Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**FAST_FEEDBACK Channel Codeword Extension**
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Source(s)	Myung-Kwang Byun, Seungjoo Maeng, Jaeho Jeon, Soonyoung Yoon, Panyuh Joo mk.byun@samsung.com Samsung Electronics Co., Ltd. Dong Suwon P.O.Box 105 416, Maetan-3dong, Yeongtong-gu, Suwon-city, Gyeonggi-do, Korea 442-600
Re:	
Abstract	FAST_FEEDBACK Channel Codeword Extension
Purpose	Adopting of proposed method into P802.16e
Notice	
Release	
Patent Policy and Procedures	

FAST_FEEDBACK Channel Codeword Extension

Introduction

In IEEE 802.16d/D5, section 8.4.5.4.10 describes FAST_FEEDBACK channels. Currently, a FAST_FEEDBACK channel delivers only 4 payload bits, which is not enough to convey necessary information. 4 payload bits can classify MCS(Modulation and Coding Scheme) level up to 16 sorts, and their SNR resolution would be 2dB with the dynamic range of 30dB. However, some MCS level has SNR resolution finer than 2dB in certain channel conditions. If the SNR resolution can be made more elaborate, performance will improve. If the number of payload bits can increase to 5, SNR resolution will become 1dB and up to 32 sorts of MCS level can be supported.

In this contribution, two methods of codeword extension of the FAST_FEEDBACK channel ~~is~~ are proposed to increase the number of payload bits. In method 1, the ~~The~~ first 16 codewords are left unchanged to provide the backward compatibility, and additional 16 codewords are appended without decreasing the minimum Hamming distance between codewords. In this way, a FAST_FEEDBACK channel can deliver 5 payload bits. Simulation results are provided to exhibit the performance of the proposed scheme. In method 2, a newly designed set of 64 codewords is provided without decreasing the minimum Hamming distance between codewords. In this way, a FAST_FEEDBACK channel can deliver 6 payload bits, which can contain fast DL measurement feedback information (or fast MIMO feedback information) and mode selection feedback information at the same time.

Suggested change to the standard

Method 1

[ADD the following text after 8.4.5.4.10]

8.4.5.4.11 Optional Enhanced FAST_FEEDBACK channels

Fast feedback slots may be individually allocated to SS for transmission of PHY related information that requires fast response from the SS. The allocations are done in unicast manner through the FAST_FEEDBACK MAC subheader (see 6.3.2.2.6), and the transmission takes place in a specific UL region designated by UIUC = 0.
Each Fast-feedback slot consists of 1 OFDMA slots mapped in a manner similar to the mapping of normal uplink data. A fast feedback slot uses QPSK modulation on the 48 data sub-carriers it contains, and can carry a data payload of 5 bits. Table zz defines the mapping between the payload bit sequences and the subcarriers modulation.

Table zz—FAST_FEEDBACK channel subcarrier modulation

5 bit payload	Fast Feedback vector indices per Tile Tile(0), Tile(1), … ,Tile(5)
0b00000	0,0,0,0,0,0
0b00001	1,1,1,1,1,1
0b00010	2,2,2,2,2,2
0b00011	3,3,3,3,3,3
0b00100	4,4,4,4,4,4
0b00101	5,5,5,5,5,5
0b00110	6,6,6,6,6,6

0b00111	7,7,7,7,7,7
0b01000	0,1,2,3,4,5
0b01001	1,2,3,4,5,6
0b01010	2,3,4,5,6,7
0b01011	3,4,5,6,7,0
0b01100	4,5,6,7,0,1
0b01101	5,6,7,0,1,2
0b01110	6,7,0,1,2,3
0b01111	7,0,1,2,3,4
0b10000	4,7,2,5,1,6
0b10001	5,0,3,6,2,7
0b10010	6,1,4,7,3,0
0b10011	7,2,5,0,4,1
0b10100	0,3,6,1,5,2
0b10101	1,4,7,2,6,3
0b10110	2,5,0,3,7,4
0b10111	3,6,1,4,0,5
0b11000	4,6,0,2,5,7
0b11001	5,7,1,3,6,0
0b11010	6,0,2,4,7,1
0b11011	7,1,3,5,0,2
0b11100	0,2,4,6,1,3
0b11101	1,3,5,7,2,4
0b11110	2,4,6,0,3,5
0b11111	3,5,7,1,4,6

The FAST_FEEDBACK channel is orthogonally modulated with QPSK symbols. Let $M_{n,8m+k}$ ($0 \le k \le 7$) be the modulation symbol index of the k-th modulation symbol in the m-th uplink tile of the n-th FAST_FEEDBACK channel. The possible modulation patterns composed of $M_{n,8m}$, $M_{n,8m+1}$, … , $M_{n,8m+7}$ in the m-th tile of the n-th FAST_FEEDBACK channel are defined in Table aa.

Table aa—Orthogonal Modulation Index in FAST_FEEDBACK Channel

Vector index	$M_{n,8m}$, $M_{n,8m+1}$, … , $M_{n,8m+7}$
0	P0, P1, P2, P3, P0, P1, P2, P3
1	P0, P3, P2, P1, P0, P3, P2, P1
2	P0, P0, P1, P1, P2, P2, P3, P3
3	P0, P0, P3, P3, P2, P2, P1, P1
4	P0, P0, P0, P0, P0, P0, P0, P0
5	P0, P2, P0, P2, P0, P2, P0, P2
6	P0, P2, P0, P2, P2, P0, P2, P0
7	P0, P2, P2, P0, P2, P0, P0, P2

Where

$$P0 = \exp(j \cdot \frac{\pi}{4}),$$

$$P1 = \exp(j \cdot \frac{3\pi}{4}),$$

$$P2 = \exp(-j \cdot \frac{3\pi}{4}),$$

$$P3 = \exp(-j \cdot \frac{\pi}{4}).$$

$M_{n,8m+k}$ is mapped to FAST_FEEDBACK channel tile as shown in Figure bb1 for PUSC uplink subchannel and in Figure bb2 for optional PUSC uplink subchannel. A FAST_FEEDBACK channel is mapped to one subchannel composed of 6 tiles.

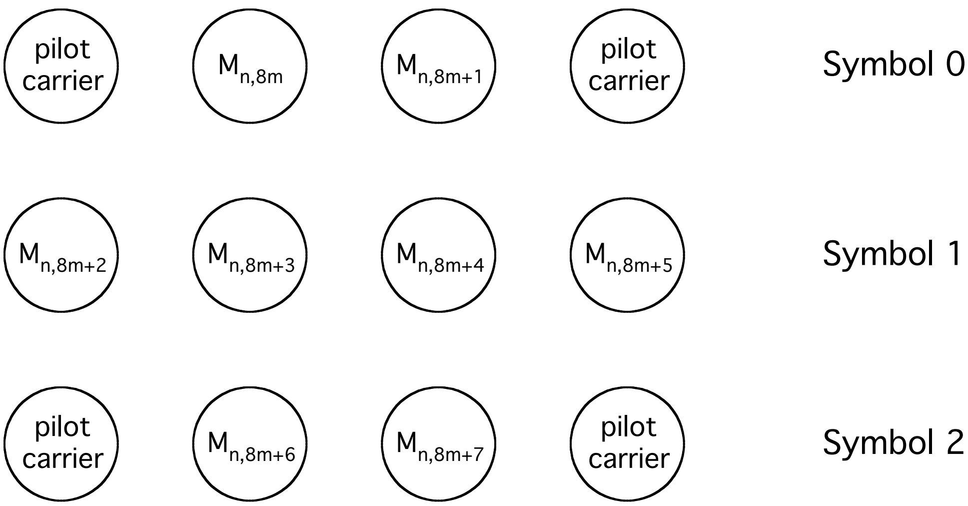

Figure bb1—Subcarrier Mapping of FAST_FEEDBACK Modulation Symbols for PUSC

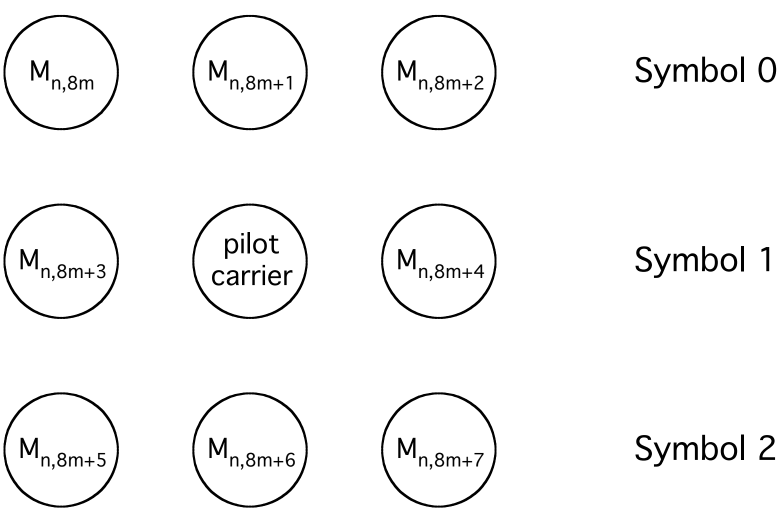

Figure bb2—Subcarrier Mapping of FAST_FEEDBACK Modulation Symbols for Optional PUSC

The fast feedback slot includes 5 bits of payload data, whose encoding depended on the instruction given in the FAST_FEEDBACK subheader. The following sections define these encoding.

8.4.5.4.10.1 Fast DL measurement feedback

When the FAST_FEEDBACK subheader Feedback Type field is ‘00’ the SS shall report the S/N it measures on the DL. The following formula shall be used:

Payload bits ~~nibble~~ =	0	S/N ≤ -3 dB
	n	n-4 < S/N ≤ n-30<n<31
	31	S/N > 27 dB

8.4.5.4.10.2 Fast MIMO feedback

When the FAST_FEEDBACK subheader Feedback Type field is ‘01’ or ‘10’ the SS shall report the MIMO coefficient the BS should use for best DL reception (see 8.4.8.1.6). The mapping for the complex weights is shown if Figure cc.

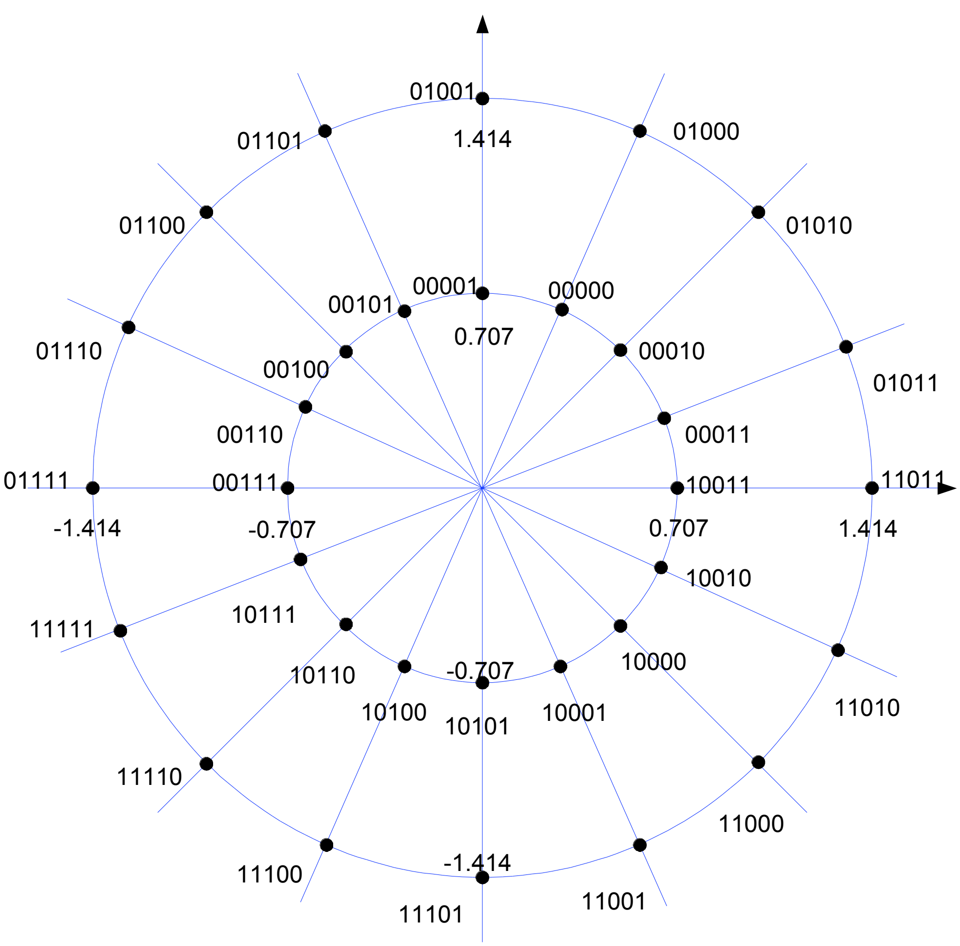

Figure cc—Mapping of MIMO coefficients for fast MIMO feedback payload bits

8.4.5.4.10.3 Mode Selection Feedback

When the FAST_FEEDBACK subheader Feedback Type field is '11' or at a specific frame indicated in the CQICH_Alloc_IE(), the SS shall send its selection in terms of MIMO mode (STTD versus SM) or permutation mode on the assigned FAST_FEEDBACK channel. Table dd shows the encoding of payload bits for the FAST_FEEDBACK slot (see 8.4.5.4.9).

Table dd—Encoding of payload bits for Fast-feedback slot

Value	Description
0b00000	STTD and PUSC/FUSC permutation
0b00001	STTD and adjacent-subcarrier permutation
0b00010	SM and PUSC/FUSC permutation
0b00011	SM and adjacent-subcarrier permutation
0b00100	Hybrid and PUSC/FUSC permutation
0b00101	Hybrid and adjacent-subcarrier permutation
0b00110	Beamforming and adjacent-subcarrier permutation
0b00111 – 0b11111	Reserved

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

11.8.3.7.6 Uplink control channel support

This field indicates the different uplink control channels supported by a WirelessMAN-OFDMA PHY SS for uplink transmission. A bit value of 0 indicates "not supported" while 1 indicates "supported."

Type	Length	Value	Scope
xxx	1	Bit #0: FAST_FEEDBACK Bit #1: Enhanced FAST_FEEDBACK Bit #2: UL ACK Bit #3: Enhanced UL ACK Bit #4-7: Reserved; shall be set to zero	SBC-REQ (see 6.3.2.3.23) SBC-RSP (see 6.3.2.3.24)

Method 2

[ADD the following text after 8.4.5.4.10]

8.4.5.4.11 Optional Enhanced FAST_FEEDBACK channels

Fast feedback slots may be individually allocated to SS for transmission of PHY related information that requires fast response from the SS. The allocations are done in unicast manner through the FAST_FEEDBACK MAC subheader (see 6.3.2.2.6), and the transmission takes place in a specific UL region designated by UIUC = 0.

Each Fast-feedback slot consists of 1 OFDMA slots mapped in a manner similar to the mapping of normal uplink data. A fast feedback slot uses QPSK modulation on the 48 data sub-carriers it contains, and can carry a data payload of 6 bits. Table zz2 defines the mapping between the payload bit sequences and the subcarriers modulation.

Table zz2—FAST_FEEDBACK channel subcarrier modulation

6 bit payload	Fast Feedback vector indices per Tile Tile(0), Tile(1), … ,Tile(5)
0b000000	0,0,0,0,0,0
0b000001	1,1,1,1,1,1
0b000010	2,2,2,2,2,2
0b000011	3,3,3,3,3,3
0b000100	4,4,4,4,4,4
0b000101	5,5,5,5,5,5
0b000110	6,6,6,6,6,6
0b000111	7,7,7,7,7,7
0b001000	2,4,3,6,7,5
0b001001	3,5,2,7,6,4
0b001010	0,6,1,4,5,7
0b001011	1,7,0,5,4,6
0b001100	6,0,7,2,3,1
0b001101	7,1,6,3,2,0
0b001110	4,2,5,0,1,3
0b001111	5,3,4,1,0,2
0b010000	4,3,6,7,5,1
0b010001	5,2,7,6,4,0
0b010010	6,1,4,5,7,3
0b010011	7,0,5,4,6,2

0b010100	0,7,2,3,1,5
0b010101	1,6,3,2,0,4
0b010110	2,5,0,1,3,7
0b010111	3,4,1,0,2,6
0b011000	3,6,7,5,1,2
0b011001	2,7,6,4,0,3
0b011010	1,4,5,7,3,0
0b011011	0,5,4,6,2,1
0b011100	7,2,3,1,5,6
0b011101	6,3,2,0,4,7
0b011110	5,0,1,3,7,4
0b011111	4,1,0,2,6,5
0b100000	6,7,5,1,2,4
0b100001	7,6,4,0,3,5
0b100010	4,5,7,3,0,6
0b100011	5,4,6,2,1,7
0b100100	2,3,1,5,6,0
0b100101	3,2,0,4,7,1
0b100110	0,1,3,7,4,2
0b100111	1,0,2,6,5,3
0b101000	7,5,1,2,4,3
0b101001	6,4,0,3,5,2
0b101010	5,7,3,0,6,1
0b101011	4,6,2,1,7,0
0b101100	3,1,5,6,0,7
0b101101	2,0,4,7,1,6
0b101110	1,3,7,4,2,5
0b101111	0,2,6,5,3,4
0b110000	5,1,2,4,3,6
0b110001	4,0,3,5,2,7
0b110010	7,3,0,6,1,4
0b110011	6,2,1,7,0,5
0b110100	1,5,6,0,7,2
0b110101	0,4,7,1,6,3

0b110110 3,7,4,2,5,0

0b110111 2,6,5,3,4,1

0b111000 1,2,4,3,6,7

0b111001 0,3,5,2,7,6

0b111010 3,0,6,1,4,5

0b111011 2,1,7,0,5,4

0b111100 5,6,0,7,2,3

0b111101 4,7,1,6,3,2

0b111110 7,4,2,5,0,1

0b111111 6,5,3,4,1,0

The FAST_FEEDBACK channel is orthogonally modulated with QPSK symbols. Let $M_{n,8m+k}$ ($0 \le k \le 7$) be the modulation symbol index of the k-th modulation symbol in the m-th uplink tile of the n-th FAST_FEEDBACK channel. The possible modulation patterns composed of $M_{n,8m}$, $M_{n,8m+1}$, … , $M_{n,8m+7}$ in the m-th tile of the n-th FAST_FEEDBACK channel are defined in Table aa.

Table aa—Orthogonal Modulation Index in FAST_FEEDBACK Channel

Vector index	$M_{n,8m}$, $M_{n,8m+1}$, …, $M_{n,8m+7}$
0	P0, P1, P2, P3, P0, P1, P2, P3
1	P0, P3, P2, P1, P0, P3, P2, P1
2	P0, P0, P1, P1, P2, P2, P3, P3
3	P0, P0, P3, P3, P2, P2, P1, P1
4	P0, P0, P0, P0, P0, P0, P0, P0
5	P0, P2, P0, P2, P0, P2, P0, P2
6	P0, P2, P0, P2, P2, P0, P2, P0
7	P0, P2, P2, P0, P2, P0, P0, P2

Where

$P0 = \exp(j \cdot \frac{\pi}{4})$,

$P1 = \exp(j \cdot \frac{3\pi}{4})$,

$$P2 = \exp(-j \cdot \frac{3\pi}{4}),$$

$$P3 = \exp(-j \cdot \frac{\pi}{4}).$$

$M_{n,8m+k}$ is mapped to FAST_FEEDBACK channel tile as shown in Figure bb1 for PUSC uplink subchannel and in Figure bb2 for optional PUSC uplink subchannel. A FAST_FEEDBACK channel is mapped to one subchannel composed of 6 tiles.

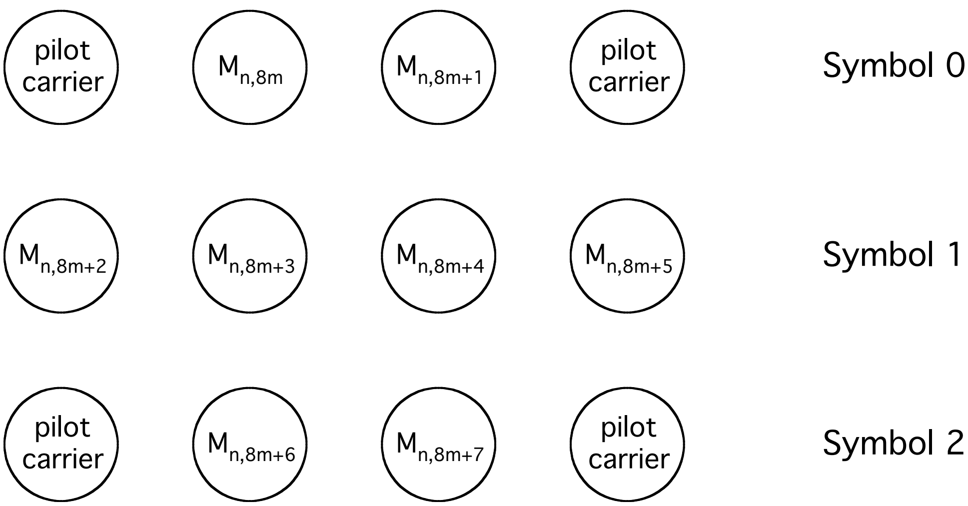

Figure bb1—Subcarrier Mapping of FAST_FEEDBACK Modulation Symbols for PUSC

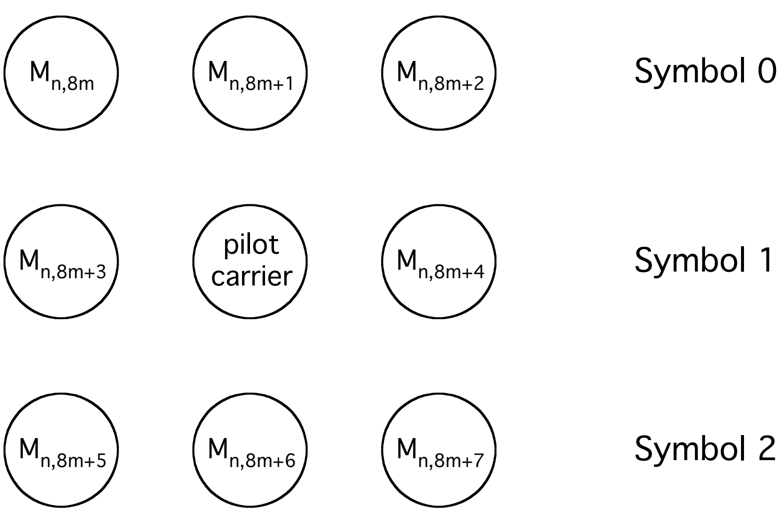

Figure bb2—Subcarrier Mapping of FAST_FEEDBACK Modulation Symbols for Optional PUSC

The fast feedback slot includes 6 bits of payload data, whose encoding depended on the instruction given in the FAST_FEEDBACK subheader. The following sections define these encoding.

8.4.5.4.10.1 Fast DL measurement feedback

When the FAST_FEEDBACK subheader Feedback Type field is ‘00’ the SS shall report the S/N it measures on the DL or send its selection in terms of MIMO mode (STTD versus SM) or permutation mode on the assigned FAST_FEEDBACK channel. For the first 32 codewords, the following formula shall be used:

Payload bits =	0	S/N ≤ -3 dB
	n	n-4 < S/N ≤ n-30<n<31
	31	S/N > 27 dB

For the remaining codewords, see 8.4.5.4.10.3.

8.4.5.4.10.2 Fast MIMO feedback

When the FAST_FEEDBACK subheader Feedback Type field is ‘01’ or ‘10’ the SS shall report the MIMO coefficient the BS should use for best DL reception (see 8.4.8.1.6) or send its selection in terms of MIMO mode (STTD versus SM) or permutation mode on the assigned FAST_FEEDBACK channel. For the first 32 codewords, the mapping for the complex weights is shown if Figure cc.

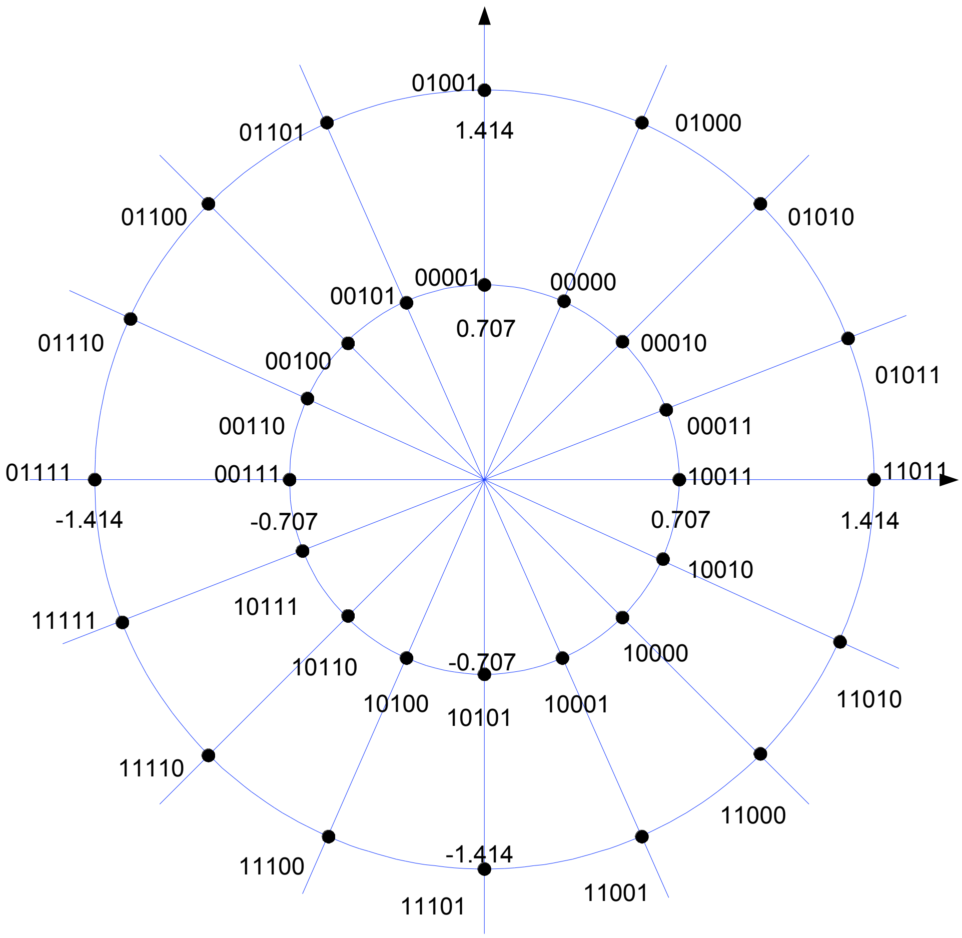

Figure cc—Mapping of MIMO coefficients for fast MIMO feedback payload bits

For the remaining codewords, see 8.4.5.4.10.3.

8.4.5.4.10.3 Mode Selection Feedback

When the FAST_FEEDBACK subheader Feedback Type field is '00' or '01' or '10' the SS may send its selection in terms of MIMO mode (STTD versus SM) or permutation mode on the assigned FAST_FEEDBACK channel using the last 32 codewords. Table dd shows the encoding of payload bits for the FAST_FEEDBACK slot (see 8.4.5.4.9).

Table dd—Encoding of payload bits for Fast-feedback slot

Value	Description
0b100000	STTD and PUSC/FUSC permutation

0b100001	STTD and adjacent-subcarrier permutation
0b100010	SM and PUSC/FUSC permutation
0b100011	SM and adjacent-subcarrier permutation
0b100100	Hybrid and PUSC/FUSC permutation
0b100101	Hybrid and adjacent-subcarrier permutation
0b100110	Beamforming and adjacent-subcarrier permutation
0b100111 – 0b111111	Reserved

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

11.8.3.7.6 Uplink control channel support

This field indicates the different uplink control channels supported by a WirelessMAN-OFDMA PHY SS for uplink transmission. A bit value of 0 indicates "not supported" while 1 indicates "supported."

Type	Length	Value	Scope
xxx	1	Bit #0: FAST_FEEDBACK Bit #1: Enhanced FAST_FEEDBACK Bit #2: UL ACK Bit #3: Enhanced UL ACK Bit #4-7: Reserved; shall be set to zero	SBC-REQ (see 6.3.2.3.23) SBC-RSP (see 6.3.2.3.24)

Performance

Simulation results of FAST_FEEDBACK channel link performance of method 1 are shown in Figure ee. In the simulations, AWGN and Ped-B (3km/h) channels with 2 receive antennas are considered. Figure ee shows FAST_FEEDBACK error rate versus SINR (Signal to Interference and Noise Ratio per subcarrier) with 4 bit and 5 bit schemes. 4 bit denotes the current scheme in 802.16d D5, whereas 5 bit denotes the proposed scheme in this contribution. We can see that in the error rate of 10-3 region, the proposed scheme requires additional SNR of 0.3 dB in AWGN channel and 0.7 dB in Ped-B channel, respectively. Therefore the proposed scheme can increase the number of payload bits from 4 bits to 5 bits at little cost of performance.

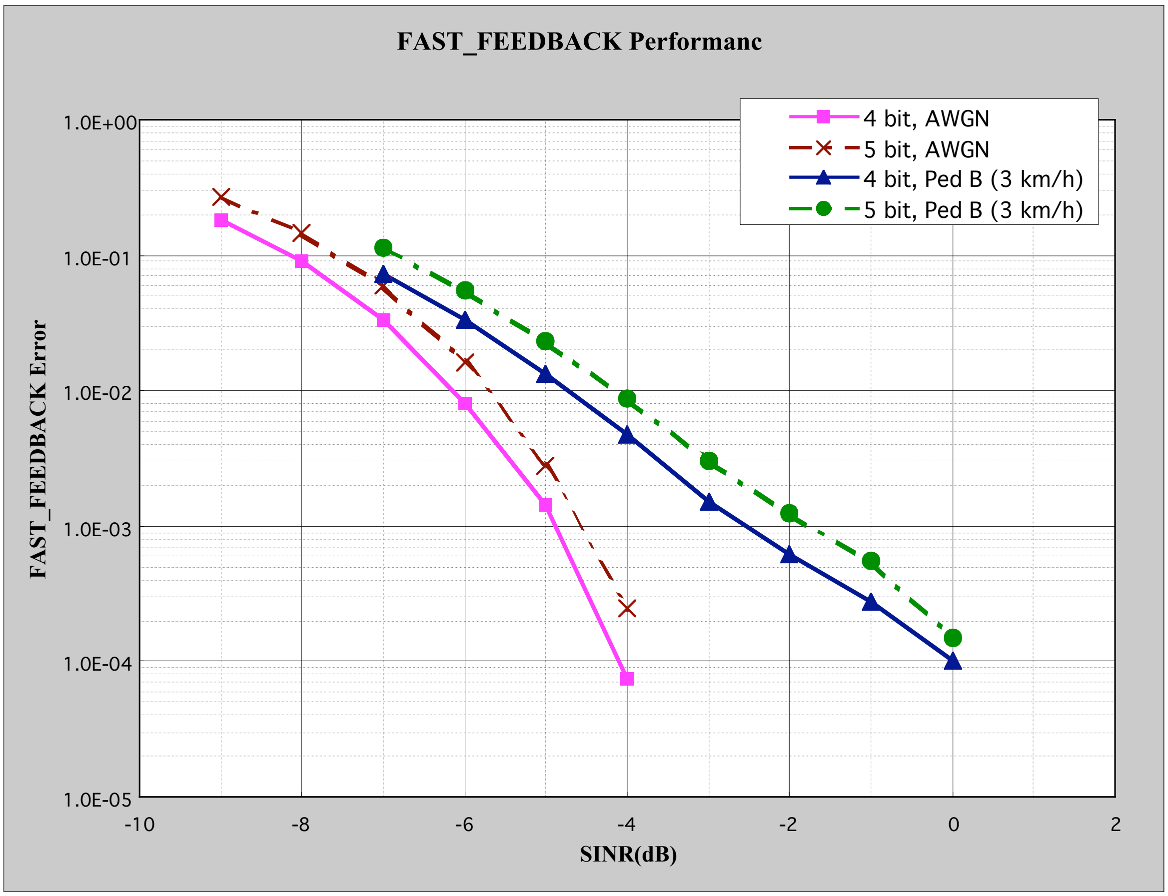

Figure ee—FAST_FEEDBACK channel link performance