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Source(s)	Qinghua Li, Xintian Eddie Lin, Shilpa Talwar, **Intel Corporation** qinghua.li@intel.com Voice: +1-408-765-9698
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Abstract	Enable closed-loop MIMO channel estimation using partially beamformed midamble
Purpose	Adoption of proposed changes into P802.16e ~~Crossed-out indicates deleted text,~~ underlined blue indicates new text change to the Standard
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Enable Closed-Loop MIMO Channel Estimation Using Partially Beamformed Midamble

Qinghua Li, Xintian Eddie Lin
Intel Corporation

Abstract

For closed-loop MIMO (i.e. MIMO precoding), there is no training mechanism in the current standard for the composite channel, which consists of the beamforming matrix, the transmit chain response at the transmitter, the, wireless medium response, and the receive chain response at the receiver. This is because all the pilots and midamble are sent without beamforming. The receiver has to rely on the assumption that the receiver knows the beamforming matrix employed in the transmitter. However, the assumption doesn't hold for two cases. First, it fails when channel sounding and channel reciprocity is employed TDD modes. Secondly, it fails when there is a feedback error in FDD modes. For both cases, the MIMO precoding doesn't work. This can be solved by sending part the midable in beamformed mode, which is employed for the data portion.

Comments from TGe group members indicate that beamforming midamble have two disadvantages. Firstly, the Cell_ID encoded in the midamble may not be correctly received by subscriber stations. Secondly, peak to average ratio of the beamformed midamble is higher than that of the non-beamformed. Two alternative solutions are proposed. Both are to beamform the pilots in the closed-loop MIMO zone. One advantage of beamformed pilot is the improvement of channel estimation for beamformed spatial channels, which actually carry the data. The other advantage is the reduction of pilot allocation.

1 System Mode

For closed-loop MIMO (i.e. MIMO precoding), there is no training mechanism in the current D5 standard for the composite channel, which consists of the beamforming matrix, the transmit chain response at the transmitter, the, wireless medium response, and the receive chain response at the receiver. This is because all the pilots and midamble are sent without beamforming. The receiver has to rely on the assumption that the receiver knows the beamforming matrix employed in the transmitter. However, the assumption doesn't hold for two cases. First, it fails when channel sounding and channel reciprocity is employed TDD modes. Secondly, it fails when there is a feedback error in FDD modes. For both cases, the MIMO precoding doesn't work. This can be solved by sending part the midable in beamformed mode, which is employed for the data portion.

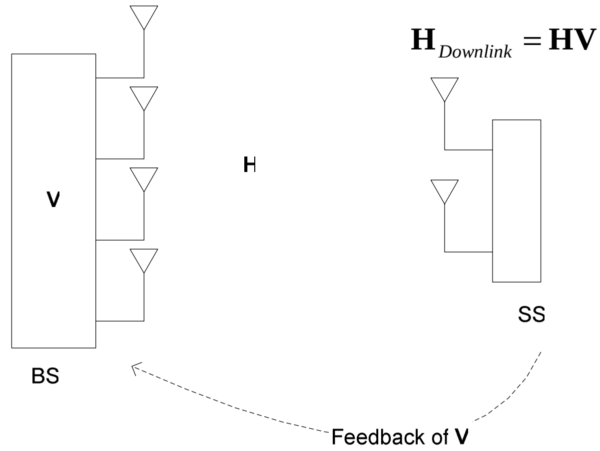


Figure 1 Illustration of a closed-loop MIMO system.

2 Beamformed Midamble

Subcarriers are sequentially and periodically assigned to transmit antennas in midamble as shown in 8.4.8.5 in [1], where the period is the number of antennas N_t. We may select the mod(k,N_t)-th subcarrier in the *k-th* period to send training signal through the mod(k,N_t)-th beamformed spatial channel, where k starts from 0. The signal sent in the beamformed channel is the same as the original specified in 8.4.8.5.1 and 8.4.8.5.2.

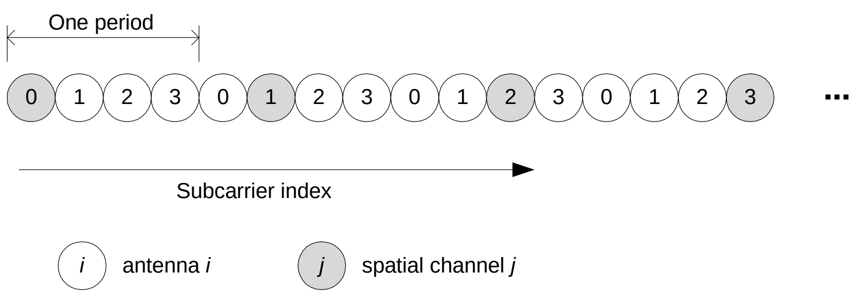


Figure 2 Midamble structure and beamforming pattern

3 Two Alternative Solutions — Beamforming Pilots

Comments from TGe group members indicate that beamforming midamble have two disadvantages. Firstly, the Cell_ID encoded in the midamble may not be correctly received by subscriber stations. Secondly, peak to average ratio of the beamformed midamble is higher than that of the non-beamformed. Two alternative solutions are proposed. Both are to beamform the pilots in the closed-loop MIMO zone. One advantage of beamformed pilot is the improvement of channel estimation for beamformed spatial channels, which actually carry the data. The other advantage is the reduction of pilot allocation.

Alternative one

When midamble is present and MIMO precoding is employed, the subsequent pilots in the MIMO precoded zone are transmitted in beamformed (precoded) mode, which are weighted by the precoding matrix that is used for the data. An example is illustrated in Figure 3. The base station (BS) has 4 transmit antennas and want to send data to the subscriber station (SS) using MIMO precoding mode (i.e. beamforming mode). The midamble is sent by 4 BS antennas using non-beamformed mode, where no precoding matrix is applied. The SSs in the cell can estimate the channel status using this non-beamformed midamble. The subsequent pilots are dedicated to the intended SS for the data portion. Pilots are sent at the same frequency-time allocation as those in the current D5 standard but precoding matrix (or beamforming matrix) is applied to them. In the figure, the pilots are sent in 4 spatial channels since the 4 BS antennas can form 4 spatial channels. The pilots for spatial channel *i* are sent in same frequency-time location at those originally used by BS antenna *i*, where *i* is 1, 2, 3, and 4. The actual data can be sent in 1, 2, 3, or 4 spatial channels.

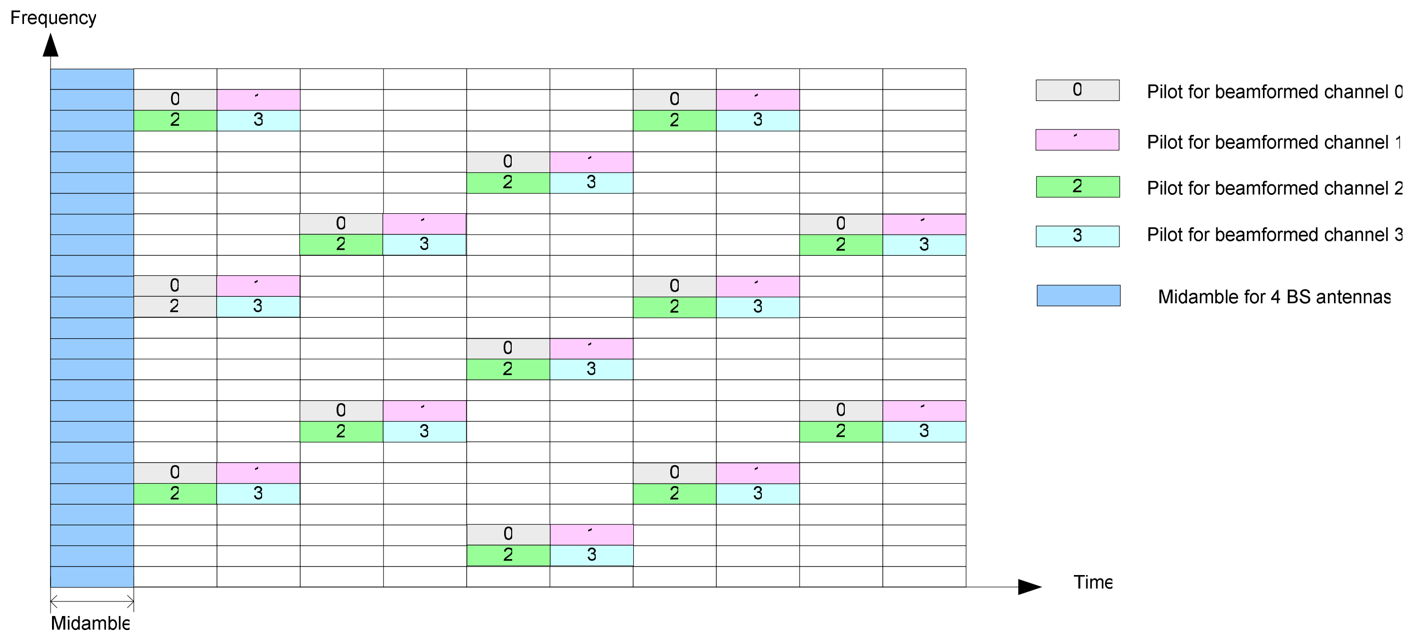


Figure 3 Illustration for a non-beamformed midamble from 4 BS antennas and beamformed pilots for all 4 spatial channels.

Alternative two

Alternative solution one has a disadvantage and can be improved further. When the number of BS antennas is greater than that of that of the SS or when the number of BS antennas is greater than that of active spatial channels, some of the beamformed pilots are redundant in alternative one. For example, in a 4x2 MIMO system where BS and SS have 4 and 2 antennas respectively, the SS can at most receive two spatial streams. Therefore, the BS only needs to send pilots over the spatial channels carrying data and can release the pilot resources originally allocated for the inactive spatial channels. Namely, when BS sends *m* data stream, it employs pilot allocation for *m* BS antenna and send the pilots over *m* beamformed spatial channels.

An example is illustrated in Figure 4Figure 3. The base station (BS) has 4 transmit antennas and want to send data to the subscriber station (SS) with 2 receive antennas using MIMO precoding mode (i.e. beamforming mode). The midamble is sent by 4 BS antennas using non-beamformed mode, where no precoding matrix is applied. The SSs in the cell can estimate the channel status using this non-beamformed midamble. The subsequent pilots are dedicated to the intended SS for the data portion. In the figure, the pilots are sent in 2 spatial channels since the BS employs only 2 spatial channels to send data. The pilots for spatial channel *i* are sent in same frequency-time location at those originally allocated for BS antenna *i*, where *i* is 1 and 2. The actual data can be sent in 1 and 2 spatial channels.

The clarifications of the number of BS antennas and the number of spatial streams are currently made in a few other contributions in Session 34.

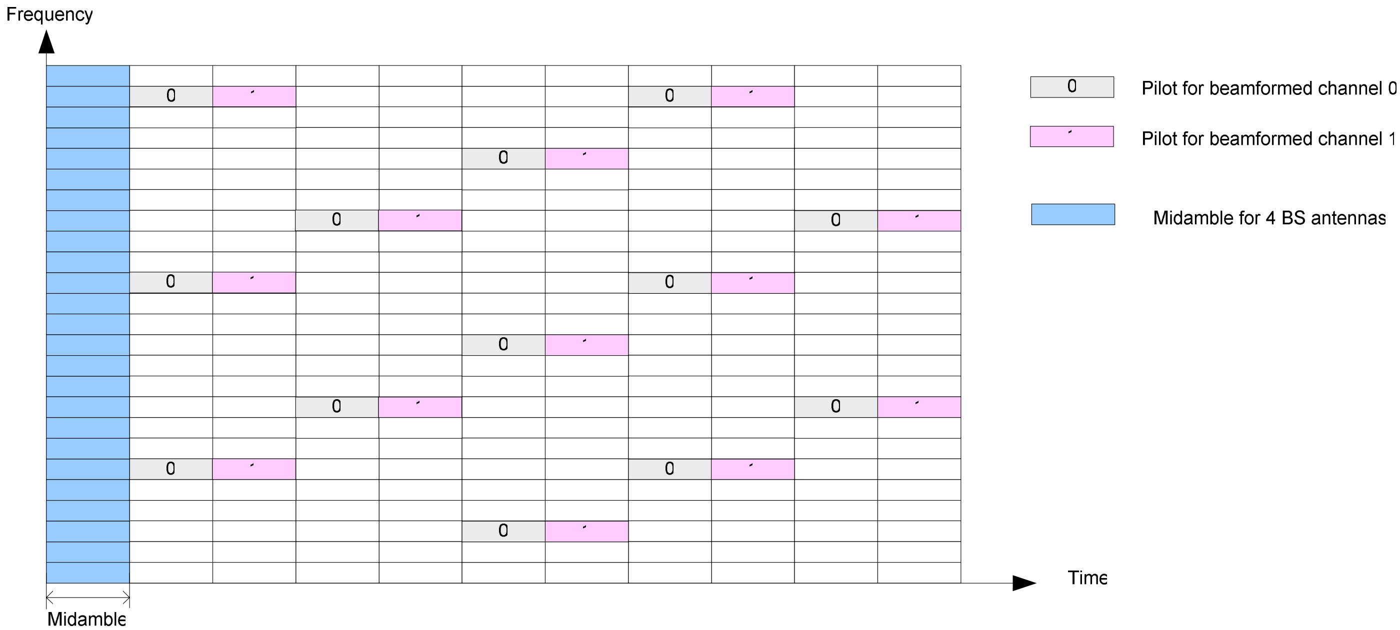


Figure 4 Illustration of a non-beamformed midamble from 4 BS antennas and beamformed pilots for 2 spatial channels.

4 Specific Text Changes

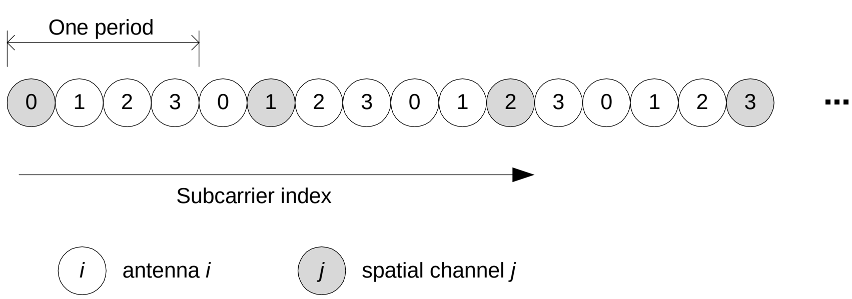
3.1 Beamforming Midamble

Modified line 6 and 7 in section 8.4.8.5 on page 245 of [1] as follows

~~The MIMO midamble consists of one OFDM symbols which is mapped onto multiple antennas. Non-overlapping subcarriers are allocated to the transmit antennas.~~

The MIMO midamble consists of one OFDM symbols which is mapped onto multiple antennas. Non-overlapping subcarriers are allocated to the transmit antennas and spatial channels. The (mN_t+j)-th subcarrier is allocated to the j-th beamformed spatial channel, where j is spatial channel index ($0, 1, \ldots, N_t$) and m is an integer starting from 0. The rest of the subcarriers are allocated to transmit antennas as follows. The (mN_t+n)-th subcarrier is allocated to the n-th antenna.

Substitude Figure 252c with



3.2 Alternative One

Added after line 31 in section 8.4.8.3.1 on page 237 of [1] as follows

When MIMO mid-amble in 8.4.8.5 is present and MIMO precoding is employed, the subsequent pilots in the same MIMO precoding zone are transmitted in precoding (or beamformed) mode, which are weighted by the precoding matrix W in 8.4.8.3.6 that is used for the data.

3.3 Alternative Two

Added after line 31 in section 8.4.8.3.1 on page 237 of [1] as follows

When MIMO mid-amble in 8.4.8.5 is present and MIMO precoding is employed, the subsequent pilots in the same MIMO precoding zone are transmitted in precoding (or beamformed) mode, which are weighted by the precoding matrix W in 8.4.8.3.6 that is used for the data. If m_s data streams are sent, the pilot allocation for m_s BS transmit antennas is employed.

References:

[1] IEEE P802.16e/D5 Air Interface for Fixed and Mobile Broadband Wireless Access Systems – Amendment for Physical and Medium Access Control Layers for Combined Fixed and Mobile Operation in Licensed Bands, 2004.

[2] IEEE P802.16-REVd/D5-2004 Draft IEEE Standards for local and metropolitan area networks, Part 16: Air interface for fixed broadband wireless access systems, 2004.