IEEE P802.11
Wireless LANs

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| D2.0 Comment Resolutions on Hybrid Beamforming – Part 1  |
| Date: 2018-11-11 |
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Introduction

This submission proposes resolutions for the following 6 comments on Hybrid Beamforming: 3236, 3276, 3279, 3280, 32891, and 3707

Revisions:

- Rev 0: Initial version of document.

Interpretation of a Motion to Adopt

A motion to approve this submission means that the editing instructions and any changed or added material are actioned in the TGay Draft. This introduction is not part of the adopted material.

***Editing instructions formatted like this are intended to be copied into the TGay Draft (i.e. they are instructions to the 802.11 editor on how to merge the text with the baseline documents).***

***TGay Editor: Editing instructions preceded by “TGay Editor” are instructions to the TGay editor to modify existing material in the TGay draft. As a result of adopting the changes, the TGay editor will execute the instructions rather than copy them to the TGay Draft.***

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **CID** | **Commenter** | **Clause**  | **Page** | **Line** | **Comment** | **Proposed Change** | **Resolution** |
| 3236 | Assaf Kasher | 10.43.9.2.4.3.2.1 | 268 | 35 | The hybrid BF, rather than complementing the analong BF procedure, allows repeating parts of it by transmitting several combinations. Since when MIMO is used, specific combinations are used, the hybrid BF procedure must use these combinations rather than allow any sectors to be used. If it repeats the procedure, then the feedback should have the same structure, and specifcally say that it replaces the analog sector combinations. | submission will be provided | RevisedAgree in principleIf the announcement phase chooses a particular TX/RX combination (a single one in both the RTS/CTS and Grant/Grant ACK options), then this is the only combination that should used, and it should be used in MIMO (i.e. all antennas transmitting together). The current language is not clear on the order of sector begin used in transmission and on reception.The solution is as follows:1) Explicitly state in announcement that we are going to perform the HBF protocol.2) If HBF protocol, then tighten language to indicate that we “shall” use the configuration specified in the announcement.TGay editor to make the changes shown in 11-18/1970r0 under all headings that include CID 3236 |
| 3276 | Dana Ciochina | 10.43.9.2.4.3.2.2 | 270 |  | Introduce a plot with the procedure for MU MIMO case also to make the flow clear. | complete the sounding and feedback flow for the MU digital bf case | RevisedAgree in principle. Added text to detail MU-MIMO case feedback in section 10.43.9.2.4.4.2 **,** added a diagram and updated the MIMO BF Poll format to include polling for HBF.TGay editor to make the changes shown in 11-18/1970r0 under all headings that include CID 3276 |
| 3279 | Dana Ciochina | 10.43.9.2.4.3.2.1 | 269 | 13 | It is not defined which is the required indication in the announcement to enable responder to compute digital bf. Also if responder starts training SIFS after BRP with CDOWN 0, then it is not defined when the feedback is sent. | include the missing parts as suggested in comment | Revised.Agree in principle. (1) 1st comment discusses need to indicate explicit start of HBF protocol in announcement. Added text in Control Trailer to indicate HBF announcement (solution to #3236). Also added some text in the sounding section to indicate fields in BRP frames that signal if digital feedback is requested.(2) 2nd comment identifies issue where initiator and responder are performing HBF protocol simultaneously. Defined feedback behavior explicitly in section 10.43.9.2.4.4.1 on SU MIMO feedback and added diagram.TGay editor to make the changes shown in 11-18/1970r0 under all headings that include CID 3279 |
| 3280 | Dana Ciochina | 29.3.3.3.5.1 | 385 |  | The behaviour in case the EDMG Tracking Field and EDMG Tracking Type fields are set in MU is not defined | Define or remove |  Revised.Beam tracking for MU-MIMO removed in prior drafts. See resolution for CID 2027 I 11-18-0715r0. Remove EDMG Beam tracking request and request type from header B.TGay editor to make the changes shown in 11-18/1970r0 under all headings that include CID 3280.  |
| 3281 | Dana Ciochina | 10.43.7 | 246 |  | The text is ambiguous as there is no clear mention of a "MIMO setup procedure" before nor of the need to compute Q matrices within this. The points are probably: requestor did not determine Q based on channel measurements reported as feedback to the MIMO training procedure or requestor did not determine during a hybrid beamforming training procedure as described in 10.43.9.2.4.3.2 | Clarify as in comment | RevisedAgree in principleUpdated text based on commentTGay editor to make the changes shown in 11-18/1970r0 under all headings that include CID 3281.  |
| 3707 | Thomas Handte | 29.3.3.3.5.1 | 385 | 1 | The behaviour of EDMG Beam Tracking Request in MU is not defined. The definition in header-B may create problems when different header-Bs hold a different setting for EDMG Beam Tracking Request. Some STAs would expect TRNs to be added whereas others would interpret it as a request | Please define. I think we need at least a statement that the setting of EDMG Beam Tracking Request is same in all header-Bs or as an alternative put it in header-A | Revised.Beam tracking for MU-MIMO removed in prior drafts. See resolution for CID 2027 I 11-18-0715r0. Remove EDMG Beam tracking request and request type from header B.TGay editor to make the changes shown in 11-18/1970r0 under all headings that include CID 3707. |

*Changes to D2.1*

***TGay Editor: Please make the following change from Pg 221 line 14 (#3236, #3279)***

**10.40.11.4.2 MIMO channel access rules**

In the transmitted Grant frame, the value of the Allocation Duration field plus the Duration field of the Grant frame indicates the estimated time offset from the PHY-TXEND.indication primitive of the Grant frame transmission when the initiator intends to initiate access to the channel to transmit to or start the hybrid beamforming protocol with the responder. For the transmitted Grant frame, the TXVECTOR parameter SCRAMBLER\_INIT\_SETTING shall be set to CONTROL\_TRAILER, the parameter CT\_TYPE shall be set to GRANT\_RTS\_CTS2Self, and the NEXT\_TX\_SISO parameter shall be set to NextTxMultiAntenna. For hybrid beamforming training, the HBF\_TRAINING parameter shall be set NextHBF to indicate that the following transmission from this STA is HBF training (#3236) (#3279). The MU\_MIMO\_NEXT parameter shall be set to NextNotMUMIMO to indicate that the following transmission (see 10.43.10.2.2) or hybrid beamforming training (see 10.43.10.2.4) is performed in SU-MIMO or shall be set to NextMUMIMO to indicate that the following transmission (see 10.43.10.2.3) or hybrid beamforming training is performed in MU-MIMO. The control trailer shall also indicate the corresponding DMG antenna configuration for the upcoming MIMO transmission or hybrid beamforming training through the TXVECTOR parameters TX\_SECTOR\_CONFIG\_INDEX, MU\_MIMO\_TX\_CONFIG\_TYPE and MU\_MIMO\_TX\_CONFIG\_INDEX.

If an EDMG STA receives a Grant frame with a control trailer indicating an SU-MIMO or MU-MIMO transmission, or hybrid beamforming training and is able to receive the SU-MIMO or MU-MIMO transmission or perform hybrid beamforming training at the target time indicated by the Grant frame, the EDMG STA shall:

* Transmit a Grant Ack frame in response to the received Grant frame. For this transmitted Grant Ack frame, the TXVECTOR parameter SCRAMBLER\_INIT\_SETTING shall be set to CONTROL\_TRAILER and the parameter CT\_TYPE shall be set to GRANT\_RTS\_CTS2Self.
* In the case when the STA received a Grant frame with a control trailer indicating SU-MIMO transmission or the start of the HBF protocol (#3236) (#3279), if it uses SU-MIMO for the transmission in the opposite direction, i.e., from the responder to the initiator, or desires to announce the hybrid beamforming protocol in the opposite direction, the TXVECTOR parameter NEXT\_TX\_SISO of the Grant Ack shall be set to NextTxMultiAntenna. For hybrid beamforming training, the HBF\_TRAINING parameter shall be set NextHBF to indicate that the following transmission from this STA is HBF training (#3236) (#3279). The control trailer shall also indicate the corresponding DMG antenna configuration for the upcoming SU-MIMO transmission or hybrid beamforming training in the opposite direction using the TXVECTOR parameter TX\_SECTOR\_CONFIG\_INDEX. If the responder STA intends to use SISO for the transmission in the opposite direction, the TXVECTOR parameter NEXT\_TX\_SISO of the Grant Ack shall be set to NextTxSingleAntenna.
* Configure its DMG antennas according to the settings included in the control trailer of the received Grant frame within a time period determined by the value of the Allocation Duration field plus the value of the Duration field of the received Grant frame starting from the PHY-TXEND.indication primitive of the Grant frame transmission.

**10.40.11.4.3 SU-MIMO channel access procedure**

An EDMG STA is SU-MIMO capable if the SU-MIMO Supported field in the STA’s EDMG Capabilities element is set to 1. The SU-MIMO channel access procedure describes how an SU-MIMO capable initiator and an SU-MIMO capable responder shall access the channel to start exchanging one or more EDMG SU 4 PPDUs using SU-MIMO, and also describes how an SU-MIMO capable initiator and responder that are also hybrid beamforming capable start an hybrid beamforming protocol.

Prior to initiating the SU-MIMO channel access with a responder, an initiator shall perform SU-MIMO beamforming with the responder (see 10.43.10.2.2).

An EDMG STA, the SU-MIMO initiator, initiates SU-MIMO channel access by transmitting an RTS frame or a DMG CTS-to-self frame to the intended SU-MIMO responder. The SU-MIMO initiator shall transmit the RTS or DMG CTS-to-self frame with a control trailer to the SU-MIMO responder. The RTS or DMG CTS-to-self frame shall be transmitted using the same set of DMG antennas and antenna configuration planned to be used during the SU-MIMO transmission or hybrid beamforming training, and with a CSD between the transmissions in different antennas as defined in 29.4.7.2. For the transmitted RTS or DMG 14 CTS-to-self frame, the TXVECTOR parameter SCRAMBLER\_INIT\_SETTING shall be set to CONTROL\_TRAILER, the parameter CT\_TYPE shall be set to GRANT\_RTS\_CTS2Self, the NEXT\_TX\_SISO parameter shall be set to NextTxMultiAntenna and the MU\_MIMO\_NEXT parameter shall be set to NextNotMUMIMO to indicate that the following transmission or hybrid beamforming training is performed in SU-MIMO. For hybrid beamforming training, the HBF\_TRAINING parameter shall be set NextHBF to indicate that the following transmission from this STA is HBF training (#3236) (#3279). The control trailer shall also indicate the corresponding DMG antenna configuration for the upcoming SU-MIMO transmission or hybrid beamforming training through the TXVECTOR parameter TX\_SECTOR\_CONFIG\_INDEX.

If an SU-MIMO initiator transmits a DMG CTS-to-self frame to a responder and if the Grant Required field within the responder’s EDMG Capabilities element is 1, following an SU-MIMO transmission to the responder the initiator should configure its receive DMG antennas according to the settings included in the control trailer of the last Grant Ack frame received from the responder.

If a responder receives an RTS frame with a control trailer indicating an SU-MIMO transmission or a hybrid beamforming announcement addressed to itself and is able to perform the SU-MIMO reception or hybrid beamforming training, the responder shall:

* Configure its DMG antennas according to the settings indicated in the RXVECTOR parameter TX\_SECTOR\_CONFIG\_INDEX of the received RTS frame.
* Transmit a DMG CTS frame with a control trailer in response of the received RTS frame. For this transmitted DMG CTS frame, the TXVECTOR parameter SCRAMBLER\_INIT\_SETTING shall be set to CONTROL\_TRAILER and the parameter CT\_TYPE shall be set to CTS\_DTS.
* If the responder uses SU-MIMO for the transmission in the opposite direction (i.e., from the EDMG STA receiving the RTS frame to the EDMG STA transmitting the RTS frame) or desires to announce the hybrid beamforming protocol in the opposite direction, the TXVECTOR parameter NEXT\_TX\_SISO of the DMG CTS frame shall be set to NextTxMultiAntenna and the MU\_MIMO\_NEXT parameter shall be set to NextNotMUMIMO. For hybrid beamforming training, the HBF\_TRAINING parameter shall be set NextHBF to indicate that the following transmission from this STA is HBF training (#3236) (#3279). The control trailer shall also indicate the corresponding DMG antenna configuration for the upcoming SU-MIMO transmission or hybrid beamforming training in the opposite direction using the TXVECTOR parameter TX\_SECTOR\_CONFIG\_INDEX. The DMG CTS frame shall be transmitted using the same set of DMG antennas and antenna configuration planned to be used during the SU-MIMO transmission or hybrid beamforming training, and with a CSD between the transmissions in different antennas as defined in 29.4.7.2.
* If the responder uses SISO for the transmission in the opposite direction, the TXVECTOR parameter NEXT\_TX\_SISO of the DMG CTS frame shall be set to NextTxSingleAntenna and the DMG CTS frame shall be sent using the SISO antenna setting.

Alternatively, if the responder is not able to perform the SU-MIMO reception or hybrid beamforming training, it may transmit a DMG DTS frame with a control trailer to the initiator to provide further information. The DMG DTS frame shall be sent using the SISO antenna setting.

A responder that receives a DMG CTS-to-self frame with a control trailer indicating a SU-MIMO transmission or hybrid beamforming training addressed to itself shall:

* Configure its DMG antennas according to the settings included in the RXVECTOR parameter TX\_SECTOR\_CONFIG\_INDEX of the received CTS-to-self frame; and
* Begin the SU-MIMO transmission or hybrid beamforming training SIFS interval following the end of the DMG CTS-to-self frame transmission by the initiator.

**10.40.11.4.4 MU-MIMO channel access procedure**

An EDMG STA is MU-MIMO capable if the MU-MIMO Supported subfield of the Beamforming Capability subelement in the STA’s EDMG Capabilities element is 1. The MU-MIMO channel access procedure describes how an MU-MIMO capable initiator and multiple MU-MIMO capable responders shall access the channel to start exchanging one or more EDMG MU PPDUs, and also describes how an MU-MIMO capable initiator and multiple MU-MIMO capable responders that are also hybrid beamforming capable (see 10.43.10.2.4) start the hybrid beamforming protocol.

Prior to initiating the MU-MIMO channel access with a set of responder STAs within an MU group, the initiator shall:

* Include the MU group within the EDMG Group ID Set element and communicate the resulting element to the STAs in the BSS (see 10.43.10.2.3.1). 18
* Perform MU-MIMO beamforming with the responders of the MU group (see 10.43.10.2.3).

An EDMG STA initiates MU-MIMO channel access by transmitting an RTS frame or a DMG CTS-to-self frame to the intended MU-MIMO group of responders. The EDMG STA shall transmit the RTS frame or DMG CTS-to-self frame with a control trailer to the group of responders. The RTS or DMG CTS-to-self frame shall be transmitted using the same set of DMG antennas and antenna configuration planned to be used during the MU-MIMO transmission or hybrid beamforming training, and a CSD between the transmissions in different antennas as defined in 29.4.7.2. 26

For the transmitted RTS or DMG CTS-to-self frame, the TXVECTOR parameter SCRAMBLER\_INIT\_SETTING shall be set to CONTROL\_TRAILER, the parameter CT\_TYPE shall be set to GRANT\_RTS\_CTS2self, the parameter NEXT\_TX\_SISO shall be set to NextTxMultiAntenna, and the parameter MU\_MIMO\_NEXT shall be set to NextMUMIMO to indicate that the following PPDU transmitted by the initiator is an EDMG MU PPDU. For hybrid beamforming training, the HBF\_TRAINING parameter shall be set NextHBF to indicate that the following transmission from this STA is HBF training (#3236) (#3279).

The TXVECTOR parameter EDMG\_GROUP\_ID shall be set to the value that identifies the corresponding group of responders that are the intended destinations of the EDMG MU PPDU to be transmitted or the intended ~~receipients~~ recipients (#3236) (#3279) of the hybrid beamforming training. The TXVECTOR parameters MU\_MIMO\_TX\_CONFIG\_TYPE and MU\_MIMO\_TX\_CONFIG\_INDEX indicate the corresponding DMG antenna configuration for the upcoming MU-MIMO transmission or hybrid beamforming training. The RA field of the RTS shall be set to the broadcast MAC address. After transmitting the RTS frame, the initiator should configure its receive antenna to a quasi-omni receive pattern to receive the DMG CTS.

An initiator that transmits an RTS frame or a DMG CTS-to-self frame addressed to an MU group shall set the TXVECTOR parameter IS\_CHANNEL\_NUMBER to ChannelWidth and shall set the BW\_IN\_CT to indicate the bandwidth to be used for all EDMG MU PPDU transmissions within the TXOP or SP allocation.

If a responder receives an RTS frame addressed to an MU group that the responder belongs to and is able to perform the MU-MIMO reception, the responder shall:

* Transmit a DMG CTS frame back to the initiator employing the most recent SISO antenna configuration used between the responder and the initiator. The TA field of the DMG CTS shall be set to the broadcast MAC address and the Scrambler Initialization field shall be set to the same value as the Scrambler Initialization field of the PPDU that contained the received RTS frame.
* Following the (#3236) transmission of the DMG CTS, the responder shall then configure its antennas according to the settings indicated in the RXVECTOR parameters MU\_MIMO\_TX\_CONFIG\_TYPE and MU\_MIMO\_TX\_CONFIG\_INDEX of the received RTS frame.

For the successful reception of the DMG CTS frame, the difference in time between all the DMG CTS transmissions as measured at the receiving STA should be no more than *TGI normal* (see 29.5.2.2). A STA that transmits the DMG CTS should pre-compensate for carrier frequency offset error to mitigate the frequency error in the transmitted signal.

The MU-MIMO transmission or hybrid beamforming training shall begin a SIFS + 10% × (aSlotTime – 30 aAirPropagationTime) interval following the reception or expected reception of the DMG CTS frame by the initiator. This is shown in Figure 123.

A responder that receives a DMG CTS-to-self frame addressed to an MU group that the responder belongs to shall configure its antennas according to the settings indicated in the RXVECTOR parameters MU\_MIMO\_TX\_CONFIG\_TYPE and MU\_MIMO\_TX\_CONFIG\_INDEX of the received CTS-to-self 35 frame. The MU-MIMO transmission or hybrid beamforming shall begin a SIFS + 10% × (aSlotTime – aAirPropagationTime) interval following the end of the DMG CTS-to-self frame transmission by the initiator. This is shown in Figure 124.

Section 10.3.2.13 describes the MU PPDU acknowledgement procedure.

The initiator may send a CF-End frame to one or more responders in an MU-MIMO TXOP to truncate the TXOP.

***TGay Editor: Please make the following change from Pg 356 line 1. In Table 43 after TXVECTOR: MU\_MIMO\_NEXT (#3236, #3279)***

**Table 43 —TXVECTOR and RXVECTOR parameters**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Parameter**  | **Condition**  | **Value**  | **TXVECTOR**  | **RXVECTOR**  |
| HBF\_TRAINING | SCRAMBLER\_INIT\_SETTING is CONTROL\_TRAILER  | Indicates whether the following transmission from this STA is for HBF training Enumerated Type: NextHBFNextNotHBF  | Y  | Y  |

***TGay Editor: Please make the following change from Pg 404 line 1 (#3236, #3279)***

**Table 76 —Control trailer definition when CT\_TYPE is CTS\_DTS** 1

|  |  |  |  |
| --- | --- | --- | --- |
| **Field**  | **Number of bits**  | **Start bit**  | **Description**  |
| Channel Aggregation  | 1  | 0  | See Table 53  |
| BW  | 8  | 1  | See Table 53  |
| Primary Channel Number  | 3  | 9  | See Table 53  |
| SISO/MIMO  | 1  | 12  | Corresponds to the TXVECTOR parameter NEXT\_TX\_SISO. Set to 0 to indicate that the following transmission from this STA is performed with a single antenna. Set to 1 to indicate that the following transmission from this STA is performed with multiple antennas.  |
| SU/MU MIMO  | 1  | 13  | Corresponds to the TXVECTOR parameter MU\_MIMO\_NEXT. Set to 0 to indicate SU-MIMO, and set to 1 to indicate MU-MIMO. Reserved when the SISO/MIMO field is set to 0.  |
| EDMG Group ID  | 8  | 14  | Corresponds to the TXVECTOR parameter EDMG\_GROUP\_ID. This field indicates the group of STAs that will be involved in the following MU-MIMO transmission. Reserved when the SU/MU MIMO field is set to 0.  |
| TX Sector Combination Index  | 6  | 22  | Indicates the TX sector combination (as defined in 9.4.2.253) and the corresponding RX AWVs to be used in the SU-MIMO transmission from the EDMG STA transmitting the CTS to the EDMG STA that transmitted the RTS. Reserved if the SISO/MIMO field is set to 0, if the SU/MU MIMO field is set to 1 or if the control trailer is sent with a DMG DTS frame.  |
| HBF(#3236) (#3279). | 1(#3236) (#3279). | 28(#3236) (#3279). | Corresponds to the TXVECTOR parameter HBF TRAINING. Set to 0 to indicate that the following transmission from this STA is HBF training. Set to 1 to indicate that the following transmission from this STA is not HBF training. Reserved when the SISO/MIMO field is set to 0 (#3236) (#3279).  |
| Reserved  | ~~100~~ 99 (#3236) (#3279) | ~~28~~ 27 (#3236) (#3279) | Set to 0 by the transmitter and ignored by the receiver.  |
| CTCS  | 16  | 128  | Control Trailer Check Sequence (CTCS) is a CRC-16 computed over the content of the control trailer. The CRC-16 is computed as defined in section 20.3.7.  |

***TGay Editor: Please make the following change from Pg 405 line 1 (#3279)***

**Table 77 —Control trailer definition when CT\_TYPE is GRANT\_RTS\_CTS2self**

|  |  |  |  |
| --- | --- | --- | --- |
| **Field**  | **Number of bits**  | **Start bit**  | **Description**  |
| Channel Aggregation  | 1  | 0  | See Table 53  |
| BW  | 8  | 1  | See Table 53  |
| Primary Channel Number  | 3  | 9  | See Table 53  |
| SISO/MIMO  | 1  | 12  | See Table 76  |
| SU/MU MIMO  | 1  | 13  | See Table 76  |
| TX Sector Combination Index  | 6  | 14  | Indicates the TX sector combination (as defined in 9.4.2.253) and the corresponding RX AWVs to be used in the following SU-MIMO transmission. Reserved if the SISO/MIMO field is 0 or the SU/MU MIMO field is 1.  |
| EDMG Group ID  | 8  | 20  | See Table 76  |
| MU-MIMO Transmission Configuration Type  | 1  | 28  | Corresponds to the TXVECTOR parameter MU\_MIMO\_TX\_CONFIG\_TYPE. Set to 1 to indicate that the MU-MIMO transmission configuration was obtained from the reciprocal MU-MIMO BF training; set to 0 to indicate that the MU-MIMO transmission configuration was obtained from the non-reciprocal MU-MIMO BF training. Reserved if the SISO/MIMO field is 0 or the SU/MU MIMO field is 0.  |
| MU-MIMO Transmission Configuration Index  | 3  | 29  | Corresponds to the TXVECTOR parameter MU\_MIMO\_TX\_CONFIG\_INDEX. Indicates the MU-MIMO transmission configuration (as defined in 9.4.2.261) to be used in the following MU-MIMO transmission. Reserved if the SISO/MIMO field is 0 or the SU/MU MIMO field is 0.  |
| Total Number of Sectors MSB  | 4  | 32  | This field is prepended to the Total Number of Sectors subfield in the BF Control field to form a single 11 bits field indicating the total number of sectors the initiator or the responder uses during an SLS. This field is reserved and set to 0 when the PPDU does not carry a Grant or Grant Ack frame with the Beamforming Training field equal to 1.  |
| Number of RX DMG Antennas MSB  | 1  | 36  | This field is prepended to the Number of RX DMG Antennas subfield in the BF Control field to form a single 3 bits field indicating the total number of repetitions of the TXSS that the initiator or the responder uses during the SLS. This field is reserved and set to 0 when the PPDU does not carry a Grant or Grant Ack frame with the Beamforming Training field equal to 1.  |
| HBF(#3236) (#3279). | 1(#3236) (#3279). | 37(#3236) (#3279). | Corresponds to the TXVECTOR parameter HBF TRAINING. Set to 0 to indicate that the following transmission from this STA is HBF training. Set to 1 to indicate that the following transmission from this STA is not HBF training. Reserved when the SISO/MIMO field is set to 0 (#3236) (#3279).  |
| Reserved  | ~~91~~ 90 (#3236) (#3279) | ~~37~~ 36 (#3236) (#3279) | Set to 0 by the transmitter and ignored by the receiver.  |
| CTCS  | 16  | 128  | Control Trailer Check Sequence (CTCS) is a CRC-16 computed over the content of the control trailer. The CRC-16 is computed as defined in section 20.3.7.  |

**10.43.10.2.4.3.2.1 SU-MIMO sounding (for both initiator and responder)**

The initiator shall initiate the sounding phase a SIFS duration (#3279) following reception of the announcement acknowledgement frame (see 10.43.10.2.4.2.2) from the responder. In the initiator sounding subphase, the initiator shall transmit BRP frames with appended (#3279) EDMG BRP-TX packets to the responder. The BRP packet shall include the EDMG BRP Request Element with the Digital BF Request field set to 1 indicating a request for performing digital beamforming, and the Feedback Type field set to 0 for SU transmission. The Nc Index field is reserved (#3279). Each EDMG BRP-TX packet shall be separated by a SIFS. Each transmitted EDMG BRP-TX packet is used to train one or more transmit sectors based on the AWVs of the DMG antennas selected during the hybrid beamforming announcement phase by the announcement frame (see 10.43.10.2.4.2.2). In each EDMG BRP-TX packet, the initiator shall include, for each selected transmit sector, TRN subfields in the TRN field of the PPDU for the responder to perform receive AWV training. Each BRP-TX packet shall use the TX Sector combination selected in the announcement phase in the transmission of the TRN subfield (#3236). For each EDMG BRP-TX packet, the TXVECTOR parameter EDMG\_TRN\_LEN shall be set to a value greater than 0, and the parameters RX\_TRN\_PER\_TX\_TRN and EDMG\_TRN\_M shall be set to values based on the desired configuration. The initiator may transmit each EDMG BRP-TX packet to train multiple TX DMG antennas simultaneously and, therefore, reduce sounding time. The TX Antenna Mask field within each EDMG BRP-TX packet shall indicate the transmit DMG antenna(s) which is being used by the initiator to transmit the EDMG BRP-TX packet. The BRP CDOWN field within each EDMG BRP-TX packet shall indicate the number of remaining EDMG BRP RX/TX packets to be transmitted by the initiator in the initiator sounding subphase.

If the responder indicates that it will use SU-MIMO in the opposite direction (from the responder to the initiator) and requests for HBF training (#3279) during the announcement phase, the initiator and responder shall delay sending feedback till the responder completes the sounding phase (#3279). T~~t~~he responder shall initiate the responder sounding subphase a SIFS following the reception of an EDMG BRP-TX packet from the initiator with the BRP CDOWN field equal to 0. In the responder sounding subphase, the responder shall transmit BRP frames with appended (#3279) EDMG BRP-TX packets to the initiator. The BRP packet shall include the EDMG BRP Request Element with the Digital BF Request field set to 1 indicating a request for performing digital beamforming, and the Feedback Type field set to 0 for SU transmission. The Nc Index field is reserved (#3279). Each EDMG BRP-TX packet shall be separated by a SIFS. In each EDMG BRP-TX packet, the responder shall include, for each selected transmit sector, TRN subfields in the TRN field of the PPDU for the initiator to perform receive AWV training. Each BRP-TX packet shall use the TX Sector combination selected in the announcement phase in the transmission of the TRN subfield (#3236). For each EDMG BRP-TX packet, the TXVECTOR parameter EDMG\_TRN\_LEN shall be set to a value greater than 0, and the parameters RX\_TRN\_PER\_TX\_TRN and EDMG\_TRN\_M shall be set to values based on the desired configuration. The responder may transmit each EDMG BRP-TX packet to train multiple TX DMG antennas simultaneously and, therefore, reduce sounding time. The TX Antenna Mask field within each EDMG BRP-TX packet shall indicate the transmit DMG antenna(s) which is being used by the responder to transmit the EDMG BRP-TX packet. The BRP CDOWN field within each EDMG BRP-TX packet shall indicate the number of remaining EDMG BRP RX/TX packets to be transmitted by the responder in the responder sounding subphase.

**10.43.10.2.4.3.2.2 MU-MIMO sounding (for initiator)**

The initiator shall initiate the hybrid beamforming sounding subphase a SIFS following the reception of the announcement acknowledgement frame(s) from the responder(s), if required, or immediately following the 6 transmission of the DMG CTS-to-self from the initiator. In the hybrid beamforming sounding subphase, the initiator shall transmit one or more BRP frames with appended (#3279) EDMG BRP-TX packets to the remaining responders in the MU group. The BRP packet shall include the EDMG BRP Request Element with the Digital BF Request field set to 1 indicating a request for performing digital beamforming, and the Feedback Type field set to 1 for MU transmission. The Nc Index field is set to the number of columns, Nc, in the compressed beamforming feedback matrix minus 1 for Digital BF Fbck in the EDMG OFDM mode. (#3279). Each EDMG BRP-TX packet shall be separated by a SIFS. Each transmitted EDMG BRP-TX packet is used to train one or more transmit sectors based on the AWVs of the DMG antennas selected during the hybrid beamforming announcement phase. In each EDMG BRP-TX packet, the initiator shall include, for each selected transmit sector, TRN subfields in the TRN field for the remaining responders to perform receive AWV sounding. Each BRP-TX packet shall use the TX Sector combination selected in the announcement phase in the transmission of the TRN subfield (#3236). For each EDMG BRP-TX packet, the TXVECTOR parameter EDMG\_TRN\_LEN shall be set to a value greater than 0. The parameters RX\_TRN\_PER\_TX\_TRN and EDMG\_TRN\_M shall be set in such a manner that the number of TRN subfields included in the TRN field used for receive AWV sounding is the maximum number of receive sectors across all the remaining responders based on the feedback from all the remaining responders in the SISO phase.

The initiator may transmit each EDMG BRP-TX packet to train multiple TX DMG antennas simultaneously to reduce the sounding time. The TX Antenna Mask field within each EDMG BRP-TX packet shall indicate the TX DMG antenna(s) which is being used by the initiator to transmit the EDMG BRP-TX packet. The BRP CDOWN field within each EDMG BRP-TX packet shall indicate the number of remaining EDMG BRP RX/TX packets to be transmitted by the initiator in the sounding subphase.

***TGay Editor: Please make the following change from Pg 272 line 30 D2.1. (#3276, #3279)***

**10.43.9.2.4.4 Feedback phase**

The feedback phase is used by the hybrid beamforming protocol to feed back the hybrid beamforming information to the transmitter for use in a subsequent hybrid beamforming transmission.

The feedback is carried in the MIMO BF Feedback frame and its contents are as follows:

* For the EDMG SC mode, when the BRP frame used during the sounding phase has the DBF FBCK REQ field equal to 1 within the DMG Refinement element, the MIMO BF Feedback frame contains the Digital BF Feedback element carrying the digital beamforming matrix information. When DBF FBCK REQ field equal to 0, the MIMO BF Feedback frame contains DMG and EDMG channel measurement.
* For the EDMG OFDM mode, the MIMO BF Feedback frame contains the Digital BF Feedback 32 element carrying the digital beamforming matrix information.

**10.43.9.2.4.4.1 SU-MIMO Feedback (#3279)**

If the HBF training is requested from the initiator to the responder only, the responder shall initiate the feedback phase a SIFS duration following reception of an EDMG BRP-TX packet from the initiator with the BRP CDOWN field equal to 0.

If the HBF training is requested from the initiator to the responder and from the responder to the initiator during the announcement phase, the initiator shall commence feedback to the responder a SIFS following the reception of an EDMG BRP-TX packet from the initiator with the BRP CDOWN field equal to 0. The responder shall then commence feedback to the initiator a SIFS duration following the reception of the feedback from the initiator to the responder.



**10.43.9.2.4.4.2 MU-MIMO Feedback (#3276)**

The initiator shall initiate the MU-MIMO BF feedback subphase a MBIFS following the transmission of the EDMG BRP TX packet with the BRP CDOWN field set to 0. In the MU-MIMO BF feedback subphase, the initiator shall transmit a MIMO BF Poll frame to poll each remaining responder to collect HBF MU-MIMO BF feedback from the preceding MU-MIMO sounding subphase. The TA field of each MIMO BF Poll frame shall be set to the BSSID of the initiator and the RA field shall be set to the MAC address of the corresponding responder. Each MIMO BF Poll frame carries the dialog token in the Dialog Token field that identifies the MU-MIMO BF sounding. In the MIMO Poll Control element of each MIMO BF Poll frame, the SU/MU field shall be set to 1 and the Poll Type field shall be set to 0. Upon receiving a MIMO BF Poll frame for which a remaining responder is the addressed recipient, the responder shall transmit a MIMO Feedback Frame which contains a Digital BF Fbck Element to the initiator. The RA field of the MIMO Feedback Frame shall be set to the BSSID of the initiator and the TA field shall be set to the MAC address of the responder. The MIMO BF Feedback frame carries the dialog token in the Dialog Token field that identifies the MU-MIMO sounding. In the MIMO Feedback Control element of the MIMO Feedback Frame, the SU/MU field shall be set to 1 and the Link Type field shall be set to 0. If the MIMO Feedback Frame contains Digital BF Fbck, the ComeBack Delay field shall be set to 0. Otherwise, the ComeBack Delay field shall be set to a nonzero value which indicates when the responder will be ready with the Digital BF Fbck.

If the ComeBack Delay field is set to 0 and for a 2.16+2.16 GHz or 4.32+4.32 GHz channel, the Channel Aggregation Present subfield of the MIMO FBCK-TYPE field should be set to 1.



***TGay Editor: Please make the following change from Pg 126 line 14 D2.1. (#3276)***

**Table 17 —MIMO Poll Control element format**

|  |  |  |
| --- | --- | --- |
| **Field**  | **Size (bits)**  | **Meaning**  |
| Poll Type  | 1  | This field is set to 1 to indicate training packet poll used in the reciprocal MU-MIMO beamforming and the MU-MIMO HBF Feedback phase. It ~~and~~ is set to 0 to indicate MIMO BF feedback poll used in the SU-MIMO beamforming or the non-reciprocal MU-MIMO beamforming.  |

***TGay Editor: Please make the following change on Pg. 389 line 2 (#3707, #3280).***

|  |  |  |  |
| --- | --- | --- | --- |
| Beamformed  | 1  | 42  | See Table 53  |
| Number of Transmit Chains  | 3  | 43  | See Table 53  |
| ~~EDMG Beam Tracking Request~~  | ~~1~~  | ~~46~~  | ~~See Table 53~~  |
| ~~EDMG Beam Tracking Request Type~~  | ~~1~~  | ~~47~~  | ~~See Table 53~~  |
| CRC  | 16  | 48  | Header Check sequence. Calculation of the header check sequence is defined  |

***TGay Editor: Please make the following change on Pg. 246 line 41 (#3281).***

**10.43.7 Beam tracking**

The requestor did not determine the spatial mapping matrix *Q* as part of the HBF ~~MIMO~~ setup procedure i.e. based on channel measurements reported as feedback to the MIMO training procedure or hybrid beamforming feedback during a hybrid beamforming training procedure as described in 10.43.9.2.4.3.2 (#3281). In this case, the AWVs of the DMG antennas at the transmitter and receiver have been identified, but a procedure to determine the spatial mapping matrix *Q* is still needed

**REFERENCES**

1. IEEE P802.11ayTM/D2.1

**Straw Poll**

Do you agree to accept comment resolutions for CIDs 3236, 3276, 3279, 3280, 32891, and 3707 as proposed in 11-18/1970r0?