Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	Enhancement for rate 1, 4-transmit antenna STC
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Re:	IEEE 802.16e D4 Draft
Abstract	Proposes an enhancement to rate 1, 4-transmit antenna space time code
Purpose	To incorporate the changes proposed here into the 802.16e D5 Draft.
Notice	
Release	
Patent Policy and Procedures	

Enhancement for rate 1, 4 transmit antenna STC

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1. Background

The 802.16e standard defines a rate 1, 4-antenna space-time-frequency code of form

$$\mathbf{A} = \begin{bmatrix} S_1 & -S_2^* & 0 & 0 \\ S_2 & S_1^* & 0 & 0 \\ 0 & 0 & S_3 & -S_4^* \\ 0 & 0 & S_4 & S_3^* \end{bmatrix},$$

Where the consecutive columns of the code span two OFDMA symbols and two sub-carriers respectively. The diversity order for this code is 2, if coding is not considered. However, with sufficient coding, code $\mathbf{A}$ is capable of attaining a diversity of order at least 4. In this proposal we propose a modification to the 4-antenna matrix $\mathbf{A}$, which increases the coding gain up to 0.7 dB. The proposed enhancement requires few changes to the transceiver specification.

2. Pair Wise Error Probability for 4-antenna Code

The signal model over two OFMA symbols[1] and a pair of frequencies can be presented in matrix form as,

$$\mathbf{y} = \mathbf{A}\mathbf{h} + \mathbf{n}$$

where $\mathbf{h} = [h_1, h_2, h_3, h_4]$ are assumed to be frequency-flat channel coefficients, $\mathbf{n}$ is a column vector composed of AWGN noise samples of variance N_0 per dimension. The modulation symbols S_k are coded across space-time-frequency dimensions. Under the assumption of ML decoding, the pair wise error probability of the 4-antenna code in AWGN channels can be upper bounded as,

$$P(c \to e) \le E\left[Q\left(\sqrt{\frac{\mathbf{hDh}^*}{N_0}} \right) \right],$$

Where expectation operation E is performed over the channel statistics. The diagonal matrix $\mathbf{D}$ contains the Hamming distances[2] seen by each channel coefficient along the error event path. Due to the presence of

[1] The channel is assumed to be time invariant during two OFDMA symbols

orthogonal STBC, the diagonal entries of $\mathbf{D} = \mathrm{diag}[d_1, d_1, d_2, d_2]$ appear in pairs. In other words, among the four space-time-frequency symbols, pairs of symbols experience the same channel due to STBC encoding.

Diversity Order:

The diversity order for the 4-antenna code is determined by the rank of $\mathbf{D}$. The presence of STBC ensures a minimum diversity of order 2. Full, 4th order diversity requires a powerful channel code. In the present case, a rate 1/2 binary convolutional code should be able to provide full 4th order diversity.

Coding Gain:

The following can maximize both diversity and coding gain of the presented code:

- Maximize the trace of $\mathbf{D}$ i.e.,

$$d_{\max}^{H} = \max \ \mathrm{Trace}[\mathbf{D}].$$

- Ensure the diagonal entries of $\mathbf{D}$ are as nearly equal as possible.

The best possible choice is for the 4-antenna code is force $d_1 = d_2$, which corresponds to the maximizing both diversity and coding gain. In practice, it is difficult to design codes with equal hamming distances for all error events, but one could always try to make them as nearly equal as possible. The condition $d_1 \neq d_2$ implies a reduction is coding gain. This loss is severe especially when there is a large imbalance between d_1, and d_2. In the following, we present a simple antenna circulation operation as a remedy for reducing the imbalance between the diagonal entries of $\mathbf{D}$, thus maximizing the coding gain.

2.1 Antenna Circulation

We propose that we switch the assignment of rows of matrix $\mathbf{A}$ according to a predetermined pattern. The switching is performed in time-frequency dimensions. We propose the following antenna assignment be performed periodically every N sub carriers, where N is design parameter.

[2] In this case both Hamming distance and Euclidean distances are synonymously used. The notation is exact is for QPSK modulation. For higher order constellations, Euclidean distance is more appropriate criterion.

$$\mathbf{A}_1 = \begin{bmatrix} S_1 & -S_2^* & 0 & 0 \\ S_2 & S_1^* & 0 & 0 \\ 0 & 0 & S_3 & -S_4^* \\ 0 & 0 & S_4 & S_3^* \end{bmatrix},\ \mathbf{A}_2 = \begin{bmatrix} S_1 & -S_2^* & 0 & 0 \\ 0 & 0 & S_3 & -S_4^* \\ S_2 & S_1^* & 0 & 0 \\ 0 & 0 & S_4 & S_3^* \end{bmatrix},\ \mathbf{A}_3 = \begin{bmatrix} S_1 & -S_2^* & 0 & 0 \\ 0 & 0 & S_3 & -S_4^* \\ 0 & 0 & S_4 & S_3^* \\ S_2 & S_1^* & 0 & 0 \end{bmatrix}.$$

The pair-wise error probability for the circulated code takes the form:

$$P(c \to e) \le E\left[Q\left(\sqrt{\frac{\mathbf{h}\Lambda\mathbf{h}^*}{N_0}} \right) \right]$$

where Λ is diagonal matrix with entries, $\Lambda = \mathrm{Diag}[\tilde{d}_1, \tilde{d}_2, \tilde{d}_3, \tilde{d}_4]$. Unlike the non-circulated case, Λ now contains distinct diagonal entries, and better approximates the equal Hamming distance criterion, thus offering an increase in coding gain. Note that the circulation principle applies to 3-antenna case as well.

3. Performance

In Figure 1, we compared the FER performance of the circulated code to Matrix A for 4 Tx and 1 Rx case in for Ped B channel, rate 1/2 convolutional code, QPSK modulation. We notice a coding gain of up to 0.7 dB. Similar gains are observed for other modulation and coding modes.

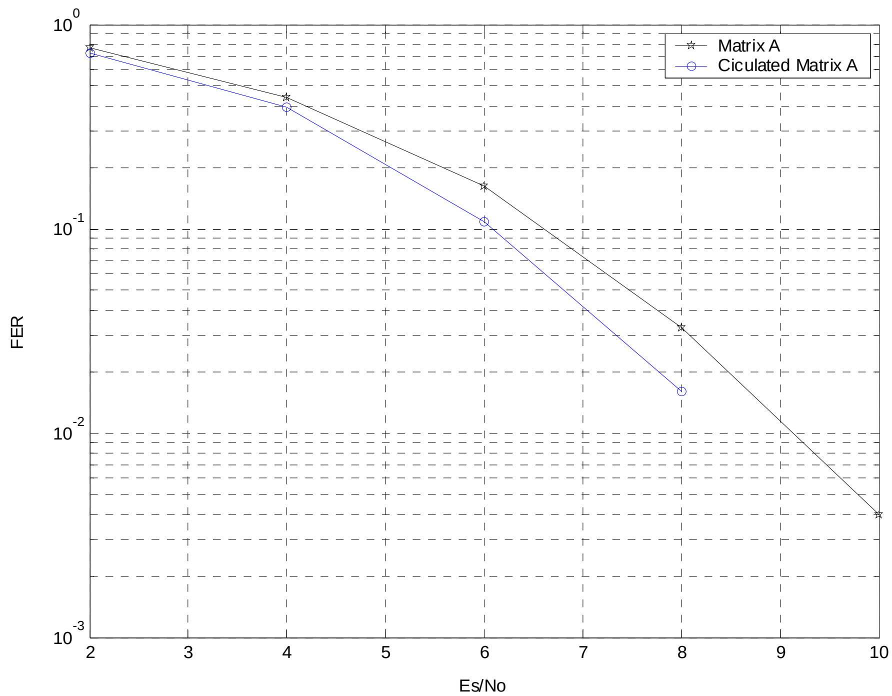

Figure1: FER performance of rate 1, circulated matrix A

4. Proposed Text Change

8.4.8.3.5 Transmission schemes for 4-antenna BS

The proposed Space-Time-Frequency code (over two OFDMA symbols and two sub-carriers) for 4Tx-Rate 1 configuration with diversity order 4 is given in three permuted versions:

$$\mathbf{A}_1=\begin{bmatrix} S_1 & -S_2^* & 0 & 0 \\ S_2 & S_1^* & 0 & 0 \\ 0 & 0 & S_3 & -S_4^* \\ 0 & 0 & S_4 & S_3^* \end{bmatrix},\ \mathbf{A}_2=\begin{bmatrix} S_1 & -S_2^* & 0 & 0 \\ 0 & 0 & S_3 & -S_4^* \\ S_2 & S_1^* & 0 & 0 \\ 0 & 0 & S_4 & S_3^* \end{bmatrix},\ \mathbf{A}_3=\begin{bmatrix} S_1 & -S_2^* & 0 & 0 \\ 0 & 0 & S_3 & -S_4^* \\ 0 & 0 & S_4 & S_3^* \\ S_2 & S_1^* & 0 & 0 \end{bmatrix}.$$

Let Nc =8 denote the number of subcarriers in a group. The choice of subscript k to determine the matrix A_k is given by the following formula: k

=mod(floor(logical_data_sub_carrier_number_for_first_tone_of_code/Nc),3)+1. where logical_data_sub_carrier_number_for_first_tone_of_code = 1,2,3,…,Total # of data sub-carriers.

5. References

[1] V. Tarokh, N. Seshadri, and A.R. Calderbank, " Space-Time Codes for High Data Rate Communication: Performance Criterion and Code Construction", IEEE Transactions on Information Theory, vol. 44, pp. 744-765, 1998.
[2] IEEE P802.16-REVd/D5-2004 Draft standards for local and metropolitan area networks part 16: Air interface for fixed broadband wireless access systems.