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Title	**DL common and dedicated pilot structures for MU-MIMO**
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Re:	IEEE 802.16m-08/005 (“Call for contributions on Project 802.16m SDD”) Target topic: “Pilot structures as relevant to downlink MIMO”
Abstract	This contribution provides the design aspect of downlink common and dedicated pilot pattern in terms of 802.16m pilot structures as relevant to downlink MIMO
Purpose	For discussion and approval by IEEE 802.16 Working Group
Notice	
Release	
Patent Policy	

DL common and dedicated pilot structures for MU-MIMO

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Introduction

This contribution describes a proposal for IEEE 802.16m downlink pilot pattern design when MU-MIMO is employed.

In MU-MIMO case, when linear precoding techniques are utilized [1] [2], one open issue in these designs is how to communicate the precoding weights to the active terminals for correct detection of the signals at the receiving antenna. In this contribution, we propose downlink common and dedicated pilot structures to enable the efficient transmission of the precoding weights.

System Model Description

In case of downlink multi-user MIMO, it assumes the system has N_t transmission antennas and N_r receiving antennas. The received signal $\mathbf{Y}$ could be modeled as

$$\mathbf{Y} = \mathbf{H}\mathbf{\Omega}\mathbf{x} + \mathbf{n} \qquad (1)$$

where $H \in C^{N_r \times N_t}$ is the channel matrix between BS and MS, $\mathbf{\Omega} = [\boldsymbol{\omega}_1, \cdots, \boldsymbol{\omega}_N]$ is an $N_t \times N$ precoding matrix consisting of N codewords, $X = [x_1, ..., x_N]^T \in C^{N \times 1}$ is the N layer of data vector, $n \in C^{N \times 1}$ is the receiving noise.

Suppose each MS is equipped with M receiving antennas, then for each user i the received signal $Y_i \in C^{M \times 1}$ is

$$\begin{aligned}\mathbf{Y}_i &= \mathbf{H}_i\mathbf{\Omega}\mathbf{x} + \mathbf{n}_i \\ &= \mathbf{H}_i[\boldsymbol{\omega}_1, \cdots, \boldsymbol{\omega}_N]\begin{bmatrix} x_1 \\ \vdots \\ x_N \end{bmatrix} = \mathbf{H}_i\boldsymbol{\omega}_i x_i + \underbrace{\mathbf{H}_i\sum_{j\neq i}\boldsymbol{\omega}_j x_j}_{\text{Interference}} + \mathbf{n}_i \\ &= \bar{\mathbf{H}}_i x_i + \underbrace{\mathbf{H}_i\sum_{j\neq i}\boldsymbol{\omega}_j x_j}_{\text{Interference}} + \mathbf{n}_i\end{aligned} \qquad (2)$$

where $H_i \in C^{M \times N_t}$ is the channel experienced by user i. In (2) we also define an effective channel $\bar{\mathbf{H}}_i$ which is the product of $\mathbf{H}_i$ and $\boldsymbol{\omega}_i$.

At the receiver, in order to decode the data correctly, the effective channel $\bar{\mathbf{H}}_i$ should be estimated firstly. To estimate effective channel $\bar{\mathbf{H}}_i$, two methods can be used. In the first method, $\boldsymbol{\omega}_i$ is explicit signaling in the downlink control channel, the channel information is estimated firstly from common pilots, say $\hat{\mathbf{H}}_i$. Then multiplying with $\boldsymbol{\omega}_i$, we get the estimated effective channel:

$$\hat{\bar{\mathbf{H}}}_i = \hat{\mathbf{H}}_i \cdot \boldsymbol{\omega}_i \tag{3}$$

With this method, the disadvantages are:

- Explicit signaling of $\boldsymbol{\omega}_i$ to each MS is needed.
- The common pilots need to be transmitted from each antenna separately, in order to get estimated channel information from n-th Tx antenna to m-th Rx antenna $\hat{H}_{m,n}$. Thus a noise component will be introduced in each $\hat{H}_{m,n}$ as $\hat{H}_{m,n} = H_{m,n} + n_m$, which will degrade the performance.

In the second method, dedicated pilots are used, or rather, $\boldsymbol{\omega}_i x_i$ are transmitted as pilots for the i th user. In this case, each dedicated pilot is precoded by one of the precoding vectors used for data and transmitted from all transmit antennas simultaneously. With this dedicated pilots, $\bar{\mathbf{H}}_i$ can be estimated directly from these pilots.

In order to reduce the signaling overhead, dedicate pilots are preferred for MU-MIMO. The use of dedicated pilots improves the dedicated MS's performance, but the price is other MS's performance degradation. The reason is that other MSs can not estimate their own channel by using these dedicated pilots, and they can only estimate their own channel by using common pilots. With this consideration, we propose to use dedicated pilots and common pilots simultaneously. In order to seamlessly support SU-MIMO schemes and keep the same pilot overhead as the legacy system, the pilot location of MU-MIMO is the same as that of current SU-MIMO and the total number of dedicated pilots and common pilots is also kept the same as that of current SU-MIMO. The details are shown in below.

Pilots allocation design

Considering the advantages of adaptive modulation and coding, we assume the AMC zone is used for downlink multi-user MIMO with high priority [3]. The basic resource unit is 'bin' which has 9 contiguous subcarriers, as shown in Figure 1. In this case, a slot consists of 2 bins over 6 OFDM symbols [4].

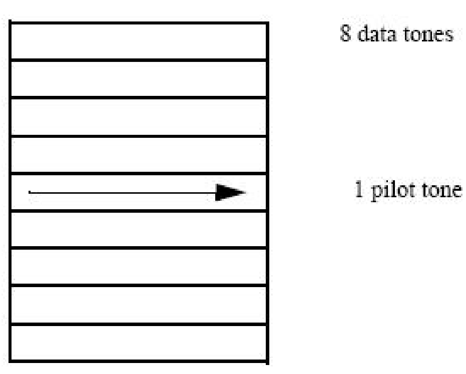

Figure 1. Bin structure.

In the following we'll show an example to explain the pilot design. Assume there are total 2 Tx & 2 Rx antennas $N_t = 2, N_r = 2,$, and two layer of data being distributed such as one layer of data for each user $N = 2$. So there are two users, and assume each user is equipped with $M = 1$ Rx antenna. Figure 2 shows the pilot allocations in this case, from which we can see that *k*-/*p*-/*q*-th subcarriers are occupied by pilots.

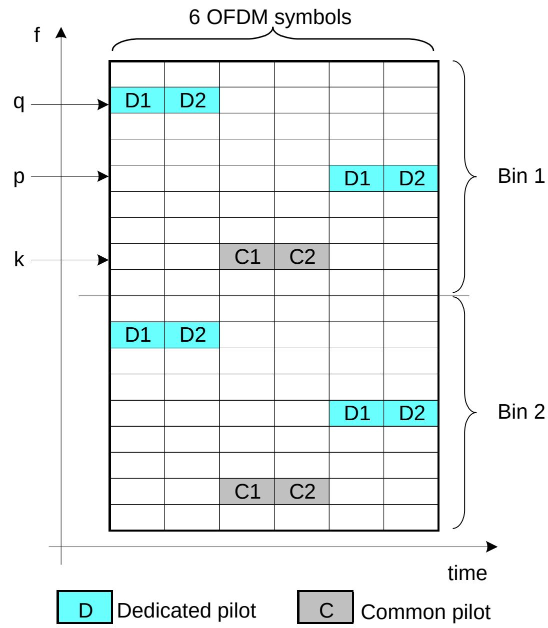

Figure 2. Pilot allocations in case of $N_t = 2, N_r = 2, N = 2, M = 1$.

Step 1: The channel information of the first user H_1^k is estimated from the k-th common pilot C1&C2, named $\hat{H}_1^k$, while the effective channel $\hat{\hat{H}}_1^p$ and $\hat{\hat{H}}_1^q$ are estimated from dedicated pilot D1 at *p*-th and *q*-th subcarriers, as shown in Figure 3.

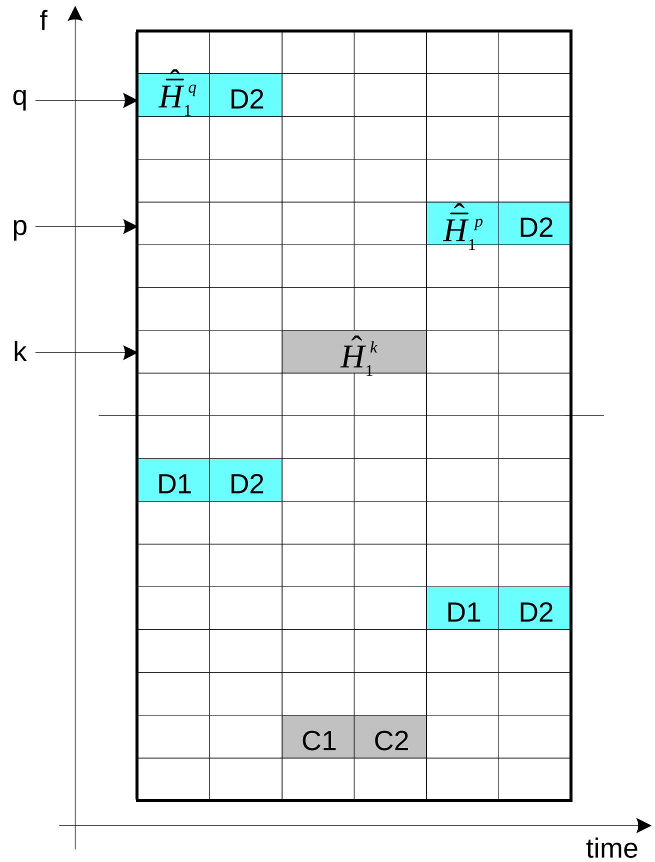

Figure 3. Step 1: estimate $\hat{H}_1^k$, $\hat{\bar{H}}_1^p$ and $\hat{\bar{H}}_1^q$.

Step 2: $\hat{H}_1^p$ and $\hat{H}_1^q$ are calculated by interpolation algorithm, e.g., linear/sinusoidal interpolation or 2D-Wiener filter, which is shown in Figure 4.

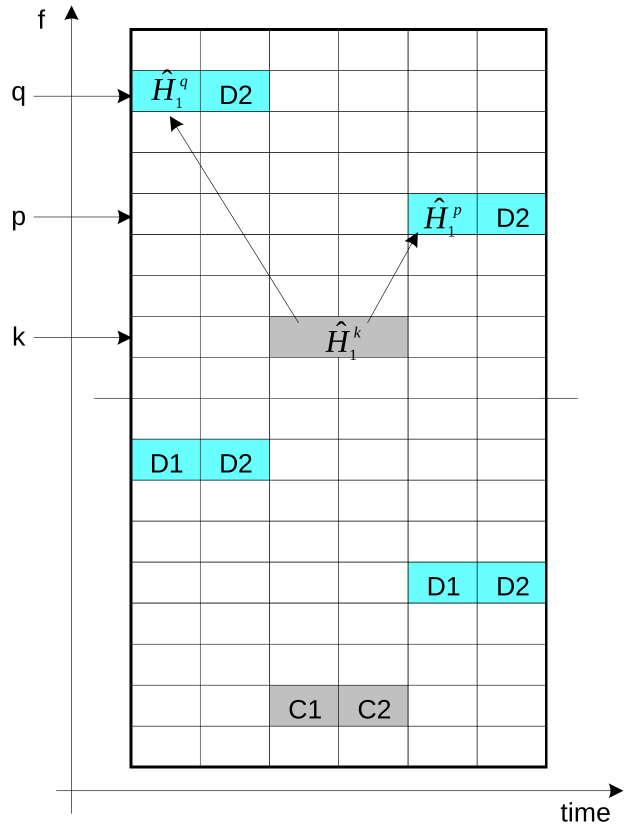

Figure 4. Step 2: calculating $\hat{H}_1^p$ and $\hat{H}_1^q$ by interpolation.

Step 3: calculating the codeword $\omega_i = [\omega_{1,i}, \omega_{2,i}]^T$ by solving the Equation (3). For each user, $\omega_i \in N_t \times 1$ has N_t unknown variables to be estimated, so N_t equations are needed. Besides, with one more receiving antenna, another observation could be gotten. Thus for each user, it needs N_t/M dedicated pilots. While for number of serving users, N_{user}, the system needs $\frac{N_t \cdot N_{user}}{M}$ dedicated pilots. It is the minimum requirement. In this case, we should have at least totally 4 dedicated pilots and 2 for each codeword.

Step 4: then $\hat{\hat{H}}_i$ is calculated by using Equation(3).

Step 5: the effective channel estimation on other subcarrier k' will be calculated by interpolation/filtering by using the channel information on *k*-/*p*-/*k*-th common and dedicated pilots, as shown in Figure 5

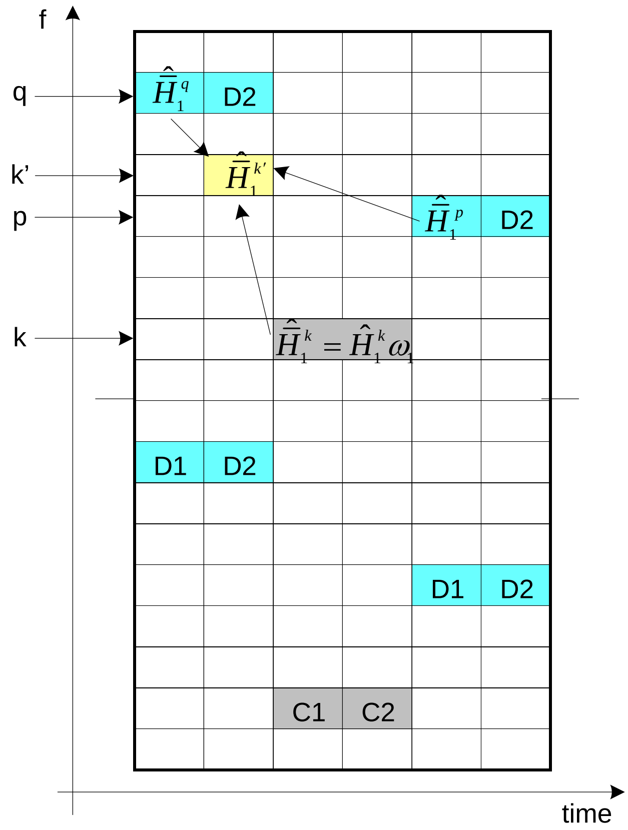

Figure 5. Calculating the effective channel information on other subcarrier k'.

According to the same principle, we can design the pilot pattern for other configuration, which are shown in the proposed text.

Proposed Text for SDD

Insert the following text into Physical Layer sub-clause (i.e. Chapter x in [1]):

------------------------------- Text Start ---

11.x Pilot structures for DL

11.x.x Pilot structures for DL with MU-MIMO

- In case of 2x2 with 2 users, $N_t = 2, N_r = 2, N = 2, M = 1$. There are total 4 dedicated pilots, 2 for each user, as shown in Figure xxx.

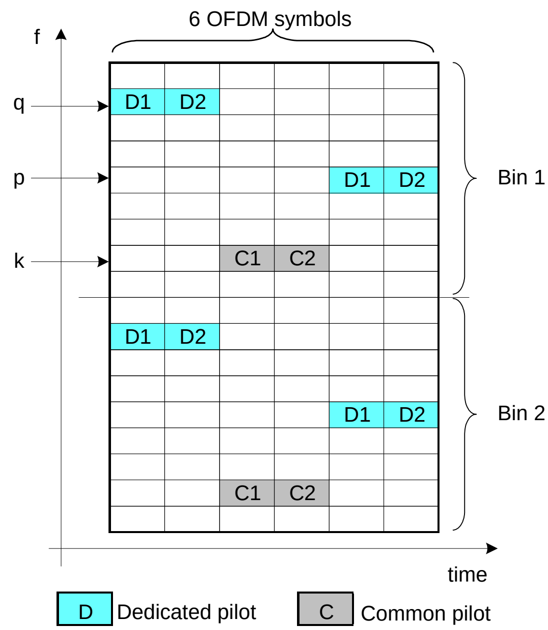

Figure xxx. Example of pilot allocations in case of $N_t = 2, N_r = 2, N = 2, M = 1$.

- In case of 4x2 with 2 users, $N_t = 4, N_r = 2, N = 2, M = 1$. There are total 8 dedicated pilots, 4 for each user, as shown in Figure yyy.

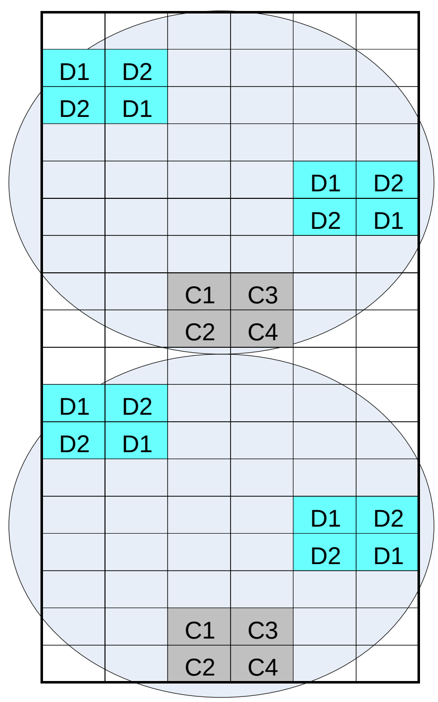

Figure yyy. Example of pilot allocations in case of $N_t = 4, N_r = 2, N = 2, M = 1$.

- In case of 4x4 with 2 users, $N_t = 4, N_r = 4, N = 2, M = 2$. There are total 4 dedicated pilots, 2 for each user, as shown in Figure zzz.

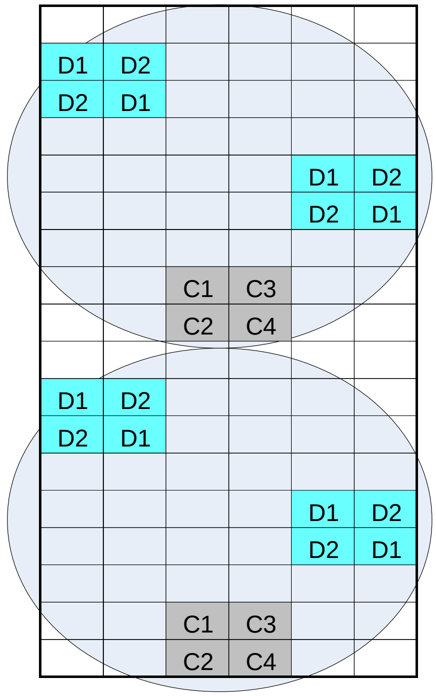

Figure zzz. Example of pilot allocations in case of $N_t = 4, N_r = 4, N = 2, M = 2$.

- In case of 4x4 with 4 users, $N_t = 4, N_r = 4, N = 4, M = 1$. There are total 16 dedicated pilots, 4 for each user, as shown in Figure ttt.

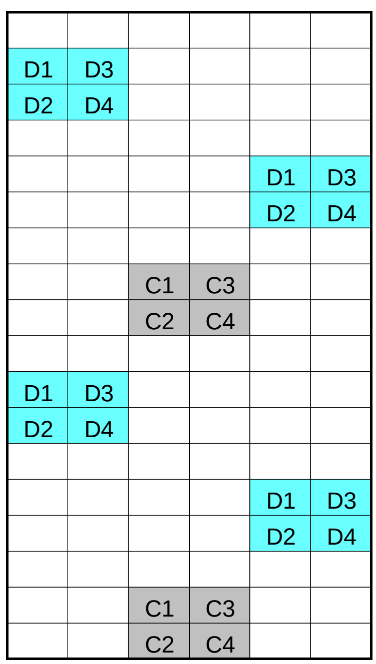

Figure ttt. Example of pilot allocations in case of $N_t = 4, N_r = 4, N = 4, M = 1$.

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References

[1]. Philips, “Comparison between MU-MIMO codebook-based channel reporting techniques for LTE downlink.” R1-062483, Oct 2006. 3GPP TGS RAN WG1 Meeting #46bis, Seoul.
[2]. IEEE C802.16m-07/167, Multi User MIMO with Downlink Adaptive Beamforming for TDD systems
[3]. IEEE 802.16e-2005, ‘Air Interface for Fixed and Mobile Broadband Wireless Access Systems’
[4]. WiMAX Forum™ Mobile System Profile Release 1.0 Approved Specification (Revision 1.4.0: 2007-05-02)