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

Erik Lindskog, V. Shashidhar, B. Sundar Rajan, Djordje Tajkovic,
Tareq Al-Naffouri, Erik Stauffer, Taiwen Tang, David Garrett,
K. Giridhar, Bob Lorenz, Babu Mandava, A. Paulraj, Trevor Pearman,
Kamlesh Rath, Aditya Agrawal, Mai Vu

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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 \( s_i = x_i e^{i\theta} \) for \( i = 1, 2, 3, 4 \), where \( \theta = 66^\circ \) for QPSK, \( \theta = 74^\circ \) for 16QAM, and \( \theta = 58^\circ \) for 64 QAM and let

\[
\tilde{s}_1 = s_{1t} + js_{3Q} ; \tilde{s}_2 = s_{2t} + js_{4Q} ; \tilde{s}_3 = s_{3t} + js_{1Q} ; \tilde{s}_4 = s_{4t} + js_{2Q} \quad \text{where} \quad s_i = s_{it} + js_{iQ}.
\]

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 \( H^{(1)} = [H_1(l) \ H_2(l) \ H_3(l) \ H_4(l)] \) 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 \( H^{(2)} = [H_1(2) \ H_2(2) \ H_3(2) \ H_4(2)] \) 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

\[
\begin{bmatrix}
Y_1^1 & Y_2^1
\end{bmatrix} = H^{(1)} A_1(1:2) + \text{noise}
\]

and for the second sub-carrier is given by

\[
\begin{bmatrix}
Y_1^2 & Y_2^2
\end{bmatrix} = H^{(2)} A_1(3:4) + \text{noise}
\]

where \( Y_j^i \) 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\(^{th}\) columns of \( A_1 \). The above measurements can be re-written as follows:

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

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.

![Graph showing performance comparison between 4x1 Matrix A and 4x1 Proposed for Pedestrian-B channel model.]

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 $\frac{3}{4}$ 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:
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 $\theta = 58^0$ for 64 QAM and also let

$$\tilde{s}_1 = s_{1l} + js_{1Q}; \tilde{s}_2 = s_{2l} + js_{2Q}; \tilde{s}_3 = s_{3l} + js_{3Q}; \tilde{s}_4 = s_{4l} + js_{4Q}$$

where $s_i = s_{il} + js_{iQ}$.

References


