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Title	**Modifications to support Analog Eigenvector Feedback for MU-MIMO Transmission in the Draft P802.16m Amendment**
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Re:	802.16m AWD – Call for Contributions IEEE 802.16m-09/0020 Category: AWD comments / Area: Chapter 15.3.9 (UL-CTRL)
Abstract	This contribution proposes modifications to the AWD to enable the “eigenvector feedback” methodology mentioned in the UL Control section of the SDD.
Purpose	Discussion and adoption by TGm
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Analog Eigenvector Feedback for MU-MIMO Transmission – Proposed Text for the Draft P802.16m Amendment Working Document

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Introduction

This contribution contains the detailed text proposal to support analog feedback in the AWD. The associated presentation slides contain performance results and additional discussion for the proposed design.

Proposed Amendment Text

[Modify Section 15.3.8.3.3 as follows]

15.3.8.3.3 Resource allocation and tile permutation for control channels

The distributed LRUs in each of uplink frequency partition may be further divided into data, bandwidth request, ~~and~~ feedback channels, and analog feedback channels. The feedback channels can be used for both HARQ ACK/NAK and fast feedback. The analog feedback channels are specifically for transmitting unquantized eigenvector feedback for supporting MU-MIMO Transmission. The allocation order of data channels and UL control channels are TBD.

[Insert new Section 15.3.8.3.3.3 immediately prior to Section 15.3.8.3.4]

15.3.8.3.3.3 Analog Feedback Channels

The number of analog feedback channels in frequency partition FP_i, $L_{AFB,FPi}$, is indicated by the (TBD)-bit field UL_AFB_SIZE in the S-SFH (TBD) in the unit of LRUs.

$$L_{AFB,FPi} = \text{UL\_AFB\_SIZE} \qquad \text{Eqn AFB-1}$$

Analog Feedback (AFB) Channels may be present in some subframes, and the AFB allocation can differ from subframe to subframe.

In MZone, the analog feedback channels are of same size as LRUs, i.e. three 6-by-6 tiles. In LZone with PUSC, the analog feedback channels consist of three 4-by-6 tiles. The analog feedback channels use LRUs constructed from the tile permutation specified in Section 15.3.8.3.2.

[Insert new Section 15.3.9.1.6 on page 113]

15.3.9.1.6 Analog Feedback channel

In the LZone with PUSC, an AFB tile is defined as 4 contiguous subcarriers by 6 OFDM symbols. The number of AFB tiles per AFB channel is 3. For 2- and 4- transmit-antenna base stations, each AFB channel can multiplex analog eigenvector feedback from up to 4 mobile stations. For 8 transmit antennas, each AFB channel can multiplex analog eigenvector feedback from up to 3 mobile stations.

In the MZone, an AFB tile is defined as 6 contiguous subcarriers by 6 OFDM symbols. Each AFB channel consists of 3 distributed AFB tiles. For 2- and 4- transmit-antenna base stations, each AFB channel can multiplex analog eigenvector feedback from up to 6 mobile stations. For 8- transmit-antenna base stations, each AFB channel can multiplex analog eigenvector feedback from up to 4 mobile stations.

[Insert new Section 15.3.9.2.6 on page 119]

15.3.9.2.6 Analog Feedback Channels

For the MZone and the LZone, the structure of the analog feedback channels is defined for the number of base station antennas equaling 2, 4, and 8.

For the MZone, the structure for 2 transmit antennas is shown in Figure UL- 12. The analog feedback (AFB) channel for 2Tx antennas contains 6 analog feedback subchannels for enabling up to 6 AMSs to send analog eigenvector feedback with a CDM factor of 4. In Figure UL- 12, the structure is shown for the first tile of all six AFB subchannels. The structure on the 2nd and 3rd tiles are identical to the structure of the first tile. A blank symbol means the AMS does not transmit on that subcarrier/OFDM symbol. The construction of the information symbols e_{ijk} and pilot symbols P_{ijk} that are transmitted in the AFB subchannels is described in Section 15.3.9.3.4.

For the MZone, the structure for 4 transmit antennas is shown in Figure UL- 13. The analog feedback channel for 4Tx antennas contains 6 analog feedback subchannels for enabling up to 6 AMSs to send analog eigenvector feedback with a CDM factor of 4. In Figure UL- 13, the structure is shown for the first and second tiles of all six analog feedback subchannels. The structure of the 3rd tile is identical to the structure of the first tile. A blank symbol means the AMS does not transmit on that subcarrier/OFDM symbol. The construction of the information symbols e_{ijk} and pilot symbols P_{ijk} that are transmitted in the AFB subchannels is described in Section 15.3.9.3.4.

For the MZone, the structure for 8 transmit antennas is shown in Figure UL- 14. The analog feedback channel for 8Tx antennas contains 4 analog feedback subchannels for enabling up to 4 AMSs to send analog eigenvector feedback with a CDM factor of 4. In Figure UL- 14, the structure is shown for all three tiles of all six analog feedback subchannels. A blank symbol means the AMS does not transmit on that subcarrier/OFDM symbol.

The construction of the information symbols e_{ijk} and pilot symbols P_{ijk} that are transmitted in the AFB subchannels is described in Section 15.3.9.3.4.

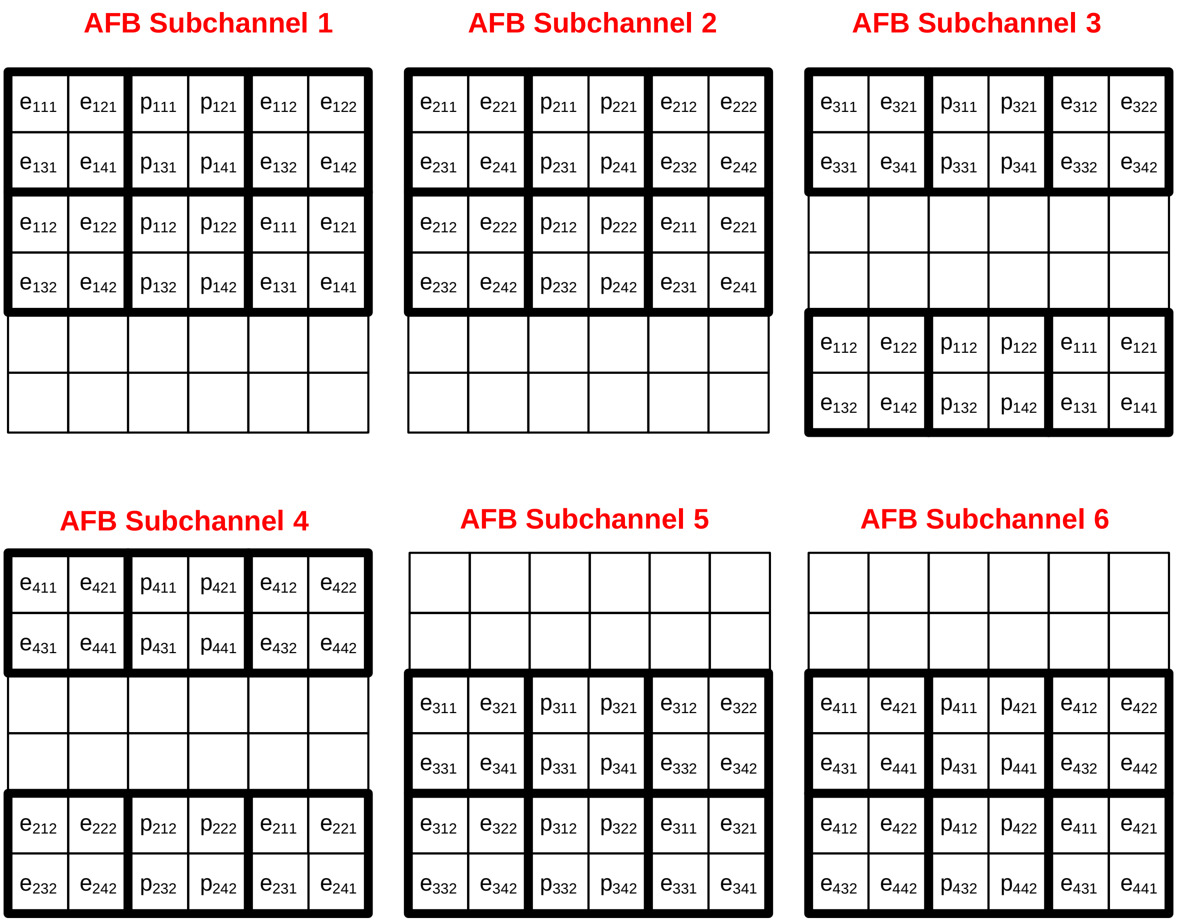

Figure UL- 1, Analog Feedback Channel Structure in the Advance Air Interface for 2 Transmit Antenna Base Stations (MZONE): 6 analog feedback subchannels for multiplexing up to 6 AMSs with a CDM factor of 4. Only Tile 1 is shown for the 6 analog feedback subchannels. Tiles 2 and 3 are identical to Tile 1.

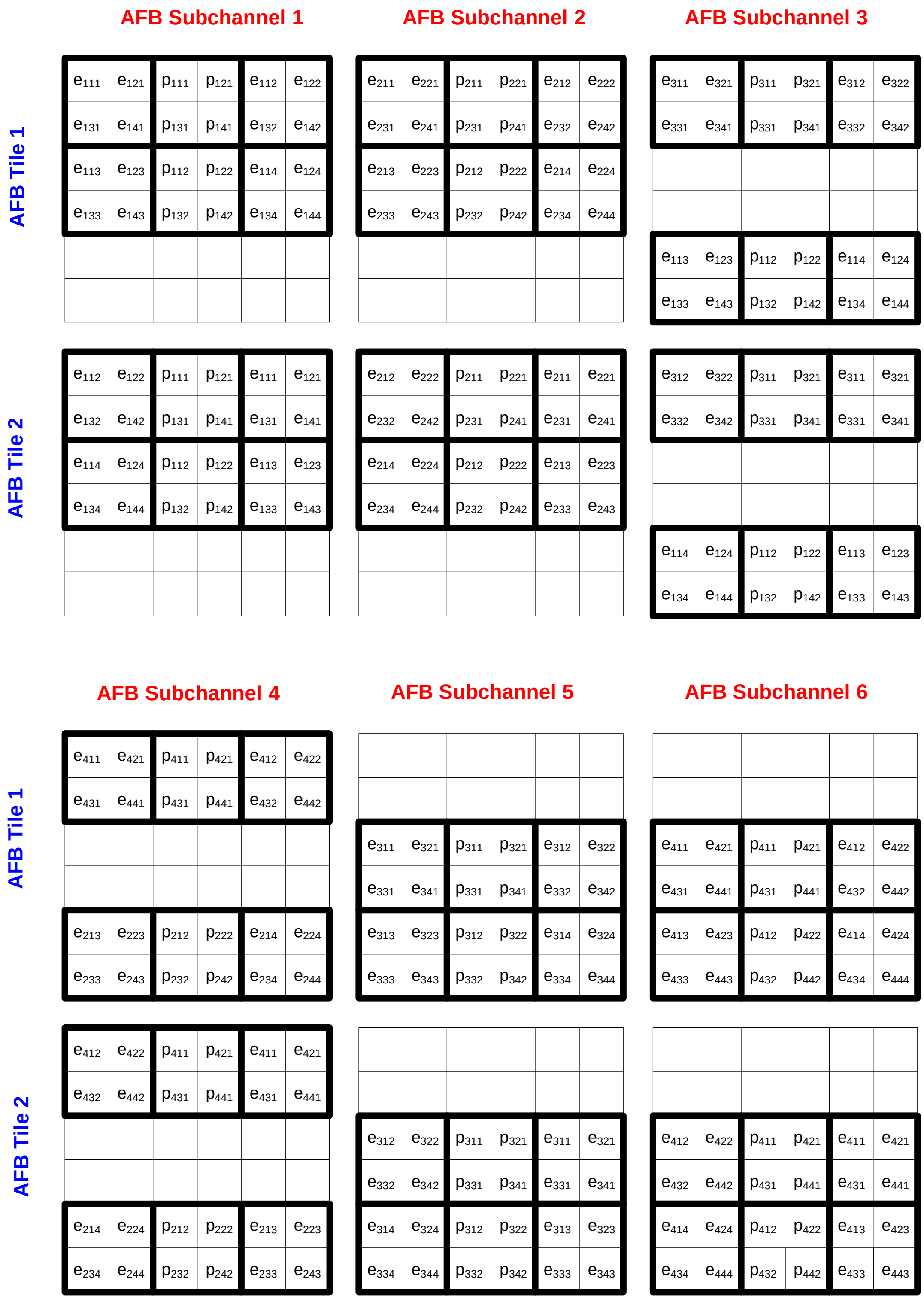

Figure UL- 2, Analog Feedback Channel Structure in the Advance Air Interface for 4 Transmit Antenna Base Stations (MZONE): 6 analog feedback subchannels for multiplexing up to 6 AMSs with a CDM factor of 4. Only Tiles 1 and 2 are shown. Tile 3 is identical to Tile 1.

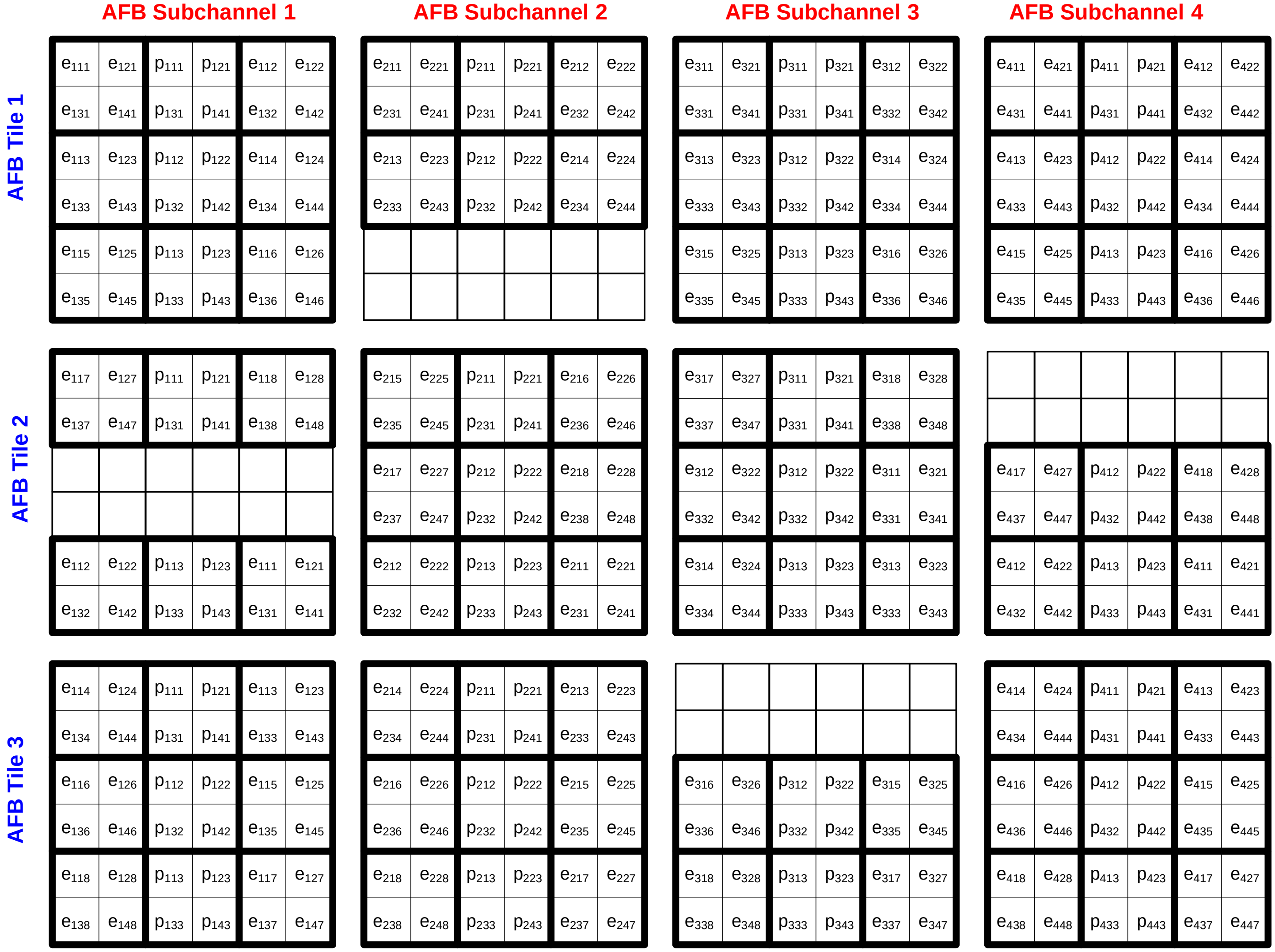

Figure UL- 3, Analog Feedback Channel Structure in the Advance Air Interface for 8 Transmit Antenna Base Stations (MZONE). 4 Analog Feedback subchannels for multiplexing up to 4 AMSs with a CDM factor of 4.

For the LZone, the structure for 2 transmit antennas is shown in Figure UL- 14. The analog feedback channel for 2Tx antennas supports up to 4 AMSs sending analog eigenvector feedback with a CDM factor of 4. In Figure UL- 14, the structure is shown for the first tile of all four users. The structure on the 2nd and 3rd tiles are identical to the structure of the first tile. A blank symbol means the AMS does not transmit on that subcarrier/OFDM symbol. The construction of the information symbols e_{ijk} and pilot symbols P_{ijk} that are transmitted in the AFB subchannels is described in Section 15.3.9.3.4.

For the LZone, the structure for 4 transmit antennas is shown in Figure UL- 15. The analog feedback channel for 4Tx antennas supports up to 4 AMSs sending analog eigenvector feedback with a CDM factor of 4. In Figure UL- 15, the structure is shown for the first and second tile of all four AMSs. The structure on the 3rd tile is identical to the structure of the first tile. A blank symbol means the AMS does not transmit on that subcarrier/OFDM symbol. The construction of the information symbols e_{ijk} and pilot symbols P_{ijk} that are transmitted in the AFB subchannels is described in Section 15.3.9.3.4.

For the LZone, the structure for 8 transmit antennas is shown in Figure UL- 16. The analog feedback channel for 8Tx antennas supports up to 3 AMSs sending analog eigenvector feedback with a CDM factor of 2. A blank symbol means the AMS does not transmit on that subcarrier/OFDM symbol. The construction of the information symbols e_{ijk} and pilot symbols P_{ijk} that are transmitted in the AFB subchannels is described in Section 15.3.9.3.4.

AFB Subchannel 1

e_{111}	e_{121}	p_{111}	p_{121}	e_{112}	e_{122}
e_{131}	e_{141}	p_{131}	p_{141}	e_{132}	e_{142}
e_{112}	e_{122}	p_{112}	p_{122}	e_{111}	e_{121}
e_{132}	e_{142}	p_{132}	p_{142}	e_{131}	e_{141}

AFB Subchannel 2

e_{211}	e_{221}	p_{211}	p_{221}	e_{212}	e_{222}
e_{231}	e_{241}	p_{231}	p_{241}	e_{232}	e_{242}
e_{212}	e_{222}	p_{212}	p_{222}	e_{211}	e_{221}
e_{232}	e_{242}	p_{232}	p_{242}	e_{231}	e_{241}

AFB Subchannel 3

e_{311}	e_{321}	p_{311}	p_{321}	e_{312}	e_{322}
e_{331}	e_{341}	p_{331}	p_{341}	e_{332}	e_{342}
e_{312}	e_{322}	p_{312}	p_{322}	e_{311}	e_{321}
e_{332}	e_{342}	p_{332}	p_{342}	e_{331}	e_{341}

AFB Subchannel 4

e_{411}	e_{421}	p_{411}	p_{421}	e_{412}	e_{422}
e_{431}	e_{441}	p_{431}	p_{441}	e_{432}	e_{442}
e_{412}	e_{422}	p_{412}	p_{422}	e_{411}	e_{421}
e_{432}	e_{442}	p_{432}	p_{442}	e_{431}	e_{441}

Figure UL- 4, Analog Feedback Channel Structure in the Advance Air Interface for 2 Transmit Antenna Base Stations (LZONE): 4 AMSs multiplexed with a CDM factor of 4. Only Tile 1 is shown for the 4 AMSs. Tiles 2 and 3 are identical to Tile 1.

AFB Subchannel 1

AFB Tile 1	e_{111}	e_{121}	p_{111}	p_{121}	e_{112}	e_{122}
	e_{131}	e_{141}	p_{131}	p_{141}	e_{132}	e_{142}
	e_{113}	e_{123}	p_{112}	p_{122}	e_{114}	e_{124}
	e_{133}	e_{143}	p_{132}	p_{142}	e_{134}	e_{144}
AFB Tile 2	e_{112}	e_{122}	p_{111}	p_{121}	e_{111}	e_{121}
	e_{132}	e_{142}	p_{131}	p_{141}	e_{131}	e_{141}
	e_{114}	e_{124}	p_{112}	p_{122}	e_{113}	e_{123}
	e_{134}	e_{144}	p_{132}	p_{142}	e_{133}	e_{143}

AFB Subchannel 2

AFB Tile 1	e_{211}	e_{221}	p_{211}	p_{221}	e_{212}	e_{222}
	e_{231}	e_{241}	p_{231}	p_{241}	e_{232}	e_{242}
	e_{213}	e_{223}	p_{212}	p_{222}	e_{214}	e_{224}
	e_{233}	e_{243}	p_{232}	p_{242}	e_{234}	e_{244}
AFB Tile 2	e_{212}	e_{222}	p_{211}	p_{221}	e_{211}	e_{221}
	e_{232}	e_{242}	p_{231}	p_{241}	e_{231}	e_{241}
	e_{214}	e_{224}	p_{212}	p_{222}	e_{213}	e_{223}
	e_{234}	e_{244}	p_{232}	p_{242}	e_{233}	e_{243}

AFB Subchannel 3

AFB Tile 1	e_{311}	e_{321}	p_{311}	p_{321}	e_{312}	e_{322}
	e_{331}	e_{341}	p_{331}	p_{341}	e_{332}	e_{342}
	e_{313}	e_{323}	p_{312}	p_{322}	e_{314}	e_{324}
	e_{333}	e_{343}	p_{332}	p_{342}	e_{334}	e_{344}
AFB Tile 2	e_{312}	e_{322}	p_{311}	p_{321}	e_{311}	e_{321}
	e_{332}	e_{342}	p_{331}	p_{341}	e_{331}	e_{341}
	e_{314}	e_{324}	p_{312}	p_{322}	e_{313}	e_{323}
	e_{334}	e_{344}	p_{332}	p_{342}	e_{333}	e_{343}

AFB Subchannel 4

AFB Tile 1	e_{411}	e_{421}	p_{411}	p_{421}	e_{412}	e_{422}
	e_{431}	e_{441}	p_{431}	p_{441}	e_{432}	e_{442}
	e_{413}	e_{423}	p_{412}	p_{422}	e_{414}	e_{424}
	e_{433}	e_{443}	p_{432}	p_{442}	e_{434}	e_{444}
AFB Tile 2	e_{412}	e_{422}	p_{411}	p_{421}	e_{411}	e_{421}
	e_{432}	e_{442}	p_{431}	p_{441}	e_{431}	e_{441}
	e_{414}	e_{424}	p_{412}	p_{422}	e_{413}	e_{423}
	e_{434}	e_{444}	p_{432}	p_{442}	e_{433}	e_{443}

Figure UL- 5, Analog Feedback Channel Structure in the Advance Air Interface for 4 Transmit Antenna Base Stations (LZONE): 4 AMSs multiplexed with a CDM factor of 4. Only Tiles 1 and 2 are shown for the 4 AMSs. Tile 3 is identical to Tile 1.

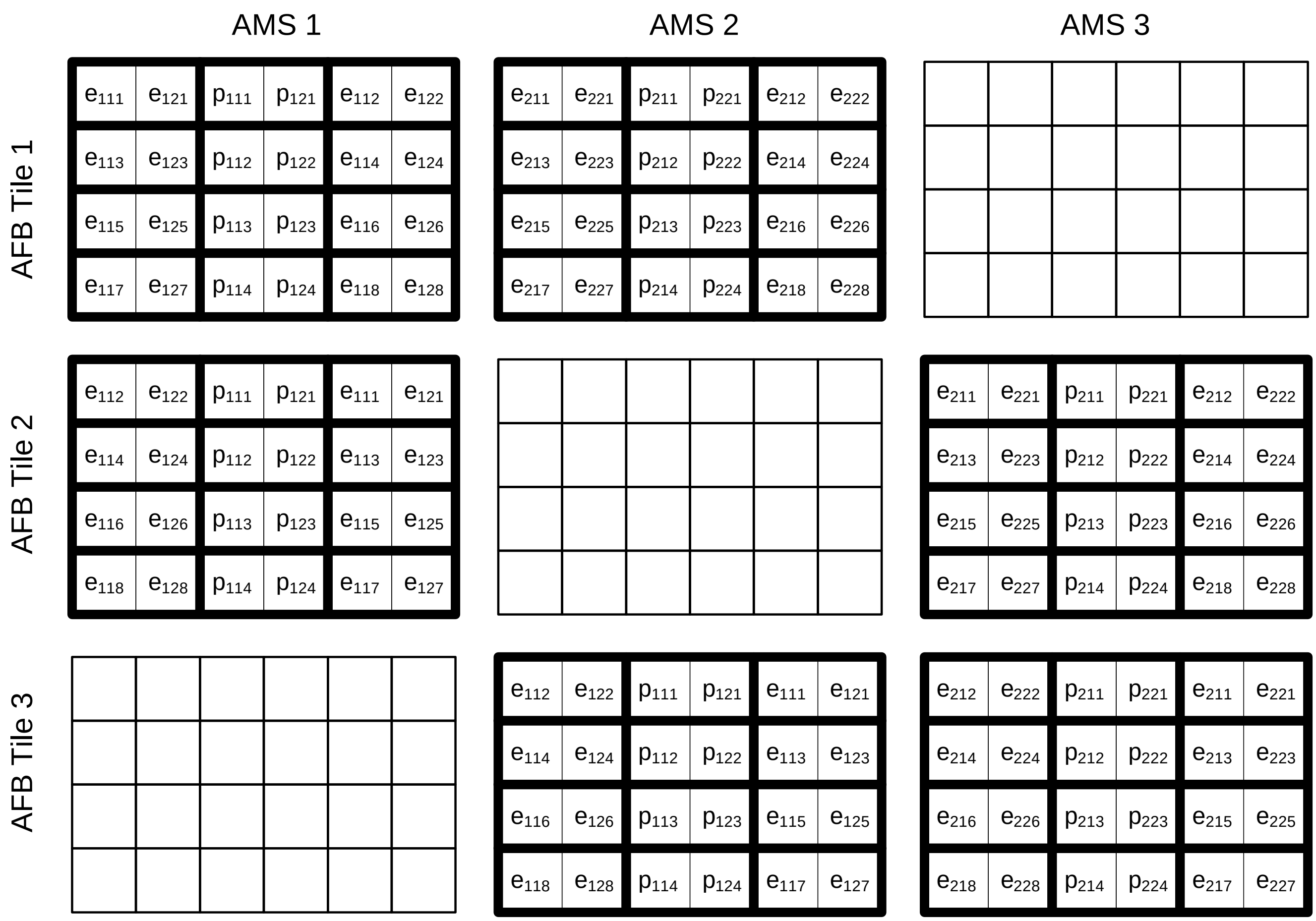

Figure UL- 6, Analog Feedback Channel Structure in the Advance Air Interface for 8 Transmit Antenna Base Stations (LZONE): 3 AMSs multiplexed with a CDM factor of 2.

[Add new Section 15.3.9.3.4]

15.3.9.3.4 Analog Feedback Channels

The analog feedback LRUs are used by the AMSs to transmit analog eigenvector feedback for enabling the ABS to compute high precision MU-MIMO transmit precoding weights. In analog eigenvector feedback, the AMS first computes an estimate of the downlink transmit spatial covariance matrix R given by:

$$\mathbf{R} = \frac{1}{N_K} \sum_{k \in S(k)} \mathbf{H}^H(k)\mathbf{H}(k)$$

where H(k) is the downlink matrix channel response (dimensioned as the number of AMS receive antennas by the number of ABS transmit antennas) at subcarrier k. The AMS may estimate H(k) from downlink measurement pilots. The S(k) denotes the set of subcarriers that the transmit covariance matrix is computed over. N_K is the number of subcarriers in the set S(k).

Two modes of analog eigenvector feedback are supported: wideband eigenvector feedback and narrowband eigenvector feedback. In wideband mode, the set of subcarriers $S(k)$ used to compute R consist of all used subcarriers. In narrowband mode, the set of subcarriers used to compute R consist of all subcarriers in the sub-band requested by the ABS in the TBD DL Control signaling. The ABS will indicate which mode (wideband or narrowband) the AMS is to use.

After computing R over the appropriate subcarriers, the AMS computes the eigenvector corresponding to the largest eigenvalue of R, where the largest eigenvector is denoted:

$$\mathbf{E} = \begin{bmatrix} c_1 \\ c_2 \\ \vdots \\ c_N \end{bmatrix}$$

where N is the number of transmit antennas at the ABS. The coefficients to be mapped to the analog feedback channels are denoted by e_i where elements $e_i = \alpha c_i$. The scale factor α is chosen by the MS to appropriately normalize the overall average transmit power to the value needed to achieve the per-subcarrier power control target for analog feedback. The ABS will indicate the per-subcarrier power control target for each user in a TBD DL control message.

The ABS will indicate to the AMS which form (wideband or narrowband) is to be transmitted and on which analog feedback subchannel to transmit the elements e_i. For narrowband mode, the ABS will indicate over which sub-band the covariance matrix R is to be computed. (The exact DL Control signaling is TBD.)

The mapping from the elements e_i to the information symbols e_{ijk} that are transmitted in the AFB subchannels shown in Section 15.3.9.2.6 is as follows. First, the entries of the unquantized eigenvector are denoted e_k, for k=1…N, where N is the number of BS transmit antennas. The symbol transmitted in the analog feedback subchannel is denoted as e_{ijk}, where $e_{ijk} = m_{ij} \times e_k$, and m_{ij} is the $(j,i)^{th}$ entry of the particular spreading matrix being used by the base station sector, where j is the row index and i is the column index of the spreading matrix. There are four choices for the spreading matrix to be used within a sector for spreading the analog feedback and those choices are denoted A, B, C, or D:

$$\mathbf{A} = \left(\frac{1}{2}\right)\begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 \\ 1 & -1 & 1 & -1 \end{bmatrix}, \mathbf{B} = \left(\frac{1}{2}\right)\begin{bmatrix} 1 & 1 & 1 & 1 \\ -1 & -1 & 1 & 1 \\ -i & i & i & -i \\ -i & i & -i & i \end{bmatrix},$$

$$\mathbf{C} = \left(\frac{1}{2}\right)\begin{bmatrix} 1 & 1 & 1 & 1 \\ -i & -i & i & i \\ -i & i & i & -i \\ -1 & 1 & -1 & 1 \end{bmatrix}, \mathbf{D} = \left(\frac{1}{2}\right)\begin{bmatrix} 1 & 1 & 1 & 1 \\ i & i & -i & -i \\ 1 & -1 & -1 & 1 \\ -i & i & -i & i \end{bmatrix}$$

The BS will indicate to the MS which spreading matrix is being used by the sector to which the MS belongs via TBD signaling/methodology. The pilot symbols P_{ijk} are similarly constructed: $P_{ijk} = m_{ij} \times P_k$, where P_k is the TBD pilot value to be transmitted by the MS assigned to the AFB subchannel and m_{ij} is given above.