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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

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Matrix codebooks

The matrix codebooks for multiple stream transmission are constructed from the vector codebooks in the previous section using three operations depicted next. We assume that all unit vectors in the section are complex with unit norm and the first entry of each vector is real. The first operation is called Householder reflection transformation mentioned above in (1). The other two operations are built on Householder transformation. One of them is called H-concatenation, and the other is called H-expansion, where the "H" stands for Householder. The H-concatenation (HC) generates a N by $M+1$ unitary matrix from a unit N vector and a unitary $N-1$ by M matrix using Householder transformation as

$$\mathrm{HC}\left(\mathbf{v}_N, \mathbf{A}_{(N-1)\times M}\right) = \mathrm{H}\left(\mathbf{v}_N\right)\begin{bmatrix} 1 & 0 & \cdots & 0 \\ 0 & & & \\ \vdots & & \mathbf{A}_{(N-1)\times M} & \\ 0 & & & \end{bmatrix}, \qquad (3)$$

where $N-1 \geq M$; the $N-1$ by M matrix unitary matrix has property $\mathbf{A}^H\mathbf{A} = \mathbf{I}$. Since both terms on the left are unitary the output of HC is a unitary matrix. The H-expansion (HE) generates a N by l matrix from a unit N vector, $\mathbf{v}_N$, by taking the last l columns of $\mathrm{H}(\mathbf{v}_N)$ as

$$\mathrm{HE}\left(\mathbf{v}_N, l\right) = \mathrm{H}\left(\mathbf{v}_N\right)_{:,N-l+1:N}. \qquad (4)$$

Three operations defined in (1), (3), and (4) jointly generate matrix codebooks as follows. In Table 55, by L bit codebook we mean the codebook has 2^L matrixes, which requires a L bit feedback index.

Table 5 Construction operations for N_t by N_s beamforming matrix codebooks with 9 bit indexes.

N_s / N_t	2	3	4
3 ant., 9 bit codebook	$\mathrm{HC}(V(3,6), V(2,3))$	$\mathrm{HC}(V(3,6), \mathrm{H}(V(2,3)))$	
4 ant., 9 bit codebook	$\mathrm{HC}(V(4,6), V(3,3))$	$\mathrm{HC}(V(4,3), \mathrm{HC}(V(3,3), V(2,3)))$	$\mathrm{HC}(V(4,3), \mathrm{HC}(V(3,3), \mathrm{H}(V(2,3))))$

The set notation $V(N_t, L)$ in the input parameter of the operations (i.e. H, HC, and HE) denotes that each vector in the codebook $V(N_t, L)$ is sequentially taken as an input parameter to the operations. The output of the operation (i.e., any one of H, HC, and HE) with a codebook as an input is also a codebook. For example, in $\mathrm{HC}(V(3,6), \mathrm{H}(V(2,3)))$, HC has two codebooks as input. The first one is $V(3,6)$ with 64 vectors and the second one is $\mathrm{H}(V(2,3))$ with 8 2 by 2 matrixes, which are computed from $V(2,3)$. The feedback index is constructed by concatenating all the indexes of the input argument vector codebooks in binary format. For example, the feedback index of $\mathrm{HC}(V(4,6), V(3,3))$ is constructed as $i_2 j_2$, where i_2 and j_2 are the indexes of the vectors in codebooks $V(4,6)$ and $V(3,3)$ in binary format respectively; $_2$ denotes binary format for the indexes.

1 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 scheme using the proposed codebooks outperforms STC significantly as shown in the following figures. MMSE receiver is employed.

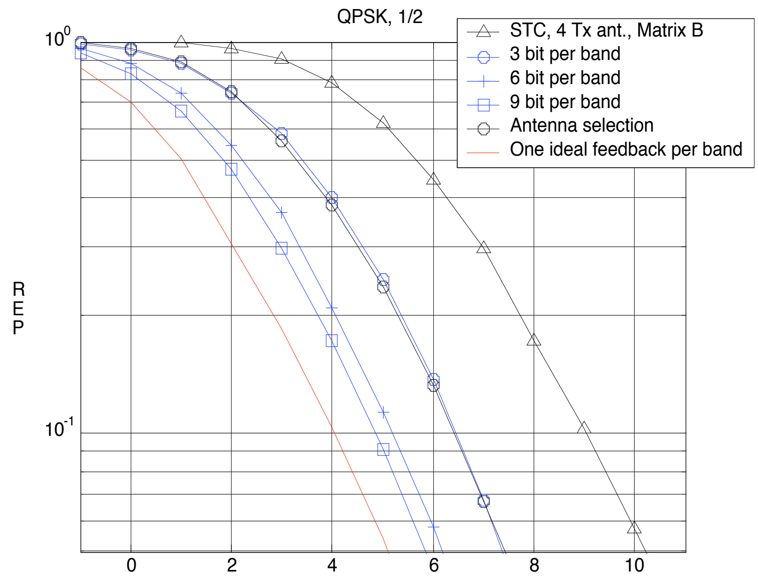

Figure 1 PER performance, 4x2 with 2 data streams, ITU pedestrian A.

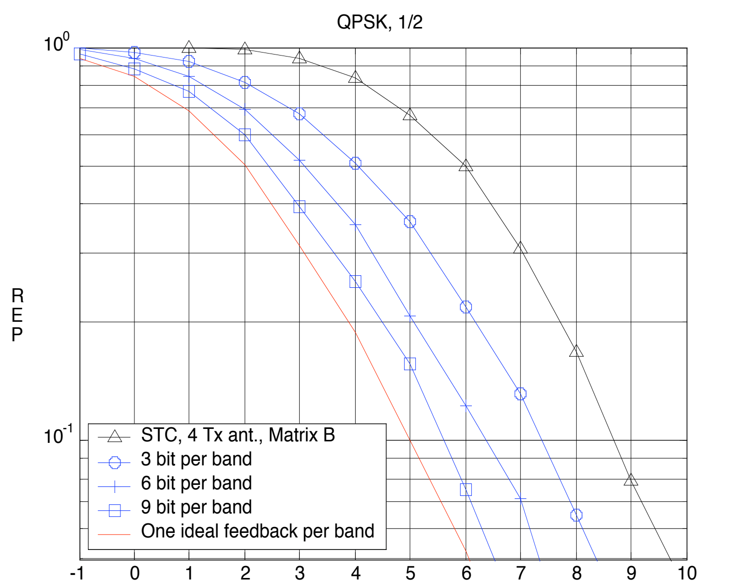

Figure 2 PER performance, 4x2 with 2 data streams, ITU pedestrian B.

2 Specific Text Changes

Added at the end (i.e., line 49) in section 8.4.5.4.10.12 on page 270 of [1] as follows

8.4.5.4.10.12 MIMO feedback for transmit beamforming

An operation, $\mathrm{H}(\mathbf{v})$, is defined. It 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 $\mathbf{e}_1 = [1 \ 0 \ \cdots \ 0]^T$; $p = \frac{2}{\|\mathbf{w}^H\mathbf{w}\|}$; $\mathbf{I}$ is the N by N identity matrix; ^{H} denotes the conjugate transpose operation.

The matrix codebooks for multiple stream transmission are constructed from the vector codebooks using three operations. The first operation is $\mathrm{H}(\mathbf{v})$. The second denoted as $\mathrm{HC}(\mathbf{v}_N, \mathbf{A}_{(N-1)\times M})$ generates a N by $M+1$ unitary matrix from a unit N vector and a unitary $N-1$ by M matrix as

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

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 denoted as $\mathrm{HE}(\mathbf{v}_N, M)$ generates a N by M matrix from a unit N vector, $\mathbf{v}_N$, by taking the last M columns of $\mathrm{H}(\mathbf{v}_N)$ as

$$\mathrm{HE}(\mathbf{v}_N, M) = \mathrm{H}(\mathbf{v}_N)_{:,N-M+1:N}.$$

The three operations jointly generate matrix codebooks as listed in Table 55.

Table 5 Generating operations for N_t by N_s codebooks with 3, 6, and 9 bit indexes.

N_t, L \ N_s	2	3	4
3 antennas, 9 bit	$\mathrm{HC}(V(3,6), V(2,3))$	$\mathrm{HC}(V(3,6), \mathrm{H}(V(2,3)))$	
4 antennas, 9 bit	$\mathrm{HC}(V(4,6), V(3,3))$	$\mathrm{HC}(V(4,3), \mathrm{HC}(V(3,3), V(2,3)))$	$\mathrm{HC}(V(4,3), \mathrm{HC}(V(3,3), \mathrm{H}(V(2,3))))$

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