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| Re: | This is a response to a Call for Comments on IEEE P802.16e-D5 |
| Abstract | The collaborative spatial multiplexing can be applied to the case in OFDMA. |
| Purpose | This document is submitted for review by 802.16e Working Group members. Green line indicates the revised text. |
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# Extension of Collaborative Spatial Multiplexing in OFDMA

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## 1. Introduction

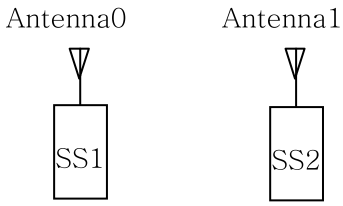
In OFDMA of the current 802.16 standard, collaborative spatial multiplexing mode is supported through MIMO_UL_BASIC_IE(). Two single transmit antenna SS's can perform collaborative spatial multiplexing onto the same subchannel. This mode can result capacity increment by assigning same uplink resource to two SS's simultaneously.

And the collaborative spatial multiplexing can be applied to the case where two SS's have 2 transmit antennas when BS has two or more receive antennas. So, we propose the MIMO_UL_Enhanced_IE( ) for applying the above case.

## 2. Feasible collaborative SM modes

There are various feasible collaborative SM modes according to the following combinations of # of transmit antennas in SS and STC configuration (STTD or SM). The current collaborative SM corresponds to the first example of the followings.

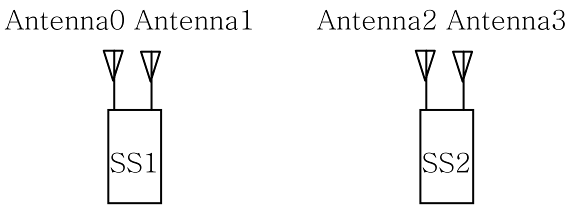
- **Collaborative SM example #1**




Transmission format uses matrix $B = \begin{bmatrix} S_i \\ S_{i+1} \end{bmatrix}$

(**See 8.4.8.3.3 Transmission schemes for 2-antenna BS in DL**)

- **Collaborative SM example #2**




Transmission format uses matrices

$$A = \begin{bmatrix} s_i & -s_{i+1}^* & 0 & 0 \\ s_{i+1} & s_i^* & 0 & 0 \\ 0 & 0 & s_{i+2} & -s_{i+3}^* \\ 0 & 0 & s_{i+3} & s_{i+2}^* \end{bmatrix}$$

$$B = \begin{bmatrix} s_i & -s_{i+1}^* & s_{i+4} & -s_{i+6}^* \\ s_{i+1} & s_i^* & s_{i+5} & s_{i+7}^* \\ s_{i+2} & -s_{i+3}^* & s_{i+6} & -s_{i+4}^* \\ s_{i+3} & s_{i+2}^* & s_{i+7} & s_{i+5}^* \end{bmatrix}$$

$$C = \begin{bmatrix} s_i \\ s_{i+1} \\ s_{i+2} \\ s_{i+3} \end{bmatrix}$$

(See 8.4.8.3.5 Transmission schemes for 4-antenna BS)

## 3. Proposition

For the purpose of realizing the above configurations, we propose more pilot patterns to support the various collaborative SM modes. The second examples in the aforementioned collaborative SM examples require four pilot patterns to distinguish the channels from each antenna of SS's.

In addition, we suggest the MIMO_UL_Enhanced_IE() to indicate the various collaborative SM modes and to support that SS has two transmit antennas.

## 4. Simulation result

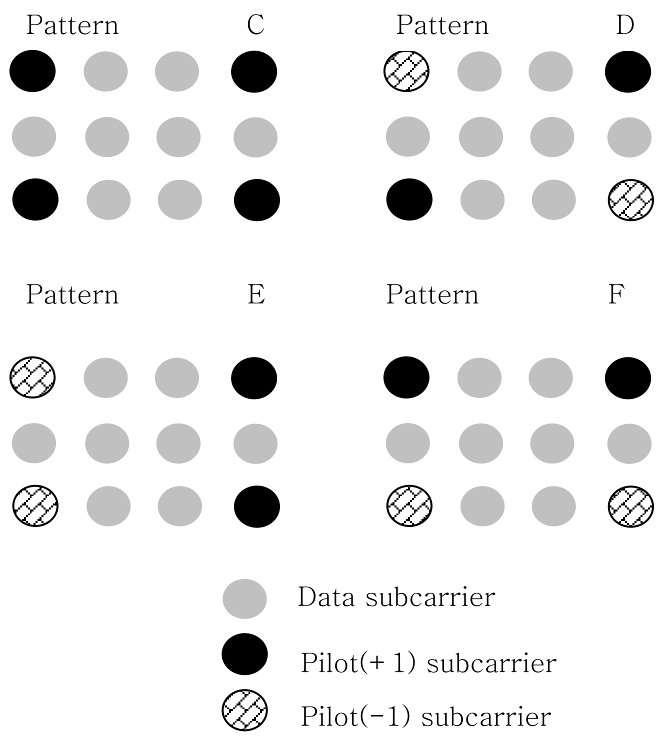



**Figure 1. Proposed patterns C/D/E/F in UL PUSC mode**

We compare the channel estimation errors in two fading channels using the conventional pattern A/B with the proposed patterns C/D/E/F in PUSC mode. The estimation results based on the proposed patterns are better up to SINR 15dB.

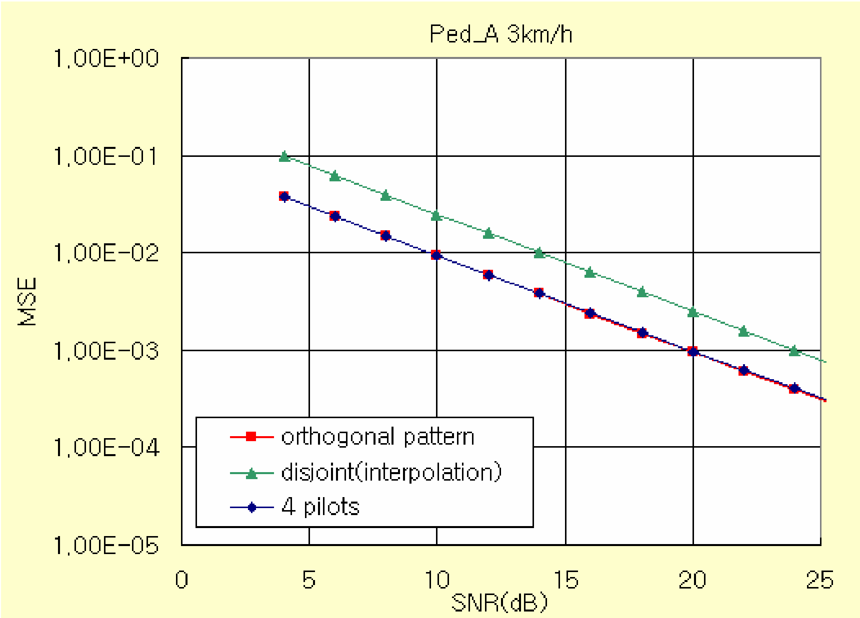



**Figure 2. Channel Estimation Error in Ped_A 3km/h**

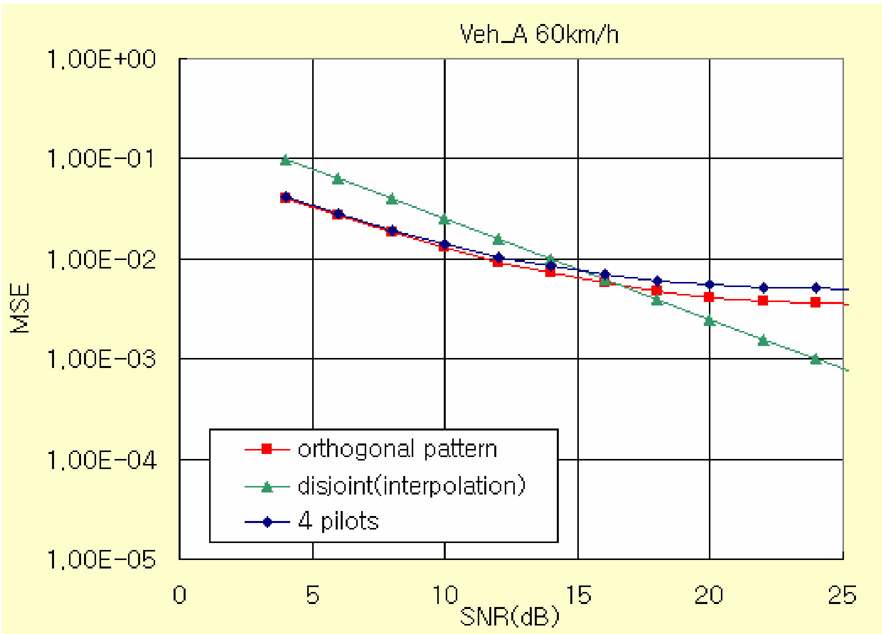



**Figure 3. Channel Estimation Error in Veh_A 60km/h**

The performance results of the proposed pilot patterns are shown in Fig 4, 5, 6, and 7.

Fig 4 and 5 are shown performances in case of single MSS with dual antennas and a BS with dual antennas. And figure 6 and 7 are in case of two MSSs with dual antennas and a BS with 4 antennas.

In the case single MSS with dual antennas and a BS with dual antennas (Fig4~Fig5), the proposed pilot patterns outperform the current pilot patterns A/B more than 1dB (Using the CC 1/2 rate QPSK, Pedestrian B channel with 10km/h, the PUSC mode and the transmission matrix A for 2-antenna MSS in UL).

And, in the case two MSSs with dual antennas and a BS with 4 antennas (Fig6~Fig7), the proposed pilot patterns cannot compare. Since current spec has not any pilot pattern for 4 antennas. The proposed pilot pattern has the FER about 1.7E-3 in 0dB (Using the CC 1/2 rate QPSK, Pedestrian B channel with 10km/h, the PUSC mode and the proposed transmission matrix B for dual 2-antenna MSS in UL (same to matrix B in 8.4.8.3.5)).

And also we add the results of figure 8 and 9 in the same simulation environments except Vehicular A channel with 60 km/h.

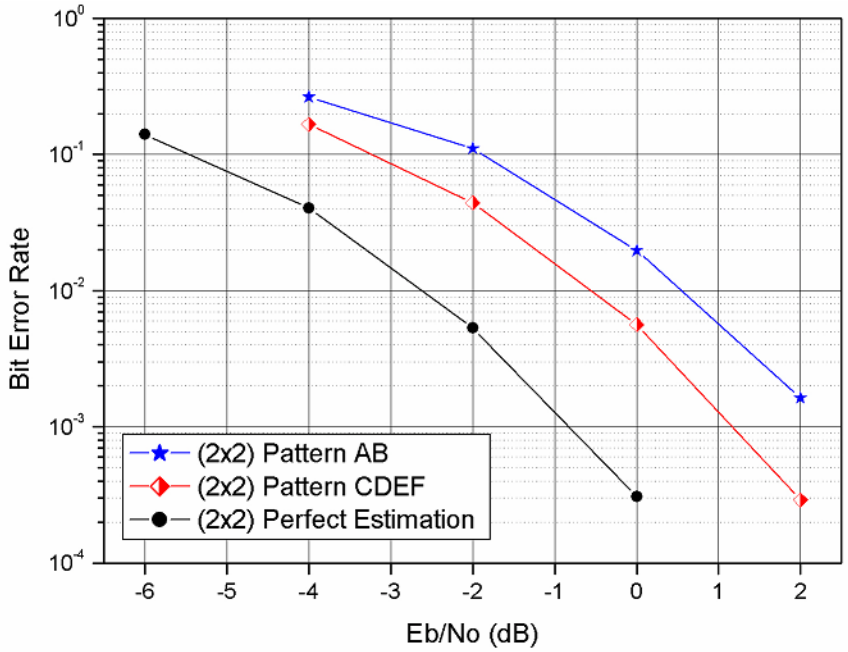



**Figure 4. BER for single MSS with dual antennas and BS with dual antennas (Pedestrian B with 10km/h)**

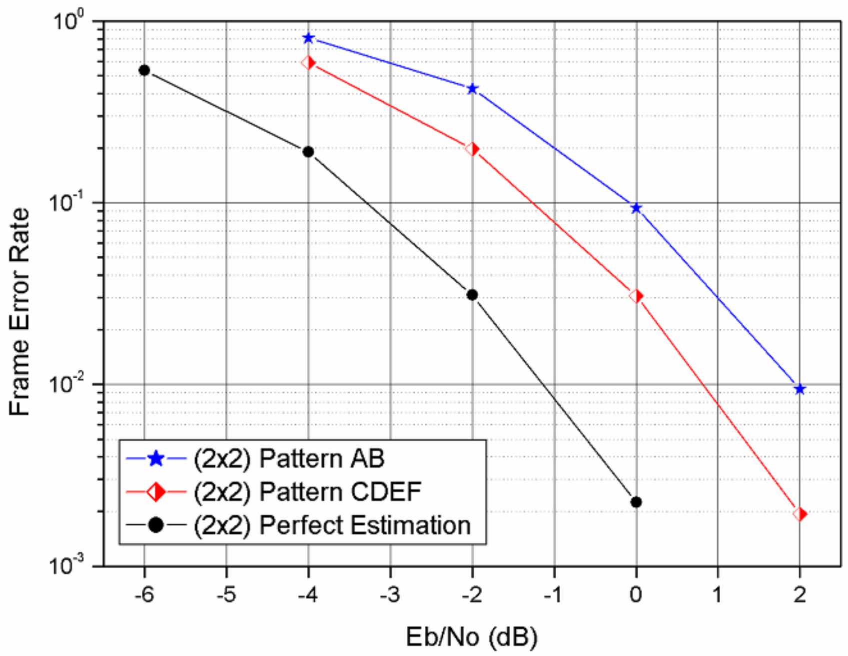



**Figure 5. FER for single MSS with dual antennas and BS with dual antennas (Pedestrian B with 10km/h)**

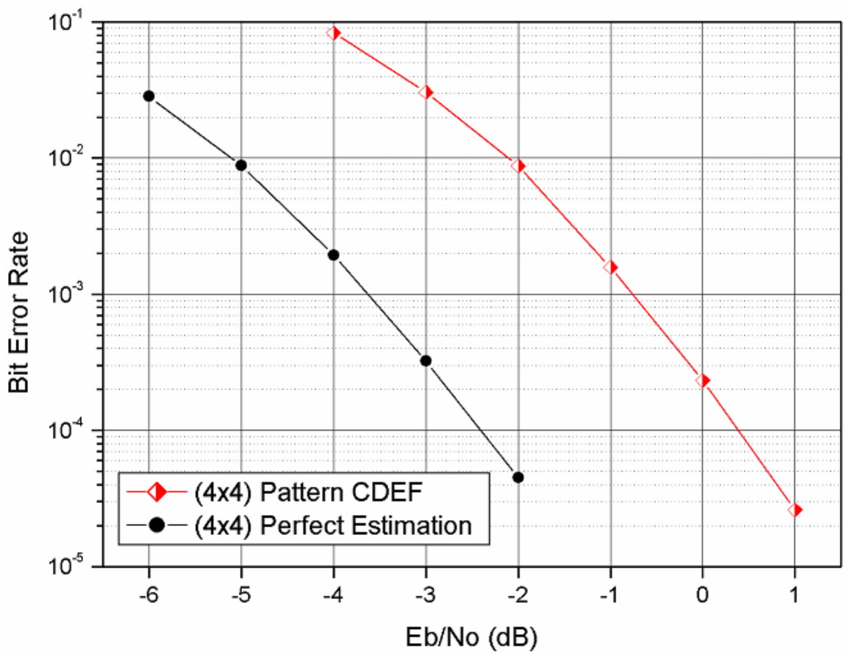



**Figure 6. BER for dual MSSs with dual antennas and BS with 4 antennas (Pedestrian B with 10km/h)**

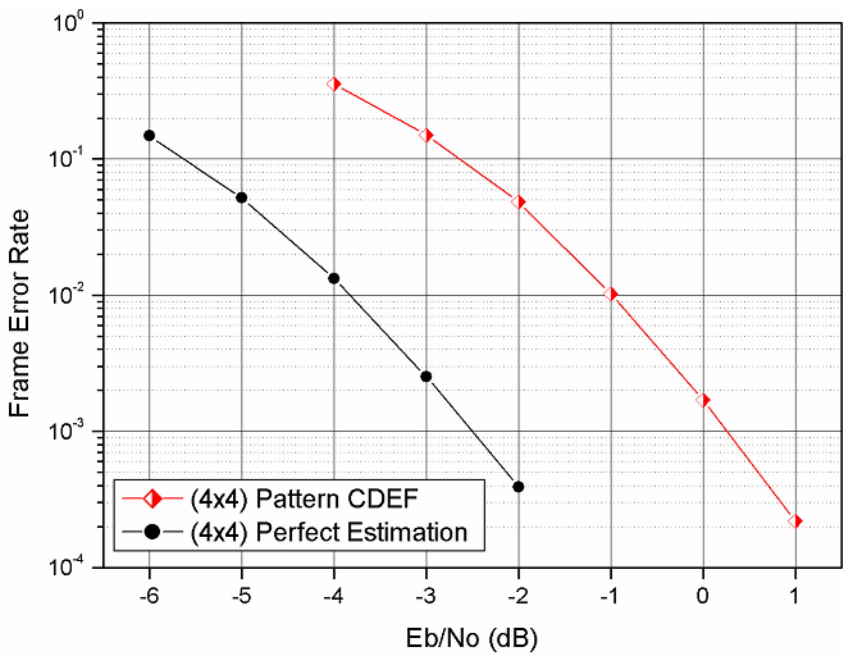



**Figure 7. FER for dual MSSs with dual antennas and BS with 4 antennas (Pedestrian B with 10km/h)**

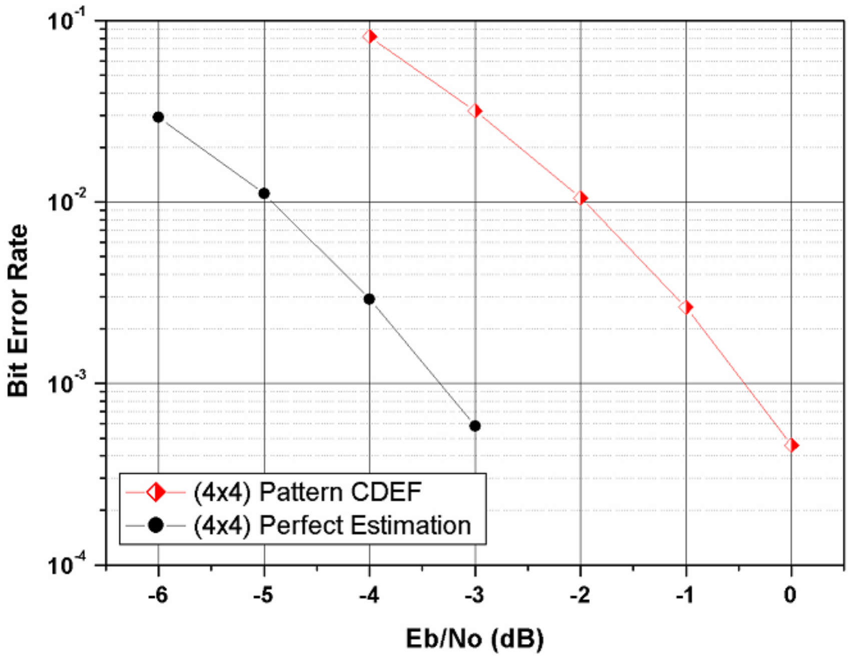



**Figure 8. BER for dual MSSs with dual antennas and BS with 4 antennas (Vehicular A with 60km/h)**

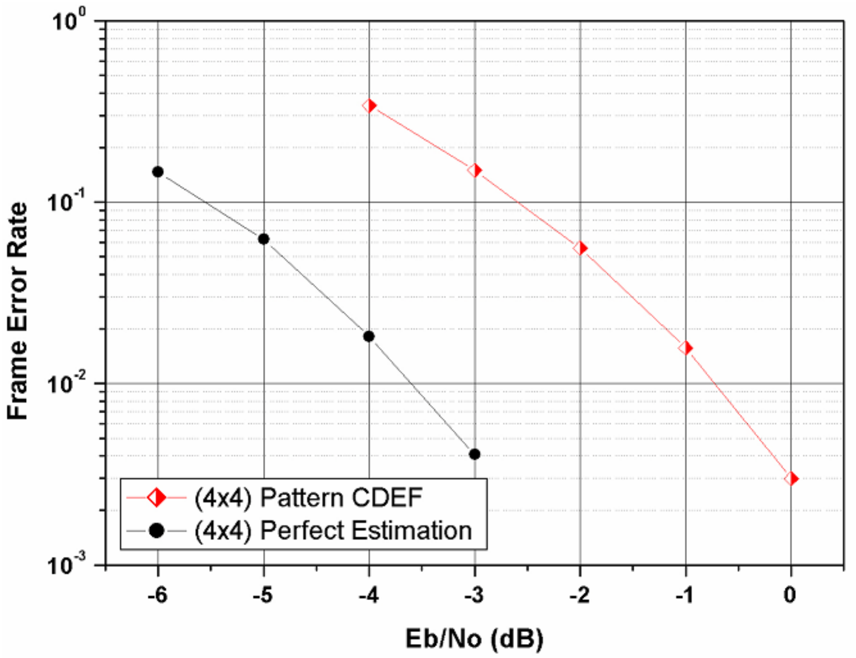



**Figure 9. FER for dual MSSs with dual antennas and BS with 4 antennas (Vehicular A with 60km/h)**

## 5. Proposed Text Change

***[Add a new Section 8.4.5.4.19]***

8.4.5.4.19 MIMO UL Enhanced IE format

In the UL-MAP, a MIMO-enabled BS may transmit UIUC=15 with the MIMO_UL_Enhanced_IE() to indicate the MIMO mode and configuration of the subsequent uplink allocation to a specific MIMO-enabled MSS CID and to define various pilot patterns in order to estimate channel of SS's. The mode indicated in the MIMO_UL_Enhanced_IE() shall only apply to the subsequent uplink allocation until the end of frame.

Table xxx – MIMO UL Enhanced IE () format

| Syntax | Size | Notes |
|---|---|---|
| MIMO_UL_Enhanced_IE () { | | |
| Extended UIUC | 4bits | Enhanced MIMO=0x0f |
| Length | 4bits | Length of the message in bytes (variable) |
| Num_Assign | 4bits | Number of burst assignment |
| For (j=0; j< Num_assign; j++){ | | |
| Num_CID | 2bits | |
| For ( i=0; i <Num_CID; i++){ | | |
| CID | 16bits | SS basic CID |
| UIUC | 4bits | |
| Matrix_Indicator | 2 bits | For dual transmission capable MSS<br>00 : STTD<br>01 : SM<br><br>For Collaborative SM capable MSS with 2-antenna<br>00: Matrix A<br>01: Matrix B<br>10: Matrix C<br>11: Reserved |
| MIMO_SM_Control | 2 bits | For Collaborative SM capable MSS<br>00: pilot pattern A<br>01: pilot pattern B<br><br>For Collaborative SM capable MSS with 2-antenna<br>00 : pilot pattern C/D<br>01 : pilot pattern E/F<br><br>10~11: Reserved |
| } | | |
| Duration | 10bits | In OFDMA slots (see 8.4.3.1) |
| } | | |
| } | | |

**Num_assign**

This field specifies the number of assignments in this IE.

**MIMO_SM_Control**

This field specifies the MIMO mode of UL burst. For a dual transmission capable MSS the value of 00 indicates STTD mode, the value of 01 indicates SM mode; For a collaborative SM capable MSS, the value of 00 indicates pilot pattern A, the value of 01 indicates pilot pattern B; For a collaborative SM capable MSS with 2-antenna, the value of 00 indicates pilot pattern C/D, the value of 01 indicates pilot pattern E/F.

***[Add a new section 8.4.8.1.5.1]***

8.4.8.1.5.1 Uplink using enhanced STC

A user supporting transmission using STC configuration in the uplink, shall use a modified uplink tile, 2-transmit diversity data or 2-transmit spatial multiplexing data can be mapped onto each subcarrier, the mandatory tile shall be modified to accommodate those configurations. Figure yyy depicts the UL tiles for enhanced STC transmission in PUSC mode.

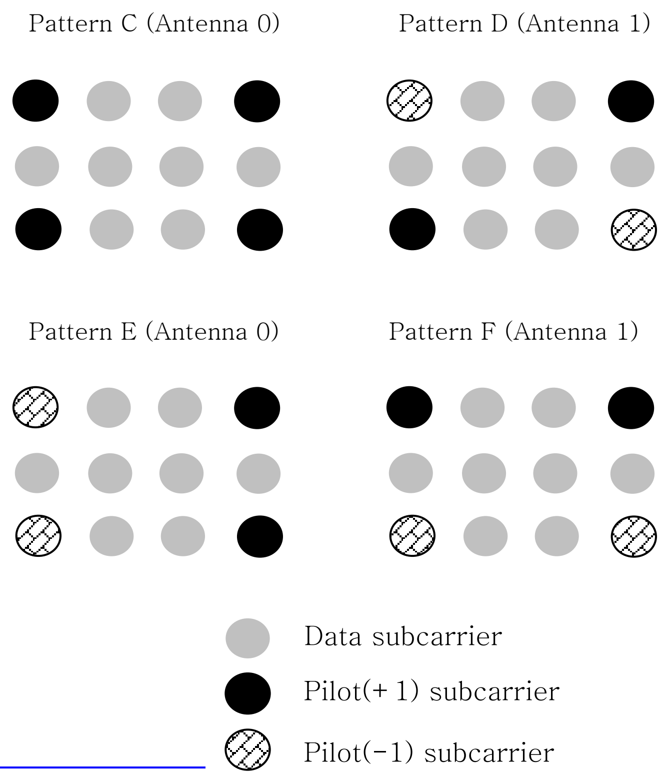



Figure yyy – MIMO tile in UL PUSC mode

Two SS's of one or two transmission antenna can perform collaborative spatial multiplexing onto the same subchannel. In this case, each SS should use the uplink tile with the pilot pattern indicated in MIMO_UL_Enhanced_IE. A dual transmit antenna SS can use the allocation in STTD, SM or collaborative SM mode with other SS. SS in collaborative SM mode with dual transmit antenna sends data in ordinary STC configurations as in section 8.4.8.1.4 using the pilot pattern pair indicated in MIMO_UL_Enhanced_IE. The first pilot pattern in each pair is for antenna 0 and the second is for antenna 1.

***[Add the following sentence at the end of section 8.4.8.4.3 Transmission schemes for 2-antenna MSS in UL. Line 65, page244]***

For two dual antenna MSSs to share the same subchannel, the matrix A, B and C for 4-antenna BS in section 8.4.8.3.5 may be used.