

Project	<b>IEEE 802.16 Broadband Wireless Access Working Group</b> < <a href="http://ieee802.org/16">http://ieee802.org/16</a> >	
Title	<b>9-bit codebooks for closed-loop MIMO</b>	
Date Submitted	<b>2005-03-12</b>	
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Re:		
Abstract		
Purpose	Adoption of proposed changes into P802.16e <del>Crossed out indicates deleted text,</del> <u>underlined blue indicates new text change to the Standard</u>	
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# 9-bit Codebooks for Closed-loop MIMO

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## 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.

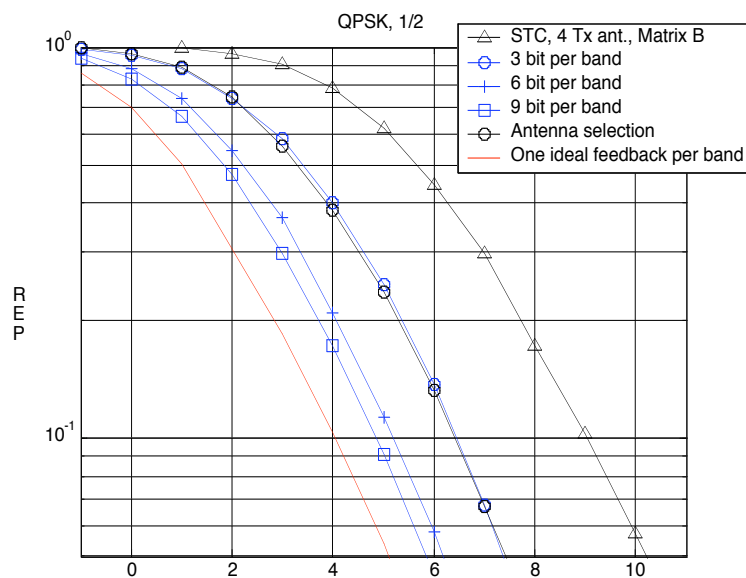


Figure 1 PER performance, 4x2 with 2 data streams, ITU pedestrian A.

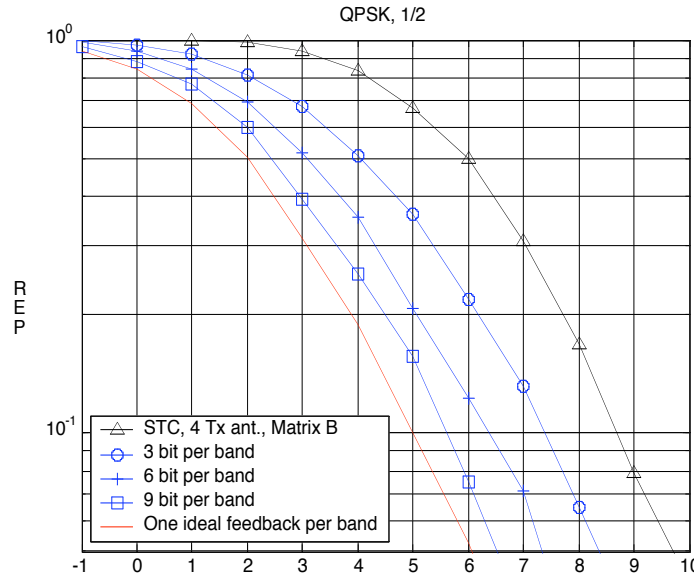


Figure 2 PER performance, 4x2 with 2 data streams, ITU pedestrian B.

### 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 employ 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  $H(\mathbf{v})$  using a  $N$  vector  $\mathbf{v}$  as

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

where  $\mathbf{w} = \mathbf{v} - \mathbf{e}_1$  and  $\mathbf{e}_1 = [1 \ 0 \ \dots \ 0]^T$ ;  $p = \frac{2}{\|\mathbf{w}^H \mathbf{w}\|}$ ;  $\mathbf{I}$  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

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

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  $H(\mathbf{v}_N)$  as

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

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  $L = 9$ .

$S \backslash N_t, L$	2	3	4
3, 9	$HC(V(3,1,6), V(2,1,3))$	$HC(V(3,1,6), H(V(2,1,3)))$	

<a href="#">4, 9</a>	$HC(V(4,1,6), V(3,1,3))$	$HC(V(4,1,3), HC(V(3,1,3), V(2,1,3)))$	$HC(V(4,1,3), HC(V(3,1,3), H(V(2,1,3))))$
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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  $HC(V(3,1,6), H(V(2,1,3)))$ , HC has two codebooks as input. The first is  $V(3,1,6)$  with 64 vectors and the second is  $H(V(2,1,3))$  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  $HC(V(3,1,6), H(V(2,1,3)))$  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.