Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**9-bit codebooks for closed-loop MIMO**
Date Submitted	**2005-03-12**
Source(s)	Qinghua Li, Xintian Eddie Lin, Ada Poon, Alexei Davydov, Minnie Ho, Nageen Himayat, Randall Schwartz, Jose Puthenkulam **Intel Corporation** qinghua.li@intel.com Voice: +1-408-765-9698 Jianzhong (Charlie) Zhang, Tony Reid, Kiran Kuchi **Nokia Inc.** charlie.zhang@nokia.com Voice: +1-972-374-0958
Re:	
Abstract	
Purpose	Adoption of proposed changes into P802.16e ~~Crossed-out indicates deleted text,~~ underlined blue indicates new text change to the Standard
Notice	
Release	
Patent Policy and Procedures	

9-bit Codebooks for Closed-loop MIMO

Qinghua Li and Xintian Eddie Lin, Jianzhong Charlie Zhang

1 Introduction

The codebooks tabulated in Section 8.4.5.4.11 employs 3 and 6 bit feedbacks. Namely, there are at most 64 codeword in each codebook. For 3x3, 4x2, 4x3, and 4x4 configurations, the beamforming accuracy can be significantly improved by adding 3 feedback bits. 9-bit codebooks are proposed.

2 Simulation results

The set of codebooks are evaluated by simulations. The channel model is ITU downlink, pedestrian A and B with 3 km/h. Transmit antenna correlation is 0.2 and receive antenna correlation is 0. The feedback delay is 2 frames, i.e. 10 ms. System bandwidth is 10 MHz with 5 ms per frame. Packet size is 64 byte. One index is fed back per AMC band. Both codebook SVD and STC are simulated. The 9-bit codebooks outperform 3- and 6-bit codebooks significantly as shown in the following figures. MMSE receiver is employed.

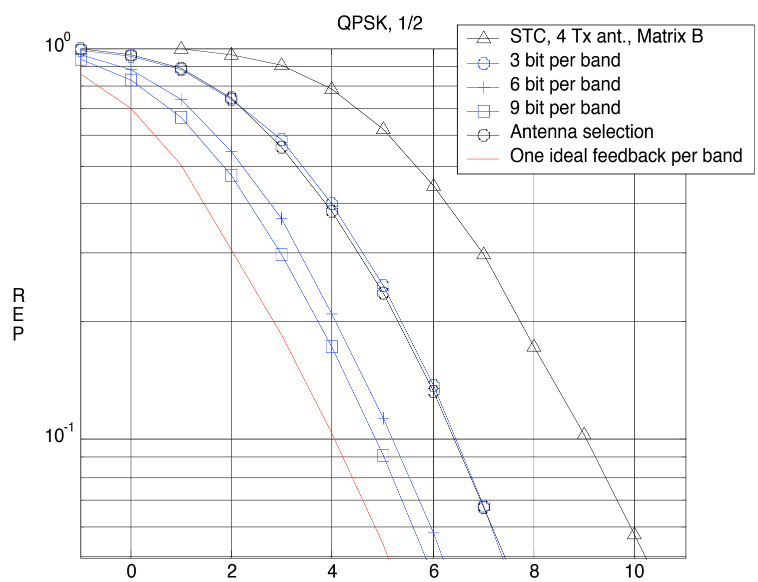

Figure 1 PER performance, 4x2 with 2 data streams, ITU pedestrian A.

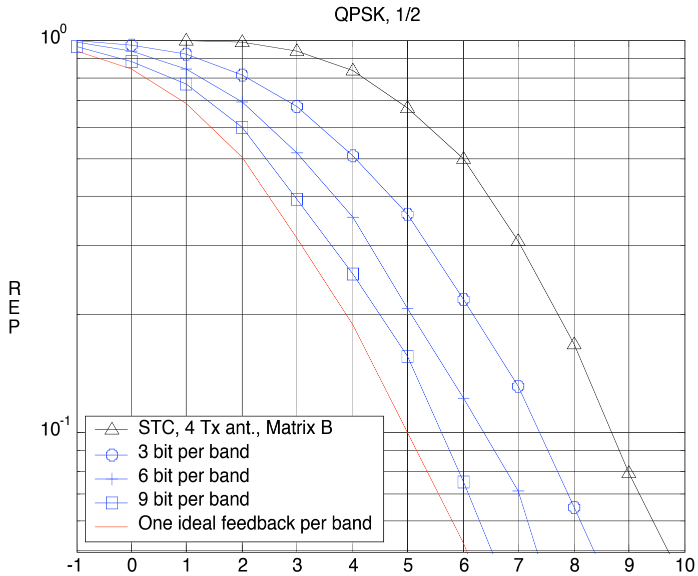

Figure 2 PER performance, 4x2 with 2 data streams, ITU pedestrian B.

3 Specific Text Changes

Added at the end of section 8.4.5.4.11 on page 334 of [1] as follows

The three operations are employed and they employs floating point arithmetic in IEEE standard 754, whose final results are rounded to 4 decimal places. The first operation generates a unitary N by N matrix $\mathrm{H}(\mathbf{v})$ using a N vector $\mathbf{v}$ as

$$\mathrm{H}(\mathbf{v}) = \begin{cases} \mathbf{I}, & \mathbf{v} = \mathbf{e}_1 \\ \mathbf{I} - p\mathbf{w}\mathbf{w}^H, & \text{otherwise} \end{cases},$$

where $\mathbf{w} = \mathbf{v} - \mathbf{e}_1$ and $\mathbf{e}_1 = \begin{bmatrix} 1 & 0 & \cdots & 0 \end{bmatrix}^T$; $p = \frac{2}{\|\mathbf{w}^H\mathbf{w}\|}$; $\mathbf{I}$ is the N by N identity matrix; ^{H} denotes the conjugate transpose operation. The second operation generates a N by $M+1$ unitary matrix from a unit N vector and a unitary $N-1$ by M matrix as

$$\mathrm{HC}\left(\mathbf{v}_N, \mathbf{A}_{(N-1)\times M}\right) = \mathrm{H}(\mathbf{v}_N)\begin{bmatrix} 1 & 0 & \cdots & 0 \\ 0 & & & \\ \vdots & & \mathbf{A}_{(N-1)\times M} & \\ 0 & & & \end{bmatrix},$$

where $N-1 \geq M$; the $N-1$ by M matrix unitary matrix has property $\mathbf{A}^H\mathbf{A} = \mathbf{I}$. The third operation generates a N by M matrix from a unit N vector, $\mathbf{v}_N$, by taking the last $N-1$ columns of $\mathrm{H}(\mathbf{v}_N)$ as

$$\mathrm{HE}(\mathbf{v}_N) = \mathrm{H}(\mathbf{v}_N)_{:,2:N}.$$

The three operations jointly generate 5 matrix codebooks as shown in Table 289k, where each entry is the generating operation of one codebook.

Table 289j Operations to generate codebooks $V(N_t, S, L)$ for N_t = 2, 3, 4, S = 2, 3, 4, and L = 9.

S / N_t, L	2	3	4
3, 9	$\mathrm{HC}(V(3,1,6), V(2,1,3))$	$\mathrm{HC}(V(3,1,6), \mathrm{H}(V(2,1,3)))$	

4, 9	$\mathrm{HC}(V(4,1,6), V(3,1,3))$	$\mathrm{HC}(V(4,1,3), \mathrm{HC}(V(3,1,3), V(2,1,3)))$	$\mathrm{HC}(V(4,1,3), \mathrm{HC}(V(3,1,3), \mathrm{H}(V(2,1,3))))$

The set notation $V(N_t,1,L)$ in the input arguments of the operations denotes that each vector in the codebook $V(N_t,1,L)$ is sequentially taken as an input to the operations. The output of the operation with one or more codebooks as input arguments is also a codebook. For example, in $\mathrm{HC}(V(3,1,6), \mathrm{H}(V(2,1,3)))$, HC has two codebooks as input. The first is $V(3,1,6)$ with 64 vectors and the second is $\mathrm{H}(V(2,1,3))$ with 8 2 by 2 matrixes, which are computed from $V(2,1,3)$. The feedback index is constructed by sequentially concatenating all the indexes of the input argument vector codebooks in binary format. For example, the feedback index of $\mathrm{HC}(V(3,1,6), \mathrm{H}(V(2,1,3)))$ is constructed as $i_2 j_2$, where i_2 and j_2 are the indexes of the vectors in codebooks $V(3,1,6)$ and $V(2,1,3)$ in binary format respectively; $_2$ denotes binary format for the indexes.

References:

[1] IEEE P802.16e/D6 Air Interface for Fixed and Mobile Broadband Wireless Access Systems – Amendment for Physical and Medium Access Control Layers for Combined Fixed and Mobile Operation in Licensed Bands, 2004.

[2] Q. Li, *et al.*, “Improved feedback for MIMO precoding,” IEEE C80216e-04/527r4, 2004.