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Title	Enhancements of the 4 transmit antenna rate 1 space-time code for the OFDMA PHY
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Re:	802.16e/D5
Abstract	We propose improved space-time codes with full diversity for 4 Tx – Rate 1.
Purpose	To propose enhancements of the space-time codes in 802.16e/D4.
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Enhancement of the 4 Transmit Antenna Rate 1 Space-Time Code for the OFDMA PHY

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Introduction

We propose a low decoding complexity (symbol by symbol decoding) improved space-time code with full diversity for 4 Tx – rate 1 configuration.

Proposed enhancement

STC for 4 Tx – Rate 1 code:

We propose to replace the existing transmission matrix

$$A = \begin{bmatrix} s_1 & -s_2^* & 0 & 0 \\ s_2 & s_1^* & 0 & 0 \\ 0 & 0 & s_3 & -s_4^* \\ 0 & 0 & s_4 & s_3^* \end{bmatrix}.$$

with the new the transmission matrix A_1 which is defined as follows:

Let the complex symbols to be transmitted be x_1, x_2, x_3, x_4 which take values from a square QAM constellation. Let $s_i = x_i e^{j\theta}$ for i= 1,2,3,4, where $\theta = 66^0$ for QPSK, $\theta = 74^0$ for 16QAM, and $\theta = 58^o$ for 64 QAM and let

$$\tilde{s}_1 = s_{1I} + js_{3Q}\,;\, \tilde{s}_2 = s_{2I} + js_{4Q}\,;\, \tilde{s}_3 = s_{3I} + js_{1Q}\,;\, \tilde{s}_4 = s_{4I} + js_{2Q} \quad \text{where } s_i = s_{iI} + js_{iQ}\,.$$

The proposed Space-Time-Frequency code for 4Tx-Rate 1 configuration is

$$A_1 = \begin{bmatrix} \tilde{s}_1 & -\tilde{s}_2^* & 0 & 0 \\ \tilde{s}_2 & \tilde{s}_1^* & 0 & 0 \\ 0 & 0 & \tilde{s}_3 & -\tilde{s}_4^* \\ 0 & 0 & \tilde{s}_4 & \tilde{s}_3^* \end{bmatrix}$$

The first two columns correspond to the two OFDM symbols and one subcarrier. Similarly the last two columns correspond to the same two OFDM symbols, but for the next subcarrier. Let $H^{(1)} = [H_1(1) \quad H_2(1) \quad H_3(1) \quad H_4(1)]$ be the channel coefficients for the first subcarrier. The channel is assumed to be quasi-static for two OFDM symbols, but could be varying across the subcarriers. Let $H^{(2)} = [H_1(2) \quad H_2(2) \quad H_3(2) \quad H_4(2)]$ be the channel coefficients for the second subcarrier. Then, the received signal (assuming a single receive antenna) on the first sub-carrier is given by

$$[Y_1^1 \quad Y_2^1] = H^{(1)} A_1(1:2) + noise$$

and for the second sub-carrier is given by

$$[Y_1^2 \quad Y_2^2] = H^{(2)} A_1(3:4) + noise$$

where Y_k^j denotes the received symbol on the j[th] subcarrier at time k. $A_1(1{:}2)$ denotes the 1[st] and 2[nd] columns of A_1 and similarly, $A_1(3{:}4)$ denotes the 3[rd] and 4[th] colums of A_1. The above measurements can be re-written as follows:

$$[Y_1^1 \quad Y_2^1 \quad Y_1^2 \quad Y_2^2] = [H_1(1) \quad H_2(1) \quad H_3(2) \quad H_4(2)] \begin{bmatrix} Alamouti(\tilde{s}_1, \tilde{s}_2) & 0 \\ 0 & Alamouti(\tilde{s}_3, \tilde{s}_4) \end{bmatrix}$$

This proposed change is guided by the following reasons: (i) The transmit diversity gain of A_1 is 4 whereas that of A in [1] is only 2; (ii) A_1 admits a decoupled symbol-by-symbol decoding for the variables which leads to a fast ML decoding (analogous to the Alamouti code for 2Tx). Fig. 1 shows the performance of this code using decoupled ML decoding of low complexity for QPSK.

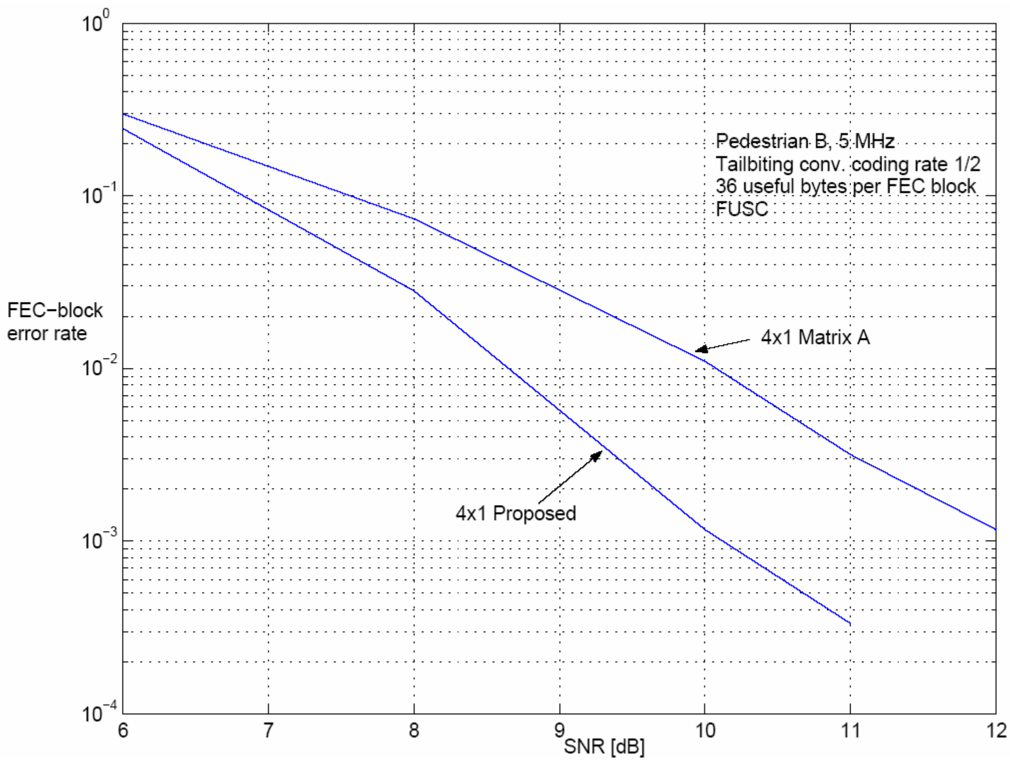

Figure 1: Performance comparison for 4Tx-Rate 1 the current matrix A in the standard and proposed matrix A_1 for Pedestrian-B channel model, QPSK modulation, and Tail-biting Convolutional Code with Hard Decision Decoding.

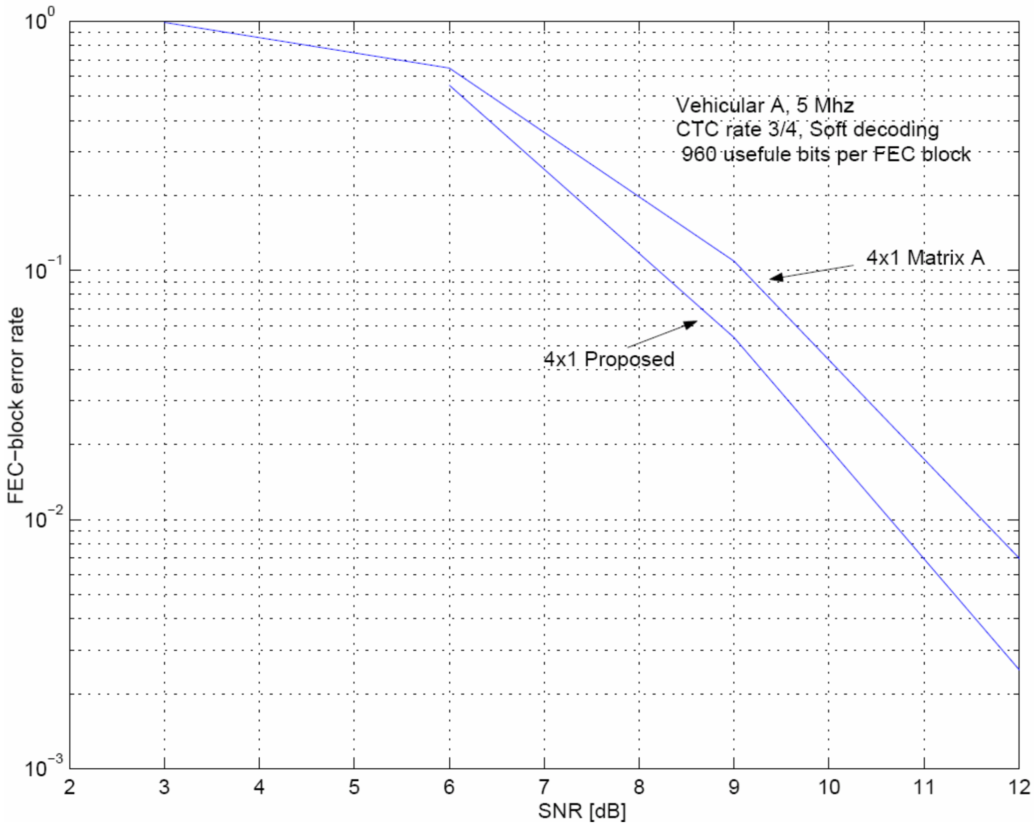

Figure 2: Performance comparison for 4Tx-Rate 1 the current matrix A in the standard and proposed matrix A_1 for Vehicular-A channel model, QPSK modulation, and rate ¾ Convolutional Turbo Code with Soft Decision Decoding.

Specific text changes

[Modify the following sections of 802.16e/D4]

8.4.8.3.4 Transmission schemes for 4-antenna BS (page 98):

Replace the existing transmission matrix A:

$$A = \begin{bmatrix} s_1 & -s_2^* & 0 & 0 \\ s_2 & s_1^* & 0 & 0 \\ 0 & 0 & s_3 & -s_4^* \\ 0 & 0 & s_4 & s_3^* \end{bmatrix}.$$

With A_1 shown below:

$$A_1 = \begin{bmatrix} \tilde{s}_1 & -\tilde{s}_2^* & 0 & 0 \\ \tilde{s}_2 & \tilde{s}_1^* & 0 & 0 \\ 0 & 0 & \tilde{s}_3 & -\tilde{s}_4^* \\ 0 & 0 & \tilde{s}_4 & \tilde{s}_3^* \end{bmatrix}.$$

where the complex symbols to be transmitted are x_1, x_2, x_3, x_4 which take values from a square QAM constellation and $s_i = x_i e^{j\theta}$ for i=1,2,3,4, where $\theta = 66^0$ for QPSK, $\theta = 74^0$ for 16QAM, and $\theta = 58^o$ for 64 QAM and also let

$\tilde{s}_1 = s_{1I} + js_{3Q}$; $\tilde{s}_2 = s_{2I} + js_{4Q}$; $\tilde{s}_3 = s_{3I} + js_{1Q}$; $\tilde{s}_4 = s_{4I} + js_{2Q}$ where $s_i = s_{iI} + js_{iQ}$.

References

[1] B.A.Sethuraman, B.Sundar Rajan and V.Shashidhar, "Full-diversity, High-rate Space-Time Block Codes from Division Algebras," IEEE Transactions on Information Theory, Vol.49, No.10, Oct. 2003, pp.2596-2616.

[1] Zafar Ali Khan, B. Sundar Rajan and Moon Ho Lee,"On single-symbol and double-symbol decodable STBCs," Proceedings of IEEE Intl. Symposium on Information Theory (ISIT-2003), Yokohama, Japan, June 2003, p.127.

[2] V.Shashidhar, B.Sundar Rajan and P.Vijay Kumar, "STBCs with optimal diversity-multiplexing trade-off for 2,3 and 4 transmit antennas," to appear Proceedings of IEEE International Symposium on Information Theory, June 27-July 3, 2004.

[3] IEEE P802.16e/D4 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