<table>
<thead>
<tr>
<th>Project</th>
<th>IEEE 802.16 Broadband Wireless Access Working Group <a href="http://ieee802.org/16">http://ieee802.org/16</a></th>
</tr>
</thead>
<tbody>
<tr>
<td>Title</td>
<td>Enhancement for rate 2, 4-transmit antenna STC</td>
</tr>
<tr>
<td>Date Submitted</td>
<td>2005-1-10</td>
</tr>
<tr>
<td>Source(s)</td>
<td>Jianzhong (Charlie) Zhang, Kiran Kuchi, Anthony Reid</td>
</tr>
</tbody>
</table>
|          | Voice: 972-374-0958, 972-374-1862  
|          | Fax: 972-894-5937  
|          | charlie.zhang@nokia.com, kiran.kuchi@nokia.com |
|          | Nokia  
|          | 6000 Connection Drive  
|          | Irving, TX 75039          |
| Re:     | IEEE 802.16e D5 Draft          |
| Abstract | Proposes an enhancement to rate 2, 4-transmit antenna space time code |
| Purpose | To incorporate the changes proposed here into the 802.16e D5 Draft. |
| Notice  | This document has been prepared to assist IEEE 802.16. It is offered as a basis for discussion and is not binding on the contributing individual(s) or organization(s). The material in this document is subject to change in form and content after further study. The contributor(s) reserve(s) the right to add, amend or withdraw material contained herein. |
| Release | The contributor grants a free, irrevocable license to the IEEE to incorporate material contained in this contribution, and any modifications thereof, in the creation of an IEEE Standards publication; to copyright in the IEEE’s name any IEEE Standards publication even though it may include portions of this contribution; and at the IEEE’s sole discretion to permit others to reproduce in whole or in part the resulting IEEE Standards publication. The contributor also acknowledges and accepts that this contribution may be made public by IEEE 802.16. |
| Patent Policy and Procedures | The contributor is familiar with the IEEE 802.16 Patent Policy and Procedures <http://ieee802.org/16/ipr/patents/policy.html>, including the statement "IEEE standards may include the known use of patent(s), including patent applications, provided the IEEE receives assurance from the patent holder or applicant with respect to patents essential for compliance with both mandatory and optional portions of the standard." Early disclosure to the Working Group of patent information that might be relevant to the standard is essential to reduce the possibility for delays in the development process and increase the likelihood that the draft publication will be approved for publication. Please notify the Chair <mailto:chair@wirelessman.org> as early as possible, in written or electronic form, if patented technology (or technology under patent application) might be incorporated into a draft standard being developed within the IEEE 802.16 Working Group. The Chair will disclose this notification via the IEEE 802.16 web site <http://ieee802.org/16/ipr/patents/notices>. |
1. Background
The current 802.16e standard defines a rate 2, 4-antenna space-time-frequency code matrix

\[ B = \begin{bmatrix}
S_1 & -S_2^* & S_3 & -S_7^* \\
S_2 & S_1^* & S_6 & -S_8^* \\
S_3 & -S_4^* & S_7 & S_5^* \\
S_4 & S_3^* & S_8 & S_6^*
\end{bmatrix}, \]

Where the consecutive columns of the code span two OFDMA symbols and two sub-carriers respectively. In this proposal we propose a modification to the 4-antenna matrix \( B \), which increases the coding gain up to 1.0 dB. The proposed enhancement requires few changes to the transceiver specification and does not require knowledge of channel state information at the transmitter.

2. Antenna Circulation Method for rate 2, 4-antenna STC
We propose that we switch the assignment of rows of matrix \( A \) in a predetermined pattern. We propose the following antenna assignment be performed periodically every \( N \) sub carriers, where \( N \) is design parameter.

\[ B_1 = \begin{bmatrix}
S_1 & -S_2^* & S_5 & -S_7^* \\
S_2 & S_1^* & S_6 & -S_8^* \\
S_3 & -S_4^* & S_7 & S_5^* \\
S_4 & S_3^* & S_8 & S_6^*
\end{bmatrix}, \quad B_2 = \begin{bmatrix}
S_1 & -S_2^* & S_5 & -S_7^* \\
S_2 & S_1^* & S_6 & -S_8^* \\
S_3 & -S_4^* & S_7 & S_5^* \\
S_4 & S_3^* & S_8 & S_6^*
\end{bmatrix}, \quad B_3 = \begin{bmatrix}
S_1 & -S_2^* & S_5 & -S_7^* \\
S_2 & S_1^* & S_6 & -S_8^* \\
S_3 & -S_4^* & S_7 & S_5^* \\
S_4 & S_3^* & S_8 & S_6^*
\end{bmatrix}, \quad B_4 = \begin{bmatrix}
S_1 & -S_2^* & S_5 & -S_7^* \\
S_2 & S_1^* & S_6 & -S_8^* \\
S_3 & -S_4^* & S_7 & S_5^* \\
S_4 & S_3^* & S_8 & S_6^*
\end{bmatrix}, \quad B_5 = \begin{bmatrix}
S_1 & -S_2^* & S_5 & -S_7^* \\
S_2 & S_1^* & S_6 & -S_8^* \\
S_3 & -S_4^* & S_7 & S_5^* \\
S_4 & S_3^* & S_8 & S_6^*
\end{bmatrix}, \quad B_6 = \begin{bmatrix}
S_1 & -S_2^* & S_5 & -S_7^* \\
S_2 & S_1^* & S_6 & -S_8^* \\
S_3 & -S_4^* & S_7 & S_5^* \\
S_4 & S_3^* & S_8 & S_6^*
\end{bmatrix}. \]
3. Performance
In Figure 1, we compared the FER performance of the circulated code to Matrix A for 4 Tx and 2 Rx case in for Ped A channel, rate 1/2 convolutional code, QPSK modulation using LMMSE receiver. We notice an increase in coding gain up to 1.0 dB. Similar gains are expected for other modulation and coding modes.

![Figure 1: FER performance of circulated matrix B](image)

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 2 configuration is given in six permuted versions:

\[
B_1 = \begin{bmatrix}
S_1 - S_2^* & S_5 - S_7^* \\
S_2 & S_1^* & S_6 - S_8^* \\
S_3 & S_4^* & S_7 & S_5^* \\
S_4 & S_3^* & S_8 & S_6^*
\end{bmatrix}, \quad
B_2 = \begin{bmatrix}
S_1 - S_2^* & S_5 - S_7^* \\
S_2 & S_1^* & S_6 - S_8^* \\
S_3 & S_4^* & S_7 & S_5^* \\
S_4 & S_3^* & S_8 & S_6^*
\end{bmatrix}, \quad
B_3 = \begin{bmatrix}
S_1 - S_2^* & S_5 - S_7^* \\
S_3 & S_4^* & S_7 & S_5^* \\
S_2 & S_1^* & S_6 - S_8^* \\
S_4 & S_3^* & S_8 & S_6^*
\end{bmatrix}
\]
Let $N_c = 8$ denote the number of subcarriers in a group. The choice of subscript $k$ to determine the matrix $B_k$ is given by the following formula: 

$$k = \text{mod}\left(\text{floor}\left(\frac{\text{logical_data_sub_carrier_number_for_first_tone_of_code}}{N_c}\right), 6\right) + 1,$$

where $\text{logical_data_sub_carrier_number_for_first_tone_of_code} = 1, 2, 3, \ldots, \text{Total # of data sub-carriers}$. 

5. References