Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**Unified MIMO Pre-Coding based on Givens Rotation**
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Re:	Response to Recirculation Sponsor Ballot
Abstract	To unify the closed loop MIMO pre-coding based Givens rotation.
Purpose	To incorporate the changes here proposed into the 802.16e D6 draft.
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Unified MIMO Pre-coding Based on Givens Rotation

1 Introduction

For the SVD based MIMO pre-coding technique, the MSS is required to send beam-forming V matrix to the BS, due to the unitary structure of matrix V, a number of research work have done to quantize the matrix V in order to reduce the feedback overhead in the UL. In this contribution, we show that by using Givens decomposition of matrix V, the Givens parameter can be further quantized by using simple 1-bit scalar delta modulation to allow the further reduction of the redundancy in time/frequency, the differential-Givens (D-Givens) provide an straightforward scalability to arbitrary antenna configurations while achieve the much less computational complexity, lower quantization noise and requires less feedback resource. The D-Givens method discussed in this contribution is compared with the Householder method introduced in [1].

2 Background

2.1 Givens Rotation

In the following, we assume that the number of BS transmit antennas is *M* and the number of MSS receive antennas is *N* and the vector representation of the received signal is: *Y=HX+n*. In the beam-forming MIMO pre-coding method, the BS transmitter needs to know the right-singular matrix *V*, when the channel matrix is singular-value decomposed as $H=USV^H$. The number of non-zero singular values is at most *min (M,N)*. The matrix *V* contains M^2 complex elements but based on the fact that it is a unitary matrix, the number of independent variables is *M(M-1)* real values. By using the Givens decomposition, the matrix *V* is decomposed to a set of *M(M-1)/2* unitary matrices. Each matrix is an identity matrix except for four of its elements and can be represented by two real values. Besides their ability to decompose the unitary matrix to the minimum number of parameters, the resulting parameters are statistically independent. The independence property facilitates the quantization procedure. In this contribution, we chose a Givens representation as:

$$G(c,\theta) = \begin{bmatrix} \hat{c} & |\hat{s}|e^{j\hat{\theta}} \\ -|\hat{s}|e^{-j\hat{\theta}} & \hat{c} \end{bmatrix}$$

where the distribution of $\hat{\theta}$ and $\hat{c}$ are independent and $s=\sqrt{1-|c|^2}$, in particular, $\hat{\theta}$ is uniformly distributed and $\hat{c}$ is non-uniformly distributed. Based on the statistical distribution of Givens, the optimum quantizer can be designed to achieve maximum compression ratio.

2.2 Delta Modulation

The Givens parameters $\hat{\theta}$ and $\hat{c}$ are further compressed by using the simplest delta modulator to exploit the channel correlation in time or frequency domain, the delta modulator is shown in Figure 1.

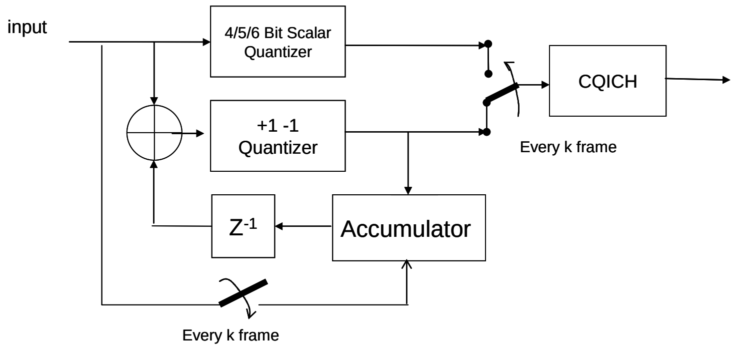

Figure 1 Delta Modulator

3 Proposed Solution

For the unitary pre-coding feedback, the MSS is required to perform the Givens decomposition of unitary matrix, the Givens expansions can be truncated (variable number of Givens rotations) to allow feedback partial or full the unitary pre-coding vectors. The parameters of each Givens rotations can be quantized and compressed by scalar quantizer such as delta modulation and feedback to BS. The BS reconstructs the unitary pre-coding vectors/matrix.

4 Advantages

- Scalability:
  - Scalable to MIMO pre-coding with large number of transmit antennas to allow standard future proof.
  - Scalable to MIMO pre-coding stream selection. The Givens expansion can be shortened to scale the feedback of partial or full set of the Givens rotations to allow BS to perform sub-space or full-space pre-coding
  - Givens decomposition will significantly reduce the complexity since the code books search complexity, since for Householder based method increases *exponentially* with respect of the number of transmit antennas, the complexity of Givens rotation based method increases *polynomial* with respect of the number of transmit antennas.
  - Lower quantization noise
  - Lower feedback resource required.
- Reuse:
  - The Givens rotation engine can be implemented with very efficient ORDIC computing. It can be used to compute:
    - The decomposition of unitary matrix, such as V for the compression of the feedback of V [1],[2],[3]
    - The Gentleman-Kung systolic based matrix inversion the receiver based schemes [4],[5]

5 Simulation Results

The simulation conditions and set-up is listed in Table 1

Table 1 Simulation Set Up

Configurations	Parameters	Comments
Optional BAND AMC sub-channel		The band allocation in time-direction shall be fixed at center band
Coding Modulation Set	CC coding , K=7, TB	Coded Symbol Puncture for MIMO Pilot
	QPSK ½, QPSK, ¾, 16QAM ½, 16QAM R=¾, 64QAM R=1/2, 64QAM R= 3/4	
Code Modulation Mapping	Single encoder block with uniform bit-loading	
MIMO Receiver	MMSE-one-shot for SVD	

	MLD receiver for OL and CL SM	
FFT parameters	Carrier 2.6GHz, 10MHz, 1024-FFT Guard tone 79 left, 80 right CP=11.2ms, Sampling rate = 8/7, Sub-carrier spacing = 11.2kHz	
Frame Length	5ms frame, DL:UL=2:1	
Feedback delay	2 frames	
MIMO Configurations	4x2	
Channel Model	ITU-PA, 3km/h, Antenna Correlation: 20% Perfect Channel Estimation	
Feedback	SVD: perfect pre-coding matrix V without quantization D-Givens: per this contribution Householder: Ref[1]	

5.1.1 Performance

The partial simulation results based on 0 frame delay are shown in Figure 2. and Figure 3.

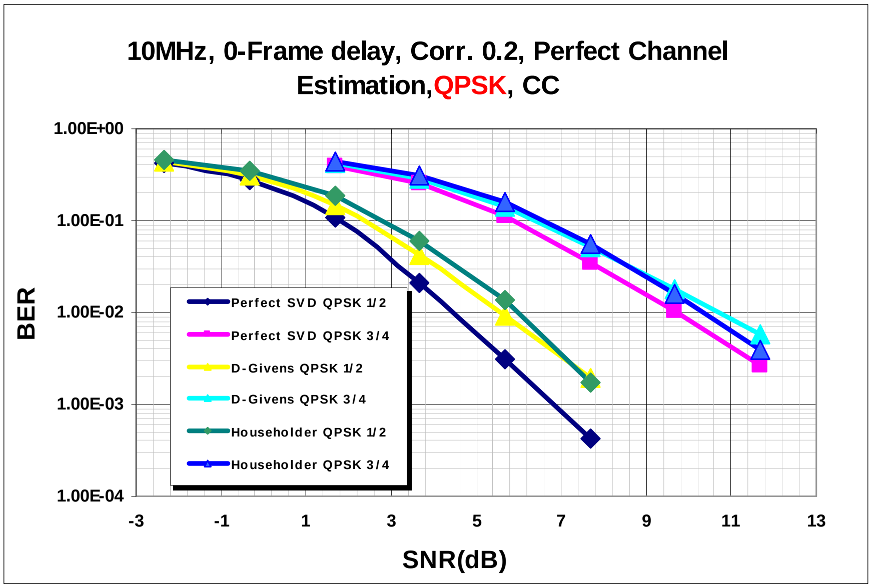

Figure 2 Performance Comparison of D-Givens/Householder based pre-coding

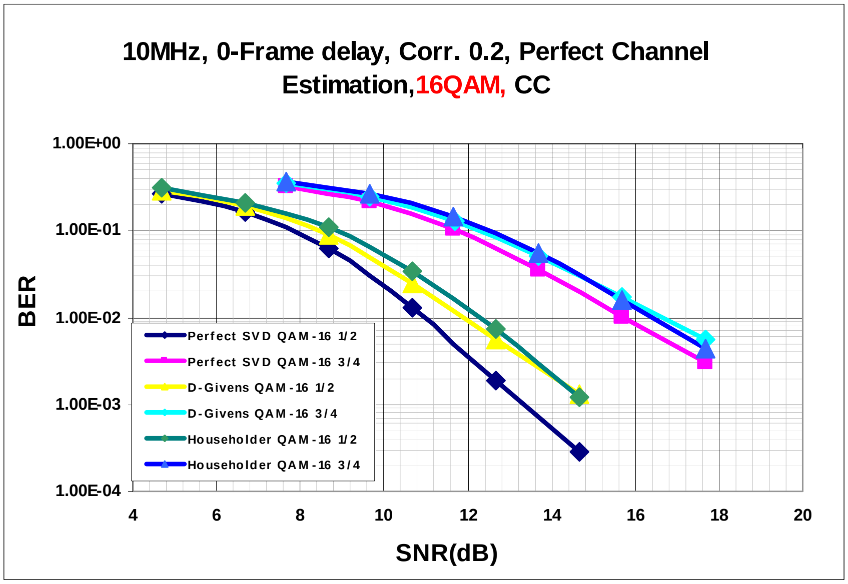

Figure 3 Performance Comparison of Givens/Householder based pre-coding

It can be seen that the D-Givens based method achieve the better performance than the Householder method. Figure 4 shows the throughout curve for comparing perfect SVD, D-Givens and Householder based methods with 2-frame delay.

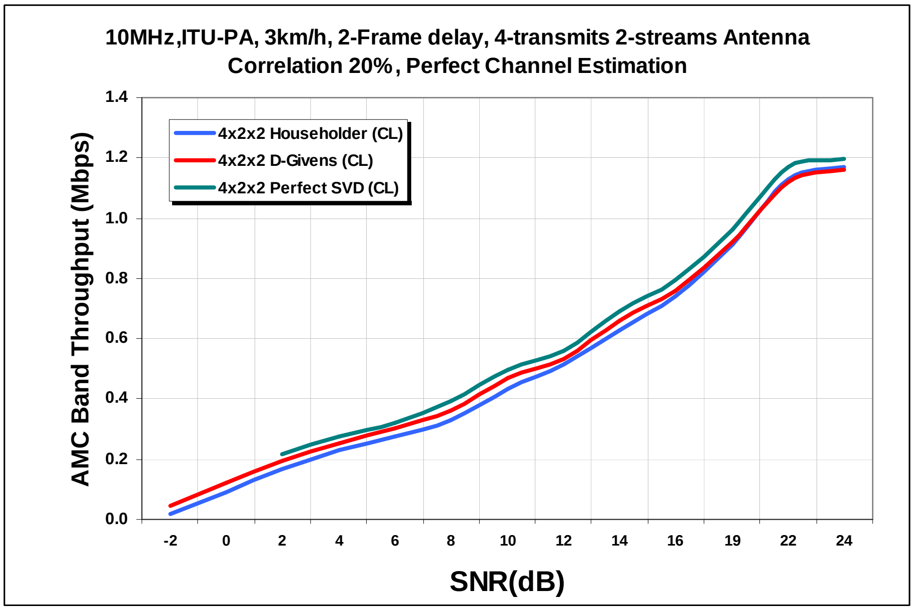

Figure 4 Comparison of perfect SVD, D-Givens and Householder

5.1.2 Feedback Resource Requirement

The feedback resources requirement and comparison is shown in Figure 5. As we can see the D-Givens requires less feedback resources. See Appendix-A for details.

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