Project	IEEE 802.16 Broadband Wireless Access Working Group <**http://ieee802.org/16**>	
Title	Space-Time Codes for 3 Transmit antennas for the OFDMA PHY	
Date Submitted	2004-07-14	
Source(s)	Erik Lindskog, V. Shashidhar, B. Sundar Rajan, Djordje Tajkovic, K. Giridhar, Erik Stauffer, Taiwen Tang, Tareq Al-Naffouri, David Garrett, Bob Lorenz, Babu Mandava, A. Paulraj, Trevor Pearman, Kamlesh Rath, Aditya Agrawal, Mai Vu, Brett Schein Beceem Communications, Inc. Freedom Circle, Suite 101 Santa Clara, CA 95054	elindskog@beceem.com Voice: +1-408-387-5021 Fax: +1-408-496-0040
	Wonil Roh, JeongTae Oh, Chan-Byoung Chae, Kyunbyoung Ko, Hongsil Jeong, Sung-Ryul Yun, Samsung Electronics Co., Ltd.	wonil.roh@samsung.com Voice: +82-31-279-3868
	Wen Tong, Peiying Zhu, Jianglei Ma, Ming Jia, Hang Zhang and Mo-Han Fong Nortel Networks 3500 Carling Avenue Ottawa, ON. K2H 8E9 Canada	wentong@nortelnetworks.com Voice: (613)-763-1315 Fax: (613)-765-7723
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.	
Notice		

Space-Time Codes for 3 Transmit antennas for the OFDMA PHY

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

Beceem Communications, Inc.

Wonil Roh, JeongTae Oh, Chan-Byoung Chae, Kyunbyoung Ko, Hongsil Jeong, Sung-Ryul Yun

Samsung Electronics

Wen Tong, Peiying Zhu, Jianglei Ma, Ming Jia, Hang Zhang and Mo-Han Fong

Nortel Networks

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 $x_1, x_2, x_3, \ldots, x_8$ 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

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

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

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

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

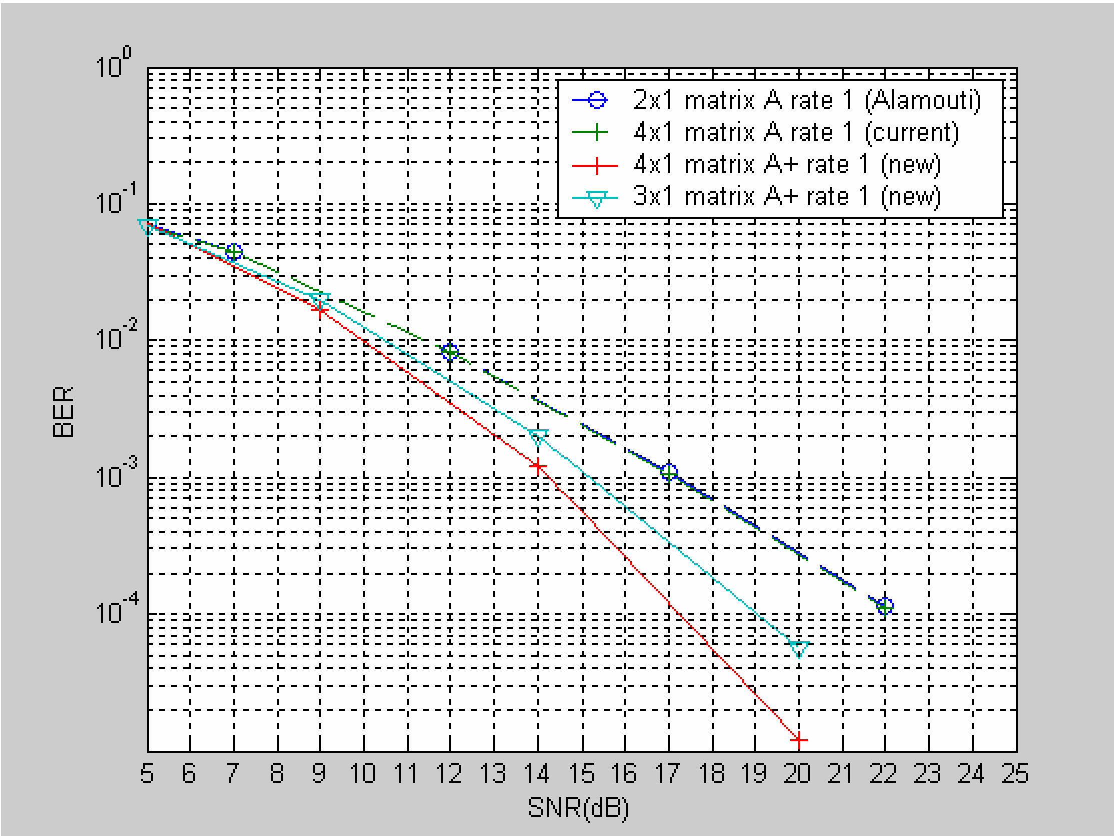
The 3 Tx – Rate 2 code we propose, with full diversity order of 3 is given below.

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

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

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

~~Code for 3x3 deleted~~

~~where $\omega_k = e^{\frac{2\pi}{k}j}$, $k = 3,9$. 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 $x_1, x_2, x_3, \ldots x_8$ 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

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

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~~1~~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

		10 = Matrix C 11 = Reserved }

[Modify the Table 282a in Section 8.4.5.3.9]

Table 282aa – MIMO DL Enhanced 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
		10 = Matrix C
		11 = Reserved
		}

[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.

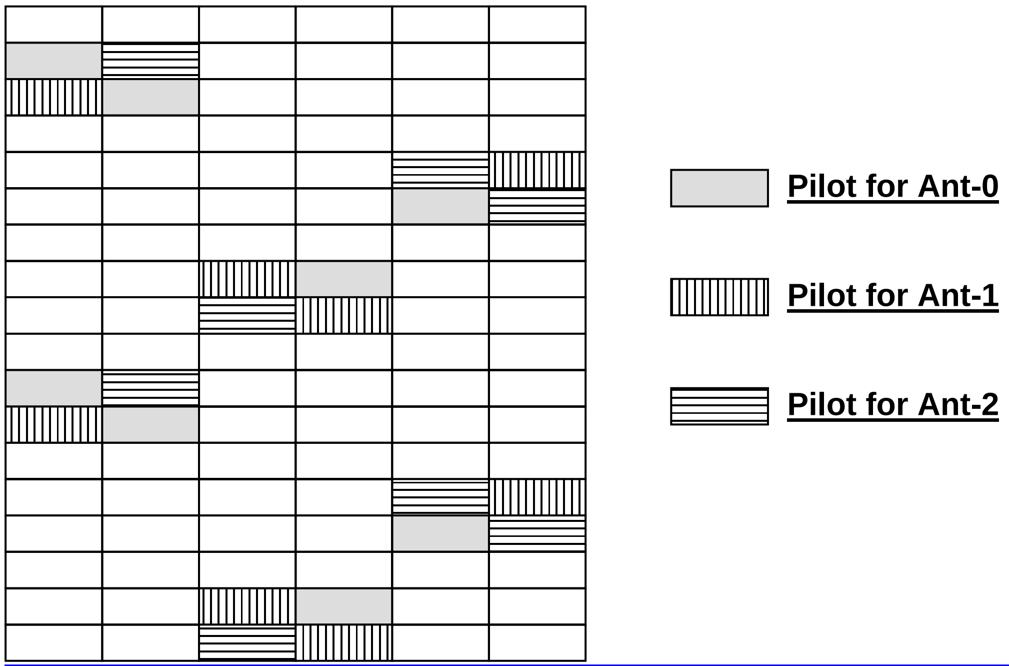


Figure ccc - Pilot allocation for 3-antenna BS for the optional FUSC and the optional AMC zones

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~~