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| Re: | 802.16e/D4 | |
| Abstract | Space-time codes for 3 transmit antennas with full diversity. | |
| Purpose | To propose 3 transmit antenna space-time codes for 802.16e/D4. | |
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Space-Time Codes for 3 Transmit antennas for the OFDMA PHY

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Introduction

We propose space-time codes for 3 transmit antennas with full diversity. ~~While these codes are specified as Space-time codes, they may also be used as space frequency codes or as hybrids.~~

Proposed Space-Time Codes for 3 Antenna BS

We here propose rate 1, rate 2 and rate 3 codes with 3Tx schemes for the standard.

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

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

The proposed Space-Time-Frequency code (over two OFDMA symbols and two sub-carriers) for 3Tx-Rate 1 configuration with diversity order 3 is

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

where the ML decoding can be achieved by symbol-by-symbol decoding.

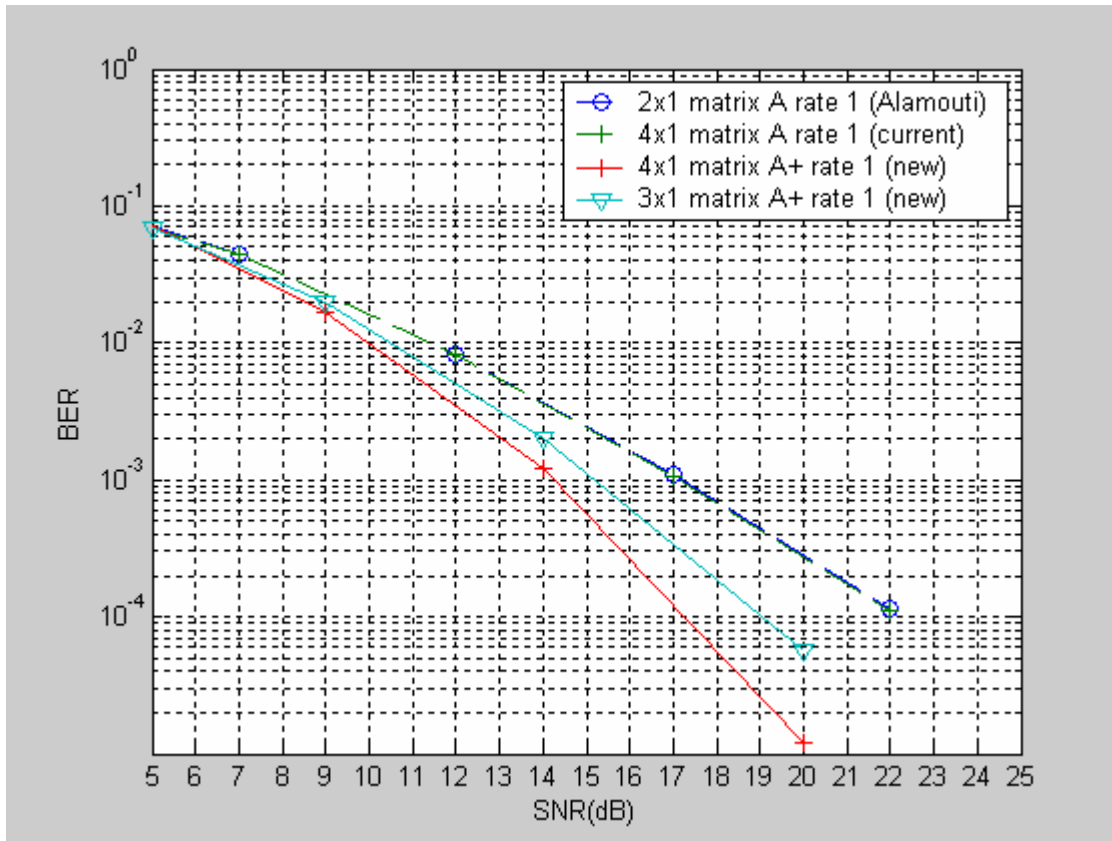
The 3 Tx – Rate 2 code we propose, with full diversity order of 3 is given below.

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

where the definition for the remaining variables are as follows:

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

The uncoded BER for a flat, Rayleigh channel is included below, where the channel is assumed to be quasi-static over 2 OFDMA symbols. These codes are sent over 2 OFDMA symbols, and over 2 subcarriers. Please refer to [3] for details of 4x1 matrix A+.



~~where $\omega_k = e^{\frac{2\pi j}{4}}$, $k = 3, 9$.~~

~~The 3Tx Rate 3 code we propose is~~

~~Code for 3x3 deleted~~

~~where $\omega_k = e^{\frac{2\pi j}{4}}$, $k = 3, 9$. This code is the counterpart of 2Tx Rate 2 and 4Tx Rate 4 codes discussed above and provides diversity order 3.~~

The matrix C is used for spatial multiplexing. [Specific text changes](#)
 [Add to 802.16e/D3]

Add new section '8.4.8.3.5 Transmission schemes for 3 antenna BS'

STC for 3Tx-Rate 1,2 and 3:

For three antenna BS, one of the three transmission matrices A, B or C, shall be used:

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

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

The proposed Space-Time-Frequency code (over two OFDMA symbols and two sub-carriers) for 3Tx-Rate 1 configuration with diversity order 3 is

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

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

where the definition for the remaining variables are as follows:

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

The matrix C is used for spatial multiplexing.

$$C = \begin{bmatrix} s_1 \\ s_2 \\ s_3 \end{bmatrix}$$

[Modify the Table 277a in Section 8.4.5.3.4]

Table 277a -OFDMA downlink STC_ZONE IE format

| Syntax | Size (bits) | Notes |
|-----------------|-------------|---------------|
| STC_ZONE_IE() { | | |
| Extended DIUC | 4 | STC/ZONE=0x01 |

| | | |
|---------------------------------|----------------|--|
| Length | 4 | Length = 0x02 |
| Permutation | 2 | 00 = PUSC permutation 01 = FUSC permutation 10 = Optional FUSC permutation 11 = Optional adjacent subcarrier permutation |
| Use All SC indicator | 1 | 0 = Do not use all subchannels 1 = Use all subchannels |
| STC | 2 | 00 = No STC 2 antennas 01 = STC using 2 antennas 3 antennas 10 = STC using 4 antennas 11 = FHDC using 2 antennas |
| Matrix indicator | 2 | Antenna STC/FHDC matrix (see 8.4.8) 00 = Matrix A 01 = Matrix B 10 = Matrix C (applicable to 4 antennas only) 11 = Reserved |
| IDcell | 6 | |
| Midamble presence | 1 | 0 = not present 1 = present at the first symbol in STC zone |
| STC using 3 antennas | 1 | for STC using 3 antennas set this bit to 1, along with setting STC = 00 |
| Reserved | 3 3 | Shall be set to zero |
| } | | |

[Modify the Table 281a in Section 8.4.5.3.8]

Table 281aa – MIMO DL basic IE format

| | | |
|------------------|---|--|
| Matrix indicator | 2 | STC matrix (see 8.4.8.1.4) STCTransmit_divesity = STCtransmit diversity mode indicated in the latest STCTD_Zone_IE(). if (STCTransmit_diversity == 01 00) { 00 = Matrix A 01 = Matrix B 10-11 = Reserved } elseif(STCTransmit_diversity == 10 01) { 00 = Matrix A 01 = Matrix B 10 = Matrix C 11 = Reserved } elseif(STCTransmit_diversity == 10){ 00 = Matrix A 01 = Matrix B |
|------------------|---|--|

| | | |
|--|--|--|
| | | <p>10 = Matrix C 11 = Reserved }</p> |
|--|--|--|

[Modify the Table 282a in Section 8.4.5.3.9]

Table 282aa – MIMO DL Enhanced IE format

| | | |
|------------------|---|--|
| Matrix indicator | 2 | <p>STC matrix (see 8.4.8.1.4) STCtransmit_diversity = STCtransmit diversity mode indicated in the latest STCTD_Zone_IE(). if (STCtransmit_diversity == 0+00) { 00 = Matrix A 01 = Matrix B 10-11 = Reserved } elseif(STCtransmit_diversity == 1001) { 00 = Matrix A 01 = Matrix B 10 = Matrix C 11 = Reserved } elseif(STCtransmit_diversity == 10){ 00 = Matrix A 01 = Matrix B 10 = Matrix C 11 = Reserved }</p> |
|------------------|---|--|

[modify section 6.3.2.3.43.6.11 as follows]

Table 99d—Compact_DL-MAP IE format for MIMO Control

| Syntax | Size (bits) | Notes |
|----------------------------|-------------|---------------------------|
| MIMO_Compact_DL-MAP_IE() { | | |
| DL-MAP Type | 3 | Type = 7 |
| DL-MAP Sub-type = 3 | 5 | MIMO Control = 0x04 |
| Length | 4 | Length of the IE in Bytes |

| | | |
|-------------------------------|----------|---|
| BITMAP length | 4 | in nibble |
| BITMAP | variable | size = BITMAP length x 4 bits |
| STC | 2 | STC order 00 = STC using 2 antennas 01 = STC using 3 antennas 10 = STC using 4 antennas 11 = Reserved |
| for (i = 0; i < count; i++) { | | count = the number of '1' in BITMAP |
| Matrix indicator | 2 | STC matrices (see 8.4.8.3) 00 = Matrix A 01 = Matrix B 10 = Matrix C 11 = Reserved |
| Num_layer | 2 | 00 – 1 layer 01 – 2 layers 10 – 3 layers 11 – 4 layers |
| for (j=1;j<Num_layer; j++) { | | This loop specifies the Nep and RCID for layers 2 and above when required for STC. Nep, Nsch and RCID for the first layer comes from the compact DL-MAP IE. |
| Nep | 4 | |
| RCID | variable | |
| } | | |
| } | | |
| Padding | variable | The padding bits are used to ensure the IE size is integer number of bytes. |
| } | | |

[Modify a new section 11.8.3.7.6 in page 687 of [1]]

11.8.3.7.6 OFDMA MSS demodulator for MIMO support

| Type | Length | Value | Scope |
|------|--------|--|--|
| 155 | 1 | Bit #0: 2 BS Tx Matrix A Bit #1: 2 BS Tx Matrix B Bit #2: 3 BS Tx Matrix A Bit #3: 3 BS Tx Matrix B Bit #4: 3 BS Tx Matrix C Bit #5: 4 BS Tx Matrix A Bit #6: 4 BS Tx Matrix B Bit #7: 4 BS Tx Matrix C | SBC-REQ (see 6.3.2.3.23) SBC-RSP (see 6.3.2.3.24) |

[Add following text to section 8.4.8.3.1 in page 96 of [1] as follows]

8.4.8.3.1 Allocation of pilot subcarriers

For 3-antenna BS, pilot allocation pattern shall first be changed as in the 2-antenna BS case, and then the neighboring two subcarriers shall be further allocated as pilots. This is shown in Figure ccc.

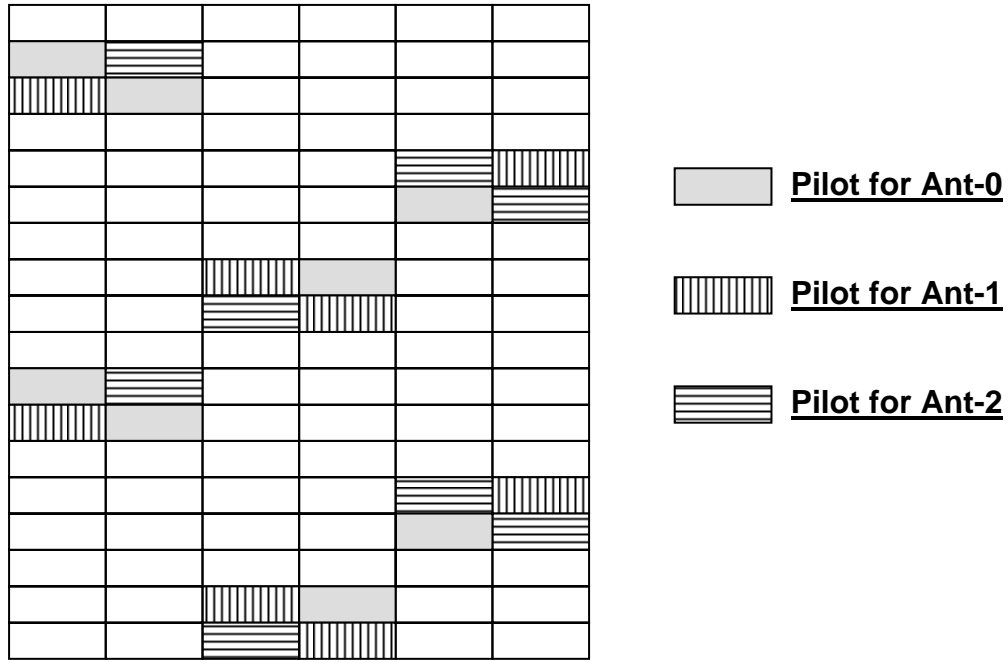


Figure ccc - Pilot allocation for 3-antenna BS for the optional FUSC and the optional AMC zones

References

- [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] IEEE P802.16e/D3 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
- [3] Erik Lindskog, et. al., "Enhancements of Space-time Codes for OFDMA PHY", C802.16e-04/204r1