

Project	IEEE 802.16 Broadband Wireless Access Working Group < http://ieee802.org/16 >	
Title	Analog Feedback – Complexity Clarification	
Date Submitted	2008-07-07	
Source(s)	Ron Porat , Yi Jiang, Keith Holt Nextwave Wireless	Voice: E-mail: rporat@nextwave.com ; * http://standards.ieee.org/faqs/affiliationFAQ.html >
Re:	The IEEE 802.16 Working Group's <i>Task Group m</i> (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	<i>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.</i>	
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 Feedback – Complexity Clarification

Ron Porat, Yi Jiang

Nextwave Wireless

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 $2 \times N$ 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 $2 \times N$ where $N \geq 2$. The singular values can be found from the

eigenvalues of HH^H which is of dimension 2×2 by solving the simple two equations

$$\begin{aligned} \sigma_1^2 + \sigma_2^2 &= \text{Tr}(HH^H) \\ \sigma_1^2 \sigma_2^2 &= \det(HH^H) \end{aligned}$$

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 $N \times 2$, 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 $H^H = V \Sigma U^H$ 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

$\theta, \phi = \arg \max_{\theta, \phi} \left\| H^H \begin{pmatrix} \cos \theta \\ \sin \theta e^{j\phi} \end{pmatrix} \right\|$ 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 $UH^H = V \Sigma$ 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 $2 \times N$ 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