Project	**IEEE 802.16 Broadband Wireless Access Working Group** <http://ieee802.org/16>
Title	**Analog Feedback – Complexity Clarification**
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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 or UL CL-MIMO feedback
Purpose	To be discussed and adopted by 802.16m SDD.
Notice	
Release	
Patent Policy	

Analog Feedback – Complexity Clarification

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1. Introduction

In a previous contribution C802.16m-08/372r2 we proposed the idea of analog feedback. This type of feedback has several advantages from low complexity at the MS to unbounded feedback accuracy which is particularly important for MU-MIMO with uncorrelated antennas or multi-BS MIMO.

There are several options for feedback:

1. Full channel matrix H
2. Covariance matrix $H^H H$
3. Strongest right singular vector
4. Two strongest right singular vectors

In this contribution we assume that subscribers have 2 receive antennas, hence there is no need to feed back more than the strongest 2 singular vectors.

While feeding back the full channel matrix or channel covariance provide sufficient information for SU and MU-MIMO, feeding just the strongest or two strongest eigenvectors will reduce feedback overhead.

For example, a 4 antenna BS will require 8 complex values for options 1 or 2 and only 3 and 5 complex values for options 3 and 4 respectively. An 8 antenna BS or two 4 antenna BS in multi-BS MIMO will require 16/7/13 complex values for options 1/3/4 respectively while option 2 is not recommended in this case.

Chapter 3 of this contribution shows that computing feedback types 3 and 4 is actually very simple for 2xN channels and a closed form solution is given.

In addition, a typical operation of CL-MIMO in FDD may require the MS to send an initial estimate of the post precoding CINR. If codebooks are used, once the best codeword was found the subscriber can find the effective channel. In analog feedback using method 2 there is no need to find the optimal analog V but chapter 2 shows that calculating the post precoding SINR is simply done by calculating the eigenvalues.

2. SINR Calculation

Here what's required is for the MS to calculate the singular values of the channel as these will determine the post precoding SNR.

Assume the channel H is of dimension 2xN where N>=2. The singular values can be found from the eigenvalues of HH^H which is of dimension 2x2 by solving the simple two equations

$$\sigma_1^2 + \sigma_2^2 = Tr(HH^H)$$
$$\sigma_1^2 \sigma_2^2 = \det(HH^H)$$

where Tr is trace and σ_i are the two singular values of H.

3. SVD Calculation

The main idea is to concentrate on H^H which is of size Nx2, find the right singular vectors which are of size 2 and use them to find the left singular vectors which are the right singular vectors of H.

We write $H^H = V\sum U^H$ where U can be generally written as $U = \begin{pmatrix} \cos\theta & \sin\theta \\ \sin\theta e^{j\phi} & -\cos\theta e^{j\phi} \end{pmatrix}$

By the definition of SVD the first column of U is calculated according to

$\theta, \phi = \arg\max_{\theta,\phi} \| H^H \begin{pmatrix} \cos\theta \\ \sin\theta e^{j\varphi} \end{pmatrix} \|$ where ||x|| stands for Euclidean norm. The maximum Euclidean norm is the maximal singular value σ_1.

Denoting by h_i the i'th row of H and developing the above expression we can easily derive

$$e^{j\phi} = \frac{h_2^* h_1}{|h_2^* h_1|}$$

Substituting we get $\theta = \arg\max_{\theta} |h_1|^2 \cos^2\theta + |h_2|^2 \sin^2\theta + 2|h_2^* h_1| \sin\theta\cos\theta$.

Differentiating and equating to zero we can quickly find $\tan 2\theta = \frac{2|h_2^* h_1|}{|h_1|^2 - |h_2|^2}$ after which we use simple CORDIC rotation to calculate $\cos\theta, \sin\theta$.

Using $UH^H = V\sum$ we now get the strongest singular vector by normalizing $v_1 = h_1^* \cos\theta + h_2^* \sin\theta \, e^{j\phi}$

At this point we have finalized feedback option number 3.

For feedback option number 4 we need to compute $v_2 = h_1^* \sin\theta - h_2^* \cos\theta \, e^{j\phi}$ and normalize it.

The eigenvalues are the norms of those vectors.

4. Recommendation

Based on the above we can see that calculation of SVD and CINR for 2xN configuration is simple and requires just few operations.

We therefore recommend adding analog feedback to the DL MIMO SDD as specified in C80216m-DL_MIMO-08_008r1_Analog_Feedback_Nextwave