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Title	**UL MIMO Text for the IEEE 802.16m Amendment**
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Re:	IEEE 802.16m-08/053r1, "Call for Contributions on Project 802.16m Draft Amendment Content" providing text for the topic of "Uplink MIMO"
Abstract	The contribution provides Uplink MIMO text for the IEEE 802.16m amendment.
Purpose	To be incorporated into the initial IEEE 802.16 amendment
Notice	
Release	
Patent Policy	

Uplink MIMO Text for the IEEE 802.16m Amendment

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1. Introduction

This contribution proposes the text for UL-MIMO to be included in the 802.16m amendment. The proposed text is developed so that it can be readily combined with IEEE P802.16 Rev2/D8 [1], it is compliant to the 802.16m SRD [2] and the 802.16m SDD [3], and it follows the style and format guidelines in [4].

2. Outline

The following is a high level outline of the proposed UL MIMO Text:

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15.3.11. Uplink MIMO Transmission Schemes
15.3.11.1 Antenna Configurations Supported
15.3.11.2 UL-MIMO Architecture and Data Processing
15.3.11.3 Transmission Modes for Data Channels
15.3.11.3.1 Single User MIMO
15.3.11.3.1.1 Open-Loop SU-MIMO
15.3.11.3.1.1.1 Overview of Supported Modes
15.3.11.3.1.1.2 Transmit Diversity Methods
15.3.11.3.1.1.3 Spatial Multiplexing Modes
15.3.11.3.1.1.4 OL-SU-MIMO Precoding Matrix
15.3.11.3.1.2 Closed-Loop SU-MIMO
15.3.11.3.1.2.1 Codebook-based precoding for CL-SU-MIMO
15.3.11.3.1.2.2 Downlink-pilot-based precoding for CL-SU-MIMO
15.3.11.3.1.3 Mapping the MIMO precoder output to subcarriers for SU-MIMO
15.3.11.3.2 Multi-user MIMO
15.3.11.3.2.1 Open-Loop MU-MIMO
15.3.11.3.2.2 Closed-Loop MU-MIMO
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3. References

[1] IEEE P802.16 Rev2/D8, "Draft IEEE Standard for Local and Metropolitan Area Networks: Air Interface for Broadband Wireless Access," Oct. 2008.

[2] IEEE 802.16m-07/002r7, "802.16m System Requirements"

[3] IEEE 802.16m-08/003r6, "The Draft IEEE 802.16m System Description Document"

[4] IEEE 802.16m-08/043, "Style guide for writing the IEEE 802.16m amendment"

Text proposal for inclusion in the 802.16m amendment

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Insert a new section 15:

15. Advanced Air Interface

15.3. Physical layer

15.3.5.

15.3.6.

15.3.7.

15.3.8.

15.3.9.

15.3.10.

15.3.11. Uplink MIMO Transmission Schemes

15.3.11.1. Antenna Configurations Supported

The antenna configurations are denoted by (N_T, N_R) where N_T denotes the number of AMS transmit antennas and N_R denotes the number of ABS receive antennas. The supported antenna configurations are N_T = 1, 2, or 4 and $N_R \geq 2$.

15.3.11.2. UL-MIMO Architecture and Data Processing

The general architecture of uplink MIMO on the transmitter side is shown in Figure 1.

In SU-MIMO, only one AMS is scheduled in a resource allocation. In MU-MIMO, more than one AMS is scheduled in a resource allocation.

A "layer" is defined as a coding / modulation path fed to the MIMO encoder as an input. Vertical encoding is supported (Single Codeword or SCW), which means there is only one encoder block (one "layer") for each AMS assigned to the resource allocation. A "stream" is defined as an output of the MIMO encoder that is passed to a beamformer / precoder.

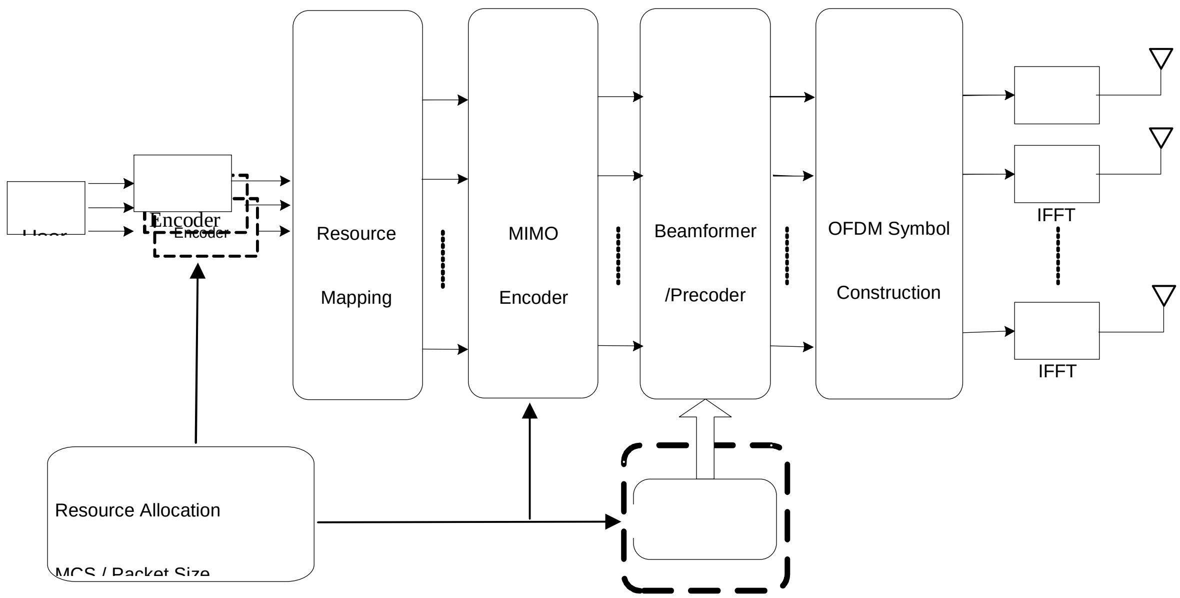

Figure 1 Uplink MIMO Architecture

The encoder block contains the channel encoder, interleaver, rate-matcher, and modulator for each layer.

The Resource Mapping block maps the modulated symbols to the corresponding time-frequency resources in the allocated resource units (RUs).

The MIMO encoder block maps the L=1 layer onto N_S (≥L) streams, which are fed to the Beamformer/Precoder block.

The Beamformer/Precoder block maps streams to antennas by generating the antenna-specific data symbols according to the selected MIMO mode.

The OFDM symbol construction block maps antenna-specific data to the OFDM symbol.

If only one transmit antenna is used, the codeword to stream mapping, MIMO encoding and precoder are removed in Figure 1.

The ABS will schedule users to resource blocks and decides their MCS level, MIMO parameters (MIMO mode, rank). PMI may be calculated at the ABS or AMS.

The mapping from layers to streams depends on the specific MIMO mode being employed by the MIMO encoder block, where the collection of supported MIMO modes will be described below. The MIMO encoder in each MIMO mode operates in batch mode on a length M vector of input modulation symbols $\mathbf{x}$ and produces a $N_S \times N_F$ STC matrix $\mathbf{z}$.

$$\mathbf{z} = \mathbf{S}(\mathbf{x}), \qquad \text{Equation 1}$$

where N_S is the number of streams, N_F is the number of subcarriers occupied by the output of the MIMO encoder, and **S(x)** is the mapping function of the MIMO mode.

The mapping from the N_S streams to the N_T antennas is defined by the following formula:

$$\mathbf{y} = \mathbf{W} \times \mathbf{z} = \mathbf{W} \times \mathbf{S}(\mathbf{x}), \qquad \text{Equation 2}$$

where y is the $N_T \times N_F$ output of the precoder/beamformer, **W** is a $N_T \times N_S$ pre-coding matrix, **S(x)** is an STC matrix according to the MIMO mode, and **x** is the length M vector of input symbols.

All supported UL MIMO modes may be employed in contiguous or distributed resource allocations.

15.3.11.3. Transmission Modes for Data Channels

15.3.11.3.1. Single User-MIMO

15.3.11.3.1.1. Open-Loop SU-MIMO

15.3.11.3.1.1.1. Overview of Supported MIMO Encoding Modes

The following table lists the MIMO encoding modes for 2 transmit antennas at the AMS.

MIMO Encoding Mode	***Type***	***Description***	N_T	**Rate**	***M***	N_S	N_F
0	TX Diversity	Rank 1 Precoder	2	1	1	1	1
1	TX Diversity	SFBC	2	1	2	2	2
2	Spatial Multiplexing	Rate 2 SM with Precoding	2	2	2	2	1

Table 1 Matrix dimensions for open-loop SU-MIMO modes for 2 transmit antennas at the AMS

The following table lists the MIMO encoding modes for 4 transmit antennas at the AMS.

MIMO Encoding Mode	*Type*	*Description*	N_T	**Rate**	*M*	N_S	N_F
0	TX Diversity	Rank 1 Precoder	4	1	1	1	1
1	TX Diversity	SFBC with Precoder	4	1	2	2	2
2	Spatial Multiplexing	Rate 2 SM with Precoding	4	2	2	2	1
3	Spatial Multiplexing	Rate 3 SM with Precoding	4	3	3	3	1
4	Spatial Multiplexing	Rate 4 SM	4	4	4	4	1

Table 2 Matrix dimensions for open-loop SU-MIMO modes for 4 transmit antennas as the AMS

For each resource allocation the MIMO encoding mode is signaled in the allocation grant message as described in Section (DL-Control). The number of AMS transmit antennas is signaled in the registration process as described in Section (TBD).

15.3.11.3.1.1.2. Transmit Diversity Modes

The transmit diversity modes are the rate 1 MIMO Encoding Modes listed in Tables 1 through 2 (Modes 0 and 1 for N_T=2, 4). Mode 0 has M=1 and Mode 1 has M=2, where M is the number of modulation symbols that are batch processed by the MIMO encoder at a time.

For the transmit diversity modes with M=1, the MIMO encoder operates on one symbol at a time, and the input to MIMO encoder is $x=s_1$. The output of the MIMO encoder is a scalar, z=x. The output of MIMO encoder is multiplied by an $N_T \times 1$ matrix **W**, where **W** is described in Section 15.3.11.2.

$$\mathbf{y} = \mathbf{W} \times z = \begin{bmatrix} y_{1,1} \\ y_{2,1} \\ \vdots \\ y_{N_T,1} \end{bmatrix}, \quad \text{Equation 3}$$

where $y_{j,k}$ is the output symbol to be transmitted via the j-th physical antenna on the k-th subcarrier.

For the transmit diversity modes with M=2, the MIMO encoder operates on two symbols at a time, where the input to the MIMO encoder is represented a 2×1 vector.

$$\mathbf{x} = \begin{bmatrix} s_1 \\ s_2 \end{bmatrix}, \quad \text{Equation 4}$$

The output of the MIMO encoder is a Space-Frequency Block Coding (SFBC) matrix.

$$\mathbf{z} = \begin{bmatrix} s_1 & -s_2^* \\ s_2 & s_1^* \end{bmatrix}, \qquad \text{Equation 5}$$

The output of the MIMO encoder is then multiplied by $N_T \times 2$ precoding matrix W, where W is described in Section 15.3.11.2.

$$\mathbf{y} = \mathbf{W} \times z = \begin{bmatrix} y_{1,1} & y_{1,2} & \cdots & y_{1,N_F} \\ y_{2,1} & y_{2,2} & \cdots & y_{2,N_F} \\ \vdots & \vdots & \ddots & \vdots \\ y_{N_T,1} & y_{N_T,2} & \cdots & y_{N_T,N_F} \end{bmatrix}, \text{Equation 6}$$

where $y_{j,k}$ is the output symbol to be transmitted via the j-th physical antenna on the k-th subcarrier. Note N_F is the number of subcarriers used to transmit the MIMO signals derived from the input vector x. For the transmit diversity modes $N_F = M$=2. For open-loop SU-MIMO, the rate of a mode is defined as $R = M / N_F$.

15.3.11.3.1.1.3. Spatial Multiplexing Modes

The MIMO Modes listed in Tables 1 through 3 with rates greater than 1 are the spatial multiplexing modes (Modes 2, 3, 4 for N_T=2, 4, and 8). For the rate-R spatial multiplexing modes, the input and the output of MIMO encoder is represented by an $R \times 1$ vector

$$\mathbf{x} = \mathbf{z} = \begin{bmatrix} s_1 \\ s_2 \\ \vdots \\ s_R \end{bmatrix}, \qquad \text{Equation 7}$$

The output of the MIMO encoder is then multiplied by the $N_T \times R$ matrix **W**, where **W** is described in Section 15.3.11.2.

$$\mathbf{y} = \mathbf{W} \times \mathbf{z} = \begin{bmatrix} y_{1,1} \\ y_{2,1} \\ \vdots \\ y_{N_T,1} \end{bmatrix}, \text{Equation 8}$$

where $y_{j,k}$ is the output symbol to be transmitted via the j-th physical antenna on the k-th subcarrier. Note N_F is the number of subcarriers used to transmit the MIMO signals derived from the input vector x and is equal to one for the spatial multiplexing modes.

15.3.11.3.1.1.4. OL-SU-MIMO Precoding Matrix

The matrix W is held fixed across a PRU and may change from PRU to PRU and from subframe to subframe. The pilots in the PRU that are associated with antenna i are precoded with the i^{th} column of **W**. for both OL-SU-MIMO and CL-SU-MIMO.

15.3.11.3.1.2. Closed-Loop SU-MIMO

For closed-loop SU-MIMO, all the MIMO encoding modes and associated descriptions in Section 15.3.11.3.1 are supported. The allocation grant indicates which MIMO encoding mode is used on the resource allocation. For Closed-Loop SU-MIMO, there are two supported methodologies for assisting the AMS in determining the value of the precoding matrix **W**, and these are described in the following.

15.3.11.3.1.2.1. Codebook-based Precoding for CL-SU-MIMO (FDD & TDD)

In this mode, the precoding matrix **W** is selected from the codebook specified in Section (DL-MIMO). The AMS may transmit an uplink sounding signal in the uplink to assist the ABS in selecting the optimal **W**. The index of the selected precoding matrix is signaled to the AMS in the allocation grant as described in Section (DL-Control).

15.3.11.3.1.2.2. Downlink-Pilot-based Precoding for CL-SU-MIMO (TDD)

In this mode, the AMS may calculate the precoding matrix **W** based on pilot signals received on the downlink.

15.3.11.3.1.3. Mapping the MIMO precoder output to subcarriers for SU-MIMO

As mentioned in Section 15.3.11.2, the MIMO encoder operates on M symbols at a time from the output of the encoder block. Each block of M symbols are ultimately transformed into the $N_T \times N_F$ $\mathbf{y}$ matrix that specifies the signal to be transmitted on the N_T transmit antennas over N_F successive carriers, as described in Sections 15.3.11.3.1.1.2 and 15.3.11.3.1.1.3. Each successive block of M symbols from the encoder block is mapped to successive groups of N_F contiguous physical subcarriers belonging to the resource allocation, starting with the uppermost physical subcarrier of the first symbol interval of the resource allocation, continuing down the band to the lowermost physical subcarrier of the resource allocation, and then to the uppermost subcarrier of the second symbol of the resource allocation, and so on until the lowermost subcarrier of the last symbol interval of the resource allocation is reached.

15.3.11.3.2. Multi-User-MIMO

Uplink Multi-user MIMO is supported to enable multiple AMSs spatially multiplexed on the same resource allocation for uplink transmission. Both open-loop and closed-loop MU-MIMO are supported. AMS precoding and/or beamforming is supported.

15.3.11.3.2.1. Open-Loop MU-MIMO

AMSs with single transmit antenna are supported in open-loop MU-MIMO transmissions.

AMSs with multiple transmit antennas are also supported in open-loop MU-MIMO transmissions. All uplink open-loop SU-MIMO encoding modes are supported in open loop MU-MIMO for AMSs with more than one transmit antenna.

The ABS is responsible for scheduling users and the number of transmitted streams such that it can appropriately decode the received signals according to the number of transmitted streams and to the number of receive antennas. The total number of transmitted streams shall not exceed the number of receive antennas at the ABS.

15.3.11.3.2.2. Closed-Loop MU-MIMO

Codebook based precoding is supported for both TDD and FDD using the codebook specified in Section (DL-MIMO). In this case, the AMS shall follow the indication of PMI from the ABS in the allocation grant and perform codebook based precoding.

Downlink pilot based precoding is supported in TDD systems. In this case, the precoder may be vendor-specific.

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