Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**Low Complexity Feedback of the MIMO Channel Information**
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Re:	Response to Recirculation Sponsor Ballot
Abstract	A low complexity MIMO channel feedback solution to IEEE802.16e
Purpose	To incorporate the changes here proposed into the 802.16e D6 draft.
Notice	
Release	
Patent Policy and Procedures	

Low Complexity Feedback of MIMO Channel Information

1 Introduction

The closed-loop MIMO feedback mechanism is specified in IEEEE802.16-2004, which allows MSS to feedback full MIMO channel information in the fixed deployment scenario. In the mobility application, this requires a large amount of UL resource, and results in a tremendous overhead in the UL. Furthermore, in order to allow the BS to exploit multi-user diversity; a number of MSS are required to concurrently feedback the MIMO channel information to the network. It is desirable to reduce the MIMO channel feedback. In the context of closed-loop MIMO pre-coding, several proposals attempt to address this issue, in general, these proposals employ the code-book based vector quantization to compress the MIMO channel feedback resource and or use the unitary matrix to provide the BS transmit antenna weights. In this contribution, we present a very simple and straight-forward MIMO channel feedback approach by using the single-bit delta modulation to compress the MIMO channel coefficients.
The current solution of the MIMO channel quantization is shown in Figure 1, in IEEE802.16e the 4/5/6 bits quantizers are specified. However, two major issues are (1) quantization error is high around 10dB, this prevents the use of high QAM modulation such as 64QAM (2) the feedback resource requirement is high, for each MIMO sub-channel it requires 4,5,6 bits respectively.

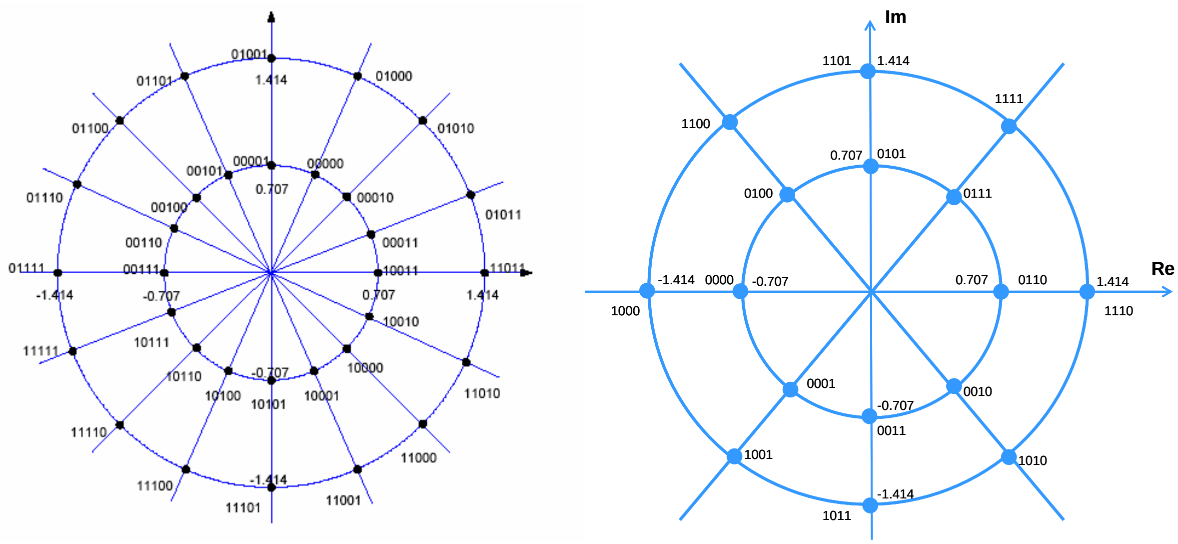

Figure 1 4-bit and 5-bit Quantizer

2 Proposed Solution

2.1 Delta Modulation

For the MIMO channel measured at MSS as: H_{MxN}, where M is the number of transmit antenna at BS and N is the number of receive antenna at MSS, each MIMO sub-channel elements $h_{i,j}$ is a complex random process, a simple 1-bit delta modulator can be used (see Figure 1) to perform quantize the real/imaginary part of the $h_{i,j}$.

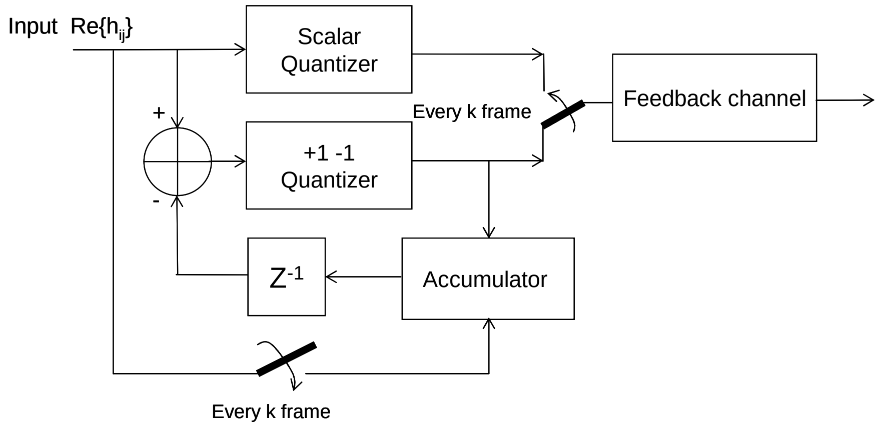

Figure 2 Delta Modulator

The compression ratio is 2~3 times comparing to the current specification. The MSS transmit the quantized MIMO channel coefficients directly to the BS, and the BS can recover MIMO channel with much less loss than IEEEE802.16-2004. The full scalar quantized MIMO channel coefficients are sent at the initial feedback and periodically transmitted by header message at every *k* frame to prevent the feedback channel error.

2.2 Direct MIMO channel Feedback

The proposed MIMO channel feedback solution is as follows:

1. Use 5-bit or 4-bit quantizer in the IEEE802.16 as initial MIMO channel feedback
2. Apply 1-bit delta modulation to the real and imaginary part of each MIMO channel element

3 Simulation Results

3.1 Simulation Set up

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	
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, 3 km/h, Antenna Correlation: 20% Perfect Channel Estimation	
Feedback	SVD: perfect pre-coding matrix V without quantization Delta Modulation: 2-bitper MIMO channel coefficient	

3.2 Performance

The simulation result for the ITU-PA, 3km/h channel is shown in Figure 1

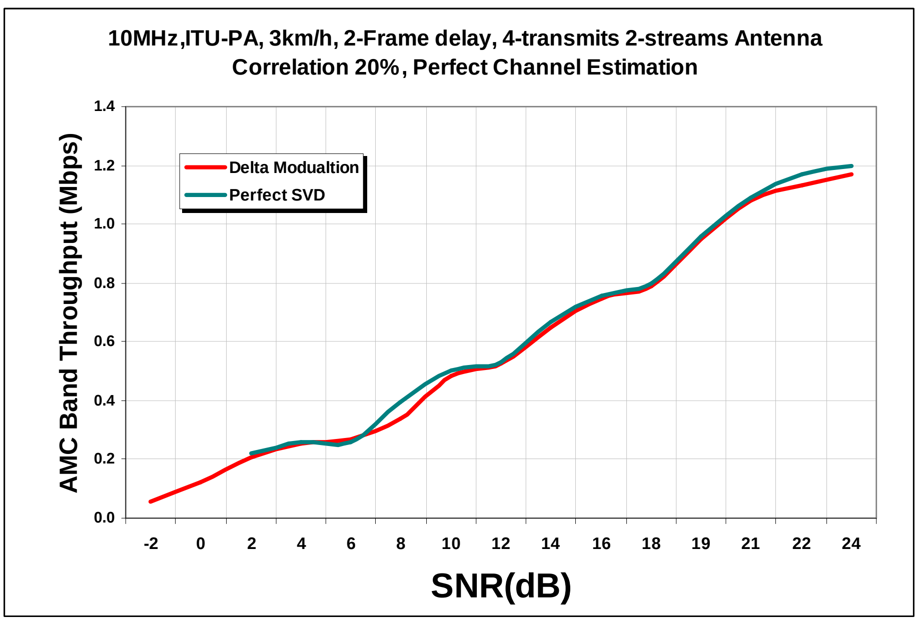

Figure 1 Comparison of Perfect SVD feedback and Delta Modulation MIMO Channel Feedback

3.2.1 Quantization SNR Performance

The performance of each schemes are evaluated based on the following metric,

$$SIR = mean\left[10 * \log_{10}\left(\gamma_{k,l}\right)\right]$$

where $\gamma_{k,l}$ is the signal-to-interference ratio for the l -th sub-carrier of the k -th frame due to quantization. It is defined by

$$\gamma_{k,l} = \frac{|h(k,l)|^2}{|h(k,l) - h(\hat{k},l)|^2}$$

The $h(k,l)$ is the ideal channel coefficient, and $h(\hat{k},l)$ is reconstructed channel coefficient for the l -th sub-carrier of the k -th frame, respectively.

Bits	2	4	5
ITU-PA	15.4	20.7	21.6
ITU-PB	14.9	19.3	20.1

Table 2: SIR for PA/PB channels

3.3 Feedback Resource Requirement

The comparison of the CQICH resource requirement for proposed 2-bit per MIMO channel element delta modulator based quantizer and 5-bit per MIMO channel element quantizer is listed in Table 3

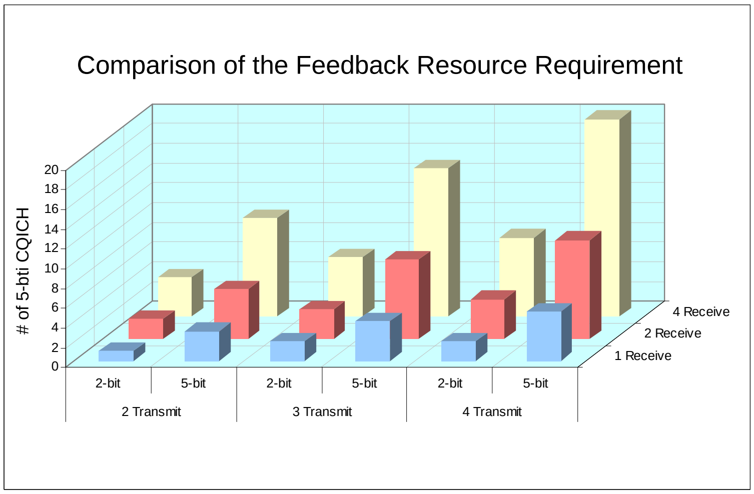

Figure 2 CQICH channel resource requirement comparison

	2 Transmit		3 Transmit		4 Transmit	
	2-bit	5-bit	2-bit	5-bit	2-bit	5-bit
1 Receive	1	3	2	4	2	5
2 Receive	2	5	3	8	4	10
4 Receive	4	10	6	15	8	20

Table 3 CQICH channel resource requirement comparison

3.3.1 Comparison with unitary feedback method

The typical unitary pre-coding based method is presented in [1], in this case the V matrix quantization feedback resource are listed in Table 4, in [1] the combined CQI index are introduced for each MIMO configurations, and for each configuration we have 12 coding modulation combinations. i.e. 4 bits are required to feedback the CQI information.

	2x2	3x2	4x2

		2-stream	2-stream	2-stream
Ref [1]	Index for V	4	9	11
	CQI for active streams	4	4	4
	Total	8	13	15
This Proposal	Delta Modulator	8	12	16

Table 4 Feedback resource requirement comparison

For the proposed direct MIMO matrix feedback approach, since the entire MIMO channel matrix is sent back to BS, BS can compute the eigen-modes and there for the value directly from the MIMO channel matrix. As we can see from Table 4, the direct MIMO channel feedback and the unitary based channel feedback require about similar amount the CQICH resources.

4 Discussion

Several advantages of the proposed solution:

1. Eliminate the complexity of codebook search at both MSS and BS, zero memory is required to store the codebook
2. Full MIMO channel information is sent to the BS, rather than only partial MIMO channel information (decomposed unitary matrix), which imposes limitation for BS to perform multi-user processing such as advanced beam-forming for multi-user and dirty-paper coding.
3. The proposed solution requires similar or even less feedback than the code-book based approach when $M > N$ (most applicable to closed loop based MIMO pre-coding), for the codebook based approach, in addition to send the codeword index, it is required to send the eigen mode strength (i.e. per-stream CQI information) to the BS. For the proposed solution, if SVD is required, the full channel information is available by computing the unitary beam-former and associated eigen values at BS.

5 Text Proposal

--------------------- *Start text proposal* --

[Add a new section 8.4.5.4.16 as follows]

The delta modulation can be applied to the MIMO channel coefficients $h_{ij}(k)$, where *i* is transmit antenna index, and *j* is the receive antenna index, and denote real part of the channel coefficients as $x(k) = real\{h_{ij}(k)\}$ and the imaginary part of the channel coefficients as $y(k) = imag\{h_{ij}(k)\}$. For $x(k)$, delta $d(k) = x(k) - \hat{x}(k-1)$ is quantized by a 1-bit quantizer which outputs $\tilde{x}(k) = Q[d(k)]$. $\hat{x}(k-1) = \sum_{i=1}^{k-1} \tilde{x}(i) + x(1)$ is the reconstruction of $x(k-1)$. The same procedure is applied to $y(k)$. 1-bit quantization index for $\tilde{x}(k)$ and $\tilde{y}(k)$ is mapped onto CQICH and fed back to BS.

-------------------- *End text proposal*--------------------------------

6 Reference

[1] Intel: Improved MIMO Feedback and Per-Stream ABL for OFDMA/OFDM Systems