>.	

Analog vs. Codebook Feedback – Performance Comparison

Ron Porat

Nextwave Wireless

1. Introduction

In a previous contribution C802.16m-08372r2 we proposed the idea of analog feedback.

The current trend of digital communications is based on Shannon's source channel separation theorem.

However, in some cases this approach is suboptimal when for example

- The communication system is delay constrained and operating in time selective Rayleigh fading (where strong FEC codes and HARQ can't be used)
- The SNR is unknown at the transmitter.

As is known, digital communication suffer a cliff effect more noticeable than analog communication. When SNR is below the design point, performance deteriorates rapidly whereas above the design point there is no throughput improvement as the system throughput is limited by the choice of input MCS.

This problem causes wasteful overhead in CL-MIMO operation as the subscriber can't assume a given UL SINR and needs to use suboptimal short length coding designed for worst case.

In CL MU-MIMO the problem is even more pronounced as the required accuracy of the source (DL channel) increases with SNR and quantizing it to N bits is either insufficient at high SNR or not needed and increases UL overhead at lower SNR.

As we mentioned in previous contributions several types of analog feedback are possible from the actual DL channel or channel covariance to the right most singular vectors and values.

Here we compare the performance of two of them relative to the 802.16e 6 bit codebook.

2. Simulation Results

In the following plots we show DL ergodic or outage capacity loss for 4-antenna BS and 2-antenna subscriber. The DL flat fading channel was fed back to the BS through Rayleigh fading Ped-B 10MHz 3kmph channel using 802.16e UL CQICH channel with modifications.

We simulated 3 types of feedback content:

- 16e – 6 bit codebook
- Analog covariance matrix (R) as explained in C802.16m-08372r2
- Rank-1 or rank-2 analog V

At the BS the estimated V was used to calculate the capacity.

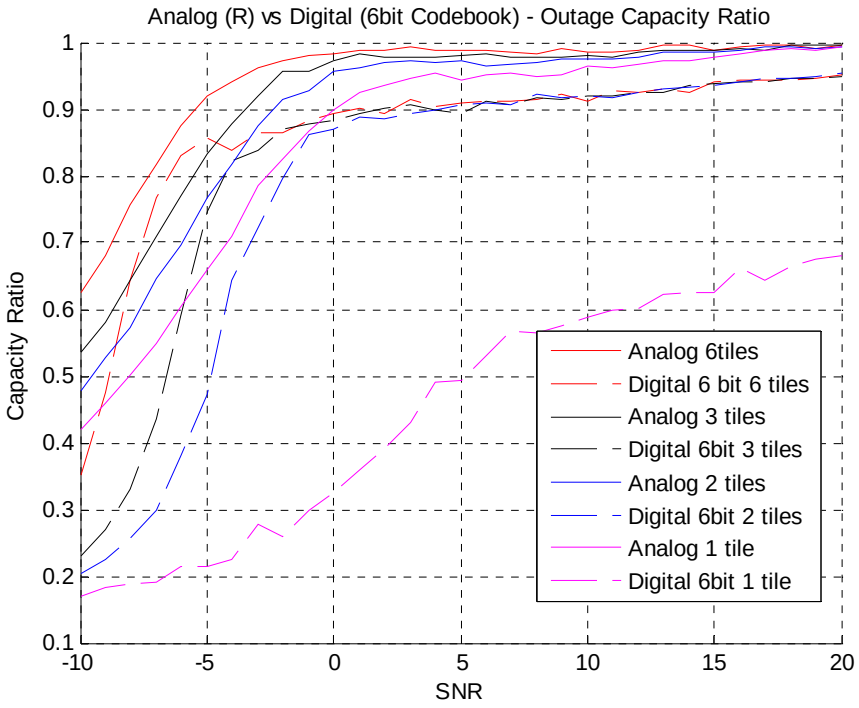
Note that feeding back R provides more information than either analog V or quantized V (codebook) and is more optimal especially for MU-MIMO.

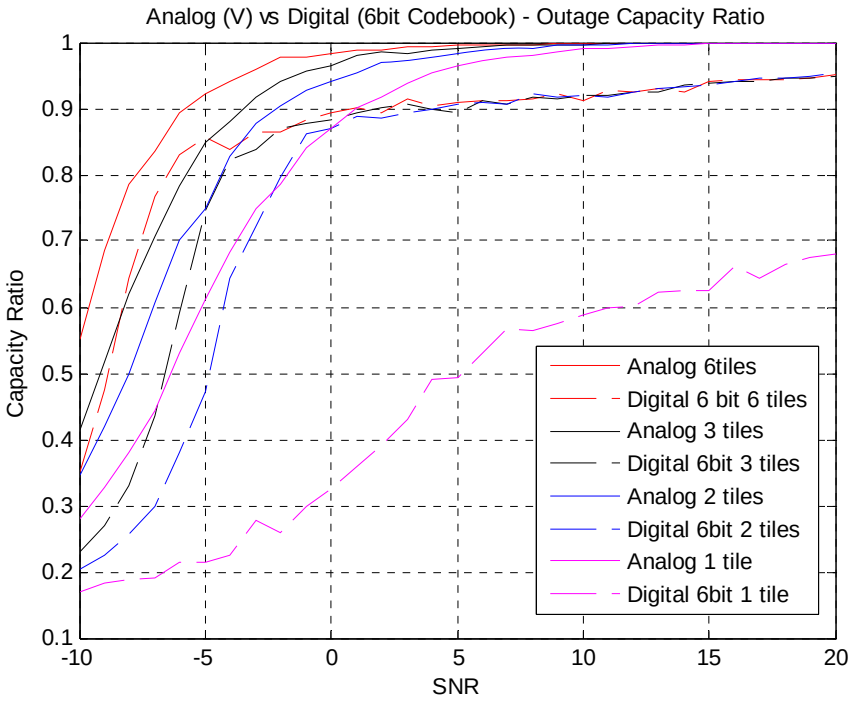
The mapping to 6 tiles was identical to 802.16e for digital (codebook) or C802.16m-08372r2 for analog (R) The mapping of V is similar to R when rank-2 is considered (8 complex values) and is repeated twice in a tile when rank-1 is considered). Note that we didn't attempt here to optimize feedback overhead for V as it can easily be shown that 3 and 5 complex values are required for rank-1 and rank-2 respectively.

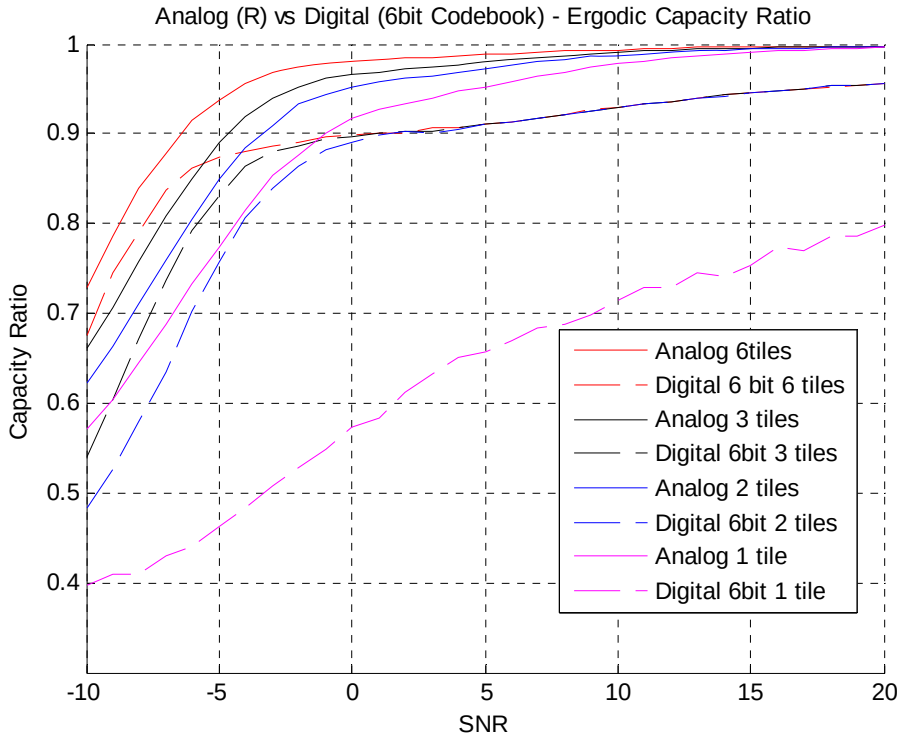
The mapping to 3, 2 or 1 tile basically used the same mapping as 6 tiles but receiver integration was done over 3, 2 or 1 tile.

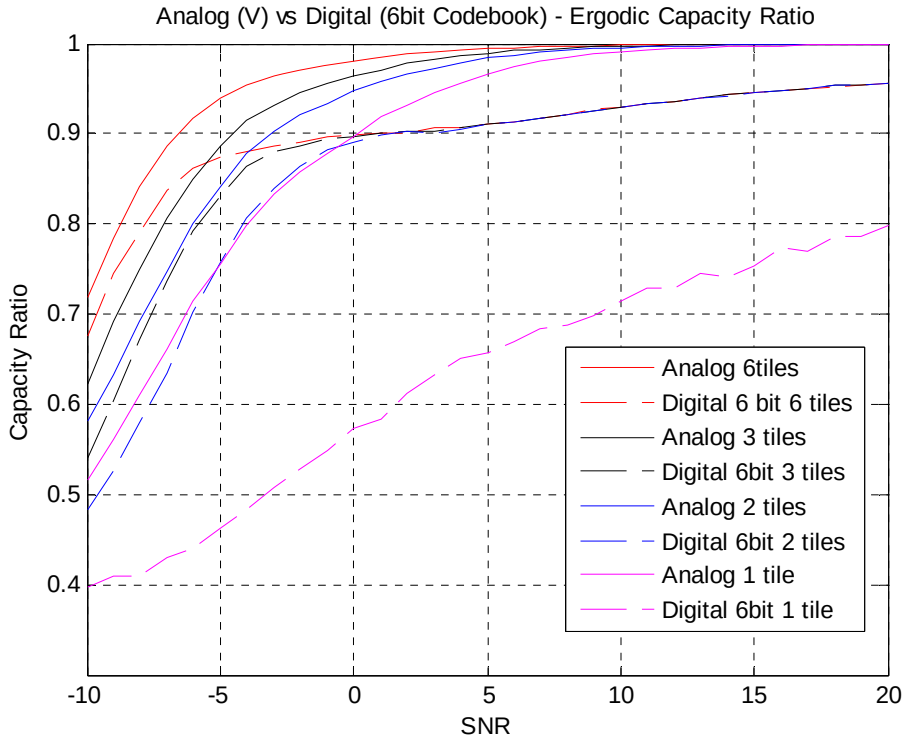
It can be clearly seen that every form of analog feedback is superior to 6 bit codebook in every form of capacity metric. It is also clear that 1 tile using the 802.16e mapping can't be used for codebook feedback (it is not easy to transmit reliably 6 bits over 8 subcarriers!).
The cliff effect of digital transmission can be clearly seen from the outage plots.

Note also that feeding back the codebook information via encoded rate ½ QPSK message is less reliable than feeding it over 2 tiles based on our simulations.




Analog (V) vs Digital (6bit Codebook) - Outage Capacity Ratio
Capacity Ratio
SNR
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
-10
-5
0
5
10
15
20
Analog 6tiles
Digital 6 bit 6 tiles
Analog 3 tiles
Digital 6bit 3 tiles
Analog 2 tiles
Digital 6bit 2 tiles
Analog 1 tile
Digital 6bit 1 tile


Analog (R) vs Digital (6bit Codebook) - Ergodic Capacity Ratio
Capacity Ratio
SNR
1
0.9
0.8
0.7
0.6
0.5
0.4
-10
-5
0
5
10
15
20
Analog 6tiles
Digital 6 bit 6 tiles
Analog 3 tiles
Digital 6bit 3 tiles
Analog 2 tiles
Digital 6bit 2 tiles
Analog 1 tile
Digital 6bit 1 tile



3. Recommendation

We therefore recommend adding analog feedback to the DL MIMO SDD as specified in C80216m-DL_MIMO-08_008r2_Analog_Feedback