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Re:	802.16e/D5
Abstract	Space-time codes for 3 transmit antennas with full diversity.
Purpose	Modify the 3 transmit antenna space-time codes in 802.16e/D4.
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Modifications to the Space-Time Codes for 3 Transmit antennas for the OFDMA PHY

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1 Introduction

We propose modifications to the space-time codes for 3 transmit antennas in the OFDMA PHY.

2 Proposed Modifications to the Space-Time Codes for 3 Antenna BS

2.1 Unequal power per antenna for the 3Tx rate 2 code, i.e. Matrix B

We propose that the 3 Tx antenna rate 2 code, i.e. Matrix B, be changed to:

2.1.1 STC for 3Tx-Rate 2:

For three antenna BS, for transmission matrix B the following STF code shall be used:

Let the complex symbols to be transmitted be x_1, x_2, x_3,… x_8 which take values from a square QAM constellation. Let $s_i = x_i e^{j\theta}$ for i=1,2,…,8, where $\theta = \frac{1}{2}\tan^{-1} 2$ and let

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

The STF code matrix to be use is

$$B = \begin{bmatrix} \sqrt{\frac{3}{4}} & 0 & 0 \\ 0 & \sqrt{\frac{3}{4}} & 0 \\ 0 & 0 & \sqrt{\frac{3}{2}} \end{bmatrix} \begin{bmatrix} \tilde{s}_1 & -\tilde{s}_2^* & \tilde{s}_5 & -\tilde{s}_6^* \\ \tilde{s}_2 & \tilde{s}_1^* & \tilde{s}_6 & \tilde{s}_5^* \\ \tilde{s}_7 & -\tilde{s}_8^* & \tilde{s}_3 & -\tilde{s}_4^* \end{bmatrix} \quad \text{----- (1)}$$

where the definition for the remaining variables are as follows:

$\tilde{s}_5 = s_{5I} + js_{7Q}$; $\tilde{s}_6 = s_{6I} + js_{8Q}$; $\tilde{s}_7 = s_{7I} + js_{5Q}$; $\tilde{s}_8 = s_{8I} + js_{6Q}$

2.2 Cyclic permutation of codes

~~For both Matrix A and Matrix B the power to the different antennas are unequal. In order to avoid this, we propose a cyclic permutation scheme that distributes the rows of the code matrices assigned to a particular antenna over 2 frequencies across all antennas over 6 frequencies. This is shown in figure xxx.~~

For both Matrix A and Matrix B the power to the different antennas are unequal. In order to avoid this, we propose a cyclic permutation scheme that distributes the rows, or semi-rows, of the code matrices assigned to a particular antenna over 2 frequencies across all antennas over 6 frequencies.

Matrix A is permuted into three different versions:

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

$$A_2 = \begin{bmatrix} \tilde{s}_1 & -\tilde{s}_2^* & \tilde{s}_3 & -\tilde{s}_4^* \\ \tilde{s}_2 & \tilde{s}_1^* & 0 & 0 \\ 0 & 0 & \tilde{s}_4 & \tilde{s}_s^* \end{bmatrix}$$

and

$$A_3 = \begin{bmatrix} \tilde{s}_1 & -\tilde{s}_2^* & 0 & 0 \\ 0 & 0 & \tilde{s}_3 & -\tilde{s}_4^* \\ \tilde{s}_2 & \tilde{s}_1^* & \tilde{s}_4 & \tilde{s}_s^* \end{bmatrix}$$

Likewise, Matrix B is permuted into three different versions:

$$B_1 = \begin{bmatrix} \sqrt{\frac{3}{4}} & 0 & 0 \\ 0 & \sqrt{\frac{3}{4}} & 0 \\ 0 & 0 & \sqrt{\frac{3}{2}} \end{bmatrix} \begin{bmatrix} \tilde{s}_1 & -\tilde{s}_2^* & \tilde{s}_5 & -\tilde{s}_6^* \\ \tilde{s}_2 & \tilde{s}_1^* & \tilde{s}_6 & \tilde{s}_5^* \\ \tilde{s}_7 & -\tilde{s}_8^* & \tilde{s}_3 & -\tilde{s}_4^* \end{bmatrix}$$

$$B_2 = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ 1 & 0 & 0 \end{bmatrix} B_1$$

and

$$B_3 = \begin{bmatrix} 0 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix} B_1$$

The matrices A_1 to A_3 and the matrices B_1 to B_3 then applied in a cyclic manner as they are deployed on the subcarriers. This is illustrated in Figure 1.

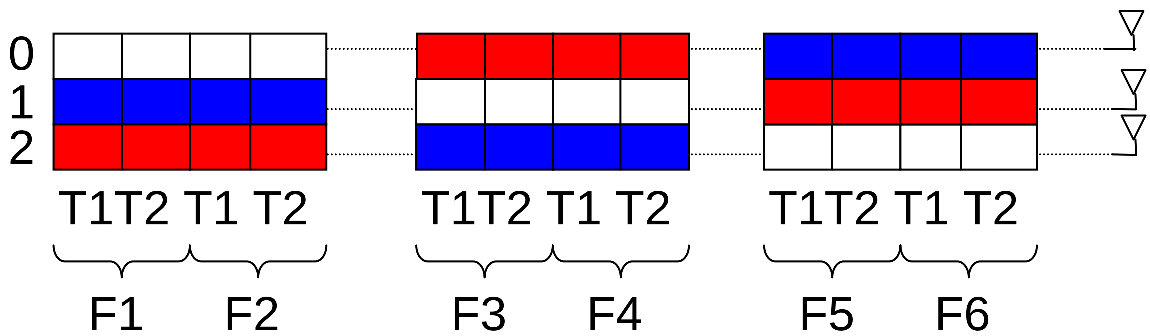

Figure 1

~~The 3 Tx antenna Matrix A and B in 802.16e/D4 are defined over 2 OFDM symbols and 2 frequencies. This is represented by the left-most rectangle in figure XXX.~~

~~In case of Matrix A, the zeros in the row 0 and 2 result in higher power on row 1. Permuting all the rows across 6 frequencies balances the power on each antenna.~~

~~In case of Matrix B, the power boost introduced on row 2 by Equation (1) is distributed equally over all antennas by permuting all the rows across 6 frequencies. This balances the power assigned to each antenna.~~

White color represents use of the matrix, A or B, with index 1. Blue color represents the use of the matrix with index two and red indicates the use of the matrix with index 3.

The 3 Tx antenna Matrix A and B in 802.16e/D4 are defined over 2 OFDM symbols and 2 frequencies. This is represented by the left-most rectangle in Figure 1..

In case of Matrix A, the zeros in the row 0 and 2 result in higher power on row 1. Cycling through its permutated versions across 6 frequencies balances the power on each antenna.

In case of Matrix B, the power boost introduced on row 2 by Equation (1) is distributed equally over all antennas by cycling through its permuted versions across 6 frequencies. This again balances the power assigned to each antenna.

This can also be represented by the formula below:

~~Row *k* (k = 1, 2, 3) in Matrix A and Matrix B is mapped to antenna:~~

~~mod(*logical_data_sub-carrier_number_for_first_tone_of_code + k , 3*)~~

~~where *logical_data_sub-carrier_number_for_first_tone_of_code* = 1, …, Total # of data sub-carriers~~

The index, k, of the permuted version of Matrix A and Matrix B to use for a particular deployment is given by:

k = mod(*logical_data_sub-carrier_number_for_first_tone_of_code* , *3*) + 1

where *logical_data_sub-carrier_number_for_first_tone_of_code* = 1, …, Total # of data sub-carriers

Specific text changes
[Modify in 802.16e/D4]

2.2.1 Modify in Section ‘8.4.8.3.5 Transmission schemes for 3 antenna BS’

Replace:

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

with:

The Matrix A is given in three permuted versions:

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

$$A_2 = \begin{bmatrix} \tilde{s}_1 & -\tilde{s}_2^* & \tilde{s}_3 & -\tilde{s}_4^* \\ \tilde{s}_2 & \tilde{s}_1^* & 0 & 0 \\ 0 & 0 & \tilde{s}_4 & \tilde{s}_s^* \end{bmatrix}$$

and

$$A_3 = \begin{bmatrix} \tilde{s}_1 & -\tilde{s}_2^* & 0 & 0 \\ 0 & 0 & \tilde{s}_3 & -\tilde{s}_4^* \\ \tilde{s}_2 & \tilde{s}_1^* & \tilde{s}_4 & \tilde{s}_s^* \end{bmatrix}$$

Replace:

$$B = \begin{bmatrix} \tilde{s}_1 & -\tilde{s}_2^* & \tilde{s}_5 & -\tilde{s}_6^* \\ \tilde{s}_2 & \tilde{s}_1^* & \tilde{s}_6 & \tilde{s}_5^* \\ \tilde{s}_7 & \tilde{s}_8 & \tilde{s}_3 & \tilde{s}_4 \end{bmatrix}$$

with:

$$B = \begin{bmatrix} \sqrt{\frac{3}{4}} & 0 & 0 \\ 0 & \sqrt{\frac{3}{4}} & 0 \\ 0 & 0 & \sqrt{\frac{3}{2}} \end{bmatrix} \begin{bmatrix} \tilde{s}_1 & -\tilde{s}_2^* & \tilde{s}_5 & -\tilde{s}_6^* \\ \tilde{s}_2 & \tilde{s}_1^* & \tilde{s}_6 & \tilde{s}_5^* \\ \tilde{s}_7 & \tilde{s}_8 & \tilde{s}_3 & \tilde{s}_4 \end{bmatrix}$$

The matrix B is given in three permuted versions:

$$B_1 = \begin{bmatrix} \sqrt{\frac{3}{4}} & 0 & 0 \\ 0 & \sqrt{\frac{3}{4}} & 0 \\ 0 & 0 & \sqrt{\frac{3}{2}} \end{bmatrix} \begin{bmatrix} \tilde{s}_1 & -\tilde{s}_2^* & \tilde{s}_5 & -\tilde{s}_6^* \\ \tilde{s}_2 & \tilde{s}_1^* & \tilde{s}_6 & \tilde{s}_5^* \\ \tilde{s}_7 & -\tilde{s}_8^* & \tilde{s}_3 & -\tilde{s}_4^* \end{bmatrix}$$

$$B_2 = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ 1 & 0 & 0 \end{bmatrix} B_1$$

and

$$B_3 = \begin{bmatrix} 0 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix} B_1$$

[Add in 802.16e/D4]

2.2.2 Add in Section '8.4.8.3.5 Transmission schemes for 3 antenna BS'

~~Row *k* (k = 1, 2, 3) in Matrix A and Matrix B is mapped to antenna:~~

~~mod(*logical_data_sub-carrier_number_for_first_tone_of_code + k* , *3*)~~

~~where *logical_data_sub-carrier_number_for_first_tone_of_code* = 1, …, Total # of data sub-carriers~~

The index, k, of the permuted version of Matrix A and Matrix B to use for a particular deployment is given by:

k = mod(*logical_data_sub-carrier_number_for_first_tone_of_code* , *3*) + 1

where *logical_data_sub-carrier_number_for_first_tone_of_code* = 1, …, Total # of data sub-carriers