IEEE P802.11  
Wireless LANs

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| Proposed TGac Draft Amendment | | | | |
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Abstract

This document contains a proposal for the TGac draft amendment. It captures the feature requirements outlined in the TGac specification framework document (11-09/0992) in detailed draft text.

Table of Contents

[1 Preface 10](#_Toc283104675)

[1.1 Revision History 10](#_Toc283104676)

[1.2 Notation 10](#_Toc283104677)

[1.3 Baseline document 10](#_Toc283104678)

[2 Normative references 10](#_Toc283104680)

[3 Definitions, acronyms and abbreviations 10](#_Toc283104681)

[3.1 Definitions 10](#_Toc283104682)

[3.2 Definitions specific to IEEE 802.11 10](#_Toc283104683)

[3.3 Abbreviations and acronyms 12](#_Toc283104684)

[7 Frame formats 13](#_Toc283104691)

[7.1 MAC frame formats 13](#_Toc283104692)

[7.1.1 Conventions 13](#_Toc283104693)

[7.1.2 General frame format 13](#_Toc283104694)

[7.1.3 Frame fields 13](#_Toc283104695)

[7.1.4 Duration/ID field 16](#_Toc283104696)

[7.2 Format of individual frame types 16](#_Toc283104697)

[7.2.1 Control frames 16](#_Toc283104698)

[7.2.2 Data frames 18](#_Toc283104699)

[7.2.3 Management frames 18](#_Toc283104700)

[7.3 Management frame body components 20](#_Toc283104701)

[7.3.1 Fields that are not information elements 20](#_Toc283104702)

[7.3.2 Information elements 30](#_Toc283104703)

[7.4 Action frame format details 35](#_Toc283104704)

[**7.4.1** 35](#_Toc283104705)

[**7.4.2** 35](#_Toc283104706)

[7.4.3 DLS Action frame details 35](#_Toc283104707)

[**7.4.4** 36](#_Toc283104708)

[**7.4.5** 36](#_Toc283104709)

[**7.4.6** 36](#_Toc283104710)

[**7.4.7** 36](#_Toc283104711)

[**7.4.8** 36](#_Toc283104712)

[**7.4.9** 36](#_Toc283104713)

[**7.4.10** 36](#_Toc283104714)

[7.4.11 TDLS Action frame details 36](#_Toc283104715)

[7.4.12 VHT Action frame details 36](#_Toc283104716)

[7.4a Aggregate MPDU (A-MPDU) 37](#_Toc283104717)

[7.4a.1 A-MPDU format 37](#_Toc283104718)

[7.4a.3 A-MPDU contents 39](#_Toc283104719)

[8 Security 41](#_Toc283104720)

[8.4 RSNA security association management 41](#_Toc283104724)

[**8.4.1** 41](#_Toc283104725)

[**8.4.2** 41](#_Toc283104726)

[8.4.3 RSNA policy selection in an ESS 41](#_Toc283104727)

[8.4.4 RSNA policy selection in an IBSS and for DLS 41](#_Toc283104728)

[9 MAC sublayer functional description 42](#_Toc283104729)

[9.1 MAC architecture 42](#_Toc283104730)

[**9.1.1** 42](#_Toc283104731)

[**9.1.2** 42](#_Toc283104732)

[**9.1.3** 42](#_Toc283104733)

[**9.1.4** 42](#_Toc283104734)

[9.1.5 Fragmentation/defragmentation overview 42](#_Toc283104735)

[9.2 DCF 42](#_Toc283104736)

[9.2.0a General 42](#_Toc283104737)

[9.2.0b Procedures common to both DCF and EDCAF 42](#_Toc283104738)

[9.6 Multirate support 44](#_Toc283104742)

[9.7c A-MSDU operation 45](#_Toc283104743)

[9.7d A-MPDU operation 46](#_Toc283104744)

[9.7d.1 A-MPDU contents 46](#_Toc283104745)

[9.7d.2 A-MPDU length limit rules 46](#_Toc283104746)

[9.7d.3 Minimum MPDU Start Spacing field 46](#_Toc283104747)

[9.7d.4 A-MPDU aggregation of group addressed data frames 46](#_Toc283104748)

[9.7d.5 Transport of A-MPDU by the PHY data service 46](#_Toc283104749)

[9.7d.6 A-MPDU padding for VHT format PPDU 46](#_Toc283104750)

[9.7d.7 Transport of VHT single MPDUs 47](#_Toc283104751)

[9.7x Partial AID in VHT PPDUs 47](#_Toc283104752)

[9.9 HCF 48](#_Toc283104755)

[9.9.1 HCF contention-based channel access (EDCA) 48](#_Toc283104756)

[9.15 Reverse Direction Protocol 51](#_Toc283104762)

[**9.15.1** 51](#_Toc283104763)

[**9.15.2** 51](#_Toc283104764)

[9.15.3 Rules for RD initiator 51](#_Toc283104765)

[9.15.4 Rules for responder 51](#_Toc283104766)

[9.18 Link adaptation 51](#_Toc283104769)

[**9.18.1** 51](#_Toc283104770)

[**9.18.2** 51](#_Toc283104771)

[9.18.3 Link adaptation using the VHT Control field 51](#_Toc283104772)

[9.21 Null data packet (NDP) sounding 54](#_Toc283104773)

[**9.21.1** 54](#_Toc283104774)

[**9.21.2** 54](#_Toc283104775)

[**9.21.3** 54](#_Toc283104776)

[**9.21.4** 54](#_Toc283104777)

[9.21.5 VHT sounding protocol 54](#_Toc283104778)

[9.21.6 Transmission of a VHT NDP 56](#_Toc283104779)

[10 Layer Management 57](#_Toc283104780)

[10.1 Overview of management model 57](#_Toc283104781)

[10.2 Generic management primitives 57](#_Toc283104782)

[10.3 MLME SAP interface 57](#_Toc283104783)

[10.4 PLME SAP interface 57](#_Toc283104784)

[**10.4.1** 57](#_Toc283104785)

[**10.4.2** 57](#_Toc283104786)

[**10.4.3** 57](#_Toc283104787)

[**10.4.4** 57](#_Toc283104788)

[**10.4.5** 57](#_Toc283104789)

[**10.4.6** 57](#_Toc283104790)

[10.4.7 PLME-TXTIME.confirm 57](#_Toc283104791)

[11 MLME 58](#_Toc283104792)

[11.2 Power management 58](#_Toc283104794)

[11.2.1 Power management in an infrastructure network 58](#_Toc283104795)

[11.20 VHT BSS operation 58](#_Toc283104813)

[11.20.1 Basic VHT BSS functionality 58](#_Toc283104814)

[11.20.2 STA CCA sensing in a VHT BSS 59](#_Toc283104815)

[11.20.3 NAV assertion in a VHT BSS 60](#_Toc283104816)

[12 PHY service specification 61](#_Toc283104817)

[12.3 Detailed PHY service specifications 61](#_Toc283104818)

[**12.3.1** 61](#_Toc283104819)

[**12.3.2** 61](#_Toc283104820)

[**12.3.3** 61](#_Toc283104821)

[**12.3.4** 61](#_Toc283104822)

[12.3.5 PHY-SAP detailed service specification 61](#_Toc283104823)

[17 Orthogonal frequency division multiplexing (OFDM) PHY specification 63](#_Toc283104824)

[17.2 OFDM PHY specific service parameter list 63](#_Toc283104825)

[**17.2.1** 63](#_Toc283104826)

[17.2.2 TXVECTOR parameters 63](#_Toc283104827)

[17.2.3 RXVECTOR parameters 63](#_Toc283104828)

[17.3 OFDM PLCP sublayer 64](#_Toc283104829)

[17.3.1 Introduction 64](#_Toc283104830)

[17.3.2 PLCP frame format 64](#_Toc283104831)

[**17.3.3** 64](#_Toc283104832)

[**17.3.4** 64](#_Toc283104833)

[17.3.5 DATA field 64](#_Toc283104834)

[18 65](#_Toc283104846)

[22 Very High Throughput (VHT) PHY specification 66](#_Toc283104850)

[22.1 Introduction 66](#_Toc283104851)

[22.1.1 Introduction to the VHT PHY 66](#_Toc283104852)

[22.1.2 Scope 66](#_Toc283104853)

[22.1.3 VHT PHY functions 66](#_Toc283104854)

[22.1.4 PPDU formats 66](#_Toc283104855)

[22.2 VHT PHY service interface 66](#_Toc283104856)

[22.2.1 Introduction 66](#_Toc283104857)

[22.2.2 TXVECTOR and RXVECTOR parameters 67](#_Toc283104858)

[22.2.3 Effects of CH\_BANDWIDTH, CH\_OFFSET, MCS and NUM\_STREAMS parameters on PPDU format 74](#_Toc283104859)

[22.2.4 Support for NON\_HT formats 74](#_Toc283104860)

[22.2.5 Support for HT formats 74](#_Toc283104861)

[22.3 VHT PLCP sublayer 74](#_Toc283104862)

[22.3.1 Introduction 74](#_Toc283104863)

[22.3.2 VHT PPDU format 75](#_Toc283104864)

[22.3.3 Transmitter block diagram 75](#_Toc283104865)

[22.3.4 Overview of the PPDU encoding process 78](#_Toc283104866)

[22.3.5 Modulation and coding scheme (MCS) 81](#_Toc283104867)

[22.3.6 Timing-related parameters 82](#_Toc283104868)

[22.3.7 Mathematical description of signals 84](#_Toc283104869)

[22.3.8 Transmission of PPDU with bandwidth less than the BSS bandwidth 87](#_Toc283104870)

[22.3.9 VHT preamble 88](#_Toc283104871)

[22.3.10 Transmission of NON\_HT format PPDUs with more than one antenna 103](#_Toc283104872)

[22.3.11 Data field 103](#_Toc283104873)

[22.3.12 SU-MIMO and MU-MIMO Beamforming 118](#_Toc283104874)

[22.3.13 VHT preamble format for sounding PPDUs 119](#_Toc283104875)

[22.3.14 Regulatory requirements 119](#_Toc283104876)

[22.3.15 Channelization 119](#_Toc283104877)

[22.3.16 Transmit RF delay 121](#_Toc283104878)

[22.3.17 Slot time 121](#_Toc283104879)

[22.3.18 Transmit and receive port impedance 121](#_Toc283104880)

[22.3.19 PMD transmit specification 121](#_Toc283104881)

[22.3.20 VHT PMD receiver specification 126](#_Toc283104882)

[22.3.21 PLCP transmit procedure 129](#_Toc283104883)

[22.3.22 PLCP receive procedure 132](#_Toc283104884)

[22.4 VHT PLME 136](#_Toc283104885)

[22.4.1 PLME\_SAP sublayer management primitives 136](#_Toc283104886)

[22.4.2 PHY MIB 137](#_Toc283104887)

[22.4.3 TXTIME and PSDU\_LENGTH calculation 137](#_Toc283104888)

[22.4.4 PHY characteristics 139](#_Toc283104889)

[22.5 Parameters for VHT MCSs 139](#_Toc283104890)

# Preface

## Revision History

|  |  |  |
| --- | --- | --- |
| **Revision** | **Date** | **Comments** |
| r0 | 11/10/2010 | First draft |
| r1 | 11/11/2010 | Added authors |
| r2 | 11/11/2010 | Additional authors. Added editor’s note on dimension reduction. Fixed typo on T\_L-LTF. |
| r3 | 1/18/2011 | Revised to accommodate new specification framework requirements |

## Notation

Editing instructions are shown in ***bold italic***.

Editor’s notes in ***red*** ***bold*** ***italics*** are provided to aid in drafting the document. For example, missing text or indicating the placement of future text.

## Baseline document

This document is written as an amendment to the Draft P802.11-REVmb/D4.01 revision of the 802.11 specification.



# Normative references

# Definitions, acronyms and abbreviations

## Definitions

***Insert the following definitions:***

**multi-user, multiple input, multiple output (MU-MIMO):** A technique where multiple STAs, each with potentially multiple antennas, transmit and/or receive independent data streams simultaneously.

**downlink MU-MIMO (DL MU-MIMO):** MU-MIMO transmitted by an AP to multiple receiving non-AP STAs.

**contiguous transmission:** A transmission using only one frequency segment.

**frequency segment:** Contiguous block of frequency used by a transmission. A contiguous transmission uses one frequency segment, while a non-contiguous transmission uses two frequency segments.

**non-contiguous transmission:** A transmission using two nonadjacent frequency segments.

## Definitions specific to IEEE 802.11

***Change the following definitions:***

**nonaggregate medium access control (MAC) protocol data unit (non-A-MPDU) frame**: A frame that is transmitted in a physical layer convergence procedure (PLCP) protocol data unit (PPDU) with the

TXVECTOR AGGREGATION parameter either absent or set to NOT\_AGGREGATED, or a frame that is transmitted as a VHT single MPDU.

**non-high-throughput (non-HT) duplicate**: A transmission format of the physical layer (PHY) that duplicates a 20 MHz non-HT transmission in two ~~adjacent~~or more 20 MHz channels and allows a station (STA) in a non-HT basic service set (BSS) on ~~either~~any one 20 MHz channel to receive the transmission.

**non-high-throughput (non-HT) duplicate physical layer convergence procedure (PLCP) protocol data unit (PPDU)**: A PPDU transmitted by a Clause 19 (High Throughput (HT) PHY specification) physical layer (PHY) with the TXVECTOR FORMAT parameter set to NON\_HT and the CH\_BANDWIDTH parameter set to NON\_HT\_CBW40, NON\_HT\_CBW80, NON\_HT\_CBW160 or NON\_HT\_CBW80+80.

***Insert the following definitions:***

**primary AC:** the AC associated with the EDCAF that gains channel access. There can be only one primary AC at a given time.

**secondary AC:** an AC that is not associated with the EDCAF that gains channel access. There could be multiple secondary ACs at a given time.

**primary destinations:** destinations targeted by the frames belonging to the primary AC. There could be one or more primary destinations at any time.

**secondary destinations:** destinations targeted by the frames belonging to secondary ACs. There could be one or more secondary destinations at any time.

**primary 40 MHz channel:** In an 80, 160 or 80+80 MHz VHT BSS, the 40 MHz subchannel that includes the primary 20 MHz channel and can be used to setup a VHT 40 MHz BSS.

**primary 80 MHz channel:** In a 160 or 80+80 MHz VHT BSS, the 80 MHz subchannel that includes the primary 40 MHz channel (and thus the primary 20 MHz channel) and can be used to setup a VHT 80 MHz BSS.

**secondary 40 MHz channel**: In an 80 MHz VHT BSS, the 40 MHz subchannel adjacent to the primary 40 MHz channel that together form the 80 MHz channel of the 80 MHz VHT BSS. In a 160 or 80+80 MHz VHT BSS, the 40 MHz subchannel adjacent to the primary 40 MHz channel that together form the primary 80 MHz channel.

**secondary 80 MHz channel**: In a 160 or 80+80 MHz VHT BSS, the 80 MHz subchannel not including the primary 20 MHz channel, that together with the primary 80 MHz channel forms the 160 MHz or 80+80 MHz channel of the 160 or 80+80 MHz VHT BSS.

**non-primary channel**: In a 40, 80, 160 or 80+80 MHz VHT BSS, any 20 MHz subchannel other than the primary 20 MHz channel.

**very high throughput (VHT) physical (PHY) layer protocol data unit (PPDU)**: A PPDU transmitted using the TXVECTOR FORMAT parameter equal to VHT.

**very high throughput (VHT) single medium access control (MAC) protocol data unit (VHT single MPDU)**: An MPDU that is the only MPDU carried in an A-MPDU carried in a VHT PPDU, and with the EOF subfield of the MPDU delimiter field equal to 1.

**80 MHz mask physical layer convergence procedure (PLCP) protocol data unit (PPDU):** One of the

following PPDUs:

1. an 80 MHz VHT PPDU (TXVECTOR parameter CH\_BANDWIDTH set to HT\_CBW80);
2. an 80 MHz non-HT duplicate PPDU (TXVECTOR parameter CH\_BANDWIDTH set to NON\_HT\_CBW80);
3. a 20 MHz non-HT, HT or VHT PPDU with the TXVECTOR parameter CH\_BANDWIDTH set to NON\_HT\_CBW20 or HT\_CBW20. The PPDU is transmitted using a 40 MHz transmit spectral mask defined in Clause 22. Or,
4. a 40 MHz non-HT duplicate, HT or VHT PPDU with the TXVECTOR parameter CH\_BANDWIDTH set to NON\_HT\_CBW40 or HT\_CBW40. The PPDU is transmitted using a 40 MHz transmit spectral mask defined in Clause 22.

## Abbreviations and acronyms

***Insert the following acronym definitions:***

MU Multi-user

SU Single user

VHT Very high throughput

MU-MIMO Multi-user, multiple input, multiple output

DL MU-MIMO Downlink MU-MIMO

NDPA Null Data Packet Announcement



# Frame formats

## MAC frame formats

### Conventions

### General frame format

***Change the second paragraph as follows:***

The Frame Body field is of variable size, but constrained by the maximum MPDU size of 11,454 octets. The PPDU in which the frame is transmitted, the maximum MSDU size (2304 octets) and the maximum A-MSDU size supported by the recipient (3839, 7935 or 11,398 octets) may further limit the maximum MPDU size. ~~The maximum frame body size is determined by the maximum MSDU size (2304 octets) or the maximum A-MSDU size (3839 or 7935 octets, depending upon the STA’s capability), plus any overhead from security encapsulation.~~

***Replace Figure 7-1 with the following figure (changing the frame body length range):***

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Octets: 2 | 2 | 6 | 6 | 6 | 2 | 6 | 2 | 4 | 0-11414 | 4 |
| Frame Control | Duration/ID | Address 1 | Address 2 | Address 3 | Sequence Control | Address 4 | QoS Control | HT Control | Frame Body | FCS |

Figure ‑--MAC frame format

*NOTE--the maximum A-MSDU size (11,398 octets) is arrived at by subtracting the length of the longest QoS Data frame MAC header, the CCMP header, the CCMP MIC and FCS from the maximum MPDU length of 11,454 octets. The longest QoS Data frame MAC header includes fields shown in Figure 7-1.*

### Frame fields

#### Frame Control field

##### More Data field

***Append the following paragraph to section 7.1.3.1.7:***

The More Data field is set to 1 in frames transmitted by VHT AP during a downlink MU TXOP to indicate to the non-AP VHT STA that AP has more frames for transmission when the non-AP VHT STA is in TXOP power save mode as described in section 11.1.2.4b

#### Duration/ID field

#### Address fields

##### TA field

***Change the paragraph in this section as follows:***

The TA field contains an IEEE MAC individual address that identifies the STA that has transmitted, onto the WM, the MPDU contained in the frame body field. The Individual/Group bit is always transmitted as a zero in the transmitter address for non-VHT STAs. For VHT STAs, the Individual/Group bit is set to one in the transmitter address of control frames that carry the bandwidth indication field and that are transmitted in non-HT or non-HT duplicate format and set to zero otherwise.

#### Sequence Control field

#### QoS Control field

#### 7.1.3.5a HT Control field

***Change section 7.1.3.5a as follows:***

***Modify Figure 7-4b – Link Adaptation Control subfield, changing the reserved bit B0 from “reserved” to “HT/VHT”.***

***Modify Table 7-6a – Subfields of Link Adaptation Control subfield, adding a new row before the row containing the value “TRQ” in the column “Subfield” with the contents of the new row as shown below (header row shown only for reference):***

Table 7-6aX — Changes to Table 7-6a

|  |  |  |
| --- | --- | --- |
| **Subfield** | **Meaning** | **Definition** |
| HT/VHT | HT/VHT format indication | Set to 0 to indicate that the HT Control field uses the HT format. Set to 1 to indicate that the HT Control field uses the VHT format. |

***Modify Table 7-6a – Subfields of Link Adaptation Control subfield, by changing the Definition column entry in the last row of the table as shown:***

|  |  |  |
| --- | --- | --- |
| MFB/ASELC | MCS feedback and antenna selection command/data | When the MAI subfield is set to the value ASELI, this subfield is interpreted as defined in Figure 7-4d (ASELC subfield) and Table 7-6c (ASEL Command and ASEL Data subfields).  Otherwise, if the HT/VHT subfield is set to the value 0, this subfield contains recommended MFB expressed as an HT MCS, and if the HT/VHT subfield is set to the value 1, the 4 highest numbered bits of this subfield contain a recommended VHT MCS and the lowest numbered 3 bits of this subfield contain a recommended VHT NSTS.  A value of 127 indicates that no feedback is present. |

***Insert the remaining text and figures after Table 7-6g:***

If the HT/VHT subfield of the HT/VHT Control field is set to 1, then the format of the HT/VHT control field is shown in Figure 7-4e.



Figure 7-4e—VHT Control field

The format of the MFB of VHT Control field are defined in Figure 7-4f.



Figure 7-4f—MFB subfield in VHT Control

The subfields of VHT Control field are defined in Table 7-6h.

Table 7-6h—VHT Control subfields

|  |  |  |
| --- | --- | --- |
| **Subfield** | **Meaning** | **Definition** |
| Unsolicited MFB | Unsolicited MCS feedback indicator | Set to 1 if the MFB is not a response to an MRQ.  Set to 0 if the MFB is a response to an MRQ. |
| MRQ | MCS request | Set to 1 to request MCS feedback (solicited MFB), otherwise set to 0. |
| MSI | MRQ sequence identifier | When the MRQ subfield is set to 1, the MSI subfield contains a sequence number in the range 0 to 6 that identifies the specific request. When the MRQ subfield is set to 0, the MSI subfield is reserved. |
| MFSI/GID-L | MFB sequence identifier/LSB of Group ID | If the Unsolicited MFB subfield is set to 0, the MFSI/GID-L subfield contains the received value of MSI contained in the frame to which the MFB information refers.  If the Unsolicited MFB subfield is set to 1, the MFSI/GID-L subfield contains the lowest 3 bits of Group ID of the PPDU to which the unsolicited MFB refers. |
| MFB | NSTS, MCS and SNR feedback | MFB subfield is interpreted as defined in Table 7-6i. This subfield contains the recommended MFB. Value of 127, it indicates that no feedback is present. |
| GID-H | MSB of Group ID | If the Unsolicited MFB subfield is set to 1, the GID-H subfield contains the highest 3 bits of Group ID of the PPDU to which the unsolicited MFB refers.  Otherwise this subfield is reserved. |
| Coding Type | Coding type of MFB response | If the Unsolicited MFB subfield is set to 1, Coding Type subfield contains the Coding information (set to 0 for BCC and set to 1 for LDPC) in which the unsolicited MFB refers.  Otherwise this subfield is reserved. |
| FB Tx Type | Transmission type of MFB response | If the Unsolicited MFB subfield is set to 1 and  FB Tx Type subfield is set to 0, the unsolicited MFB refers to either unbeamformed VHT PPDU, transmit diversity utilizing Alamouti coding VHT PPDU.  If the Unsolicited MFB subfield is set to 1 and the FB Tx Type subfield is set to 1, the unsolicited MFB refers to a beamformed SU-MIMO VHT PPDU.  Otherwise this subfield is reserved. |

The MFB subfields of VHT Control field are defined in Table 7-6i.

Table 7-6i—MFB subfield in VHT Control

|  |  |  |
| --- | --- | --- |
| **Subfield** | **Meaning** | **Definition** |
| NSTS | Recommended VHT NSTS | NSTS subfield contains the recommended VHT NSTS |
| MCS | Recommended MCS feedback | MCS subfield contains the recommended VHT MCS |
| SNR | Average SNR | SNR subfield contains the average SNR, which is a SNR averaged over data subcarriers and spatial streams |

##### TID subfield

##### EOSP (end of service period) subfield

##### Ack Policy subfield

***Change Table 7-6 as follows:***

Table 7-6—Ack Policy subfield in QoS Control field of QoS data frames

|  |  |  |
| --- | --- | --- |
| **Bits in QoS Control field** | | **Meaning** |
| **Bit 5** | **Bit 6** |
| 0 | 0 | Normal Ack or Implicit Block Ack Request.  ~~In a frame that is a non-A-MPDU frame~~ When not carried in an A-MPDU subframe or carried in an A-MPDU subframe with EOF subfield of the A-MPDU delimiter field set to 1:  The addressed recipient returns an ACK or QoS +CF-Ack frame after a short interframe space (SIFS) period, according to the procedures defined in 9.2.0b.9 (ACK procedure) and 9.9.2.3 (HCCA transfer rules). For QoS Null (no data) frames, this is the only permissible value for the Ack Policy subfield.  ~~In a frame that is part of~~ When carried in an A-MPDU subframe with EOF subfield of the A-MPDU delimiter field set to 0:  The addressed recipient returns a BlockAck MPDU, either individually or as part of an A-MPDU starting a SIFS after the PPDU carrying the frame, according to the procedures defined in 9.2.0b.10 (BlockAck procedure), 9.10.7.5 (Generation and transmission of BlockAck by an HT STA), 9.10.8.3 (Operation of HT delayed Block Ack), 9.15.3 (Rules for RD initiator), 9.15.4 (Rules for RD responder) and 9.19.3 (Explicit feedback beamforming). |

### Duration/ID field

## Format of individual frame types

### Control frames

#### RTS frame format

***Change the third paragraph as follows:***

The TA field is the address of the STA transmitting the RTS frame. If the RTS frame is transmitted by a VHT STA in a non-HT or non-HT duplicate format and the INDICATED\_CH\_BANDWIDTH and INDICATED\_DYN\_BANDWIDTH TXVECTOR parameters present, then the Individual/Group bit in the TA field is set to 1 to indicate that the scrambling sequence carries a bandwidth and dynamic/static indication (see section 17.3.2.1). Otherwise the Individual/Group bit in the TA field is set to 0.

#### CTS frame format

***Change the second paragraph as follows:***

When the CTS frame follows an RTS frame, the RA field of the CTS frame is copied from the TA field of the immediately previous RTS frame to which the CTS is a response and the Individual/Group bit in the RA field is set to 0. If the CTS is a response to an RTS with the Individual/Group bit in the TA set to 1, then the CTS response is transmitted in a non-HT or non-HT duplicate format with the INDICATED\_CH\_BANDWIDTH TXVECTOR parameter present. When the CTS is the first frame in a frame exchange, the RA field is set to the MAC address of the transmitter.

***Insert sections 7.2.1.11 and 7.2.1.12:***

#### NDPA

The frame format for the NDPA is shown in Figure 7-16e.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Frame Control | Duration | RA | TA | Sounding Sequence | STA Info 1 | … | STA Info *n* | FCS |
| Octets: 2 | 2 | 6 | 6 | 1 | 2 |  | 2 | 4 |

Figure 7-16e—NDPA

The Duration field is set as defined in 7.1.4 (Duration/ID field (QoS STA)).

The NDPA contains at least one STA Info field. If the NDPA contains only one STA Info field, then the RA field is set to the address STA identified by the STA ID in the STA Info field. If the NDPA contains more than one STA Info, then the RA field is set to the broadcast address.

The TA field is set to the address of the STA transmitting the NDPA.

The Sounding Sequence field indicates a sequence number associated to the current sounding sequence.

The format of the STA Info field is shown in Figure 7‑2.

|  |  |  |  |
| --- | --- | --- | --- |
|  | B0-B11 | B12 | B13-B15 |
|  | STA ID | Feedback type | Nc Index |
| Bits: | 12 | 1 | 3 |

Figure ‑--STA Info field

The subfields in the STA Info are described in Table 7‑1.

Table ‑--STA Info Element subfields

|  |  |
| --- | --- |
| **Field** | **Description** |
| STA ID | <Add reference to STA ID section> |
| Feedback Type | Indicates the type of feedback requested.  Set to 0 for SU.  Set to 1 for MU. |
| Nc Index | Feedback dimension requested for MU feedback:  Set to 0 to request *Nc* = 1  Set to 1 to request *Nc* = 2  …  Set to 7 to request *Nc* = 8  Reserved if the Feedback Type field is set to SU. |

#### Sounding Poll

The Sounding Poll frame is shown in Figure 7-16f



Figure 7-16f—Sounding Poll

The Duration field is set to TBD

The RA field is the address of the intended recipient

The TA field is the address of the STA transmitting the Sounding Poll

The Sounding Poll frame may include additional fields TBD

### Data frames

### Management frames

#### 7.2.3.0a Format of management frames

***Change Figure 7-18 as follows (maximum length of the Frame Body):***

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Octets: 2 | 2 | 6 | 6 | 6 | 2 | 4 | 0-~~2324~~ 11422 | 4 |
| Frame Control | Duration | Address 1 (DA) | SA | BSSID | Sequence Control | HT Control | Frame Body | FCS |

**Figure 7-18—MAC frame format**

***Insert as the second paragraph in 7.2.3.0a the following:***

If a management MPDU is sent using a VHT PPDU, the size of the MPDU is constrained by the maximum MPDU size supported by the recipient. Otherwise, the maximum management MPDU size is 2356 octets.

#### Beacon frame format

***Change Table 7-8, adding rows with Order 42 and 43 following row with Order 41:***

**Table 7-8—Beacon frame body**

|  |  |  |
| --- | --- | --- |
| **Order** | **Information** | **Notes** |
| 42 | VHT Capabilities | The VHT Capabilities element is present when the dot11VHTOptionImplemented attribute is true |
| 43 | VHT Operation | The VHT Capabilities element is present when the dot11VHTOptionImplemented attribute is true |

#### Association Request frame format

***Change Table 7-10, adding row with Order 16 following row with Order 15:***

**Table 7-10—Association Request frame body**

|  |  |  |
| --- | --- | --- |
| **Order** | **Information** | **Notes** |
| 16 | VHT Capabilities | The VHT Capabilities element is present when the dot11VHTOptionImplemented attribute is true |

#### Association Response frame format

***Change Table 7-11, adding rows with Order 19 and 20 following row with Order 18:***

**Table 7-11—Association Response frame body**

|  |  |  |
| --- | --- | --- |
| **Order** | **Information** | **Notes** |
| 19 | VHT Capabilities | The VHT Capabilities element is present when the dot11VHTOptionImplemented attribute is true |
| 20 | VHT Operation | The VHT Capabilities element is present when the dot11VHTOptionImplemented attribute is true |

#### Reassociation Request frame format

***Change Table 7-12, adding row with Order 19 following row with Order 18:***

**Table 7-12—Reassociation Request frame body**

|  |  |  |
| --- | --- | --- |
| **Order** | **Information** | **Notes** |
| 19 | VHT Capabilities | The VHT Capabilities element is present when the dot11VHTOptionImplemented attribute is true |

#### Reassociation Response frame format

***Change Table 7-13, adding rows with Order 21 and 22 following row with Order 20:***

**Table 7-13—Association Response frame body**

|  |  |  |
| --- | --- | --- |
| **Order** | **Information** | **Notes** |
| 21 | VHT Capabilities | The VHT Capabilities element is present when the dot11VHTOptionImplemented attribute is true |
| 22 | VHT Operation | The VHT Capabilities element is present when the dot11VHTOptionImplemented attribute is true |

#### Probe Request frame format

***Change Table 7-14, adding row with Order 19 following row with Order 18:***

**Table 7-14—Probe Request frame body**

|  |  |  |
| --- | --- | --- |
| **Order** | **Information** | **Notes** |
| 10 | VHT Capabilities | The VHT Capabilities element is present when the dot11VHTOptionImplemented attribute is true |

#### Probe Response frame format

***Change Table 7-15, adding rows with Order 40 and 41 following row with Order 39:***

**Table 7-15—Probe Response frame body**

|  |  |  |
| --- | --- | --- |
| **Order** | **Information** | **Notes** |
| 40 | VHT Capabilities | The VHT Capabilities element is present when the dot11VHTOptionImplemented attribute is true |
| 41 | VHT Operation | The VHT Capabilities element is present when the dot11VHTOptionImplemented attribute is true |

## Management frame body components

### Fields that are not information elements

#### Action field

***Add the following row to Table 7-24:***

**Table 7-24— Category values**

|  |  |  |  |
| --- | --- | --- | --- |
| **Code** | **Meaning** | **See subclause** | **Robust** |
| <ANA> | VHT | 7.4.11 | TBD |

***Insert section 7.3.1.31:***



#### VHT MIMO Control field

The VHT MIMO Control field is defined in Figure 7-2.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| B0-B2 | B3-B5 | B6-B7 | B8-B9 | B10 | B11 | B12-B15 | B16-B23 |
| Nc Index | Nr Index | Channel Width | Grouping | Codebook Information | Feedback Type | Reserved | Sounding Sequence |
| Bits: 3 | 3 | 2 | 2 | 1 | 1 | 4 | 8 |

Figure ‑--VHT MIMO Control field

The subfields of the VHT MIMO Control field are defined in Table 7‑2.

Table ‑--Subfields of the VHT MIMO Control field

|  |  |
| --- | --- |
| **Subfield** | **Description** |
| Nc Index | Indicates the number of columns in a matrix minus one:  Set to 0 for *Nc*=1  Set to 1 for *Nc*=2  …  Set to 7 for *Nc*=8 |
| Nr Index | Indicates the number of rows in a matrix minus one:  Set to 0 for *Nr*=1  Set to 1 for *Nr*=2  …  Set to 7 for *Nr*=8 |
| Channel Width | Indicates the width of the channel in which a measurement was made:  Set to 0 for 20 MHz  Set to 1 for 40 MHz  Set to 2 for 80 MHz  Set to 3 for 160 MHz or 80+80 MHz |
| Grouping | Number of carriers grouped into one:  Set to 0 for *Ng* = 1 (No grouping)  Set to 1 for *Ng* = 2  Set to 2 for *Ng* = 4  The value 3 is reserved |
| Feedback Type | Set to 0 if the feedback report is for SU-BF. If it is set to 0, the feedback report frame shall not include the MU Exclusive Beamforming Report field (see 7.3.1.33)  Set to 1 if the feedback report is for MU-BF. If it is set to 1, the feedback report frame shall include the MU Exclusive Beamforming Report field (see 7.3.1.62) |
| Codebook Information | Indicates the size of codebook entries:  If Feedback Type is set to 0 (SU-BF)  Set to 0 for 2 bit for ψ, 4 bits for   Set to 1 for 4 bit for ψ, 6 bits for   If Feedback Type is set to 1 (MU-BF)  Set to 0 for 5 bit for ψ, 7 bits for   Set to 1 for 7 bit for ψ, 9 bits for  |
| Sounding Sequence | Sequence number from the NDPA soliciting feedback |

***Insert section 7.3.1.32:***

#### VHT Compressed Beamforming Report field

The VHT Compressed Beamforming Report field is used by the VHT Compressed Beamforming frame (see 7.4.12.2) to carry explicit feedback information in the form of angles representing compressed beamforming feedback matrices *V* for use by a transmit beamformer to determine steering matrices *Q*, as described in 9.19.3 (Explicit feedback beamforming) and 20.3.12.2 (Explicit feedback beamforming).

The size of the VHT Compressed Beamforming Report field depends on the values in the VHT MIMO Control field.

The VHT Compressed Beamforming Report field contains the channel matrix elements indexed, first, by matrix angles in the order shown in Table 7‑3 to Table 7‑7 (Order of angles in the Compressed Beamforming Report field) and, second, by data subcarrier index from lowest frequency to highest frequency. The explanation on how these angles are generated from the beamforming feedback matrix V is given in 20.3.12.2.5 (Compressed beamforming feedback matrix).

Table ‑—Order of angles in the MIMO Compressed Steering Matrices Report field for Nr <= 4

|  |  |  |
| --- | --- | --- |
| **Size of V(*Nr* x *Nc*)** | **Number of angles (Na)** | **The order of angles in the Quantized Steering Matrices Feedback Information field** |
| 2x1 | 2 | 11, 21 |
| 2x2 | 2 | 11, 21 |
| 3x1 | 4 | 11, 21, 21, 31, |
| 3x2 | 6 | 11, 21, 21, 31, 22, 32 |
| 3x3 | 6 | 11, 21, 21, 31, 22, 32 |
| 4x1 | 6 | 11, 21, 31, 21, 31, 41 |
| 4x2 | 10 | 11, 21, 31, 21, 31, 41, 22, 32, 32, 42 |
| 4x3 | 12 | 11, 21, 31, 21, 31, 41, 22, 32, 32, 42, 33, 43 |
| 4x4 | 12 | 11, 21, 31, 21, 31, 41, 22, 32, 32, 42, 33, 43 |

Table ‑—Order of angles in the MIMO Compressed Steering Matrices Report field for Nr = 5

|  |  |  |
| --- | --- | --- |
| **Size of *V*  (*Nr × Nc)*** | **Number of angles (Na)** | **The order of angles in the Quantized Beamforming Feedback Matrices Information field** |
| 5×1 | 8 | 11, 21, 31, 41, ψ21, ψ31, ψ41, ψ51 |
| 5×2 | 14 | 11, 21, 31, 41, ψ21, ψ31, ψ41, ψ51, 22, 32, 42, ψ32, ψ42, ψ52 |
| 5×3 | 18 | 11, 21, 31, 41, ψ21, ψ31, ψ41, ψ51, 22, 32, 42, ψ32, ψ42, ψ52, 33, 43, ψ43, ψ53 |
| 5×4 | 20 | 11, 21, 31, 41, ψ21, ψ31, ψ41, ψ51, 22, 32, 42, ψ32, ψ42, ψ52, 33, 43, ψ43, ψ53, 44, ψ54 |
| 5×5 | 20 | 11, 21, 31, 41, ψ21, ψ31, ψ41, ψ51, 22, 32, 42, ψ32, ψ42, ψ52, 33, 43, ψ43, ψ53, 44, ψ54 |

Table ‑—Order of angles in the MIMO Compressed Steering Matrices Report field for Nr = 6

|  |  |  |
| --- | --- | --- |
| **Size of *V*  (*Nr × Nc)*** | **Number of angles (Na)** | **The order of angles in the Quantized Beamforming Feedback**  **Matrices Information field** |
| 6×1 | 10 | 11, 21, 31, 41, 51, ψ21, ψ31, ψ41, ψ51, ψ61 |
| 6×2 | 18 | 11, 21, 31, 41, 51, ψ21, ψ31, ψ41, ψ51, ψ61, 22, 32, 42, 52, ψ32, ψ42, ψ52, ψ62 |
| 6×3 | 24 | 11, 21, 31, 41, 51, ψ21, ψ31, ψ41, ψ51, ψ61, 22, 32, 42, 52, ψ32, ψ42, ψ52, ψ62, 33, 43, 53, ψ43, ψ53, ψ63 |
| 6×4 | 28 | 11, 21, 31, 41, 51, ψ21, ψ31, ψ41, ψ51, ψ61, 22, 32, 42, 52, ψ32, ψ42, ψ52, ψ62, 33, 43, 53, ψ43, ψ53, ψ63, 44, 54, ψ54, ψ64 |
| 6×5 | 30 | 11, 21, 31, 41, 51, ψ21, ψ31, ψ41, ψ51, ψ61, 22, 32, 42, 52, ψ32, ψ42, ψ52, ψ62, 33, 43, 53, ψ43, ψ53, ψ63, 44, 54, ψ54, ψ64, 55, ψ65 |
| 6×6 | 30 | 11, 21, 31, 41, 51, ψ21, ψ31, ψ41, ψ51, ψ61, 22, 32, 42, 52, ψ32, ψ42, ψ52, ψ62, 33, 43, 53, ψ43, ψ53, ψ63, 44, 54, ψ54, ψ64, 55, ψ65 |

Table ‑—Order of angles in the MIMO Compressed Steering Matrices Report field for Nr = 7

|  |  |  |
| --- | --- | --- |
| **Size of *V*  (*Nr × Nc)*** | **Number of angles**  **(Na)** | **The order of angles in the Quantized Beamforming Feedback**  **Matrices Information field** |
| 7×1 | 12 | 11, 21, 31, 41, 51, 61, ψ21, ψ31, ψ41, ψ51, ψ61, ψ71 |
| 7×2 | 22 | 11, 21, 31, 41, 51, 61, ψ21, ψ31, ψ41, ψ51, ψ61, ψ71, 22, 32, 42, 52, 62, ψ32, ψ42, ψ52, ψ62, ψ72 |
| 7×3 | 30 | 11, 21, 31, 41, 51, 61, ψ21, ψ31, ψ41, ψ51, ψ61, ψ71, 22, 32, 42, 52, 62, ψ32, ψ42, ψ52, ψ62, ψ72, 33, 43, 53, 63, ψ43, ψ53, ψ63, ψ73 |
| 7×4 | 36 | 11, 21, 31, 41, 51, 61, ψ21, ψ31, ψ41, ψ51, ψ61, ψ71, 22, 32, 42, 52, 62, ψ32, ψ42, ψ52, ψ62, ψ72, 33, 43, 53, 63, ψ43, ψ53, ψ63, ψ73, 44, 54, 64, ψ54, ψ64, ψ74 |
| 7×5 | 40 | 11, 21, 31, 41, 51, 61, ψ21, ψ31, ψ41, ψ51, ψ61, ψ71, 22, 32, 42, 52, 62, ψ32, ψ42, ψ52, ψ62, ψ72, 33, 43, 53, 63, ψ43, ψ53, ψ63, ψ73, 44, 54, 64, ψ54, ψ64, ψ74, 55, 65, ψ65, ψ75 |
| 7×6 | 42 | 11, 21, 31, 41, 51, 61, ψ21, ψ31, ψ41, ψ51, ψ61, ψ71, 22, 32, 42, 52, 62, ψ32, ψ42, ψ52, ψ62, ψ72, 33, 43, 53, 63, ψ43, ψ53, ψ63, ψ73, 44, 54, 64, ψ54, ψ64, ψ74, 55, 65, ψ65, ψ75, 66, ψ76 |
| 7×7 | 42 | 11, 21, 31, 41, 51, 61, ψ21, ψ31, ψ41, ψ51, ψ61, ψ71, 22, 32, 42, 52, 62, ψ32, ψ42, ψ52, ψ62, ψ72, 33, 43, 53, 63, ψ43, ψ53, ψ63, ψ73, 44, 54, 64, ψ54, ψ64, ψ74, 55, 65, ψ65, ψ75, 66, ψ76 |

Table ‑—Order of angles in the MIMO Compressed Steering Matrices Report field for Nr = 8

|  |  |  |
| --- | --- | --- |
| **Size of *V*  (*Nr × Nc)*** | **Number of angles**  **(Na)** | **The order of angles in the Quantized Beamforming Feedback**  **Matrices Information field** |
| 8×1 | 14 | 11, 21, 31, 41, 51, 61, 71, ψ21, ψ31, ψ41, ψ51, ψ61, ψ71, ψ81 |
| 8×2 | 26 | 11, 21, 31, 41, 51, 61, 71, ψ21, ψ31, ψ41, ψ51, ψ61, ψ71, ψ81, 22, 32, 42, 52, 62, 72, ψ32, ψ42, ψ52, ψ62, ψ72, ψ82 |
| 8×3 | 36 | 11, 21, 31, 41, 51, 61, 71, ψ21, ψ31, ψ41, ψ51, ψ61, ψ71, ψ81, 22, 32, 42, 52, 62, 72, ψ32, ψ42, ψ52, ψ62, ψ72, ψ82, 33, 43, 53, φ63, 73, ψ43, ψ53, ψ63, ψ73, ψ83 |
| 8×4 | 44 | 11, 21, 31, 41, 51, 61, 71, ψ21, ψ31, ψ41, ψ51, ψ61, ψ71, ψ81, 22, 32, 42, 52, 62, 72, ψ32, ψ42, ψ52, ψ62, ψ72, ψ82, 33, 43, 53, 63, 73, ψ43, ψ53, ψ63, ψ73, ψ83,44, 54, 64, 74, ψ54, ψ64, ψ74, ψ84 |
| 8×5 | 50 | 11, 21, 31, 41, 51, 61, 71, ψ21, ψ31, ψ41, ψ51, ψ61, ψ71, ψ81, 22, 32, 42, 52, 62, 72, ψ32, ψ42, ψ52, ψ62, ψ72, ψ82, 33, 43, 53, 63, 73, ψ43, ψ53, ψ63, ψ73, ψ83,44, 54, 64, 74, ψ54, ψ64, ψ74, ψ84, 55, 65, 75, ψ65, ψ75, ψ85 |
| 8×6 | 54 | 11, 21, 31, 41, 51, 61, 71, ψ21, ψ31, ψ41, ψ51, ψ61, ψ71, ψ81, 22, 32, 42, 52, 62, 72, ψ32, ψ42, ψ52, ψ62, ψ72, ψ82, 33, 43, 53, 63, 73, ψ43, ψ53, ψ63, ψ73, ψ83,44, 54, 64, 74, ψ54, ψ64, ψ74, ψ84, 55, 65, 75, ψ65, ψ75, ψ85, 66, 76, ψ76, ψ86 |
| 8×7 | 56 | 11, 21, 31, 41, 51, 61, 71, ψ21, ψ31, ψ41, ψ51, ψ61, ψ71, ψ81, 22, 32, 42, 52, 62, 72, ψ32, ψ42, ψ52, ψ62, ψ72, ψ82, 33, 43, 53, 63, 73, ψ43, ψ53, ψ63, ψ73, ψ83,44, 54, 64, 74, ψ54, ψ64, ψ74, ψ84, 55, 65, 75, ψ65, ψ75, ψ85, 66, 76, ψ76, ψ86, 77, ψ87 |
| 8×8 | 56 | 11, 21, 31, 41, 51, 61, 71, ψ21, ψ31, ψ41, ψ51, ψ61, ψ71, ψ81, 22, 32, 42, 52, 62, 72, ψ32, ψ42, ψ52, ψ62, ψ72, ψ82, 33, 43, 53, 63, 73, ψ43, ψ53, ψ63, ψ73, ψ83,44, 54, 64, 74, ψ54, ψ64, ψ74, ψ84, 55, 65, 75, ψ65, ψ75, ψ85, 66, 76, ψ76, ψ86, 77, ψ87 |

The angles are quantized as defined in Table 7‑8 (Quantization of angles). All angles are transmitted LSB to MSB.

Table ‑--Quantization of angles

|  |  |
| --- | --- |
| **Quantized** | **Quantized** |
| radians  where    *b* is the number of bits used to quantize (defined by the Codebook Information field of the VHT MIMO Control field (see 7.3.1.12) |    radians  where  *b* is the number of bits used to quantize (defined by the Codebook Information field of the VHT MIMO Control field (see 7.3.1.12) |

The VHT Compressed Beamforming Report field for 20 MHz has the structure defined in Table 7‑9 (VHT Compressed Beamforming Report field (20 MHz)), where *Na* is the number of angles used for beamforming feedback matrix *V* (see Table 7‑3 to Table 7‑7).

Table ‑—VHT Compressed Beamforming Report field (20 MHz)

|  |  |  |
| --- | --- | --- |
| **Field** | **Size**  **(bits)** | **Meaning** |
| SNR in space-time stream 1 | 8 | Average signal-to-noise ratio in the STA  sending the report for space-time stream 1 |
| ... |  |  |
| SNR in space-time stream *Nc* | 8 | Average signal-to-noise ratio in the STA  sending the report for space-time stream *Nc* |
| Beamforming Feedback Matrix *V* for carrier –28 | *Na×*(*b +b*)/2 | Beamforming feedback matrix *V* |
| Beamforming Feedback Matrix *V* for carrier –28+Ng | *Na×*(*b +b*)/2 | Beamforming feedback matrix *V* |
| Beamforming Feedback Matrix *V* for carrier –28+2Ng | *Na×*(*b +b*)/2 | Beamforming feedback matrix *V* |
| ... |  |  |
| Beamforming Feedback Matrix *V* for carrier –1 | *Na*×( *b +b*)/2 | Beamforming feedback matrix *V* |
| Beamforming Feedback Matrix *V* for carrier 1 | *Na*×( *b +b*)/2 | Beamforming feedback matrix *V* |
| Beamforming Feedback Matrix *V* for carrier 2 | *Na*×( *b +b*)/2 | Beamforming feedback matrix *V* |
| Beamforming Feedback Matrix *V* for carrier 2+Ng | *Na*×( *b +b*)/2 | Beamforming feedback matrix *V* |
| Beamforming Feedback Matrix *V* for carrier 2+2Ng | *Na*×( *b +b*)/2 | Beamforming feedback matrix *V* |
| ... |  |  |
| Beamforming Feedback Matrix *V* for carrier 28 | *Na*×( *b +b*)/2 | Beamforming feedback matrix *V* |

The VHT Compressed Beamforming Report field for 40 MHz has the structure defined in Table 7‑10

(VHT Compressed Beamforming Report field (40 MHz)), where *Na* is the number of angles used for the beamforming feedback matrix *V* (see Table 7‑3 to Table 7‑7).

Table ‑—VHT Compressed Beamforming Report field (40 MHz)

|  |  |  |
| --- | --- | --- |
| **Field** | **Size**  **(bits)** | **Meaning** |
| SNR in space-time stream 1 | 8 | Average signal-to-noise ratio in the STA  sending the report for space-time stream 1 |
| ... |  |  |
| SNR in space-time stream *Nc* | 8 | Average signal-to-noise ratio in the STA  sending the report for space-time stream *Nc* |
| Beamforming Feedback Matrix *V* for carrier –58 | *Na×*(*b +b*)/2 | Beamforming feedback matrix *V* |
| Beamforming Feedback Matrix *V* for carrier –58+Ng | *Na×*(*b +b*)/2 | Beamforming feedback matrix *V* |
| Beamforming Feedback Matrix *V* for carrier –58+2Ng | *Na×*(*b +b*)/2 | Beamforming feedback matrix *V* |
| ... |  |  |
| Beamforming Feedback Matrix *V* for carrier –2 | *Na*×( *b +b*)/2 | Beamforming feedback matrix *V* |
| Beamforming Feedback Matrix *V* for carrier 2 | *Na*×( *b +b*)/2 | Beamforming feedback matrix *V* |
| Beamforming Feedback Matrix *V* for carrier 2+Ng | *Na×*(*b +b*)/2 | Beamforming feedback matrix *V* |
| Beamforming Feedback Matrix *V* for carrier 2+2Ng | *Na×*(*b +b*)/2 | Beamforming feedback matrix *V* |
| ... |  |  |
| Beamforming Feedback Matrix *V* for carrier 58 | *Na*×( *b +b*)/2 | Beamforming feedback matrix *V* |

The VHT Compressed Beamforming Report field for 80 MHz has the structure defined in Table 7‑11 (VHT Compressed Beamforming Report field (80 MHz)), where *Na* is the number of angles used for the beamforming feedback matrix *V* (see Table 7‑3 to Table 7‑7).

Table ‑—VHT Compressed Beamforming Report field (80 MHz)

|  |  |  |
| --- | --- | --- |
| **Field** | **Size**  **(bits)** | **Meaning** |
| SNR in space-time stream 1 | 8 | Average signal-to-noise ratio in the STA  sending the report for space-time stream 1 |
| ... |  |  |
| SNR in space-time stream *Nc* | 8 | Average signal-to-noise ratio in the STA  sending the report for space-time stream *Nc* |
| Beamforming Feedback Matrix *V* for carrier –122 | *Na×*(*b +b*)/2 | Beamforming feedback matrix *V* |
| Beamforming Feedback Matrix *V* for carrier –122+Ng | *Na×*(*b +b*)/2 | Beamforming feedback matrix *V* |
| Beamforming Feedback Matrix *V* for carrier –122+2Ng | *Na×*(*b +b*)/2 | Beamforming feedback matrix *V* |
| ... |  |  |
| Beamforming Feedback Matrix *V* for carrier –2 | *Na*×( *b +b*)/2 | Beamforming feedback matrix *V* |
| Beamforming Feedback Matrix *V* for carrier 2 | *Na*×( *b +b*)/2 | Beamforming feedback matrix *V* |
| Beamforming Feedback Matrix *V* for carrier 2+Ng | *Na×*(*b +b*)/2 | Beamforming feedback matrix *V* |
| Beamforming Feedback Matrix *V* for carrier 2+2Ng | *Na×*(*b +b*)/2 | Beamforming feedback matrix *V* |
| ... |  |  |
| Beamforming Feedback Matrix *V* for carrier 122 | *Na*×( *b +b*)/2 | Beamforming feedback matrix *V* |

The VHT Compressed Beamforming Report field for non-contiguous 80+80 MHz has the structure defined in Table 7‑11 (VHT Compressed Beamforming Report field (80 MHz)) for each frequency segment. For contiguous 160MHz, the VHT Compressed Beamforming Report field has the structure defined in Table 7‑11 (VHT Compressed Beamforming Report field (80 MHz)) with tone shifting ±256. *Na* is the number of angles used for beamforming feedback matrix *V* (see Table 7‑3 to Table 7‑7).

The SNR values in Table 7‑9 (VHT Compressed Beamforming Report field (20 MHz)), Table 7‑10

(VHT Compressed Beamforming Report field (40 MHz)) and Table 7‑11 (VHT Compressed Beamforming Report field (80 MHz)) are encoded as an 8-bit twos complement value of 4 ×(SNR\_average – 22), where SNR\_average is the sum of the values of SNR per tone (in decibels) divided by the number of tones represented. This encoding covers the SNR range from –10 dB to 53.75 dB in 0.25 dB steps. Each SNR value per tone in stream *i* (before being averaged) corresponds to the SNR associated with the column *i* of the beamforming feedback matrix *V* determined at the beamformee. Each SNR corresponds to the predicted SNR at the beamformee when the beamformer applies the matrix *V*.

Grouping is a method that reduces the size of the VHT Compressed Beamforming Report field by reporting a single value for each group of *Ng* adjacent subcarriers. With grouping, the size of the VHT Compressed Beamforming Report field is *Nc×8+Ns×*(*Na×*( *b +b*)/2) bits, where the number of subcarriers sent, *Ns*, is a function of *Ng* and the channel width defined by the Channel Width field in VHT MIMO Control field (see 7.3.1.12). The value of *Ns* and the specific carriers for which matrices are sent is defined in Table 7‑12 (Number of subcarriers and tone mapping). If the size of the VHT Compressed Beamforming Report field is not an integral multiple of 8 bits, up to 7 zeros are appended to the end of the report to make its size an integral multiple of 8 bits.

Table ‑--Number of subcarriers and tone mapping

|  |  |  |  |
| --- | --- | --- | --- |
| **BW** | **Grouping (Ng)** | **Ns** | **Carriers for which matrices are sent** |
| 20 MHz | 1 | 52 | All subcarriers -28 to 28 except ±21, ±7 and 0. |
| 2 | 30 | ±28, ±26, ±24, ±22, ±20, ±18, ±16, ±14, ±12, ±10, ±8, ±6, ±4, ±2, ±1 |
| 4 | 16 | ±28, ±24, ±20, ±16, ±12, ±8, ±4, ±1 |
| 40 MHz | 1 | 108 | All subcarriers -58 to 58 except ±53, ±25, ±11, ±1 and 0 |
| 2 | 58 | ±58, ±56, ±54, ±52, ±50, ±48, ±46, ±44, ±42, ±40, ±38, ±36, ±34, ±32, ±30, ±28, ±26, ±24, ±22, ±20, ±18, ±16, ±14, ±12, ±10, ±8, ±6, ±4, ±2 |
| 4 | 30 | ±58, ±54, ±50, ±46, ±42, ±38, ±34, ±30, ±26, ±22, ±18, ±14, ±10, ±6, ±2 |
| 80 MHz | 1 | 234 | All subcarriers -122 to 122 except ±103, ±75, ±39, ±11, ±1 and 0. |
| 2 | 122 | ±122, ±120, ±118, ±116, ±114, ±112, ±110, ±108, ±106, ±104, ±102, ±100, ±98, ±96, ±94, ±92, ±90, ±88, ±86, ±84, ±82, ±80, ±78, ±76, ±74, ±72, ±70, ±68, ±66, ±64, ±62, ±60, ±58, ±56, ±54, ±52, ±50, ±48, ±46, ±44, ±42, ±40, ±38, ±36, ±34, ±32, ±30, ±28, ±26, ±24, ±22, ±20, ±18, ±16, ±14, ±12, ±10, ±8, ±6, ±4, ±2 |
| 4 | 62 | ±122, ±118, ±114, ±110, ±106, ±102, ±98, ±94, ±90, ±86, ±82, ±78, ±74, ±70, ±66, ±62, ±58, ±54, ±50, ±46, ±42, ±38, ±34, ±30, ±26, ±22, ±18, ±14, ±10, ±6, ±2 |

Note: When BW=160MHz, the above BW=80MHz table indicates the subcarrier indices to be fed back for each 80MHz frequency segment.

When operating with a 40MHz, 80MHz, and 160MHz channel width, feedback with BW=20MHz corresponds to the tones in the primary 20 MHz channel.

When operating with an 80MHz and 160MHz channel width, feedback with BW=40MHz corresponds to the tones in the primary 40 MHz channel.

When operating with a 80+80 MHz or 160MHz channel width, feedback with BW=80MHz corresponds to the tones in the primary 80 MHz channel.

***Insert section 7.3.1.33:***

#### MU Exclusive Beamforming Report field

The MU Exclusive Beamforming Report field is included in the VHT Compressed Beamforming frame if the Feedback Type subfield in the VHT MIMO Control field is set to MU (see 7.3.1.12).

The format of the MU Exclusive Beamforming Report field is shown in Table 7‑13 and consists of Delta SNR subfields for each space-time stream (1 through *Nc*) of a subset of the subcarriers spaced *Ng’* apart, starting from the lowest frequency subcarrier and continuing to the highest frequency subcarrier. The subset of subcarriers included is determined by the values of the Channel Width and Grouping subfields of the VHT MIMO Control field as listed in Table 7‑14. For each subcarrier included, the deviation in dB of the SNR of that subcarrier for each column of *V* relative to the average SNR of the corresponding space-time stream is computed using Equation .



where

 is the estimated MIMO channel for subcarrier *k*

 is column *i* of the beamforming matrix  for subcarrier *k*

 is the noise plus interference power measured at the beamformee

 is the average SNR of space-time stream *i* reported in the VHT Compressed Beamforming Report field (SNR in space-time stream *i* field)

Each Delta SNR subfield contains the  computed using Equation quantized to 4 bits in the range -8 dB to 7 dB and with 1 dB granularity.

Table ‑—MU Exclusive Beamforming Report field

|  |  |  |
| --- | --- | --- |
| **Field** | **Size (Bits)** | **Meaning** |
| Delta SNR for space-time stream 1 for carrier at negative band edge | 4 | in dB with range -8 dB to 7 dB with 1 dB granularity for  and |
| … |  |  |
| Delta SNR for space-time stream *Nc* for carrier at negative band edge | 4 | in dB with range -8 dB to 7 dB with 1 dB granularity for  and |
| Delta SNR for space-time stream 1 for carrier at negative band edge + *Ng*’ | 4 | in dB from -8 dB to 7 dB with 1 dB granularity for  and |
| … |  |  |
| Delta SNR for space-time stream *Nc* for carrier at negative band edge + *Ng*’ | 4 | in dB from -8 dB to 7 dB with 1 dB granularity for  and |
| … |  |  |
| Delta SNR for space-time stream 1 for carrier at negative band edge + *(m-1)Ng*’ | 4 | in dB from -8 dB to 7 dB with 1 dB granularity for and |
| … |  |  |
| Delta SNR for space-time stream *Nc* for carrier at negative band edge + *(m-1)Ng*’ | 4 | in dB from -8 dB to 7 dB with 1 dB granularity for and |
| Delta SNR for space-time stream 1 for carrier at negative DC edge | 4 | in dB from -8 dB to 7 dB with 1 dB granularity for and |
| … |  |  |
| Delta SNR for space-time stream *Nc* for carrier at negative DC edge | 4 | in dB from -8 dB to 7 dB with 1 dB granularity for  and |
| Delta-SNR for space-time stream 1 for carrier at positive DC edge | 4 | in dB from -8 dB to 7 dB with 1 dB granularity for  and |
| … |  |  |
| Delta-SNR for space-time stream *Nc* for carrier at positive DC edge | 4 | in dB from -8 dB to 7 dB with 1 dB granularity for  and |
| Delta-SNR for space-time stream 1 for carrier at positive band edge – *(m-1)Ng’* | 4 | in dB from -8 dB to 7 dB with 1 dB granularity for  and |
| … |  |  |
| Delta-SNR for space-time stream *Nc* for carrier at positive band edge – *(m-1)Ng’* | 4 | in dB from -8 dB to 7 dB with 1 dB granularity for  and |
| … |  |  |
| Delta SNR for space-time stream 1 for carrier at positive band edge - *Ng’* | 4 | in dB from -8 dB to 7 dB with 1 dB granularity for  and |
| … |  |  |
| Delta SNR for space-time stream *Nc* for carrier at positive band edge - *Ng’* | 4 | in dB from -8 dB to 7 dB with 1 dB granularity for  and |
| Delta SNR for space-time stream 1 for carrier at positive band edge | 4 | in dB from -8 dB to 7 dB with 1 dB granularity for  and |
| … |  |  |
| Delta SNR for space-time stream *Nc* for carrier at positive band edge | 4 | in dB from -8 dB to 7 dB with 1 dB granularity for  and |

In Table 7‑13,

where  is the smallest integer greater than or equal to 

** is the absolute value of the band edge subcarrier index; 28 for 20 MHz, 58 for 40 MHz and 122 for 80 MHz,

** is the absolute value of the DC edge subcarrier index; 1 for 20 MHz, 2 for 40 MHz and 2 for 80 MHz,

*Ng’*=2*Ng* where *Ng* is the value in the Grouping subfield of the VHT MIMO Control field.

Table ‑--Number of subcarriers and subcarrier mapping

|  |  |  |  |
| --- | --- | --- | --- |
| **Channel Width** | **Grouping (Ng)** | **Ns** | **Subcarriers (*k*) for which** **is sent** |
| 20 MHz | 1 | 30 | ±28, ±26, ±24, ±22, ±20, ±18, ±16, ±14, ±12, ±10, ±8, ±6, ±4, ±2, ±1 |
| 2 | 16 | ±28, ±24, ±20, ±16, ±12, ±8, ±4, ±1 |
| 4 | 10 | ±28, ±20, ±12, ±4, ±1 |
| 40 MHz | 1 | 58 | ±58, ±56, ±54, ±52, ±50, ±48, ±46, ±44, ±42, ±40, ±38, ±36, ±34, ±32, ±30, ±28, ±26, ±24, ±22, ±20, ±18, ±16, ±14, ±12, ±10, ±8, ±6, ±4, ±2 |
| 2 | 30 | ±58, ±54, ±50, ±46, ±42, ±38, ±34, ±30, ±26, ±22, ±18, ±14, ±10, ±6, ±2 |
| 4 | 16 | ±58, ±50, ±42, ±34, ±26, ±18, ±10, ±2 |
| 80 MHz | 1 | 122 | ±122, ±120, ±118, ±116, ±114, ±112, ±110, ±108, ±106, ±104, ±102, ±100, ±98, ±96, ±94, ±92, ±90, ±88, ±86, ±84, ±82, ±80, ±78, ±76, ±74, ±72, ±70, ±68, ±66, ±64, ±62, ±60, ±58, ±56, ±54, ±52, ±50, ±48, ±46, ±44, ±42, ±40, ±38, ±36, ±34, ±32, ±30, ±28, ±26, ±24, ±22, ±20, ±18, ±16, ±14, ±12, ±10, ±8, ±6, ±4, ±2 |
| 2 | 62 | ±122, ±118, ±114, ±110, ±106, ±102, ±98, ±94, ±90, ±86, ±82, ±78, ±74, ±70, ±66, ±62, ±58, ±54, ±50, ±46, ±42, ±38, ±34, ±30, ±26, ±22, ±18, ±14, ±10, ±6, ±2 |
| 4 | 32 | ±122, ±114, ±106, ±98, ±90, ±82, ±74, ±66, ±58, ±50, ±42, ±34, ±26, ±18, ±10, ±2 |

For 160 MHz and 80+80 MHz, the subcarrier indices for 80MHz from Table 7‑14 are used for each 80MHz frequency segment, with the low frequency segment appearing first, followed by the high frequency segment.

***Insert section 7.3.1.34:***

#### Operating Mode field

The Operating Mode field is used in a Operating Mode Notification frame (see 7.4.12.4) to indicate the operating channel width and Nss on which the sending STA is able to receive. The length of the field is 1 octet.

The Operating Mode field is shown in Figure 7‑4.

|  |  |  |  |
| --- | --- | --- | --- |
| B0-B1 | B2-B3 | B4-B6 | B7 |
| Channel Width | Reserved | Rx Nss | Max Nss for SU Present |

Figure ‑--Operating Mode field

The STA transmitting this field indicates its current operating channel width and the number of spatial streams it can receive using the settings defined in Table 7‑15.

Table ‑—Subfield values of the Operating Mode field

|  |  |
| --- | --- |
| **Subfield** | **Description** |
| Channel Width | If Max Nss for SU Present is set to 0, indicates the supported channel width:  Set to 0 for 20MHz  Set to 1 for 40MHz  Set to 2 for 80MHz  Set to 3 for 160MHz or 80+80MHz  Reserved if Max Nss For SU Present is set to 1. |
| Rx Nss | The maximum number of spatial streams the STA can receive interpreted according to the Max Nss For SU Present setting:  Set to 0 for *NSS*= 1  Set to 1 for *NSS*= 2  …  Set to 7 for *NSS*= 8 |
| Max Nss for SU Present | Set to 0 if Rx Nss indicates the supported number of spatial streams.  Set to 1 if Rx Nss indicates the maximum number of spatial streams the beamformee can receive in a single user beamformed transmission when an MU type feedback is used to do the transmission. |

If Max Nss For SU Present is set to 1, bits Rx Nss indicates the maximum number of spatial streams the beamformee can receive in a single user beamformed transmission when an MU type feedback is used to do the transmission. A beamformer is allowed to ignore this threshold when an SU type feedback is used to make a single user beamformed transmission.

### Information elements

#### 7.3.2.0a General

***Add elements to Table 7-26 (Element IDs) as shown below:***

**Table 7-26—Element IDs**

|  |  |  |  |
| --- | --- | --- | --- |
| **Element** | **Element ID** | **Length (in octets)** | **Extensible** |
| VHT Capability | <ANA> | TBD |  |
| VHT Operation | <ANA> | TBD |  |
| VHT BSS Load | <ANA> |  |  |

***Insert section 7.3.2.61:***

#### VHT Capabilities element

##### VHT Capabilities element structure

A VHT STA declares that it is a VHT STA by transmitting the VHT Capabilities element.

The VHT Capabilities element contains a number of fields that are used to advertise additional optional VHT capabilities of a VHT STA. The VHT Capabilities element is present in Beacon, Association Request, Association Response, Reassociation Request, Reassociation Response, Probe Request, and Probe Response frames. The VHT Capabilities element is defined in Figure 7‑5.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Element ID | Length | VHT Capabilities Info | VHT A-MPDU Parameters | VHT Supported MCS Set |
| Octets: 1 | 1 | TBD | 1 | TBD |

Figure ‑--VHT Capabilities element format

##### VHT Capabilities Info field

The VHT Capabilities Info field is 4 octets in length. The structure of this field is defined in Figure 7‑6.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | B0-B1 | B2-B3 | B4 | B5-B6 | B7 | B8 | B9 | B10 |
|  | Maximum MPDU Length | Supported Channel Width Set | LDPC Coding Capability | Short GI for 20/40/80/160 | Tx STBC | Rx STBC | SU Beamformer Capable | SU Beamformee Capable |
| Bits: | 2 | 2 | 1 | 2 | 1 | 1 | 1 | 1 |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| B11-B12 | B13-B15 | B16-B18 | B19 | B20 | B21 | B22-B31 |
| Grouping Set | Compressed Steering Number of Beamformer Antennas Supported | Number Of Sounding Dimensions | MU Tx Capable | MU Rx Capable | VHT TXOP PS | Reserved |
| 2 | 3 | 3 | 1 | 1 | 1 | 13 |

Figure ‑--VHT Capabilities Info field

The subfields of the VHT Capabilities Info field are defined in Table 7‑16.

Table ‑--Subfields of the VHT Capabilities Info field

|  |  |  |
| --- | --- | --- |
| **Subfield** | **Definition** | **Encoding** |
| Maximum MPDU Length | Indicates the maximum MPDU length. See 9.7c. | Set to 0 for 3895 octets when Maximum A-MSDU Length in HT Capabilities set to 3839  Set to 1 for 7991 octets (Maximum A-MSDU Length in HT Capabilities set to 7935)  Set to 2 for 11454 octets (Maximum A-MSDU Length in HT Capabilities set to 7935)  The value 3 is reserved |
| Supported Channel Width Set |  | Set to 0 if the STA does not support either 160 or 80+80 MHz  Set to 1 if the STA supports 160 MHz  Set to 2 if the STA supports 160 MHz and 80+80 MHz  The value 3 is reserved |
| LDPC Coding Capability | Indicates support for receiving LDPC coded packets | Set to 0 if not supported  Set to 1 if supported |
| Short GI for 20/40/80/160 | Indicates support for receiving packets using the short guard interval in various bandwidths | TBD |
| Tx STBC | Indicates support for the transmission of at least 2x1 STBC | Set to 0 if not supported  Set to 1 if supported |
| Rx STBC | Indicates support for the reception of PPDUs using STBC | TBD |
| SU Beamformer Capable | Indicates support for operation as a single user beamformer | Set to 0 if not supported  Set to 1 if supported |
| SU Beamformee Capable | Indicates support for operation as a single user beamformee | Set to 0 if not supported  Set to 1 if supported |
| Grouping Set | Indicates acceptable values for the VHT MIMO Control Grouping parameter with sounding feedback | Set to 0 for *Ng* = 1  Set to 1 for *Ng* = 1 or 2  Set to 2 for *Ng* = 1 or 4  Set to 3 for *Ng* = 1, 2 or 4 |
| Compressed Steering Number of Beamformer Antennas Supported | Indicates the maximum number of beamformer antennas the beamformee can support when sending compressed beamforming feedback | Set to maximum value minus 1 |
| Number of Sounding Dimensions | Indicates the number of antennas used by the beamformer when sending beamformed transmissions | Set to value minus 1 |
| MU Tx Capable | Indicates whether or not the STA supports operation as an MU beamformer | Set to 0 if not supported  Set to 1 if supported |
| MU Rx Capable | Indicates whether or not the STA supports operation as an MU beamformee | Set to 0 if not supported  Set to 1 if supported |
| VHT TXOP PS | Indicates whether or not AP supports VHT TXOP PS Mode for STAs in BSS when included in Beacon/Probe Response frames.  Indicates whether or not STA is in VHT TXOP PS mode when included on Association/Re-association requests | Set to 0 if VHT TXOP PS Mode at STAs in the BSS is not allowed.  Otherwise, set to 1.  Set to 0 if STA is not in VHT TXOP PS mode.  Otherwise, set to 1. |

*Note—A STA that sets MU Rx Capable to 0 is not able to demodulate an MU VHT PPDU with only one non-zero Nsts subfield.*

*Note—The Compressed Steering Number of Beamformer Antennas Supported field also indicates the maximum number of space time streams in the NDP packet that the STA can support as a beamformee.*

##### VHT A-MPDU Parameters field

The structure of the A-MPDU Parameters field of the VHT Capabilities element is shown in Figure 7‑7.

|  |  |
| --- | --- |
| B0-B2 | B3-B7 |
| Maximum A-MPDU Length Exponent | Reserved |

Figure ‑--VHT A-MPDU Parameters field

The subfields of the A-MPDU Parameters field are defined in Table 7‑17.

Table ‑--Subfields of the A-MPDU Parameters field

|  |  |  |
| --- | --- | --- |
| **Subfield** | **Definition** | **Encoding** |
| Maximum A-MPDU Length Exponent | Indicates the maximum length of A-MPDU that the STA can receive. | This field is an integer in the range of 0 to 7.  The length defined by this field is equal to  octets. |

##### VHT Supported MCS Set field

The VHT Supported MCS Set field is 8 octets in length. This field is used to convey the combinations of MCSs and spatial streams a STA supports for both reception and transmission. The structure of the field is shown in Figure 7‑8.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | B0-B15 | B16-B28 | B29 | B30-B45 | B46-B58 | B59-B63 |
|  | Rx MCS Map | Rx Highest Supported Data Rate | Tx MCS Set Defined | Tx MCS Map | Tx Highest Supported Data Rate | Reserved |
| Bits: | 16 | 13 | 1 | 16 | 13 | 5 |

Figure ‑--VHT Supported MCS Set

The Rx MCS Map subfield and the Tx MCS Map subfield are each 2 octets in length and have the structure shown in Figure 7‑9.



Figure ‑—Rx MCS Map and Tx MCS Map

The VHT Supported MCS Set subfields are defined in Table 7‑18.

Table ‑--VHT Supported MCS Set subfields

|  |  |  |
| --- | --- | --- |
| **Subfield** | **Definition** | **Encoding** |
| Rx MCS Map | Indicates the maximum MCS that can be received for each number of spatial streams. | The 2-bit max MCS for each spatial stream number is encoded as follows:   * 00 indicates support for MCS 0-7 * 01 indicates support for MCS 0-8 * 10 indicates support for MCS 0-9 * 11 indicates no support for that *NSS* |
| Rx Highest Supported Data Rate | Indicates the max data rate the STA can receive. | In units of 1 Mb/s where 1 represents 1 Mb/s, and incrementing in steps of 1 Mb/s |
| Tx MCS Set Defined | Indicates whether or not the STA is advertising its transmit MCS capability | Set to 0 if transmit MCS capability is not advertised  Set to 1 if transmit MCS capability is advertised |
| Tx MCS map | If Tx MCS Set Defined is 1, this indicates the maximum MCS that can be transmitted for each number of spatial streams. | If Tx MCS Set Defined is set to 1, then the 2-bit max MCS for each spatial stream number is encoded as follows:   * 00 indicates support for MCS 0-7 * 01 indicates support for MCS 0-8 * 10 indicates support for MCS 0-9 * 11 indicates no support for that *NSS*   If Tx MCS Set Defined is set to 0, then this field is reserved. |
| Tx Highest Supported Data Rate | If Tx MCS Set Defined is set to 1, indicates the max data rate that the STA will transmit. | If Tx MCS Set Defined is set to 1, then set to the highest supported data rate in units of 1 Mb/s where 1 represents 1 Mb/s, and incrementing in steps of 1 Mb/s.  If Tx MCS Set Defined is set to 0, then this field is reserved. |

***Insert section 7.3.2.62:***

#### VHT Operation element

The operation of VHT STAs in the BSS is controlled by the HT Operation element and the VHT Operation element. The format of the VHT Operation element is defined in Figure 7‑10.

|  |  |  |  |
| --- | --- | --- | --- |
| Element ID | Length | VHT Operational Information | Basic MCS Set |
| Octets: 1 | 1 | TBD | TBD |

Figure ‑--VHT Operation element format

The Element ID field is set to the value for VHT Operation element defined in Table 7-26 (Element IDs).

The structure of the VHT Operation Information field is defined in Figure 7‑11.

|  |  |  |  |
| --- | --- | --- | --- |
| STA Channel Width | Channel Center Frequency  Segment 1 | Channel Center Frequency  Segment 2 | Other Fields |
| Octets: 1 | 1 | 1 | TBD |

Figure ‑--VHT Operation Information field

The VHT STA gets the primary channel information from the HT Operation element. The fields of the VHT Operation Information field are shown below in Table 7‑19.

Table ‑--VHT Operational Information element fields

|  |  |  |
| --- | --- | --- |
| **Field** | **Definition** | **Encoding** |
| STA Channel Width | Defines the channel widths that may be used to transmit to the STA. | Set to 0 for 20 MHz channel width.  Set to 1 for 40 MHz channel width.  Set to 2 for 80 MHz channel width.  Set to 3 for 160 MHz channel width  Set to 4 for 80 + 80 MHz channel width. |
| Channel Center Frequency Segment 1 | Defines the channel center frequency for 20, 40, 80 and 160 MHz. Defines the segment 1 channel center frequency for 80+80 MHz channel width. | Set to n, the channel number corresponding to the channel center frequency of segment 1. |
| Channel Center Frequency Segment 2 | Defines the segment 2 channel center frequency for 80+80 MHz channel width. | Set to n, the channel number corresponding to the channel center frequency of segment 2 for 80+80 MHz channel width. Reserved otherwise. |

***Insert section 7.3.2.63:***

#### VHT BSS Load element

The VHT BSS Load element contains additional information on bandwidth utilization and MU-MIMO spatial stream underutilization. The element information format is defined in Figure 7‑12 (VHT BSS Load element format). The element may be used by the STA for vendor-specific AP selection algorithm.

|  |  |  |
| --- | --- | --- |
| Element ID | Length | Bandwidth Utilization and Spatial Stream Underutilization |
| Octets: 1 | 1 | TBD |

Figure ‑--VHT BSS Load element format

***Editor’s note: details on the element body (Bandwidth Utilization and Spatial Stream Underutilization) are pending.***

## Action frame format details



### DLS Action frame details

#### DLS Setup Request frame format

***Change Table 7-51, inserting the rows for order 10 and 11:***

**Table 7-51—DLS Request frame Action field format**

|  |  |  |
| --- | --- | --- |
| **Order** | **Information** | **Notes** |
| 10 | Source Association ID | The Association ID (as specified in 7.3.1.8) of the STA sending the frame |
| 11 | VHT Capabilities | The VHT Capabilities element is present if the dot11VHTOptionImplemented attribute is true |

#### DLS Setup Response frame format

***Change Table 7-52, inserting the rows for order 10 and 11:***

**Table 7-52—DLS Response frame Action field format**

|  |  |  |
| --- | --- | --- |
| **Order** | **Information** | **Notes** |
| 10 | Destination Association ID | The Association ID (as specified in 7.3.1.8) of the STA sending the frame |
| 11 | VHT Capabilities | The VHT Capabilities element is present if the dot11VHTOptionImplemented attribute is true |

***Insert the following paragraph at the end of this section:***

The Destination Association ID field is the AID of the target STA that is defined in 7.3.1.8.



### TDLS Action frame details

#### TDLS Setup Request frame format

***Change Table 7-57v2, appending the rows for Order 18 and 19:***

**Table 7-57v2—Information for TDLS Setup Request frame**

|  |  |  |
| --- | --- | --- |
| **Order** | **Information** | **Notes** |
| 18 | Source Association ID | The Association ID (as specified in 7.3.1.8) of the STA sending the frame |
| 19 | VHT Capabilities | The VHT Capabilities element is present if the dot11VHTOptionImplemented attribute is true |

#### TDLS Setup Response frame format

***Change Table 7-57v3, appending the rows for Order 19 and 20:***

**Table 7-57v3—Information for TDLS Setup Response frame**

|  |  |  |
| --- | --- | --- |
| **Order** | **Information** | **Notes** |
| 19 | Destination Association ID | The Association ID (as specified in 7.3.1.8) of the STA sending the frame |
| 20 | VHT Capabilities | The VHT Capabilities element is present if the dot11VHTOptionImplemented attribute is true |

***Insert section 7.4.12:***

### VHT Action frame details

#### VHT Action field

Several Action frame formats are defined to support VHT frames. The Action field values associated with each frame format within the VHT category are defined in Table 7‑20.

Table ‑--VHT Action field values

|  |  |
| --- | --- |
| **Value** | **Meaning** |
| 0 | VHT Compressed Beamforming |
| 1 | Group ID Management |
| 2 | Operating Mode Notification |
|  |  |

#### VHT Compressed Beamforming frame format

The VHT Compressed Beamforming frame format is an Action No Ack frame of category VHT. The frame format is defined below in Table 7‑21.

Table ‑--VHT Compressed Beamforming frame body

|  |  |
| --- | --- |
| **Order** | **Information** |
| 1 | Category |
| 2 | Action |
| 3 | VHT MIMO Control (see 7.3.1.12) |
| 4 | VHT Compressed Beamforming Report (see 7.3.1.32) |
| 5 | MU Exclusive Beamforming Report (see 7.3.1.33) |

The Category field is set to the value for VHT.

The Action field is set to the value for VHT Compressed Beamforming, specified in Table 7‑20.

The MU Exclusive Beamforming Report field is only present when the Feedback Type subfield in the VHT MIMO Control field is set to 1.

#### Group ID Management

The Group ID Management frame is used to assign or change STA positions corresponding to one or more Group IDs. The frame body in such frames shall consist of a 24 octet Group ID Assignment field that contains 3 bits for each one of the 64 group IDs. The 3 bits for each group ID consist of the following:

* 1 bit “membership status” that specifies whether or not the STA is a member of the corresponding group ID
* 2 bit STA position that specifies spatial stream position of the STA in the corresponding group ID

The classification of this action frame as “robust” is TBD. The exact location of the above fields within the frame body is also TBD.

#### Operating Mode Notification

The Operating Mode Notification frame is used to notify STAs that the transmitting STA is changing its operating channel width, the maximum number of spatial streams it can receive, or both. See definition in 11.14.2. This frame can be sent by both non-AP STA and AP. If an AP wishes to change its operating mode, it broadcasts this Action frame to all STAs in the BSS.

The format of the Operating Mode Notification Action frame body is defined in Table 7‑22.

Table ‑--Operating Mode Notification

|  |  |
| --- | --- |
| **Order** | **Information** |
| 1 | Category |
| 2 | Action |
| 3 | Operating Mode (see 7.3.1.34) |

The Category field is set to the value for VHT, specified in Table 7-24.

The Action field is set to the value for Operating Mode Notification, specified in Table 7‑20.

## 7.4a Aggregate MPDU (A-MPDU)

### 7.4a.1 A-MPDU format

***Change section 7.4a.1 as follows:***

An A-MPDU consists of a sequence of one or more A-MPDU subframes and 0 to 3 octets of EOF Pad, as shown in Figure 7-101o (A-MPDU format).

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | A-MPDU subframe 1 | A-MPDU subframe 2 | … | A-MPDU subframe n | EOF Pad |
| Octets: | variable | variable |  | variable | 0-3 |

Figure 7-101o—A-MPDU format

The structure of the A-MPDU subframe is shown in Figure 7-101p (A-MPDU subframe format). Each A-MPDU subframe consists of an MPDU delimiter followed by an MPDU. Except when an A-MPDU subframe is the last one in an A-MPDU and there are zero octets EOF Pad, padding octets are appended to make each A-MPDU subframe a multiple of 4 octets in length. The last A-MPDU subframe is padded to the last octet of the PSDU or to a multiple of 4 octets in length, whichever comes first. The A-MPDU maximum length for an HT\_MF or HT\_GF format PPDU is 65,535 octets. The A-MPDU maximum length for a VHT format PPDU excluding EOF delimiters and EOF Pad is 1,048,575 octets. The length of an A-MPDU addressed to a particular STA may be further constrained as described in 9.7d.2 (A-MPDU length limit rules).



The MPDU delimiter is 4 octets in length. The structure of the MPDU delimiter is defined in Figure 7-101p1 (MPDU delimiter).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| B0 | B1 | B2 B15 | B16 B23 | B24 B31 |
| EOF | Reserved | MPDU Length | CRC | Delimiter Signature |

Figure 7-101p1—MPDU delimiter

The fields of the MPDU delimiter are defined in Table 7-57w (MPDU delimiter fields).

Table 7-57w— MPDU delimiter fields

|  |  |  |
| --- | --- | --- |
| **Field** | **Size (bits)** | **Description** |
| EOF | 1 | End of Frame indication. Set to 1 in all zero length A-MPDU subframes following the last non-zero length A-MPDU subframe in a VHT PPDU. May be set to 1 in a single A-MPDU subframe of non-zero length as described in 9.7d.7. Set to 0 otherwise. |
| Reserved | ~~4~~1 |  |
| MPDU length | ~~12~~14 | Length of the MPDU in octets. |
| CRC | 8 | 8-bit CRC of the preceding 16-bits |
| Delimiter Signature | 8 | Pattern that may be used to detect an MPDU delimiter when scanning for a delimiter.  The unique pattern is set to the value 0x4E.  NOTE—As the Delimiter Signature field was created by the IEEE 802.11 Task Group n, it chose the ASCII value for the character ‘N’ as the unique pattern. |

The format of the MPDU Length field is shown in Figure 7‑13. The MPDU Length High and MPDU Length Low subfields contain the two high order and 12 low order bits respectively of the MPDU length.

|  |  |
| --- | --- |
| B2-B3 | B4-B15 |
| MPDU Length High | MPDU Length Low |

Figure 7‑13--MPDU Length field

*NOTE—The format of the MPDU Length field maintains a common encoding structure for both VHT and HT format PPDUs. For HT PPDUs only the MPDU Length Low field is used, while for VHT format PPDUs both subfields are used.*

The purpose of the MPDU delimiter is to locate the MPDUs within the A-MPDU so that the structure of the A-MPDU can usually be recovered when one or more MPDU delimiters are received with errors. See T.2 (A-MPDU deaggregation) for a description of a deaggregation algorithm.

A delimiter with MPDU length zero is valid. This value is used as defined in 9.7d.3 (Minimum MPDU Start Spacing field) to meet the minimum MPDU start spacing requirement and also to pad the A-MPDU to fill the available octets in a VHT PPDU as defined in 9.7d.6 (A-MPDU padding for VHT format PPDUs).

### 7.4a.3 A-MPDU contents

***Change 7.4a.3 as follows:***

An A-MPDU is a sequence of MPDUs carried in a single PPDU either with FORMAT set to VHT or with FORMAT set to HT\_MF or HT\_GF and with the TXVECTOR/RXVECTOR AGGREGATION parameter set to 1.

All the MPDUs within an A-MPDU are addressed to the same RA. All QoS data frames within an A-MPDU that have a TID for which an HT-immediate Block Ack agreement exists have the same value for the Ack Policy subfield of the QoS Control field.

All protected MPDUs within an A-MPDU have the same Key ID.

The Duration/ID fields in the MAC headers of all MPDUs in an A-MPDU carry the same value.

An A-MPDU is transmitted in one of the contexts specified in . Ordering of MPDUs within an A-MPDU is not constrained, except where noted in these tables. See 9.7d.1 (A-MPDU contents).

NOTE 1—The TIDs present in a data enabled A-MPDU context are also constrained by the channel access rules (for a TXOP holder, see 9.9.1 (HCF contention-based channel access (EDCA)) and 9.9.2 (HCCA)) and the RD response rules (for an RD responder, see 9.15.4 (Rules for RD responder)). This is not shown in these tables.

NOTE 2—~~MPDUs carried in an A-MPDU are limited to a maximum length of 4095 octets.~~ If a STA supports A-MSDUs of 7935 octets (indicated by the Maximum A-MSDU Length field in the HT Capabilities element), A-MSDUs transmitted by that STA within an A-MPDU carried in a PPDU with FORMAT HT\_MF or HT\_GF are constrained so that the length of the QoS data MPDU carrying the A-MSDU is no more than 4095 octets. The use of A-MSDU within A-MPDU can be further constrained as described in 7.3.1.14 through the operation of the A-MSDU Supported field. The 4095 octet MPDU length limit does not apply to A-MPDUs carried in VHT format PPDUs.

***Change Table 7-57x as follows:***

|  |  |  |
| --- | --- | --- |
| * A-MPDU Contexts | | |
| Name of Context | Definition of Context | Table defining permitted contents |
| VHT single MPDU context | The A-MPDU contains a single MPDU of non-zero length. | Table 7-57ab1 |
| Data Enabled Immediate Response | The A-MPDU is transmitted outside a PSMP sequence by a TXOP holder or an RD responder including potential immediate responses. | Table 7-57z |
| Data Enabled No Immediate Response | The A-MPDU is transmitted outside a PSMP sequence by a TXOP holder that does not include or solicit an immediate response.  See NOTE. | Table 7-57aa |
| PSMP | The A-MPDU is transmitted within a PSMP sequence. | Table 7-57ab |
| Control Response | The A-MPDU is transmitted by a STA that is neither a TXOP holder nor an RD responder that also needs to transmit one of the following immediate response frames:  Ack  BlockAck with a TID for which an HT-immediate Block Ack agreement exists |  |
| MU PPDU | The A-MPDU is transmitted within a MU PPDU | Table 7-57ab2 |
| NOTE—This context includes cases when no response is generated or when a response is generated later by the operation of the delayed Block Ack rules. | | |

***Insert table 7-57ab1 as follows:***

|  |  |
| --- | --- |
| Table 7-57ab1--A-MPDU contents MPDUs in VHT single MPDU context | |
| MPDU | Conditions |
| Any MPDU | Any single MPDU.  [The A-MPDU is carried in a PPDU with the TXVECTOR FORMAT parameter set to VHT.]  The delimiter preceding the MPDU has the EOF field set to 1. |

***Add the following table:***

|  |  |
| --- | --- |
| Table 7-57ab2--A-MPDU contents MPDUs in MU PPDU context | |
| MPDU | Conditions |
| Any MPDU | At most one A-MPDU in the MU PPDU is allowed to contain one or more MPDUs that solicit an immediate response |

# Security



## RSNA security association management



### RSNA policy selection in an ESS

***Insert the following text at the end of the 3rd paragraph of section 8.4.3:***

Within an ESS, a VHT STA shall eliminate TKIP and GCMP as choices for the pairwise cipher suite if CCMP is advertised by the AP or if the AP included either an HT Capabilities element or a VHT Capabilities element in its Beacon and Probe Response frames. The elimination of TKIP and GCMP as choices for the pairwise cipher suite may result in a lack of overlap of the remaining pairwise cipher suite choices, in which case the VHT STA shall decline to create an RSN association with that AP.

### RSNA policy selection in an IBSS and for DLS

***Insert the following text after the 3rd paragraph of section 8.4.4:***

A VHT STA that is in an IBSS or that is transmitting frames through a direct link shall eliminate TKIP and GCMP as choices for the pairwise cipher suite if CCMP is advertised by the other STA or if the other STA included either an HT Capabilities element or a VHT Capabilities element in any of its Beacon, Probe Response, DLS Request, or DLS Response messages.

*NOTE—The elimination of TKIP and GCMP as choices for the pairwise cipher suite might result in a lack of overlap of the remaining pairwise cipher suites choices, in which case the STAs will not exchange encrypted frames.*

# MAC sublayer functional description

## MAC architecture



### Fragmentation/defragmentation overview

***Change the second and fifth paragraphs of 9.1.5 as follows:***

An MSDU transmitted under HT-immediate or HT-delayed Block Ack agreement shall not be fragmented even if its length exceeds dot11FragmentationThreshold. An MSDU transmitted within an A-MPDU that is not a VHT single MPDU shall not be fragmented even if its length exceeds dot11FragmentationThreshold. Group addressed MSDUs or MMPDUs shall not be fragmented even if their length exceeds dot11FragmentationThreshold.

Except as described below, when an individually addressed MSDU is received from the LLC or an individually addressed MMPDU is received from the MLME that would result in an MPDU of length greater than dot11FragmentationThreshold, the MSDU or MMPDU shall be fragmented. The exception applies when an MSDU is transmitted using an HT-immediate or HT-delayed Block Ack agreement or when the MSDU or MMPDU is carried in an A-MPDU that is not a VHT single MPDU, in which case the MSDU or MMPDU is transmitted without fragmentation. Each fragment is a frame no longer than dot11FragmentationThreshold, if security encapsulation is not invoked for the MPDU. If security encapsulation is active for the MPDU, then the fragments shall be expanded by the encapsulation overhead and this may result in a fragment larger than dot11FragmentationThreshold. It is possible that any fragment may be a frame smaller than dot11FragmentationThreshold. An illustration of fragmentation is shown in Figure 9-2 (Fragmentation).

## DCF

### 9.2.0a General

***Change the sixth paragraph as follows:***

The RTS/CTS exchange also performs both a type of fast collision inference and a transmission path check. If the return CTS is not detected by the STA originating the RTS, the originating STA may repeat the process (after observing the other medium-use rules) more quickly than if the long data frame had been transmitted and a return ACK frame had not been detected. For VHT STAs, the RTS/CTS exchange also performs fast collision inference on secondary channels, helping the STA originating the RTS to determine the available bandwidth at the responder.

### 9.2.0b Procedures common to both DCF and EDCAF

#### 9.2.0b.4 IFS

##### 9.2.0b.4.2 RIFS

***Insert as the last paragraph of section 9.2.0b.4.2:***

The use of RIFS is deprecated for VHT STAs; a VHT STA shall not transmit frames separated by a RIFS.

##### 9.2.0b.4.4 PIFS

***Change the second paragraph as follows:***

The PIFS may be used as described in the following list and shall not be used otherwise:

* A STA operating under the PCF as described in 9.3 (PCF)
* A STA transmitting a Channel Switch Announcement frame as described in 11.9 (DFS procedures)
* An HC starting a CFP or a TXOP as described in 9.9.2.1.2 (CAP generation)
* An HC or a non-AP QoS STA that is a polled TXOP holder recovering from the absence of an expected reception in a CAP as described in 9.9.2.1.3 (Recovery from the absence of an expected reception)
* An HT STA using dual CTS protection before transmission of the CTS2 as described in 9.2.0b.8 (Dual CTS protection)
* A TXOP holder continuing to transmit after a transmission failure as described in 9.9.1.4 (Multiple frame transmission in an EDCA TXOP)
* An RD initiator continuing to transmit using error recovery as described in 9.15.3 (Rules for RD initiator)
* An HT AP during a PSMP sequence transmitting a PSMP recovery frame as described in 9.16.1.3 (PSMP uplink transmission (PSMP-UTT))
* An HT STA performing clear channel assessment (CCA) in the secondary channel before transmitting a 40 MHz mask PPDU using EDCA channel access as described in 11.14.9 (STA CCA sensing in a 20/40 MHz BSS)
* A VHT STA performing clear channel assessment (CCA) in the secondary 20/40/80 channels before transmitting a 40/80/160/80+80 MHz mask PPDU using EDCA channel access as described in 11.20.4 (STA CCA sensing in a VHT BSS)

***Insert section 9.2.0b.6a following section 9.2.0b.6***

#### 9.2.0b.6a VHT RTS procedure

A VHT STA transmitting a RTS frame carried in non-HT or non-HT duplicate format and addressed to a VHT STA shall set the INDICATED\_CH\_BANDWIDTH TXVECTOR parameter to the same value as the CH\_BANDWIDTH TXVECTOR parameter and shall set the Individual/Group bit in the TA field to 1. If the VHT STA sending the RTS frame is using dynamic bandwidth operation, it shall set the INDICATED\_DYN\_BANDWIDTH TXVECTOR parameter to Dynamic. Otherwise, the STA shall set the INDICATED\_DYN\_BANDWIDTH TXVECTOR parameter to Static.

If a VHT STA receives a RTS frame with the Individual/Group subfield in the TA field set to 1, then the INDICATED\_DYN\_BANDWIDTH RXVECTOR parameter and the INDICATED\_CH\_BANDWIDTH RXVECTOR parameter are valid.

A VHT STA that initiates a TXOP by transmitting a RTS with the Multicast/Unicast bit in the TA set to Multicast, shall not send a RTS to a legacy STA for the duration of the TXOP.

#### 9.2.0b.7 CTS procedure

***Edit section 9.2.0b.7 as follows:***

A non-VHT STA that is addressed by an RTS frame shall transmit a CTS frame after a SIFS period if the NAV at the STA receiving the RTS frame indicates that the medium is idle.

If the INDICATED\_DYN\_BANDWIDTH RXVECTOR parameter for a RTS frame is valid and set to Static, the VHT STA addressed by the RTS frame shall respond with a non-HT or non-HT duplicate CTS frame over all channels that are specified by the INDICATED\_CH\_BANDWIDTH parameter of the RTS frame if all non-primary channels indicated by the RTS frame have met the following condition: the PHY-CCA.indication primitive indicates IDLE during an interval of PIFS before the RTS frame is received. A VHT STA that is addressed by the RTS frame shall not respond with a CTS frame if the condition is not met for any non-primary channel indicated by the RTS frame.

If the INDICATED\_DYN\_BANDWIDTH RXVECTOR parameter for a RTS frame is valid and set to Dynamic, the VHT STA that is addressed by the RTS frame shall respond with a CTS frame over the primary channel and may respond with a CTS frame over the non-primary channels that are specified in the INDICATED\_CH\_BANDWIDTH parameter for the RTS frame and have been indicated idle in the PHY-CCA.indication primitive during an interval of PIFS before the RTS frame is received.

If the NAV at the STA receiving the RTS indicates the medium is not idle and the MAC address in the TA field in the RTS frame does not match the saved TXOP holder address (see section 9.9.2.2a), that STA shall not respond to the RTS frame.

The RA field of the CTS frame shall be the value obtained from the TA field of the RTS frame to which this CTS frame is a response and the Individual/Group bit in the RA field shall be set to 0. The Duration field in the CTS frame shall be the duration field from the received RTS frame, adjusted by subtraction of aSIFSTime and the number of microseconds required to transmit the CTS frame at a data rate determined by the rules in 9.7 (Multirate support).

A VHT STA transmitting a CTS frame in response to a RTS frame with a valid INDICATED\_CH\_BANDWIDTH parameter shall set the INDICATED\_CH\_BANDWIDTH TXVECTOR parameter to the same value as the CH\_BANDWIDTH TXVECTOR parameter.

The INDICATED\_CH\_BANDWIDTH RXVECTOR parameter of a CTS frame is valid if the CTS frame is the response to a RTS frame with a valid INDICATED\_CH\_BANDWIDTH TXVECTOR parameter.



## Multirate support

#### 9.6.0e.1 General rules for rate selection for control frames

***Change the first paragraph of 9.6.0e.1 as follows:***

Control frames carried in an A-MPDU that is not a VHT single MPDU shall be sent at a rate selected from the rules defined in 9.6.0d.6 (Rate selection for other data and management frames).

#### 9.6.0e.2 Rate selection for control frames that initiate a TXOP

***Change the first paragraph of 9.6.0e.2 as follows:***

This subclause describes the rate selection rules for control frames that initiate a TXOP and that are not carried in an A-MPDU that is not a VHT single MPDU.

#### 9.6.0e.4 Rate selection for control frames that are not control response frames

***Change the first paragraph of 9.6.0e.4 as follows:***

This subclause describes the rate selection rules for control frames that are not control response frames, are not the frame that initiates a TXOP, are not the frame that terminates a TXOP, and are not carried in an A-MPDU that is not a VHT single MPDU.

#### 9.6.0e.6 Channel Width selection for control frames

***Insert the following as the first paragraph of section 9.6.0e.6:***

A VHT STA that transmits a control frame carried in non-HT or non-HT duplicate format and addressed to a VHT STA and eliciting a control response frame or a sounding feedback management frame shall set the INDICATED\_CH\_BANDWIDTH TXVECTOR parameter of the control frame to the same value as the CH\_BANDWIDTH TXVECTOR parameter and shall set the Individual/Group bit in the TA field to 1.

***Change the remainder of 9.6.0e.6 as follows:***

An HT or VHT STA that receives a frame that elicits a control frame transmission shall send the control frame response using a value for the CH\_BANDWIDTH parameter that is based on the CH\_BANDWIDTH parameter value of the received frame according to Table 9-3 (CH\_BANDWIDTH control frame response mapping).

**Table 9.3—CH\_BANDWIDTH control frame response mapping**

|  |  |
| --- | --- |
| **CH\_BANDWIDTH**  **RXVECTOR value** | **CH\_BANDWIDTH**  **TXVECTOR value** |
| HT\_CBW20 | HT\_CBW20 or NON\_HT\_CBW20 |
| HT\_CBW40 | HT\_CBW40 or NON\_HT\_CBW40 |
| HT\_CBW80 | HT\_CBW80 or NON\_HT\_CBW80 |
| HT\_CBW160 | HT\_CBW160 or NON\_HT\_CBW160 |
| HT\_CBW80+80 | HT\_CBW80+80 or NON\_HT\_CBW80+80 |
| NON\_HT\_CBW20 | HT\_CBW20 or NON\_HT\_CBW20 |
| NON\_HT\_CBW40 | HT\_CBW40 or NON\_HT\_CBW40 |
| NON\_HT\_CBW80 | HT\_CBW80 or NON\_HT\_CBW80 |
| NON\_HT\_CBW160 | HT\_CBW160 or NON\_HT\_CBW160 |
| NON\_HT\_CBW80+80 | HT\_CBW80+80 or NON\_HT\_CBW80+80 |

A VHT STA that receives a frame with a valid INDICATED\_CH\_BANDWIDTH RXVECTOR parameter and that elicits a response frame shall send the response frame with the CH\_BANDWIDTH TXVECTOR parameter set according to Table 9-3a (INDICATED\_ CH\_BANDWIDTH to CH\_BANDWIDTH response frame mapping).

Table ‑3a--INDICATED\_CH\_BANDWIDTH RXVECTOR to CH\_BANDWIDTH TXVECTOR mapping

|  |  |
| --- | --- |
| **INDICATED\_CH\_BANDWIDTH**  **RXVECTOR value** | **CH\_BANDWIDTH**  **TXVECTOR value** |
| NON\_HT\_CBW20 | HT\_CBW20 or NON\_HT\_CBW20 |
| NON\_HT\_CBW40 | HT\_CBW40, NON\_HT\_CBW20, or NON\_HT\_CBW40 |
| NON\_HT\_CBW80 | HT\_CBW80, NON\_HT\_CBW20, NON\_HT\_CBW40, or NON\_HT\_CBW80 |
| NON\_HT\_CBW160 | HT\_CBW160, NON\_HT\_CBW20, NON\_HT\_CBW40, NON\_HT\_CBW80, NON\_HT\_CBW160 |
| NON\_HT\_CBW80+80 | HT\_CBW160, NON\_HT\_CBW20, NON\_HT\_CBW40, NON\_HT\_CBW80, or NON\_HT\_CBW80+80 |

The INDICATED\_CH\_BANDWIDTH and CH\_BANDWIDTH TXVECTOR parameters for a non-HT or non-HT duplicate CTS frame sent as a response to an non-HT or non-HT duplicate RTS frame may be set to indicate a narrower bandwidth than indicated in the INDICATED\_CH\_BANDWIDTH RXVECTOR parameter of the RTS frame.

The CH\_BANDIWDTH TXVECTOR parameters for a non-HT or non-HT duplicate frame that is not a CTS and that is a response to a non-HT or non-HT duplicate frame with a valid INDICATED\_CH\_BANDWDITH RXVECTOR parameter, shall be set to the same value as the received INDICATED\_CH\_BANDWIDTH RXVECTOR parameter.

## 9.7c A-MSDU operation

***Change the last paragraph of 9.7c and insert a subsequent paragraph as follows:***

A STA shall not transmit an A-MSDU in a HT PPDU to a STA that exceeds its maximum A-MSDU length capability indicated in the HT Capabilities element.

A VHT STA that sets the Maximum MPDU Length in the VHT Capabilities element to indicate 3895 octets shall set the Maximum A-MSDU Length in the HT Capabilities element to indicate 3839 octets. A VHT STA that sets the Maximum MPDU Length in the VHT Capabilities element to indicate 7991 octets or 11454 octets shall set the Maximum A-MSDU Length in the HT Capabilities element to indicate 7935 octets.

A STA shall not transmit an MPDU in a VHT format PPDU to a STA that exceeds the maximum MPDU length capability indicated in the VHT Capability element.

## 9.7d A-MPDU operation

9.7d.1 A-MPDU contents

9.7d.2 A-MPDU length limit rules

9.7d.3 Minimum MPDU Start Spacing field

9.7d.4 A-MPDU aggregation of group addressed data frames

9.7d.5 Transport of A-MPDU by the PHY data service

***Change the paragraph in 9.7d.5 as follows:***

An A-MPDU shall be transmitted in a PSDU associated with a PHY-TXSTART.request primitive

with the TXVECTOR AGGREGATION parameter set to 1 or the TXVECTOR.FORMAT parameter set to VHT. A received PSDU is determined to be an A-MPDU when the associated PHY-RXSTART.indication primitive RXVECTOR AGGREGATION parameter is set to 1 or the TXVECTOR.FORMAT parameter is set to VHT.

***Append the following paragraph to section 9.7d.5:***

MPDUs in an A-MPDU carried in a PPDU with FORMAT HT\_MF or HT\_GF shall be limited to a maximum length of 4095 octets.

***Insert sections 9.7d.6 and 9.7d.7:***

9.7d.6 A-MPDU padding for VHT format PPDU

A VHT STA that delivers an A-MPDU to the PHY (using PHY-DATA.request primitives) as the PSDU for a VHT format PPDU shall pad the A-MPDU as described in this subclause. An A-MPDU is constructed from the MPDUs available for transmission and meeting the A-MPDU content, length limit and MPDU start spacing constraints. The length of the resulting A-MPDU, A-MPDU\_Length, is used as the LENGTH parameter in the PLME-TXTIME.request (see 10.4.6) primitive and in the MAC padding procedure of this subclause. The PLME-TXTIME.confirm (see 10.4.7) primitive provides the TXTIME and PSDU\_LENGTH parameters for the transmission. Padding is then added to the A-MPDU such that the resulting A-MPDU contains exactly PSDU\_LENGTH octets.

Once PSDU\_LENGTH is known, A-MPDU padding proceeds as follows:

* While A-MPDU\_Length < PSDU\_LENGTH and A-MPDU\_Length mod 4 != 0, add a subframe padding octet and increment A-MPDU\_Length by 1
* While A-MPDU\_Length + 4 <= PSDU\_LENGTH, add a zero length A-MPDU subframe with EOF set to 1 and increment A-MPDU\_Length by 4
* While A-MPDU\_Length < PSDU\_LENGTH, add a padding octet and increment A-MPDU\_Length by 1

9.7d.7 Transport of VHT single MPDUs

An MPDU contained within an A-MPDU that contains a single non-zero length A-MPDU subframe with the EOF field set to 1 is called a VHT single MPDU.

The EOF field in the non-zero length A-MPDU subframe of an A-MPDU that carries a single non-zero length A-MPDU subframe may be set to 1. The EOF field of all other non-zero length A-MPDU subframes shall be set to 0.

A VHT single MPDU shall follow the rules for non-A-MPDU operation, regardless of its being transported in an A-MPDU. This affects the following behavior:

* The MPDU may carry a fragmented MSDU, A-MSDU or MMPDU (See 9.1.5)
* Rate selection of control responses (See 9.6)
* A single MSDU, MMPDU or A-MSDU may be transmitted in a SU PPDU when the TXOP limit is 0, which may result in transmission of multiple VHT single MPDUs.
* A data MPDU cannot indicate an Ack Policy of “Implicit Block Ack”, and does not generate a Block Ack response.
* A data MPDU may indicate an Ack Policy of “Normal Ack”, which generates an Ack immediate response. No Block Ack agreement is necessary in this case.
* A QoS+CF-ACK frame may also include an RDG as described in 9.15.3
* A QoS+CF-ACK may be sent in response to a QoS Data +HTC MPDU with Ack Policy set to Normal Ack and the RDG/More PPDU subfield set to 1 (see 9.15.4).
* Management frames sent in a VHT PPDU and that elicit an ACK response shall be carried as a VHT single MPDU.

## 9.7x Partial AID in VHT PPDUs

The Partial AID parameter in the TXVECTOR is set as follows:

In a VHT PPDU that carries group addressed MPDUs, the TXVECTOR PARTIAL\_AID parameter is set to 0.

In a VHT PPDU that carries MPDUs addressed to a single non-AP STA, the TXVECTOR PARTIAL\_AID parameter is set to:

Where A[b:c] indicates the bits in positions from b to c of the binary representation of A; ⨁ is a bitwise exclusive OR operation; << 5 indicates a 5 positions bit shift operation towards MSB; mod X indicates the X-modulo operation; AID is the AID of the recipient STA. BSSID is the BSSID the STA is associated with.

In DLS or TDLS transmission, the AID for the peer STA is obtained from DLS Setup Request and Response frame or TDLS Setup Request and Response frame.

In a VHT PPDU that carries MPDUs addressed to an AP STA, the TXVECTOR PARTIAL\_AID parameter is set to the lower 9 bits of the BSSID.

In a VHT PPDU addressed to an IBSS peer STA, the TXVECTOR PARTIAL\_AID parameter is set to 0



## HCF

### HCF contention-based channel access (EDCA)

#### Reference implementation

#### EDCA TXOPs

***Change the first 3 paragraphs of section 9.9.1.2 as follows:***

There are ~~two~~three modes of EDCA TXOP defined, the initiation of the EDCA TXOP, the sharing of the EDCA TXOP, and the multiple frame transmission within an EDCA TXOP. An initiation of the TXOP occurs when the EDCA rules permit access to the medium. A sharing of the EDCA TXOP occurs after an AC (the primary AC) of an AP has obtained the right to access to the medium and decided to share the TXOP with other ACs (secondary ACs) in the same AP. A multiple frame transmission within the TXOP occurs when an EDCAF retains the right to access the medium following the completion of a frame exchange sequence, such as on receipt of an ACK frame.

The TXOP limit duration values are advertised by the AP in the EDCA Parameter Set element in Beacon and Probe Response frames transmitted by the AP.

A TXOP limit value of 0 indicates that the TXOP holder may transmit or cause to be transmitted (as responses) the following within the current TXOP and using SU PPDUs:

1. A single MSDU, MMPDU, A-MSDU, or A-MPDU that is not a VHT single MPDU at any rate, subject to the rules in 9.6 (Multirate support)
2. Any required acknowledgments
3. Any frames required for protection, including one of the following:
   1. An RTS/CTS exchange
   2. CTS to itself
   3. Dual CTS as specified in 9.2.0b.8 (Dual CTS protection)
4. Any frames required for beamforming as specified in 9.17 (Sounding PPDUs)
5. Any frames required for link adaptation as specified in 9.16.2 (Scheduled PSMP)
6. Any number of BlockAckReq and BlockAck frames

In addition, a TXOP holder may transmit using a single MU PPDU A-MPDUs intended for different users.

***Insert section 9.9.1.2a***

#### 9.9.1.2a Sharing an EDCA TXOP

This mode only applies to an AP that supports DL MU-MIMO transmission. The EDCAF that is granted an EDCA TXOP, may choose to share the EDCA TXOP with EDCAFs of secondary ACs. Up to four STAs can be destinations for a DL MU-MIMO transmission. The destinations targeted by frames in the primary AC queue are primary destinations while the destinations targeted by frames in the secondary AC queues are secondary destinations. If a destination is targeted by frames in the queues of both primary AC and secondary AC, it is still a primary destination and the frames in the primary AC queue should be added to the A-MPDU for that destination first. The decision of which secondary ACs and secondary destinations are selected for TXOP sharing, as well as the order of transmissions, are implementation specific and is out of scope of this specification.

When sharing, the TXOP duration is bounded by the TXOP limit of the primary AC. In addition, the A-MPDU for one user in each DL MU-MIMO PPDU shall contain only MSDUs from the primary AC.

#### Obtaining an EDCA TXOP

#### Multiple frame transmission in an EDCA TXOP

***Change the first paragraph of section 9.9.1.4 as follows:***

Multiple frames may be transmitted in an EDCA TXOP that was acquired following the rules in 9.9.1.3 (Obtaining an EDCA TXOP) if there is more than one frame pending in the primary AC for which the channel has been acquired. However, those frames that are pending in other ACs shall not be transmitted in this EDCA TXOP except when transmitted as part of a MU-MIMO transmission and if allowed by the rules in 9.9.1.2a. If a TXOP holder has in its transmit queue an additional frame of the ~~same~~ primary AC ~~as the one just transmitted~~ and the duration of transmission of that frame plus any expected acknowledgment for that frame is less than the remaining TXNAV timer value, then the STA may commence transmission of that frame a SIFS (or RIFS, under the conditions defined in 9.3.2.4.2 (RIFS)) after the completion of the immediately preceding frame exchange sequence. An HT or VHT STA that is a TXOP holder may transmit multiple MPDUs of the same AC within an A-MPDU as long as the duration of transmission of the A-MPDU plus any expected BlockAck response is less than the remaining TXNAV timer value.

NOTE—An RD responder can transmit multiple MPDUs as described in 9.24.4 (Rules for RD responder)

The TXNAV timer is a timer that is initialized with the duration from the Duration/ID field in the frame most recently successfully transmitted by the TXOP holder. The TXNAV timer begins counting down from the end of the transmission of the PPDU containing that frame. Following the BlockAck response, the HT STA may start transmission of another MPDU or A-MPDU a SIFS after the completion of the immediately preceding frame exchange sequence. The HT STA may retransmit unacknowledged MPDUs within the same TXOP or in a subsequent TXOP.

After a valid response to the initial frame of a TXOP, if the Duration/ID field is set for multiple frame transmission and there is a subsequent transmission failure, the corresponding channel access function may transmit after the CS mechanism (see 9.3.2.2 (CS mechanism)) indicates that the medium is idle at the TxPIFS slot boundary (defined in 9.3.7 (DCF timing relations)) before the expiry of the TXNAV timer. At the expiry of the TXNAV timer, if the channel access function has not regained access to the medium, then the EDCAF shall invoke the backoff procedure that is described in 9.19.2.5 (EDCA backoff procedure). Transmission failure is defined in 9.19.2.5 (EDCA backoff procedure).

All other channel access functions at the STA shall treat the medium as busy until the expiry of the TXNAV timer.

A frame exchange may be a group addressed frame, a frame transmitted with No Ack policy (for which there is no expected acknowledgment), or an individually addressed frame followed by a correctly received ACK frame transmitted by a STA (either a non-AP STA or an AP).

Note that, as for an EDCA TXOP, a multiple frame transmission is granted to an EDCAF, not to a STA, so that the multiple frame transmission is permitted only for the transmission of a frame of the same AC as the frame that was granted the EDCA TXOP, unless the EDCA TXOP obtained is used by an AP for a PSMP sequence or a MU-MIMO transmission.

In ~~such a~~ the case of PSMP, this AC transmission restriction does not apply to either the AP or the STAs participating in the PSMP sequence, but the specific restrictions on transmission during a PSMP sequence described in 9.25 (PSMP Operation) do apply.

In the case of a MU-MIMO sequence and when permitted by the rules in 9.9.1.2a, traffic from secondary ACs may be transmitted in a MU-MIMO PPDU carrying traffic for the primary AC.

A TXOP is obtained after a STA transmitting an initial frame successfully receives a response frame. If the initial frame is a data frame with bandwidth indication, the bandwidth indicated in the data frame determines the bandwidth obtained for the TXOP. If the initial frame is a non-HT format data frame, the bandwidth obtained for the TXOP is 20MHz. For VHT STAs, if the response frame to the initial frame is the CTS frame, the bandwidth indicated in the CTS frame determines the bandwidth obtained for the TXOP. When a TXOP is obtained for a bandwidth that is greater than 20MHz, the STA may transmit PPDUs using CH\_BANDWIDTH that are up to and including the bandwidth obtained for the TXOP. During the TXOP, the STA shall not transmit PPDUs using CH\_BANDWIDTH greater than the obtained bandwidth for the TXOP.

If there is no non-HT duplicate frame exchange in a TXOP, the TXOP holder shall set the CH\_BANDWIDTH parameter in TXVECTOR of a PPDU to be the same or narrower than the CH\_BANDWIDTH parameter in TXVECTOR of the preceding PPDU that it has transmitted in the same TXOP. If there is no RTS/CTS exchange in a TXOP and there is at least one non-HT duplicate frame exchange in a TXOP, the TXOP holder shall set the CH\_BANDWIDTH parameter in TXVECTOR of a PPDU to be the same or narrower than the CH\_BANDWIDTH parameter in TXVECTOR of the initial frame in the first non-HT duplicate frame exchange in the same TXOP.

#### EDCA backoff procedure

***Change the corresponding paragraphs in 9.9.1.5 as shown here***

For the purposes of this subclause, successful transmission and transmission failure of an MPDU are defined as follows:

— After transmitting an MPDU (regardless of whether it is carried in an A-MPDU or as part of a MU-MIMO PPDU) that requires an immediate frame as a response, the STA shall wait for a timeout interval of duration of aSIFSTime + aSlotTime + aPHY-RX-START-Delay, starting at the PHY-TXEND.confirm. If a PHYRXSTART.indication does not occur during the timeout interval, the STA concludes that the

transmission of the MPDU has failed.

— If a PHY-RXSTART.indication does occur during the timeout interval, the STA shall wait for the

corresponding PHY-RXEND.indication to determine whether the MPDU transmission was

successful. The recognition of a valid response frame sent by the recipient of the MPDU requiring a

response, corresponding to this PHY-RXEND.indication, shall be interpreted as a successful

response.

— The recognition of anything else, including any other valid frame, shall be interpreted as failure of

the MPDU transmission. The recognition of a valid data frame sent by the recipient of a PS-Poll

frame shall also be accepted as successful acknowledgment of the PS-Poll frame. ~~A~~ The transmission of an MPDU that does not require an immediate frame as a response is defined as a successful transmission.

The backoff procedure shall be invoked for an EDCAF when any of the following events occurs:

a) A frame with that AC is requested to be transmitted, the medium is busy as indicated by either

physical or virtual CS, and the backoff timer has a value of zero for that AC.

b) All the MPDUs in ~~T~~the final PPDU or MU-MIMO PPDU transmission by the TXOP holder initiated during the TXOP for that AC was successful and the TXNAV timer has expired.

c) The ~~transmission of~~ expected immediate response to the initial frame of a TXOP of that AC ~~fails~~is not received,

d) The transmission attempt collides internally with another EDCAF of an AC that has higher priority,

that is, two or more EDCAFs in the same STA are granted a TXOP at the same time.

A TXOP that was initiated in response to the backoff counter for the EDCAF of an AC is a TXOP of that AC.

In addition, the backoff procedure may be invoked for an EDCAF when the transmission of one or more MPDUs in a non-initial ~~frame~~ PPDU or MU-MIMO PPDU by the TXOP holder fails.



## Reverse Direction Protocol



### Rules for RD initiator

***Change 9.15.3 as follows:***

A STA that transmits a QoS +CF-ACK data frame according to the rules in 9.9.2.3 (HCCA transfer rules) may also include an RDG in that frame provided that

— It is a non-A-MPDU frame or a VHT single MPDU, and

### Rules for responder

***Change 9.15.4 as follows:***

An RD responder may transmit a +CF-ACK non-A-MPDU frame or VHT single MPDU in response to a non-A-MPDU QoS Data+HTC MPDU that has the Ack Policy field set to Normal Ack and the RDG/More PPDU subfield set to 1.



## Link adaptation

***Insert section 9.18.3 following section 9.18.2:***



### Link adaptation using the VHT Control field

A STA that supports VHT link adaptation using the VHT Control field shall set the MCS Feedback field of the HT Extended Capabilities field to Unsolicited or Both, depending on its specific MCS feedback capability, in HT Capabilities elements that it transmits. MCS requests shall not be sent to STAs that have not advertised support for link adaptation. A STA whose most recently transmitted MCS Feedback field of the HT Extended capabilities field of the HT Capabilities element is set to Unsolicited or Both may transmit unsolicited MCS feedback in any frame that contains a +VHTC.

The MFB requester may set the MRQ field to 1 in the VHT Control field of a +VHTC frame to request a STA to provide MCS, VHT NSTS and SNR feedback. In each request the MFB requester shall set the MSI field to a value in the range 0 to 6. The choice of MSI value is implementation dependent.

*NOTE—The MFB requester can use the MSI field as an MRQ sequence number or it can implement any other encoding of the field.*

The appearance of more than one instance of a VHT Control field with the MRQ field set to 1 within a single PPDU shall be interpreted by the receiver as a single request for MCS, VHT NSTS and SNR feedback.

An MFB requester shall transmit +VHTC frames with the MRQ field set to 1 in one of the following two ways:

* within a PPDU, or
* with the NDPA frame.

In the latter case, the MFB shall be computed based on the NDP following the NDPA frame. The number of VHT-LTFs sent in the NDP is determined by the total number of spatial dimensions to be sounded for the purpose of beamforming.

An MFB responder device (identified by the MCS Feedback field in Extended HT Capabilities Info field set to 3) shall support the following:

* MFB estimate computation and feedback on the receipt of MFB request (MRQ set to 1 in +VHTC) in a PPDU.
* MFB estimate computation and feedback on the receipt of NDP (see 9.21) if this STA declares support for explicit Beamformee by setting the SU Beamformee Capability and/or the MU Rx Capability subfield of the VHT Capabilities field to 1.

On receipt of a +VHTC frame with the MRQ field set to 1, an MFB responder initiates computation of the MCS, VHT NSTS and SNR estimate based on the associated PPDU or NDP packet and labels the result of this computation with the MSI value in the MFSI field of the corresponding response frame. The MFB responder includes the received MSI value in the MFSI field of the corresponding response frame. In the case of a delayed response, this allows the MFB requester to correlate the MCS feedback with the related MCS request.

When sending a solicited MFB, the STA shall set the Unsolicited MFB field in VHT Control to 0.

The responder may send a solicited response frame with any of the following combinations of MFB and MFS:

* MFB = 127, MFSI = 7: no information is provided for the immediately preceding request or for any other pending request. This combination is used when the responder is required to include an VHT Control field due to other protocols that use this field (i.e., the Reverse Direction Protocol) and when no MFB is available. It has no effect on the status of any pending MRQ.
* MFB = 127, MFSI in the range 0 to 6: the responder is not now providing, and will never provide, feedback for the request that had the MSI value that matches the MFSI value.
* MFB contains valid MCS and VHT NSTS, MFSI in the range 0 to 6: the responder is providing feedback for the request that had the MSI value that matches the MFSI value.

An MFB responder that discards or abandons the computation for an MRQ should indicate this action to the MFB requester by setting the MFB to the value 127 in the next transmission of a frame addressed to the MFB requester that includes the VHT Control field. The value of the MFSI is set to the MSI value of the frame that contains MRQ for which the computation was abandoned.

*NOTE—The MFB requester can advertise the maximum number of spatial streams that it can transmit in its VHT Capabilities element.*

When computing the MFB estimate for an MFB requester, the VHT NSTS subfield in MFB shall not exceed the limit indicated by the Support MCS Field in the requester’s VHT Capability field.

The SNR feedback in MFB field is defined as the SNR value averaged over all the spatial streams and data subcarriers, and is encoded to 8 bits two’s complement number as below:



where  is the SNR value measured in dB at tone *k* and space-time stream *iSTS*, and  is the feedback SNR value before the 8-bit quantization. The MFB requester may use either MFB, or SNR feedback, or both to compute the appropriate MCS and *NSTS*.

When a STA is sending unsolicited MFB feedback, the STA shall set the Solicited/Unsolicited bit in the VHT Control field to 1.

Unsolicited MCS, NSTS and SNR estimates reported in MFB of a VHT Control field sent by a STA are computed based on the most recent PPDU received by the STA which matches the description indicated by GID-L, GID-H, Coding Type and FB TX Type fields in the same VHT Control field.

GID-L, GID-H, Coding Type and FB TX Type fields are set according to the RXVECTOR parameters of the received PPDU from which MCS SNR and NSTS are estimated, as follows. GID-L is set to the 3 least significant bits of the RXVECTOR GROUP\_ID parameter; GID-H is set to the 3 most significant bits of the RXVECTOR GROUP\_ID parameter; Coding Type is set to 0 if RXVECTOR FEC\_CODING parameter is equal to BCC\_CODING and set to 1 if equal to LDPC\_CODING; FB TX Type is set to 1 if RXVECTOR SU-BEAMFORMED is equal to BEMFORMED and set to 0 if equal to NON-BEAMFORMED.

*Note--The value of Unsolicited\_Type field allows to identify whether the unsolicited feedback is estimated from a SU or MU-MIMO PPDU.*

A value of MFB = 127 indicates that the +VHT Control frame is not carrying a valid MFB feedback.

If the MFB is in the same PPDU as a VHT Compressed Beamforming frame where the Feedback Type subfield in VHT MIMO Control Field is set to 0 (meaning SU-BF feedback), the MFB responder shall estimate the recommended MFB under the assumption that the MFB requester will use the steering matrices contained therein. In this case, the VHT NSTS subfield in MFB of VHT Control Field shall be the same as the value Nc Index in the VHT MIMO Control field of Compressed Beamforming frame.

If the MFB requester sends MRQ in an VHT NDP announcement frame where none of the Feedback Type subfield(s) in the STA Info field(s) is set to 1 (meaning requesting only SU-BF Feedbacks), then the MFB responder shall include the corresponding MFB feedback in the VHT Compressed Beamforming frame that is the response of the same NDP-A and NDP sequence.

When the MFB requester sets the MRQ subfield to 1 and sets the MSI subfield to a value that matches the MSI subfield value of a previous request for which the responder has not yet provided feedback, the responder shall discard or abandon the computation for the MRQ that corresponds to the previous use of that MSI subfield value.

A STA may respond immediately to a current request for MFB with a frame containing an MFSI field value and MFB field value that correspond to a request that precedes the current request.

*NOTE 1—If a VHT STA includes the VHT Control field in the initial frame of an immediate response exchange and the responding VHT STA includes the VHT Control field in the immediate response frame, the immediate response exchange effectively permits the exchange of VHT Control field elements.*

*NOTE 2—If an MRQ is included in the last PPDU in a TXOP and there is not enough time for a response, the recipient can transmit the response MFB in a subsequent TXOP.*

*NOTE 3—Bidirectional request/responses are supported. In this case, a STA acts as the MFB requester for one direction of a duplex link and a MFB responder for the other direction and transmits both MRQ and MFB in the same VHT data frame.*

*NOTE 4—A STA that sets the MCS Feedback field to 0 in the HT Extended Capabilities field of the HT Capability elements that it transmits does not respond to an MRQ.*

## Null data packet (NDP) sounding

***Insert section 9.21.5 as shown below:***



### VHT sounding protocol

Transmit Beamforming and DL MU-MIMO require knowledge of the channel state to compute a steering matrix used at the transmitter to optimize reception at one or more receivers. The STA transmitting using the steering matrix is called the beamformer and a STA for which reception is optimized is called a beamformee. An explicit feedback mechanism is used where the beamformee directly measures the channel from the training symbols transmitted by the beamformer and sends back a transformed estimate of the channel state to the beamformer. The beamformer then uses this estimate, perhaps combining estimates from multiple beamformees, to derive the steering matrix.

A STA that has the value true for dot11VHTBeamformerEnabled shall set the SU Beamformer Capability field to 1 in transmitted VHT Capabilities elements. A STA that has the value true for dot11VHTBeamformeeEnabled shall set the SU Beamformee Capability field to 1 in transmitted VHT Capabilities elements. A STA that does not have the value true for dot11VHTBeamformerEnabled shall not act in the role of a beamformer. A STA that does not have the value true for dot11VHTBeamformeeEnabled shall not act in the role of a beamformee.

The VHT sounding protocol with more than one beamformee is shown in Figure 9.37b.



Figure 9.37b—Sounding protocol with more than one beamformee

The beamformer shall initiate a sounding feedback sequence by sending a NDPA frame followed by an NDP after a SIFS. The beamformer shall include in the NDPA a STA Info field for each STA that is expected to prepare a VHT Compressed Beamforming response frame and shall identify the STA by including the STA’s AID in the STA ID subfield. The NDPA shall include at least one STA Info field.

A beamformee that receives an NDPA from an AP to which it is associated and that contains the AID assigned it during association in the STA ID subfield of the first STA Info field shall transmit its VHT Compressed Beamforming frame a SIFS after reception of the NDP. A beamformee that receives an NDPA from an AP with which it is associated and that contains the AID assigned it during association in the STA ID subfield of a STA Info field that is not the first STA Info field shall transmit its VHT Compressed Beamforming frame after receiving a Sounding Poll with RA matching its MAC address and TA matching the MAC address of the AP. If the beamformee does not have a valid VHT Compressed Beamforming Report, the beamformee shall transmit a VHT Compressed Beamforming frame without including the VHT Compressed Beamforming Report field or MU Exclusive Beamforming Report and indicating this in the VHT MIMO Control field as described in 7.3.1.31 (VHT MIMO Control field).

A beamformer that has transmitted an NDPA with more than one STA Info field should transmit any Sounding Poll frames needed to retrieve VHT Compressed Beamforming frames in the same TXOP that contained the NDPA while giving precedence in attempting to satisfy this recommendation to the rules of 9.9.1.4 (Multiple frame transmission in an EDCA TXOP).

The beamformee shall send a VHT Compressed Beamforming frame with the VHT MIMO Control Feedback Type field set to the same value as the Feedback Type field in the corresponding STA Info field in the NDPA. When the Feedback Type field is set to MU, the STA shall send a feedback with the Nc field value in the VHT MIMO Control field equal to the Nc field value in the corresponding STA Info in the NDPA provided the Nc requested is not larger than the number of currently active receive antennas. When the Feedback Type is set to SU, the Nc field in the VHT MIMO Control field may be set to any value.

The VHT sounding protocol with a single beamformee is shown in Figure 9-37c.



Figure 9.37c—Sounding protocol with a single beamformee

When a beamformer includes only one STA Info field in the NDPA, then the beamformer does not poll the STA for the initial transmission attempt of the feedback, as is shown in Figure 9.37c. Upon failure to receive the feedback, the beamformer may initiate poll-based recovery as described in 9.x.x.

An SU only beamformee is a STA that, in its VHT Capability element, has set the SU Beamformee Capable field to 1 and the MU Rx Capable field to 0. When soliciting feedback from an SU only beamformee, the beamformer shall set the RA of the NDPA to the beamformee’s MAC address and shall include a single STA Info field in the NDPA with the STA ID subfield set to the beamformee’s AID and the Feedback Type subfield set to SU.

The NDPA frame is a control frame as defined in 7.2.1.11. The sequence number in the NDPA frame identifies this NDP sequence and is also carried in the VHT Compressed Beamforming frame.

*Note—The beamformer can use the sequence number in the VHT Compressed Beamforming frame to associate the feedback with a prior NDPA-NDP sounding sequence and thus compute the delay between sounding and receiving the feedback. The beamformer can use this delay time when making a decision regarding the applicability of the feedback for the link.*

The Multi STA info field contains the IDs of the beamformees required to compute the sounding feedback and may include other information TBD.

The RA in the NDPA frame shall be set to the address of the beamformee when sounding feedback is requested from a single beamformee.

The RA field in the NDPA frame shall be set to the broadcast address when sounding feedback is requested from more than one beamformee.

A beamformee shall use the SU format for the VHT Compressed Beamforming frame when the STA Info Feedback Type field in the NDPA corresponding to that STA is set to SU. A beamformee shall use the MU format for the VHT Compressed Beamforming frame when the STA Info Feedback Type field in the NDPA corresponding to that STA is set to MU.

A beamformer that has transmitted an NDPA with more than one STA Info field should transmit any Sounding Poll frames needed to retrieve the expected VHT Compressed Beamforming frames within the TXOP that contained the NDPA while giving priority in attempting to satisfy this recommendation to the rules of 9.9.1.4 (Multiple frame transmission in an EDCA TXOP).

Recovery follows the rules for multiple frame transmission in an EDCA TXOP (9.9.1.4).

For the purpose of the recovery mechanism, the sequence [NDPA NDP VHT-CB] is a valid frame exchange, and the VHT-CB frame is a valid response to the NDPA.

*Note--Section 9.9.1.4 defines the rules that allow for sending multiple frames within a TXOP with a SIFS separation. It also defines the recovery procedure in case of a missing response to NDPA or Sounding Poll*

If it would otherwise result in an MMPDU that exceeds the maximum MPDU size, the VHT Compressed Beamforming Report field may be split into up to TBD segments. Each segment shall contain an equal number of octets except for the last segment, which may be smaller. All segments shall be sent within the same A-MPDU.

A beamformer shall only poll an SU only beamformee if it received at least one segment of the feedback from the beamformee.

### Transmission of a VHT NDP

A STA shall transmits a VHT format NDP using the following TXVECTOR parameters:

— LENGTH shall be set to 0.

— NUM\_USERS shall be set to 1.

— GROUP ID shall be set to 63 (all ones).

— NUM\_STS shall indicate two or more space-time streams.

The number of space time streams sounded and as indicated by the NUM\_STS parameter shall not exceed the value indicated in the Compressed Steering Number of Beamformer Antennas Supported field in the VHT Capability element of the STA that is the intended recipient of the VHT NDP. The NUM\_STS parameter may be set to any value, subject to the constraint of the previous sentence, regardless of the value of the Supported MCS Set field of the VHT Capabilities field at either the transmitter or recipient of the NDP.

A STA shall not transmit an NDPA addressed to a STA or broadcast and including a STA’s AID in one of the STA Info fields in the frame unless it has received from that STA a VHT Capability element where the last VHT Capability element received has the SU Beamformee Capable field set to 1 or the MU Rx Capable field is set to 1 or both fields set to 1.

# Layer Management

## Overview of management model

## Generic management primitives

## MLME SAP interface

## PLME SAP interface



### PLME-TXTIME.confirm

***Change section 10.4.7 as follows:***

#### Function

This primitive provides the time that will be required to transmit the PPDU described in the corresponding PLME-TXTIME.request.

When the TXVECTOR FORMAT parameter is VHT, it also provides per user the number of octets required to fill the PPDU.

#### Semantics of the service primitive

This primitive provides the following parameters:

PLME-TXTIME.confirm(TXTIME, PSDU\_LENGTH[])

The TXTIME represents the time, in microseconds, required to transmit the PPDU described in the corresponding PLME-TXTIME.request primitive. If the calculated time includes a fractional microsecond, the TXTIME value is rounded up to the next higher integer.

The PSDU\_LENGTH[] parameter is an array of TXVECTOR NUM\_USERS values. Each value indicates the number of octets required to fill the PPDU for the user represented by that index. The parameter is present only when the TXVECTOR FORMAT parameter is VHT.

#### When generated

This primitive is issued by the local PHY entity in response to a PLME-TXTIME.request primitive.

#### Effect of receipt

The receipt of this primitive provides the MAC sublayer with the PPDU transmission time.

# MLME



## Power management

### Power management in an infrastructure network

***Insert new sections 11.2.1.4a and 11.2.1.4b below following section 11.2.1.4:***

#### *11.2.1.4a* Power management during VHT transmissions

The power management scheme described in this section is applicable only when VHT AP allows VHT TXOP power save mode (see section 11.2.1.4b) at non-AP VHT STAs. A VHT AP that obtains a TXOP for VHT transmissions shall indicate non-AP VHT STAs using TXOP\_PS\_NOT\_ALLOWED in TXVECTOR whether or not they are allowed to enter Doze state.

If non-AP VHT STAs are allowed to enter Doze state during a TXOP, then the non-AP VHT STA that is in VHT TXOP power save mode may enter the Doze state till the end of that TXOP when one of the following conditions exists:

* A non-AP VHT STA finds that it is not a member of group indicated by RXVECTOR GROUP\_ID parameter.
* A non-AP VHT STA finds that PARTIAL\_AID in the RXVECTOR does not matches with its partial AID or it finds that the frame is not destined to it.
* A non-AP VHT STA receives RXVECTOR with NUM\_STS parameter set to 0, if it is a member of group indicated by RXVECTOR GROUP\_ID.
* A non-AP VHT STA sends an appropriate acknowledgement in response to frame received with More Data field set to 0.

Note that, a VHT AP shall include NAV-set sequence (e.g. RTS/CTS) at the beginning of such a TXOP with the Duration/ID value set to the remainder of the TXOP duration. A VHT AP shall not transmit frames to a non-AP VHT STA that is in the Doze state for the remainder of the TXOP.

#### 10.2.1.4b VHT TXOP power mode

A non-AP VHT STA may either be in the Awake or Doze state during a TXOP obtained by the VHT AP for VHT transmissions. Only the non-AP VHT STAs that are in Active mode (see Table 10-1) shall operate VHT TXOP power save mode. A non-AP VHT STA enters Doze state as mentioned in 11.2.1.4a during a TXOP when it is in VHT TXOP PS mode.VHT AP shall not transmit to non-AP VHT STA that is in Doze state till the end of TXOP.

Note that, the state of the non-AP VHT STA at the end of the TXOP could be governed by other power save mechanisms. When the non-AP VHT STA in not in VHT TXOP power save mode, its operation is the same as in Active power management mode.

If the TXOP is truncated, then the VHT AP shall not transmit frames to non-AP VHT STAs in the Doze state until the NAV duration of the TXOP has expired.

***Insert the new section 11.20 below following section 11.19:***



## VHT BSS operation

### Basic VHT BSS functionality

A VHT STA that is a member of a VHT BSS shall not transmit a 20 MHz VHT PPDU that does not use the primary 20 MHz channel of the BSS.

A VHT STA that is a member of a VHT 40 MHz, 80 MHz, 160 MHz or 80+80 MHz BSS shall not transmit a 40 MHz PPDU that does not use the primary 20 MHz channel of the BSS.

A VHT STA that is part of a VHT 80 MHz, 160 MHz or 80+80 MHz BSS shall not transmit an 80 MHz PPDU that does not use the primary 20 MHz channel of the BSS.

A VHT STA shall not transmit a 160 MHz VHT PPDU using a 160 MHz channel that cannot be used to setup a VHT 160 MHz BSS.

A VHT STA shall not transmit a 80+80 MHz VHT PPDU using two nonadjacent 80 MHz channels if either channel cannot be used to setup a VHT 80 MHz BSS.

The Operating Mode Notification Action frame may be used by a VHT STA to notify another VHT STA that it is capable of receiving frames with a bandwidth up to and including the indicated Channel Width and with a *NSS* up to and including the indicated Rx Nss.

*NOTE—It may take a long time for a STA to change its operating mode following the transmission of the Operating Mode Notification frame and during that time the STA may not be able to receive frames resulting in frame loss. If a non-AP STA cannot tolerate frame loss during that period it can set the Frame Control Power Management subfield of the Operating Mode Notification frame to 1 to indicate that the STA has entered power save. When the non-AP STA has completed its operating mode change, it can send another frame (such as a QoS Null) with the Frame Control Power Management subfield set to 0 to indicate that the STA has exited power save.*

The use of RIFS in a VHT BSS is deprecated. As such, a VHT AP shall set the RIFS Mode field in the HT Operation element to 0.

### STA CCA sensing in a VHT BSS

A STA may transmit a 20 MHz mask PPDU in the primary 20 MHz channel following the rules in 9.19.2 (HCF contention-based channel access (EDCA)).

A STA transmitting a 40 MHz mask PPDU that begins a TXOP using EDCA as described in 9.19.2.3

(Obtaining an EDCA TXOP) or that is using a PIFS as permitted in 9.2.0b.4.4 (PIFS) shall sense CCA on both the primary 20 MHz channel and the secondary 20 MHz channel immediately before issuing a PHY-TXSTART.request for a 40 MHz mask PPDU.

A STA transmitting an 80 MHz mask PPDU that begins a TXOP using EDCA as described in 9.19.2.3

(Obtaining an EDCA TXOP) or that is using a PIFS as permitted in 9.2.0b.4.4 (PIFS) shall sense CCA on the primary 20 MHz channel, the secondary 20 MHz channel, and the secondary 40 MHz channel before the 80 MHz mask PPDU transmission starts.

A STA transmitting a 160 MHz mask PPDU or a 80+80 MHz mask PPDU that begins a TXOP using EDCA as described in 9.19.2.3 (Obtaining an EDCA TXOP) or that is using a PIFS as permitted in 9.2.0b.4.4 (PIFS) shall sense CCA on the primary 20 MHz channel, the secondary 20 MHz channel, the secondary 40 MHz channel, and the secondary 80 MHz channel before the PPDU transmission starts.

Unless explicitly stated otherwise, a STA may treat a PHY-CCA.indication primitive that is BUSY as though it were IDLE in the following cases:

— If the channel-list parameter is present but does not contain primary as an element and the STA is transmitting a 20 MHz mask PPDU, or

— If the channel-list parameter is present but does not contain primary or secondary as elements and the STA is transmitting a 20 MHz mask PPDU or the STA is transmitting a 40 MHz mask PPDU, or

— If the channel-list parameter is present but does not contain primary, secondary or secondary40 as elements and the STA is transmitting a 20 MHz mask PPDU or the STA is transmitting a 40 MHz mask PPDU, or the STA is transmitting an 80 MHz mask PPDU.

At the specific slot boundaries (defined in 9.3.7 (DCF timing relations)) determined by the STA based on the primary 20 MHz channel CCA, when the transmission begins a TXOP using EDCA (as described in

9.19.2.3 (Obtaining an EDCA TXOP)), the STA may transmit a pending greater than 20 MHz mask PPDU only if the secondary 20 MHz channel, secondary 40 MHz channel and secondary 80 MHz channel that would be occupied by the PPDU have also been idle during the times the primary 20 MHz channel CCA is performed (defined in 9.3.7 (DCF timing relations)) during an interval of a PIFS immediately preceding the expiration of the backoff counter.

If the secondary channel, secondary 40 MHz channel or secondary 80 MHz channel are busy during this interval, the STA may take one of the following steps:

1. Transmit an 80 MHz mask PPDU on the primary 80 MHz channel if both the secondary channel and the secondary 40 MHz channel were idle during this interval.
2. Transmit a 40 MHz mask PPDU on the primary 40 MHz channel if the secondary channel was idle during this interval.
3. Transmit a 20 MHz mask PPDU on the primary 20 MHz channel
4. Restart the channel access attempt. In this case, the STA shall invoke the backoff procedure as specified in 9.19.2 (HCF contention-based channel access (EDCA)) as though the medium is busy as indicated by either physical or virtual CS and the backoff timer has a value of zero.

*NOTE—As a result of this rule, the STA selects a new random number using the current value of CW[AC], and the retry counters are not updated.*

If a transmitter follows the rule defined in step d) when one or more channels are busy within its operating bandwidth, the transmitter operates in static BW operation mode. Otherwise, the transmitter operates in dynamic BW operation mode.

### NAV assertion in a VHT BSS

A VHT STA shall update its NAV using the Duration/ID field value in any frame received in a 20 MHz PPDU in the primary 20 MHz channel or received in a 40 MHz PPDU in the primary 40 MHz channel or received in a 80MHz PPDU in the primary 80 MHz channel or received in a 160 MHz or 80+80 MHz PPDU and that does not have an RA matching the STA’s MAC address.

*NOTE—A STA need not set its NAV in response to 20/40/80 MHz frames received on any channel that is not or does not include the primary channel, even if it is capable of receiving those frames.*

# PHY service specification

## Detailed PHY service specifications



### PHY-SAP detailed service specification

#### PHY-CCA.indication

##### Semantics of the service primitive

***Change the third paragraph as follows:***

When STATE is IDLE or when, for the type of PHY in operation, CCA is determined by a single channel, the channel-list parameter is absent. Otherwise, it carries a set indicating which channels are busy~~, represented by the values {primary}, {primary, secondary}, and {secondary}~~. Potential elements of this set are listed in Table 12‑1.

***Append the following table, paragraph and figure:***

Table ‑—Channel-list parameter elements

|  |  |
| --- | --- |
| **channel-list elements** | **Meaning** |
| primary | Indicates that the primary 20 MHz channel is busy |
| secondary | Indicates that the secondary 20 MHz channel is busy. The secondary 20 MHz channel is the 20 MHz channel adjacent to the primary 20 MHz channel, which together form a 40 MHz channel. |
| secondary40 | Indicates that at least one of the 20 MHz subchannels in the secondary 40 MHz channel is busy. The secondary 40 MHz channel is the 40 MHz channel adjacent to the primary 40 MHz channel, which together form the primary 80 MHz channel. |
| secondary80 | Indicates that at least one of the 20 MHz subchannels in the secondary 80 MHz channel is busy. The secondary 80 MHz channel is the 80 MHz channel that does not include the primary 20 MHz channel and which together with the primary 80 MHz channel forms the 160 MHz channel or the 80+80 MHz channel. |

The relationship of the channel-list elements to the 40 MHz, 80 MHz, 160 MHz BSS operating channel is illustrated in Figure 12‑1. Note that for a 80+80 MHz BSS the subchannels represented by secondary80 are the same as shown for the 160 MHz channel except that they occur in a non-adjacent 80 MHz channel.



Figure ‑—Relationship between the channel-list elements and the operating channel bandwidth

##### When generated

***Change section 12.3.5.10.3 as follows:***

This primitive is generated within aCCATime of the occurrence of a change in the status of the channel(s)

from channel idle to channel busy or from channel busy to channel idle. This includes the period of time

when the PHY is receiving data. Refer to specific PHY clauses for details about CCA behavior for a given PHY.

If the STA is an HT STA or a VHT STA and the operating channel width is 20 MHz, the PHY maintains the channel busy indication until the period indicated by the LENGTH field has expired, where the LENGTH field is

— In a valid SIG field if the format of the PPDU is NON\_HT

— In a valid HT-SIG field if the format of the PPDU is HT\_MF or HT\_GF

— In a valid L-SIG field if the format of the PPDU is VHT

If the STA is an HT STA or a VHT STA and the operating channel width is ~~40 MHz~~ greater than 20 MHz, the PHY maintains the channel busy indication until the period indicated by the LENGTH field has expired, where the LENGTH field is

— In a valid SIG field if the format of the PPDU is NON\_HT and the PPDU is received in the primary 20 MHz channel

— In a valid HT-SIG field if the format of the PPDU is HT\_MF or HT\_GF provided that the PPDU is either a 20 MHz PPDU received in the primary 20 MHz channel or a 40 MHz PPDU

— In a valid SIG field if the format of the PPDU is VHT

# Orthogonal frequency division multiplexing (OFDM) PHY specification

## OFDM PHY specific service parameter list



### TXVECTOR parameters

***Insert new rows at the end of the Table 17-1***

Table 17-1—TXVECTOR parameters

|  |  |  |
| --- | --- | --- |
| **Parameter** | **Associate primitive** | **Value** |
| INDICATED\_CH\_BANDWIDTH | PHY-TXSTART.request  (TXVECTOR) | If present, NON\_HT\_CBW20, NON\_HT\_CBW40, NON\_HT\_CBW80 and NON\_HT\_CBW160 |
| INDICATED\_DYN\_BANDWIDTH | PHY-TXSTART.request  (TXVECTOR) | If present, Static and Dynamic |

***Insert sections 17.2.2.14 and 17.2.2.15 following 17.2.2.13 as follows:***

#### TXVECTOR INDICATED\_CH\_BANDWIDTH

If present, the allowed values for INDICATED\_CH\_BANDWIDTH are NON\_HT\_CBW20, NON\_HT\_CBW40, NON\_HT\_CBW80, and NON\_HT\_CBW160. If present, this parameter is used to modify the first 7 bits of the scrambling sequence in the Service field to indicate the duplicated bandwidth of the PPDU.

*NOTE--The INDICATED\_CH\_BANDWIDTH parameter is not present when the frame is transmitted by a non-VHT STA.*

#### TXVECTOR INDICATED\_DYN\_BANDWIDTH

If present, the allowed values for INDICATED\_DYN\_BANDWIDTH are Static and Dynamic. If present, this parameter is used to modify the first 7 bits of the scrambling sequence to indicate if the transmitter is capable of Static or Dynamic bandwidth operation. If INDICATED\_DYN\_BANDWIDTH is present, then CH\_BANDWIDTH is also present.

*NOTE--The INDICATED\_DYN\_BANDWIDTH parameter is not present when the frame is transmitted by a non-VHT STA.*

### RXVECTOR parameters

***Insert new rows at the end of the Table 7-2:***

Table 17-2—RXVECTOR parameters

|  |  |  |
| --- | --- | --- |
| **Parameter** | **Associate primitive** | **Value** |
| INDICATED\_CH\_BANDWIDTH | PHY-RXSTART.request  (RXVECTOR) | If present, NON\_HT\_CBW20, NON\_HT\_CBW40, NON\_HT\_CBW80 and NON\_HT\_CBW160 |
| INDICATED\_DYN\_BANDWIDTH | PHY-RXSTART.request  (RXVECTOR) | If present, Static and Dynamic |

#### RXVECTOR INDICATED\_CH\_BANDWIDTH

If present, the allowed values for INDICATED\_CH\_BANDWIDTH are NON\_HT\_CBW20, NON\_HT\_CBW40, NON\_HT\_CBW80, and NON\_HT\_CBW160. If present and valid, this parameter indicates the duplicated bandwidth of the PPDU. The validity of this parameter is determined by the MAC.

*NOTE--The INDICATED\_CH\_BANDWIDTH parameter is not present when the frame is received by a non-VHT STA.*

#### RXVECTOR INDICATED\_DYN\_BANDWIDTH

If present, the allowed values for INDICATED\_DYN\_BANDWIDTH are Static and Dynamic. If present and valid, this parameter indicates whether the transmitter is capable of Static or Dynamic bandwidth operation. The validity of this parameter is determined by the MAC. If INDICATED\_DYN\_BANDWIDTH is present, then INDICATED\_CH\_BANDWIDTH is also present.

*NOTE--The INDICATED\_DYN\_BANDWIDTH parameter is not present when the frame is received by a non-VHT STA.*

## OFDM PLCP sublayer

### Introduction

### PLCP frame format

#### Overview of the PPDU encoding process

***Modify step e) as follows:***

1. If the TXVECTOR parameter INDICATED\_CH\_BANDWIDTH is not present, i~~I~~nitiate the scrambler with a pseudo-random nonzero seed~~,~~ and generate a scrambling sequence. If the TXVECTOR parameter INDICATED\_CH\_BANDWIDTH is present, construct the first 7 bits of the scrambling sequence from a pseudo-random nonzero integer, INDICATED\_CH\_BANDWIDTH and, if present, INDICATED\_DYN\_BANDWIDTH, then set the scrambler state to these 7 bits and generate the remainder of the scrambling sequence. , and XOR ~~it~~ the scrambling sequence with the extended string of data bits. Refer to 17.3.5.4 (PLCP DATA scrambler and descrambler) for details.

### DATA field

#### PLCP DATA scrambler and descrambler

***Change section 17.3.5.4 as follows:***

The DATA field, composed of SERVICE, PSDU, tail, and pad parts, shall be scrambled with a length-127 frame-synchronous scrambler. The octets of the PSDU are placed in the transmit serial bit stream, bit 0 first and bit 7 last. The frame synchronous scrambler uses the generator polynomial *S(x)* as follows, and is illustrated in Figure 17-7 (Data scrambler):

 (17-14)

The 127-bit sequence generated repeatedly by the scrambler shall be (leftmost used first), 00001110 11110010 11001001 00000010 00100110 00101110 10110110 00001100 11010100 11100111 10110100 00101010 11111010 01010001 10111000 1111111, when the all ones initial state is used. The same scrambler is used to scramble transmit data and to descramble receive data. If the TXVECTOR parameter INDICATED\_CH\_BANDWIDTH is not present, w~~W~~hen transmitting, the initial state of the scrambler will be set to a pseudo-random nonzero state. If the TXVECTOR parameter INDICATED\_CH\_BANDWIDTH is present,

* the first 7 bits of the scrambling sequence shall be set as shown in Table 17-6ac and shall be also used to initialize the state of the scrambler, and
* the scrambler with this initialization shall generate the remainder (i.e. after the first 7 bits) of the scrambling sequence as shown in Figure 17-7.

Table 17-6ac: Contents of First 7 Bits of Scrambling Sequence

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| INDICATED\_CH\_BANDWIDTH | INDICATED\_DYN\_BANDWIDTH | First 7 Bits of Scrambling Sequence | | |
| Not present | - | Unused | | |
| Present | Not present | 5 bit pseudo-random nonzero integer | | 00 (NON\_HT\_CBW20),  01 (NON\_HT\_CBW40),  10 (NON\_HT\_CBW80),  11 (NON\_HT\_CBW160) |
| Present | Present | 4 bit pseudo-random nonzero integer | 0 (Static)  1 (Dynamic) |
|  |  | B0 B3 | B4 | B5 B6 |
|  |  | Transmit order  -----------------------------------------------> | | |

The seven LSBs of the SERVICE field will be set to all zeros prior to scrambling to enable estimation of the initial state of the scrambler in the receiver.

***Replace Figure 17-7 with the following:***



**Figure 17-7—Data scrambler**

An example of the scrambler output is illustrated in G.1.5.2 (Scrambling the BCC example).



# 



# Very High Throughput (VHT) PHY specification

## Introduction

### Introduction to the VHT PHY

Clause 22 specifies the PHY entity for a very high throughput (VHT) orthogonal frequency division multiplexing (OFDM) system.

In addition to the requirements in Clause 22, a VHT STA shall be capable of transmitting and receiving frames that are compliant with the mandatory PHY specifications defined in Clause 20.

The VHT PHY is based on the HT PHY defined in Clause 20, which in turn is based on the OFDM PHY defined in Clause 17. The VHT PHY extends the number of spatial streams supported to eight and provides support for multi-user (MU) transmission. In the case of a MU transmission, the number of users is limited to four and the number of streams per user is limited to four.

The VHT PHY provides support for 20 MHz, 40 MHz, 80 MHz, and 160 MHz channel widths as well as 80+80 MHz non-contiguous channel width.

The VHT PHY data subcarriers are modulated using binary phase shift keying (BPSK), quadrature phase shift keying (QPSK), 16-quadrature amplitude modulation (16-QAM), 64-QAM or 256-QAM. Forward error correction (FEC) coding (convolutional or LDPC) is used with a coding rate of 1/2, 2/3, 3/4, or 5/6.

A VHT STA shall support:

* 20 MHz, 40 MHz and 80 MHz channel widths
* MCSs 0 through 7 in all supported channel widths

Optional features for a VHT STA are:

* 2 or more streams (transmit and receive)
* 400 ns short guard interval (transmit and receive)
* Respond to transmit beamforming sounding (provide compressed V feedback)
* STBC (transmit and receive)
* LDPC (transmit and receive)
* MU-MIMO PPDUs (transmit and receive)
* Support for 160 MHz channel width
* Support for 80+80 MHz channel width
* MCSs 8 and 9 (transmit and receive)

### Scope

### VHT PHY functions

### PPDU formats

## VHT PHY service interface

### Introduction

The PHY interfaces to the MAC through the TXVECTOR, RXVECTOR, and PHYCONFIG\_VECTOR.

The TXVECTOR supplies the PHY with per-packet transmit parameters. Using the RXVECTOR, the PHY informs the MAC of the received packet parameters. Using the PHYCONFIG\_VECTOR, the MAC configures the PHY for operation, independent of frame transmission or reception.

This interface is an extension of the generic PHY service interface defined in 12.3.4 (Basic service and options).

### TXVECTOR and RXVECTOR parameters

The parameters in Table 22‑1 are defined as part of the TXVECTOR parameter list in the PHY-TXSTART.request primitive and/or as part of the RXVECTOR parameter list in the PHY-RXSTART.indication primitive.

Table 22‑1--TXVECTOR and RXVECTOR parameters

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Parameter** | **Condition** | **Value** | **TXVECTOR** | **RXVECTOR** |
| FORMAT |  | Determines the format of the PPDU.  Enumerated type:  NON\_HT indicates Clause 17(Orthogonal frequency division multiplexing (OFDM) PHY specification) or non-HT duplicated PPDU format. In this case, the modulation is determined by the NON\_HT\_MODULATION parameter.  HT\_MF indicates HT-mixed format.  HT\_GF indicates HT-greenfield format.  VHT indicates VHT format. | Y | Y |
| NON\_HT\_MODULATION | FORMAT is NON\_HT | Enumerated type:  OFDM  NON\_HT\_DUP\_OFDM | Y | Y |
| Otherwise | Not present |  |  |
| L\_LENGTH | FORMAT is NON\_HT | Indicates the length of the PSDU in octets in the range of 1 to 4095. This value is used by the PHY to determine the number of octet transfers that occur between the MAC and the PHY. | Y | Y |
| FORMAT is HT\_MF | Indicates the value in the Length field of the L-SIG in the range of 1 to 4095. | Y | Y |
| FORMAT is HT\_GF | Not present | N | N |
| FORMAT is VHT | Not present | N | N |
| L\_DATARATE | FORMAT is NON\_HT | Indicates the rate used to transmit the PSDU in megabits per second. Allowed values depend on the value of the NON\_HT\_MODULATION parameter as follows:  NON\_HT\_DUP\_OFDM:  6, 9, 12, 18, 24, 36, 48, and 54  OFDM: 6, 9, 12, 18, 24, 36, 48, and 54 |  |  |
| FORMAT is HT\_MF | Indicates the data rate value that is in the L-SIG. This use is defined in 9.13.4 (L\_LENGTH and L\_DATARATE parameter values for HT-mixed format PPDUs). |  |  |
| FORMAT is HT\_GF | Not present |  |  |
| FORMAT is VHT | Not present |  |  |
| LSIGVALID | FORMAT is HT\_MF or VHT | True if L-SIG Parity is valid  False if L-SIG Parity is not valid | N | Y |
| Otherwise | Not present | N | N |
| SERVICE | FORMAT is NON\_HT and NON\_HT\_MODULATION is OFDM | Scrambler initialization, 7 null bits + 9 reserved null bits | Y | N |
| FORMAT is HT\_MF or HT\_GF | Scrambler initialization, 7 null bits + 9 reserved null bits | Y | N |
| FORMAT is VHT | Not present | N | N |
| Otherwise | Not present | N | N |
| SMOOTHING | See corresponding entry in Table 20-1 | | | |
| AGGREGATION | See corresponding entry in Table 20-1 | | | |
| NUM\_EXTEN\_SS | See corresponding entry in Table 20-1 | | | |
| ANTENNA\_SET | See corresponding entry in Table 20-1 | | | |
| N\_TX | FORMAT is HT\_MF, HT\_GF or VHT | The N\_TX parameter indicates the number of transmit chains. | Y | N |
| Otherwise | Not present | N | N |
| CHAN\_MAT\_TYPE | FORMAT is HT\_MF or HT\_GF | Enumerated type:  COMPRESSED\_SV indicates that CHAN\_MAT is a set of compressed beamforming vector matrices.  NON\_COMPRESSED\_SV indicates that CHAN\_MAT is a set of noncompressed beamforming vector matrices.  CSI\_MATRICES indicates that CHAN\_MAT is a set of channel state matrices. | N | Y |
| FORMAT is VHT | Set to COMPRESSED\_SV | N | Y |
| Otherwise | Not present | N | N |
| CHAN\_MAT | FORMAT is HT\_MF and CHAN\_MAT\_TYPE is COMPRESSED\_SV | See corresponding entry in Table 20-1 | N | Y |
| CHAN\_MAT\_TYPE is NON\_COMPRESSED\_SV | See corresponding entry in Table 20-1 | N | Y |
| CHAN\_MAT\_TYPE is CSI\_MATRICES | See corresponding entry in Table 20-1 | N | Y |
| FORMAT is VHT and CHAN\_MAT\_TYPE is COMPRESSED\_SV | TBD | N | Y |
| Otherwise | Not present |  |  |
| RCPI |  | Is a measure of the received RF power averaged over all the receive chains in the data portion of a received frame.  Refer to 20.3.22.6 (Received channel power indicator (RCPI)  measurement) for the definition of RCPI. | N | Y |
| SNR | FORMAT is HT\_MF and CHAN\_MAT\_TYPE is CSI\_MATRICES | See corresponding entry in Table 20-1 | N | Y |
| FORMAT is HT\_MF and CHAN\_MAT\_TYPE is COMPRESSED\_SV or NON\_COMPRESSED\_SV | See corresponding entry in Table 20-1 | N | Y |
| FORMAT is VHT and CHAN\_MAT\_TYPE is COMPRESSED\_SV | TBD | N | Y |
| NO\_SIG\_EXTN | FORMAT is VHT | Not present | N | N |
| Otherwise | See corresponding entry in Table 20-1 | | |
| FEC\_CODING | FORMAT is VHT | Indicates which FEC encoding is used.  Enumerated type:  BCC\_CODING indicates binary convolutional code.  LDPC\_CODING indicates low-density parity check code. | MU | MU |
| Otherwise | See corresponding entry in Table 20-1 | | |
| STBC | FORMAT is HT\_MF  or HT\_GF | Indicates the difference between the number of space-time streams (NSTS ) and the number of spatial streams (NSS ) indicated by the MCS as follows:  0 indicates no STBC (NSTS=NSS ).  1 indicates NSTS-NSS=1.  2 indicates NSTS-NSS=2.  Value of 3 is reserved. | Y | Y |
| FORMAT is VHT | Indicates whether or not STBC is used.  0 indicates no STBC (NSTS=NSS).  1 indicates NSTS=2NSS | Y | Y |
| Otherwise | Not present | N | N |
| GI\_TYPE | FORMAT is HT\_MF, HT\_GF or VHT | Indicates whether a short guard interval is used in the transmission of the packet.  Enumerated type:  LONG\_GI indicates short GI is not used in the packet.  SHORT\_GI indicates short GI is used in the packet. | Y | Y |
| Otherwise | Not present | N | N |
| TXPWR\_LEVEL |  | The allowed values for the TXPWR\_LEVEL parameter are in the range from 1 to 8. This parameter is used to indicate which of the available TxPowerLevel attributes defined in the MIB shall be used for the current transmission. | Y | N |
| RSSI |  | The allowed values for the RSSI parameter are in the range from 0 through RSSI maximum. This parameter is a measure by the PHY of the power observed at the antennas used to receive the current PPDU. RSSI shall be measured during the reception of the PLCP preamble. In HT-mixed format, the reported RSSI shall be measured during the reception of the HT-LTFs. In VHT format, the reported RSSI shall be measured during the reception of the VHT-LTFs. RSSI is intended to be used in a relative manner, and it shall be a monotonically increasing function of the received power. | N | Y |
| MCS | FORMAT is HT\_MF or HT\_GF | Selects the modulation and coding scheme used in the transmission of the packet. The value used in each MCS is the index defined in 20.6 (Parameters for HT MCSs).  Integer: range 0 to 76. Values of 77 to 127 are reserved.  The interpretation of the MCS index is defined in 20.6 (Parameters for HT MCSs). | Y | Y |
| FORMAT is VHT | Selects the modulation and coding scheme used in the transmission of the packet.  Integer: range 0 to 9 | MU | Y |
| Otherwise | Not present | Y | Y |
| REC\_MCS | FORMAT is HT\_MF or HT\_GF | Indicates the MCS that the STA’s receiver recommends. | N | O |
| FORMAT is VHT | TBD |  |  |
| Otherwise | Not present | N | N |
| CH\_BANDWIDTH | FORMAT is HT\_MF or HT\_GF | Indicates whether the packet is transmitted using 40 MHz or 20 MHz channel width.  Enumerated type:  HT\_CBW20 for 20 MHz and 40 MHz upper and 40 MHz lower modes HT\_CBW40 for 40 MHz | Y | Y |
| FORMAT is VHT | Indicates the channel width of the transmitted packet:  Enumerated type:  HT\_CBW20 for 20 MHz  HT\_CBW40 for 40 MHz  HT\_CBW80 for 80 MHz  HT\_CBW160 for 160 MHz  HT\_CBW80+80 for 80+80 MHz | Y | Y |
| FORMAT is NON\_HT | Enumerated type:  NON\_HT\_CBW40, NON\_HT\_CBW80, NON\_HT\_CBW160 or NON\_HT\_CBW80+80 for non-HT duplicate format  NON\_HT\_CBW20 for all other non-HT formats | Y | Y |
| INDICATED\_DYN\_BANDWIDTH | FORMAT is NON\_HT | When present, indicates whether the transmitter is capable of Static or Dynamic bandwidth operation:  Enumerated type:  Static if the transmitter is capable of Static bandwidth operation  Dynamic if the transmitter is capable of Dynamic bandwidth operation | Y | Y |
| Otherwise | Not present | N | N |
| INDICATED\_CH\_BANDWIDTH | FORMAT is NON\_HT | When present, indicates the BW to signal in the scrambler init field.  Enumerated type:  NON\_HT\_CBW20, NON\_HT\_CBW40, NON\_HT\_CBW80, NON\_HT\_CBW160 | Y | Y |
| Otherwise | Not present | N | N |
| CH\_OFFSET | FORMAT is VHT | TBD | Y | N |
| LENGTH | FORMAT is HT\_MF or HT\_GF | Indicates the length of an HT PSDU in the range of 0 to 65 535 octets. A value of zero indicates a NDP that contains no data symbols after the HT preamble (see 20.3.9 (HT preamble)). | Y | Y |
| FORMAT is VHT | Indicates the number of octets in the range 0 to 1,048,575 of useful data in the PSDU, i.e. the number of octets in the A-MPDU up to and including the last octet of the last non-zero length A-MPDU subframe but excluding the padding (if present) in the last subframe. This parameter is placed in the VHT-SIG-B Length field rounded up to a 4 octet boundary with the low order two bits removed.  *NOTE—the rounding up of the LENGTH parameter to a 4-octet word boundary may result in a LENGTH parameter that is larger than the PSDU\_LENGTH parameter.*  In the RXVECTOR, this parameter is the value obtained from the VHT-SIG-B Length field multiplied by 4 to represent a value in octets.  A value of zero indicates a NDP that contains no data symbols after the VHT preamble. | MU | O |
| Otherwise | Not present | N | N |
| PSDU\_LENGTH | FORMAT is VHT | Indicates the number of octets in the VHT PSDU in the range of 0 to 1,048,575 octets. | N | Y |
| Otherwise | Not present | N | N |
| USER\_INDEX | FORMAT is VHT | Index for user in MU transmission. Integer: range 0-3 | MU | N |
| Otherwise | Not present | N | N |
| NUM\_STS | FORMAT is VHT | Indicates the number of space-time streams  Integer: range 1-8 for SU, 0-4 for MU | MU | Y |
| Otherwise | Not present | N | N |
| GROUP\_ID | FORMAT is VHT | Indicates the Group ID. | Y | Y |
| Otherwise | Not present | N | N |
| PARTIAL\_AID | FORMAT is VHT and NUM\_USERS set to 1 | Indicates the least significant 9 bits of the AID of the intended recipient or 0 if intended for multiple recipients | Y | Y |
| Otherwise | Not present | N | N |
| NUM\_USERS | FORMAT is VHT | Indicates the number of users in rage 1 through 4. A value of 1 indicates an SU transmission, while a value greater than 1 indicates a MU transmission. | Y | N |
| Otherwise | Not present | N | N |
| TXOP\_PS\_NOT\_ALLOWED | FORMAT is VHT | 0 indicates AP allows non-AP VHT STAs to enter doze mode during a TXOP.  1 indicates AP does not allow non-AP VHT STAs to enter doze mode during a TXOP. | Y | Y |
| NOTE— In the “TXVECTOR” and “RXVECTOR” columns, the following apply:  Y = Present;  N = Not present;  O = Optional;  MU indicates that the parameter is present per user. Parameters specified to be present per user are conceptually supplied as an array of values indexed by USER\_NUM, where USER\_NUM takes values 1 through NUM\_USERS. | | | | |

### Effects of CH\_BANDWIDTH, CH\_OFFSET, MCS and NUM\_STREAMS parameters on PPDU format

TBD

### Support for NON\_HT formats

When the FORMAT parameter is set to NON\_HT, the behavior of the VHT PHY is defined in Clause 17. In this case, the PHY-TXSTART.request is handled by mapping the TXVECTOR parameters as defined in Table 22‑2 and following the operation as defined in Clause 17. Likewise the PHY-RXSTART.indication emitted when a NON\_HT PPDU is received is defined in Clause 17, with mapping of RXVECTOR parameters as defined in Table 22‑2. VHT PHY parameters not listed in the table are not present.

Table 22‑2 -- Mapping of the VHT PHY parameters for NON\_HT operation

|  |  |
| --- | --- |
| **VHT PHY Parameter** | **5.0 GHz operation defined by Clause 17** |
| L\_LENGTH | LENGTH |
| L\_DATARATE | DATARATE |
| TXPWR\_LEVEL | TXPWR\_LEVEL |
| RSSI | RSSI |
| SERVICE | SERVICE |
| RCPI | RCPI |
| INDICATED\_CH\_BANDWIDTH | INDICATED\_CH\_BANDWIDTH |
| INDICATED\_DYN\_BANDWIDTH | INDICATED\_DYN\_BANDWIDTH |

### Support for HT formats

When the FORMAT parameter is set to HT\_MF or HT\_GF, the behavior of the HT PHY is defined by Clause 20. The VHT PHY parameters in the PHY-TXSTART.request are mapped directly to the HT PHY parameters and the operation is as defined in Clause 20. Likewise the PHY-RXSTART.indication emitted when an HT\_MF or HT\_GF PPDU is received has parameters directly mapped from the VHT PHY RXVECTOR.

## VHT PLCP sublayer

### Introduction

This subclause provides a convergence procedure in which PSDUs are converted to and from PPDUs.

During transmission, the PSDU is processed (i.e., scrambled and coded) and appended to the PLCP preamble to create the PPDU. At the receiver, the PLCP preamble is processed to aid in demodulation and delivery of the PSDU.

### VHT PPDU format

A single PPDU format is defined for the PLCP: the VHT PPDU format. Figure 22‑1 shows the VHT PPDU format. The elements of the VHT PPDU format are summarized in Table 22‑3.



Figure 22‑1 -- VHT PPDU format

Table 22‑3 -- Elements of the VHT PLCP packet

|  |  |
| --- | --- |
| **Element** | **Description** |
| L-STF | Non-HT Short Training field |
| L-LTF | Non-HT Long Training field |
| L-SIG | Non-HT SIGNAL field |
| VHT-SIG-A | VHT Signal Field A |
| VHT-STF | VHT Short Training Field |
| VHT-LTFs | VHT Long Training fields |
| VHT-SIG-B | VHT Signal Field B |
| Data | The data field includes the PSDU (PHY Service Data Unit) |

The VHT-SIG-A , VHT-STF, VHT-LTFs, and VHT-SIG-B exist only in VHT packets. In non-HT , non-

HT duplicate formats, and in HT formats, these fields are not present. The number of VHT-LTFs, , can be either 1, 2, 4, 6 or 8 and is determined by the total number of space time streams across all users being transmitted in the frame (see Table 22‑10).

### Transmitter block diagram

The VHT PPDU can be generated using a transmitter consisting of the following blocks:

1. PHY Padding
2. Scrambler
3. Encoder parser
4. FEC encoders
5. Stream parser
6. Segment parser (for non-contiguous transmission)
7. BCC Interleaver
8. Constellation mapper
9. LDPC tone mapper
10. Space time block encoder
11. Spatial mapper
12. Inverse discrete Fourier transform (IDFT)
13. Cyclic shift (CSD) insertion
14. Guard interval (GI) insertion
15. Windowing



Figure 22‑2 -- Transmitter block diagram 1 (L-SIG and VHT-SIG-A)



Figure 22‑3 -- Transmitter block diagram 2 (VHT-SIG-B)



Figure 22‑4 -- Transmitter block diagram 3 (Data field in SU packet)

Note:

* There may be 1 or more FEC encoders when BCC encoding is used.
* The stream parser may have 1-8 outputs.
* For streams encoded using LDPC, the BCC interleavers are not used.
* For streams encoded using BCC, the LDPC tone mappers are not used,
* When STBC is used, the STBC block has more outputs than inputs.
* When spatial mapping is used, there may be more transmit chains than space time streams.
* The number of inputs to the spatial mapper may be 1-8.



Figure 22‑5 -- Transmitter block diagram 4 (Data field in MU packet, with LDPC and BCC encoding)



Figure 22‑6 -- Transmitter block diagram 5 (contiguous 160 MHz)



Figure ‑--Transmitter block diagram 6 (non-contiguous 80+80 MHz)

Figure 22‑2 through Figure 22‑7 show example transmitter block diagrams. Specifically, Figure 22‑2 shows the transmit process for the VHT-SIG-A field of VHT packet. These transmit blocks are also used to generate the non-VHT portion of the VHT packet, except that the BCC encoder and interleaver are not used when generating the L-STF and L-LTF fields. Figure 22‑4 shows the transmitter blocks used to generate the data field of the 20 MHz, 40 MHz and 80 MHz VHT format PPDUs. A subset of these transmitter blocks consisting of the constellation mapper and CSD blocks, as well as the blocks to the right of, and including, the spatial mapping block, are also used to generate the VHT-STF, VHT-LTF fields as illustrated in Figure 22‑11. Figure 22‑3 shows the transmit process for generating the VHT-SIG-B field of the VHT PPDUs. Figure 22‑5 shows the transmit process for generating the Data field of DL MU-MIMO VHT PPDUs assuming linear precoding. Figure 22-6 and Figure 22‑7 show the transmit process for generating the Data field of contiguous 160 MHz and non-contiguous 80+80 MHz VHT PPDUs, respectively.

### Overview of the PPDU encoding process

#### General

This subclause provides an overview of the VHT PPDU encoding process.

#### Construction of L-STF and L-LTF

Construct the L-STF and L-LTF as defined by Clause 17.

1. Before Sequence generation: From the TXVECTOR, determine the CH\_BANDWIDTH.
2. Sequence generation: L-STF and L-LTF sequence is generated as described in 17.3.3.
3. IDFT: Duplicate the L\_STF and L\_LTF over each 20 MHz of the CH\_BANDWIDTH. Apply appropriate phase rotation for each 20MHz sub-band as described in 22.3.7 and compute the Inverse Fourier Transform.
4. CSD: Apply CSD for each transmit chain as described in 22.3.9.1.1.
5. Insert GI and Window: Prepend a GI (800ns) and apply windowing as described in 17.3.2.4.
6. Analog and RF: Up-convert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 22.3.7 and 22.3.8 for details.

#### Construction of L-SIGNAL

Construct the L-SIGNAL as defined by Clause 17.

1. Before FEC Encoder: For VHT PPDU set the RATE in the SIGNAL field to 6 Mbps. Set the LENGTH in the SIGNAL field according to section 22.3.9.1.4. Add calculated one bit parity and 6 tail bits into the L-SIGNAL symbol.
2. FEC Encoder: Encode the L-SIGNAL symbol of the PLCP header by a convolution code at the rate of R=1/2 as described in 17.3.5.5.
3. BCC Interleaver: Interleave as described in 17.3.5.6.
4. Constellation Mapper: BPSK modulate described in 17.3.5.6.
5. IDFT: Insert pilots. Duplicate the L-SIGNAL over each 20 MHz of the CH\_BANDWIDTH. Apply appropriate phase rotation for each 20MHz sub-band and compute the Inverse Fourier Transform.
6. CSD: Apply CSD for each transmit chain as described in 22.3.9.1.1.
7. Insert GI and Window: Prepend a GI (800ns) and apply windowing as described in 17.3.2.4.
8. Analog and RF: Up-convert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 22.3.7 and 22.3.8 for details.

#### Construction of VHT-SIG-A

The VHT-SIG-A consists of two symbols VHT-SIG-A1 and VHT-SIG-A2 as defined in section 22.3.2.

1. Before FEC Encoder: Obtain the CH\_BANDWIDTH, STBC, GROUP\_ID, PARTIAL\_AID (for SU only), NUM\_STS, GI\_TYPE, FEC\_CODING, MCS (for SU only), [SU-Beamformed], NUM\_USERS from the TX\_VECTOR. Add the appropriate reserved bit and 6 tail bits as shown in section 22.3.9.2.3. Calculate the CRC and append it. Partition the VHT-SIG-A bits such that the first 24 uncoded bits are modulated by the VHT-SIG-A1 symbol, and the second 24 uncoded bits are modulated by the VHT-SIG-A2 symbol.
2. FEC Encoder: Encode the data by a convolution coder at the rate of R=1/2 as described in 17.3.5.5.
3. BCC Interleaver: Interleave as described in 17.3.5.6.
4. Constellation Mapper: VHT-SIG-A1 is BPSK modulated described in 17.3.5.6. VHT-SIG-A2 is rotated by 90° relative to VHT-SIG-A1.
5. IDFT: Insert pilots for both the symbols. Duplicate VHT-SIG-A1 and VHT-SIG-A2 over each 20 MHz of the CH\_BANDWIDTH. Apply appropriate phase rotation for each 20MHz sub-band. Compute the Inverse Fourier transform.
6. CSD: Apply CSD for each transmit chain as described in 22.3.9.2.2.
7. Insert GI and Window: Prepend a GI (800ns) and apply windowing as described in 17.3.2.4.
8. Analog and RF: Up-convert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 22.3.7 and 22.3.8 for details.

#### Construction of VHT-STF

Construct the VHT-STF according to section 22.3.9.2.4.

1. Sequence generation: VHT-STF sequence is generated in the frequency-domain over bandwidth indicated by CH\_BANDWIDTH as described in 22.3.9.2.4.
2. IDFT: Apply appropriate phase rotation for each 20MHz sub-band and compute the Inverse Fourier transform.
3. CSD: Apply CSD for each transmit chain as described in 22.3.9.2.2.
4. Insert GI and Window: Prepend a GI (800ns) and apply windowing as described in 17.3.2.4.
5. Analog and RF: Up-convert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 22.3.7 and 22.3.8 for details.

#### Construction of VHT-LTF

The VHT-LTF allows the receiver to estimate the MIMO channels. The transmitter provides training for exactly the space time streams used for transmission of the PSDU.

1. Sequence generation: VHT-LTF sequence is generated in the frequency-domain over bandwidth indicated by CH\_BANDWIDTH as described in 22.3.9.2.5.
2. Pilot insertion: Insert pilots and apply appropriate phase rotation for each 20MHz sub-band.
3. VHT-LTF matrix mapping: P Matrix is applied to VHT-LTF sequence and R matrix is applied to pilot tones as described in 22.3.9.2.5.
4. CSD: Apply CSD for each transmit chain as described in 22.3.9.2.2.
5. Spatial Mapping: Q matrix is applied as described in 22.3.11.10.1.
6. IDFT: compute the Inverse Fourier transform.
7. Insert GI and Window: Prepend a GI (800ns) and apply windowing as described in 17.3.2.4.
8. Analog and RF: Up-convert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 22.3.7 and 22.3.8 for details.

#### Construction of VHT-SIG-B

VHT-SIG-B is constructed as follows:

1. Before VHT-SIG-B Bits: Obtain the MCS (for MU only), PSDU\_LENGTH from the TX\_VECTOR.
2. VHT-SIG-B Bits: For VHT PPDU set the MCS (for MU only) and the Length field according to section 22.3.9.2.6. Add the reserved bits (for SU only) and 6 bits tail. For an NDP packet, the unique fixed bit pattern is defined.
3. VHT-SIG-B Bit Repetition: VHT-SIG-B bits are repeated over bandwidth indicated by CH\_BANDWIDTH.
4. BCC Encoder: The VHT-SIG-B is encoded using BCC at rate R=1/2 as described in 17.3.5.5.
5. BCC Interleaver: Interleave as described in 22.3.11.7.
6. Constellation Mapper: Map to a BPSK constellation.
7. Multiply with 1st Column of [P]u: Have pilots inserted and 1st column of P matrix calculation is applied. The total number of data and pilot subcarriers is the same as the data PSDU.
8. CSD: Apply CSD for each transmit chain as described in 22.3.9.2.2.
9. Spatial Mapping: Q matrix is applied as described in 22.3.11.10.1.
10. IDFT: Apply appropriate phase rotation for each 20MHz sub-band and compute the Inverse Fourier transform.
11. Insert GI and Window: Prepend a GI (800ns) and apply windowing as described in 17.3.2.4.
12. Analog and RF: Up-convert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 22.3.7 and 22.3.8 for details.

#### Construction of the Data field in an SU packet

##### Using BCC

The construction of the Data field in a VHT SU packet with BCC encoding proceeds as follows:

1. Before PHY Padding: Append the PSDU to the SERVICE field (16 bits) including the CRC calculated for VHT-SIG-B as described in 22.3.11.1.
2. PHY Padding: PHY pad bits and 6NES tail bits are appended to the PSDU.
3. Scrambler: Scramble the PHY padded data with the initial state of the scrambler according to INDICATED\_CH\_BANDWIDTH and INDICATED\_DYN\_BANDWIDTH as described in 17.3.5.4.
4. Encoder Parser: the scrambled bits are divided between the encoders by sending bits to different encoders in a round robin manner. The number of encoders is determined by rate-dependent parameters as described in 22.5.
5. BCC Encoder: BCC encode as described in 22.3.11.4.
6. Stream Parser: The output of the BCC encoders are re-arranged into blocks as described in 22.3.11.5.
7. Segment Parser (if needed): When contiguous 160 MHz or non-contiguous 80+80 MHz transmission is used, the output bits of each stream parser are divided into two frequency segments as described in 22.3.11.6. In contiguous 160MHz transmission, each segment is mapped to the upper and the lower part of one IDFT, respectively. In non-contiguous 80+80MHz transmission, each segment is mapped to the separate IDFT. This block is bypassed in case of 20, 40 and 80MHz VHT PPDU transmissions.
8. BCC Interleaver: Interleave as described in 22.3.11.7.
9. Constellation Mapper: Map to constellation points for BPSK, QPSK, 16-QAM, 64-QAM and 256-QAM as described in 22.3.11.8.
10. STBC: STBC is applied as described in 22.3.11.8.3.
11. CSD: Insert pilots and apply CSD for each transmit chain as described in 22.3.9.2.2.
12. Spatial Mapping: Q matrix is applied as described in 22.3.11.10.1.
13. IDFT: Apply appropriate phase rotation for each 20MHz sub-band and compute the Inverse Fourier transform.
14. Insert GI and Window: Prepend a GI (400 ns or 800 ns) and apply windowing as described in 17.3.2.4.
15. Analog and RF: Up-convert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 22.3.7 and 22.3.8 for details.

##### Using LDPC

The construction of the Data field in a VHT SU packet with LDPC encoding proceeds as follows:

1. Before PHY Padding: Append the PSDU to the SERVICE field (16 bits) including the CRC calculated for VHT-SIG-B as described in 22.3.11.1.
2. PHY Padding: PHY pad bits are appended to the PSDU. There are no tail bits.
3. Scrambler: Scramble the PHY padded data with the initial state of the scrambler according to INDICATED\_CH\_BANDWIDTH and INDICATED\_DYN\_BANDWIDTH as described in 17.3.5.4.
4. LDPC Encoder: The scrambled bits are encoded using the LDPC code as described in 22.3.11.4.2.
5. Stream Parser: The output of the LDPC encoder is re-arranged into blocks as described in 22.3.11.5.
6. Segment Parser (if needed): When contiguous 160 MHz or non-contiguous 80+80 MHz transmission is used, the output bits of each stream parser are divided into two frequency segments as described in 22.3.11.6. In contiguous 160 MHz transmission, each segment is mapped to the upper and the lower part of one IDFT, respectively. In non-contiguous 80+80 MHz transmission, each segment is mapped to the separate IDFT. This block is bypassed in case of 20, 40 and 80MHz VHT PPDU transmissions.
7. Constellation Mapper: Map to constellation points for BPSK, QPSK, 16-QAM, 64-QAM and 256-QAM as described in 22.3.11.8.
8. LDPC Tone Mapper: The LDPC tone mapping shall be performed on all LDPC coded streams as described in 22.3.11.8.2.
9. STBC: STBC is applied as described in 22.3.11.8.3.
10. CSD: Apply CSD for each transmit chain as described in 22.3.9.2.2.
11. Spatial Mapping: Q matrix is applied as described in 22.3.11.10.1.
12. IDFT: Apply appropriate phase rotation for each 20MHz sub-band and compute the Inverse Fourier transform.
13. Insert GI and Window: Prepend a GI (400ns or 800ns) and apply windowing as described in 17.3.2.4.
14. Analog and RF: Up-convert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 22.3.7 and 22.3.8 for details.

#### Construction of the Data field in an MU packet

##### General

In case of an MU transmission, the PPDU encoding process is performed on a per-user basis and combine all users’ data in the spatial mapping.

##### Using BCC

It is the same to the process described in 22.3.4.8.1 before the spatial mapping block.

##### Using LDPC

It is the same to the process described in 22.3.4.8.2 before the spatial mapping block.

##### Combining to form MU packet

The per-user data is combined as follows:

1. Spatial Mapping: Q matrix is applied as described in 22.3.11.10.1. Combining all users’ data is done in this block.
2. IDFT: Apply appropriate phase rotation for each 20MHz sub-band and compute the Inverse Fourier transform.
3. Insert GI and Window: Prepend a GI (400ns or 800ns) and apply windowing as described in 17.3.2.4.
4. Analog and RF: Up-convert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 22.3.7 and 22.3.8 for details.

### Modulation and coding scheme (MCS)

The MCS is a value that determines the modulation and coding used in the Data field of the packet. It is a compact representation that is carried in the VHT-SIG-A for SU or VHT-SIG-B for MU. Rate-dependent parameters for the full set of MCSs are shown in Table 22‑25 through (in 22.5). These tables give rate-dependent parameters for MCSs with indices 0 through 9, with number of spatial streams from 1 to 8 and bandwidth options of 20 MHz, 40 MHz, 80 MHz and 160 MHz. Equal modulation (EQM) is applied to all streams for a particular user.

Table 22‑25 through show rate-dependent parameters for MCSs for one through eight streams for 20 MHz operation. Table 22‑33 through show rate-dependent parameters for MCSs for one through eight streams for 40 MHz operation. Table 22‑41 through show rate-dependent parameters for MCSs for one through eight streams for 80 MHz operation. Table 22‑49 through show rate-dependent parameters for MCSs for one through eight streams for 160 MHz and 80+80 MHz operation.

Transmit and receive support for MCS 0 through 7 in single stream 20 MHz, 40 MHz and 80 MHz PPDUs with 800 ns GI is mandatory in both APs and non-AP STAs. All other modes are optional, specifically including transmit and receive support for 400 ns GI, operation in 160 MHz channel width, support of MCSs 8 and 9, and support for more than 1 spatial stream.

### Timing-related parameters

Refer to Table 20-5 for timing-related parameters for non-VHT formats.

Table 22‑4 defines the timing-related parameters for VHT format.

Table 22‑4 – Timing-related constants

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Parameter** | **VHT\_CBW20** | **VHT\_CBW40** | **VHT\_CBW80** | **VHT\_CBW 80+80** | **VHT\_CBW160** |
| *NSD*: Number of complex data numbers per frequency segment | 52 | 108 | 234 | 234 | 468 |
| *NSP*: Number of pilot values per frequency segment | 4 | 6 | 8 | 8 | 16 |
| *NST*: Total number of subcarriers per frequency segment  See NOTE 1 | 56 | 114 | 242 | 242 | 484 |
| *NSR*: Highest data subcarrier index per frequency segment | 28 | 58 | 122 | 122 | 250 |
| *NSeg*: Number of frequency segments | 1 | 1 | 1 | 2 | 1 |
| ∆*F*: Subcarrier frequency spacing | 312.5 kHz | | | | |
| *TDFT*: IDFT/DFT period | 3.2 µs | | | | |
| *TGI*: Guard interval duration | 0.8 µs = *TDFT* /4 | | | | |
| *TGI2*: Double guard interval | 1.6 µs | | | | |
| *TGIS*: Short guard interval duration | 0.4 µs = *TDFT* /8 | | | | |
| *TL-STF*: Legacy short training sequence duration | 8 µs = 10 x *TDFT* /4 | | | | |
| *TL-LTF*: Legacy long training sequence duration | 8 µs = 2 x *TDFT* + *TGIS* | | | | |
| *TSYM*: Symbol interval | 4 µs = *TDFT* + *TGI* | | | | |
| *TSYMS*: Short GI symbol interval | 3.6 µs = *TDFT* + *TGIS* | | | | |
| *TL-SIG*: Legacy SIGNAL field duration | 4 µs | | | | |
| *TVHT-SIG-A*: VHT SIGNAL A field duration | 8 µs = 2*TSYM* | | | | |
| *TVHT-STF*: VHT short training field duration | 4 µs | | | | |
| *TVHT-LTF*: Duration of each VHT LTF training field | 4 µs | | | | |
| *TVHT-SIG-B*: VHT SIGNAL B field duration | 4 µs = *TSYM* | | | | |
|  | NOTE 1 – *NST* = *NSD* + *NSP* | | | | |

Table 22‑5 defines parameters used frequently in Clause 22.

Table 22‑5 – Frequently used parameters

|  |  |
| --- | --- |
| **Symbol** | **Explanation** |
|  | Number of coded bits per symbol |
|  | Number of coded bits per symbol per spatial stream |
|  | Number of data bits per symbol |
|  | Number of coded bits per subcarrier over all spatial streams |
|  | Number of coded bits per subcarrier per spatial stream |
|  | Number of receive chains |
| *Nu* | Number of users in a transmission. *Nu* = 1 for SU transmission. |
| , | is the number of space-time streams for user *u*, *u*=0,1,2,3.  For SU packets, .  For MU packets,  is undefined. |
|  | Total number of space-time streams in a packet.    Note that  for SU packets. |
| , | is the number of spatial streams for user *u*, *u*=0,1,2,3.  For SU packets, .  For MU packets,  is undefined. |
|  | Number of transmit chains |
| , | is the number of BCC encoders for the Data field for user *u*, *u*=0,1,2,3.  For SU packets, .  For MU packets,  is undefined. |
|  | Number of VHT long training fields (see 22.3.9.2.5) |
|  | Coding rate |

### Mathematical description of signals

For description on convention for mathematical description of signals, see 17.3.2.4.

For description on subcarrier indices over which signal is transmitted for non-HT and HT PPDUs, see 20.3.7.

In case of 20 MHz VHT PPDU transmission, the 20 MHz is divided into 64 subcarriers. Signal is transmitted on subcarriers -28 to -1 and 1 to 28, with 0 being the center (DC) carrier.

In case of 40 MHz VHT PPDU transmission, the 40 MHz is divided into 128 subcarriers. Signal is transmitted on subcarriers -58 to -2 and 2 to 58.

In case of 80 MHz VHT PPDU transmission, the 80 MHz is divided into 256 subcarriers. Signal is transmitted on subcarriers -122 to -2 and 2 to 122.

In case of 160 MHz VHT PPDU transmission, the 160 MHz is divided into 512 subcarriers. Signal is transmitted on subcarriers -250 to -130, -126 to -6, 6 to 126, and 130 to 250.

In case of non-contiguous 80+80 MHz VHT PPDU transmission, each 80 MHz frequency segment is divided into 256 subcarriers. In each frequency segment, signal is transmitted on subcarriers -122 to -2 and 2 to 122.

The transmitted signal is described in complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the relation shown in Equation .



where

 represents the real part of a complex variable;

 represents the number of frequency segments the transmit signal consists of.  for contiguous transmissions and for non-contiguous transmissions;

 represents the complex baseband signal of frequency segment ;

 represents the carrier center frequency of frequency segment .

*NOTE--80+80 MHz is two non-adjacent frequency segments as defined in 3.1 for non-contiguous transmission.*

The transmitted RF signal is derived by modulating the complex baseband signal, which consists of several fields. The timing boundaries for the various fields are shown in Figure 22‑8 where  is the number of VHT-LTF symbols and is defined in Table 22‑10.



Figure 22‑8--Timing boundaries for VHT PPDU fields

The time offset, , determines the starting time of the corresponding field.

The signal transmitted on frequency segment  of transmit chain  shall be as shown in Equation .

|  |  |
| --- | --- |
|  |  |

where

|  |  |  |
| --- | --- | --- |
|  |  |  |

Each baseband waveform, , is defined via the discrete Fourier transform per OFDM symbol as

|  |  |
| --- | --- |
|  |  |

This general representation holds for all fields. An example definition of the windowing function, , is given in 17.3.2.4.  represents the number of users in the transmission, and  is the user index. For SU transmissions, . The non-VHT portion (L-STF, L-LTF and L-SIG) and VHT-SIG-A of MU transmissions are common to all users, and thus shall also use  in Equation . For MU transmissions, the VHT portion starting from the VHT-STF shall have  depending on the number of users in the transmission. The frequency-domain symbols  represents the output of any spatial processing in subcarrier  of user  for frequency segment  of transmit chain  required for the field.  is the highest data subcarrier index per frequency segment, whose values are listed in Table 22‑4.

*NOTE—Some of the  with  may have a value of zero. Examples of such cases include the DC tones, guard tones on each side of the transmit spectrum, as well as the unmodulated tones of L-STF and VHT-STF symbols.*

The function  is used to represent a rotation of the tones. For 20 MHz PPDU transmissions,

|  |  |
| --- | --- |
|  |  |

For 40 MHz PPDU transmissions,

|  |  |
| --- | --- |
|  |  |

For 80 MHz PPDU transmissions,

|  |  |
| --- | --- |
|  |  |

For non-contiguous 160 MHz PPDU transmissions consisting of two 80 MHz frequency segments, each 80 MHz frequency segment shall use the phase rotation for 80 MHz PPDU transmissions as defined in Equation .

For contiguous 160 MHz PPDU transmissions,

|  |  |
| --- | --- |
|  |  |

The  scale factor in Equation ensures that the total power of the time domain signal of a frequency segment summed over all transmit chains is normalized to 1. Table 22‑6 summarizes the various values of **** as a function of bandwidth per frequency segment.

Table 22‑6--Value of tone scaling factor



|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Field** | **as a function of bandwidth per frequency segment** | | | |
| **20 MHz** | **40 MHz** | **80 MHz** | **160 MHz** |
| L-STF | 12 | 24 | 48 | 96 |
| L-LTF | 52 | 104 | 208 | 416 |
| L-SIG | 52 | 104 | 208 | 416 |
| VHT-SIG A | 52 | 104 | 208 | 416 |
| VHT-STF | 12 | 24 | 48 | 96 |
| VHT-LTF | 56 | 114 | 242 | 484 |
| VHT-SIG B | 56 | 114 | 242 | 484 |
| VHT-Data | 56 | 114 | 242 | 484 |
| NON-HT-DUP | - | 104 | 208 | 416 |

### Transmission of PPDU with bandwidth less than the BSS bandwidth

When transmitting a 20 MHz PPDU in a 40 MHz channel, the mathematical description of transmission shall follow that of a 20 MHz channel with  in Equation replaced by  MHz.

When transmitting a 20 MHz PPDU in an 80 MHz or 80+80 MHz channel, the mathematical description of transmission shall follow that of a 20 MHz channel with in Equation replaced by MHz or  MHz.



When transmitting a 20 MHz PPDU in an 160 MHz channel, the mathematical description of transmission shall follow that of a 20 MHz channel with in Equation replaced by MHz,  MHz,  MHz or  MHz.



When transmitting a 40 MHz PPDU in an 80 MHz or 80+80 channel, the mathematical description of transmission shall follow that of a 40 MHz channel with in Equation replaced by  MHz.



When transmitting a 40 MHz PPDU in a 160 MHz channel, the mathematical description of transmission shall follow that of a 40 MHz channel with in Equation replaced by  MHz or  MHz.



When transmitting an 80 MHz PPDU in a 160 MHz channel, the mathematical description of transmission shall follow that of an 80 MHz channel with in Equation replaced by  MHz.



### VHT preamble

A VHT preamble is defined to carry the required information to operate in either single-user or multi-user mode. To ensure compatibility with non-VHT STAs, specific non-VHT fields are defined that can be received by non-VHT STAs compliant with Clause 17 or Clause 20. The non-VHT fields are followed by VHT fields specific to VHT STAs.

#### Non-VHT portion of VHT format preamble

##### Cyclic shift definition

The cyclic shift value for the L-STF, L-LTF, L-SIG and VHT-SIG-A portions of the packet for transmitter out of total  are defined in Table 22-7.

Table ‑--Cyclic shift values for L-STF, L-LTF, L-SIG and VHT-SIG-A portions of the packet

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **values for L-STF, L-LTF, L-SIG and VHT-SIG-A portions of the packet** | | | | | | | | |
| **Total number of transmit antennas (*N*TX)** | **Cyclic shift for transmit antenna *i*TX (in units of ns)** | | | | | | | |
| **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
| 1 | 0 | - | - | - | - | - | - | - |
| 2 | 0 | -200 | - | - | - | - | - | - |
| 3 | 0 | -100 | -200 | - | - | - | - | - |
| 4 | 0 | -50 | -100 | -150 | - | - | - | - |
| 5 | 0 | -175 | -25 | -50 | -75 | - | - | - |
| 6 | 0 | -200 | -25 | -150 | -175 | -125 | - | - |
| 7 | 0 | -200 | -150 | -25 | -175 | -75 | -50 | - |
| 8 | 0 | -175 | -150 | -125 | -25 | -100 | -50 | -200 |

##### L-STF definition

The L-STF for 20 MHz and 40 MHz are defined by Equations (20-8) and (20-9) respectively in 20.3.9.3.3. For 80 MHz, the L-STF is defined by Equation , which does not include the phase rotation per 20 MHz subchannel.

|  |  |
| --- | --- |
|  |  |

where  is define in Equation (20-9).

For 160 MHz, the L-STF is defined by Equation .

|  |  |
| --- | --- |
|  |  |

where is defined in Equation .

For non-contiguous transmissions using two 80 MHz frequency segments, each 80 MHz frequency segment shall use the L-STF pattern for the 80 MHz () defined in Equation .

The time domain representation of the signal on frequency segment  in transmit chain  shall be:

|  |  |
| --- | --- |
|  |  |

where

represents the cyclic shift for transmit chain  with a value given in Table 22‑7.



 is defined by Equations , , and .

##### L-LTF definition

For a bandwidth of 20 MHz and 40 MHz, the L-LTF pattern in the VHT preamble are defined by Equations (20-11) and (20-12), respectively, in 20.3.9.3.4.. For a bandwidth of 80 MHz, the L-LTF pattern is defined by Equation , which does not include the phase rotations per 20 MHz subchannel.

|  |  |
| --- | --- |
|  |  |

where  is define in Equation (20-9).

For 160 MHz, L-LTF is defined by Equation , which does not include the phase rotations per 20 MHz subchannel.

|  |  |
| --- | --- |
|  |  |

Where is given by Equation .

For non-contiguous transmissions using two 80 MHz frequency segments, each 80 MHz frequency segment shall use the L-LTF pattern for the 80 MHz () defined in Equation .



The time domain representation of the signal on transmit chain  shall be as defined in Equation .

|  |  |
| --- | --- |
|  |  |

where

represents the cyclic shift for transmitter chain  with a value given in Table 22‑7.

is defined by Equations , , and .



##### L-SIG definition

The L-SIG is used to communicate rate and length information. The structure of the L-SIG is shown in Figure 22‑9.



Figure 22‑9--L-SIG structure

The Rate field shall be set to represent 6 Mbps for 20 MHz channel spacing according to Table 17-5.

The Length field shall be set according to the equation



where TXTIME (in µs) is defined in 22.4.3. A STA shall not transmit a VHT PPDU if the Length value calculated using Equation exceeds 4095 octets.

The reserved bit shall be set to 0.

The parity field has the even parity of bits 0-16.

The L-SIG shall be encoded, interleaved and mapped, and it shall have pilots inserted following the steps described in 17.3.5.5, 17.3.5.6, and 17.3.5.8. The stream of 48 complex numbers generated by the steps described in 17.3.5.6 is denoted by *dk*, k=0..47. The time domain waveform of the L-SIG shall be as given by Equation .

|  |  |
| --- | --- |
|  |  |

where

 is the number of 20 MHz subchannels used by each frequency segment, and is 1, 2, 4, 8 and 4 for 20, 40, 80, 160 and 80+80 MHz transmissions respectively







|  |  |
| --- | --- |
|  |  |

 is defined in 17.3.5.9

 is the first pilot value in the sequence defined in 17.3.5.9

 has the value given in Table 22‑6

is defined in Equations , , and



 represents the cyclic shift for transmitter chain  with a value given in Table 22‑7.

#### VHT portion of VHT format preamble

##### Introduction

When a VHT format preamble is transmitted, the VHT preamble consists of the VHT-STF, the VHT-LTFs, VHT-SIG-A and the VHT-SIG-B.

The following notational conventions are used throughout 22.3.9.2:

* indicates the element in row  and column  of matrix 
* indicates a matrix consisting of the first  columns of matrix 
* indicates a matrix consisting of columns  through of matrix 

##### Cyclic shift definition

The cyclic shift values defined in this subclause apply to the VHT-STF, VHT-LTFs, and VHT-SIG-B of the VHT format preamble. The cyclic shift values defined in 22.3.9.1.1 apply to VHT-SIG-A in the VHT format preamble.

Throughout the VHT portion of a VHT format preamble, cyclic shift is applied to prevent beamforming when similar signals are transmitted in different space-time streams. The same cyclic shift is applied to these streams during the transmission of the data portion of the frame. The cyclic shift value  for the portion of the packet following VHT-SIG-A for space-time stream *n* out of  total space-time streams is shown in Table 22‑8.

Table 22‑8--Cyclic shift values of VHT portion of packet

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **values for VHT portion of packet** | | | | | | | | |
| **Total number of space-time streams** | **Cyclic shift for space-time stream *n* (ns)** | | | | | | | |
| **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
| 1 | 0 | - | - | - | - | - | - | - |
| 2 | 0 | -400 | - | - | - | - | - | - |
| 3 | 0 | -400 | -200 | - | - | - | - | - |
| 4 | 0 | -400 | -200 | -600 | - | - | - | - |
| 5 | 0 | -400 | -200 | -600 | -350 | - | - | - |
| 6 | 0 | -400 | -200 | -600 | -350 | -650 | - | - |
| 7 | 0 | -400 | -200 | -600 | -350 | -650 | -100 | - |
| 8 | 0 | -400 | -200 | -600 | -350 | -650 | -100 | -750 |

In a MU packet, the cyclic shift are applied continuously across the space-time streams as follows: the cyclic shift of the space time stream number  of user  is given by  of the row corresponding to  in Table 22‑8 where

|  |  |
| --- | --- |
|  | is given by with , |
|  | is defined in Table 22‑5 and |
|  | is defined in Table 22‑5. |

##### VHT-SIG-A definition

The VHT-SIG-A field carries information required to interpret VHT format packets. VHT-SIG-A contains the fields listed inTable 22‑9.

Table 22‑9 - VHT-SIG-A fields

|  |  |  |  |
| --- | --- | --- | --- |
| **Bit** | **Field** | **Bit Allocation** | **Description** |
| **VHT-SIG-A1** | | | |
| B0-B1 | BW | 2 | Set to 0 for 20 MHz, 1 for 40 MHz, 2 for 80 MHz, 3 for 160 MHz and 80+80 MHz |
| B2 | Reserved | 1 | Reserved for possible expansion of BW field. Set to 1. |
| B3 | STBC | 1 | Set to 1 if all streams have space time block coding and set to 0 otherwise |
| B4-B9 | Group ID | 6 | A value of 63 (all ones) indicates:  A single user transmission  A transmission where the group membership has not yet been established  A transmission that needs to bypass a group (e.g. broadcast) |
| B10-B21 | NSTS | 12 | For MU: 3 bits/user with maximum of 4 users (user u uses bits B(10+3\*u)-B(12+3\*u), u=0,1,2,3)  Set to 0 for 0 space time streams  Set to 1 for 1 space time stream  Set to 2 for 2 space time streams  Set to 3 for 3 space time streams  Set to 4 for 4 space time streams  For SU:  B10-B12  Set to 0 for 1 space time stream  Set to 1 for 2 space time streams  Set to 2 for 3 space time streams  Set to 3 for 4 space time streams  Set to 4 for 5 space time streams  Set to 5 for 6 space time streams  Set to 6 for 7 space time streams  Set to 7 for 8 space time streams  B13-B21  Partial AID: 9 LSB bits of AID. |
| B22 | No TXOP PS | 1 | Set to 1 if TXOP PS permitted  Set to 0 otherwise |
| B23 | Reserved | 2 | All ones |
| **VHT-SIG-A2** | | | |
| B0-B1 | Short GI | 2 | B0:  Set to 0 if short guard interval is not used in the Data field.  Set to 1 if short guard interval is used in the Data field.  B1:  Set to 1 if short guard interval is used and NSYM mod 10 = 9, otherwise set to 0. NSYM is defined in section 22.4.3. |
| B2-B3 | Coding | 2 | For SU, B2 is set to 0 for BCC, 1 for LDPC  For MU, if the NSTS field for user 1 is non-zero, then B2 indicates the coding used for user 1; set to 0 for BCC and 1 for LDPC. If the NSTS field for user 1 is set to 0, then this field is reserved and set to 1.  B3: set to 1 if LDPC PPDU encoding process (or at least one LPDC user’s PPDU encoding process) results in an extra OFDM symbol (or symbols) as described in 22.3.4. Set to 0 otherwise. |
| B4-B7 | MCS | 4 | For SU:  MCS index  For MU:  If the NSTS field for user 2 is non-zero, then B4 indicates coding for user 2: set to 0 for BCC, 1 for LDPC. If NSTS for user 2 is set to 0, then B4 is reserved and set to 1.  If the NSTS field for user 3 is non-zero, then B5 indicates coding for user 3: set to 0 for BCC, 1 for LDPC. If NSTS for user 3 is set to 0, then B5 is reserved and set to 1.  If the NSTS field for user 4 is non-zero, then B6 indicates coding for user 4: set to 0 for BCC, 1 for LDPC. If NSTS for user 4 is set to 0, then B4 is reserved and set to 1.  B7 is reserved and set to 1 |
| B8 | Beamformed | 1 | For SU:  Set to 1 if a Beamforming steering matrix is applied to the waveform in an SU transmission as described in 20.3.11.10.1), set to 0 otherwise.  For MU:  Reserved and set to 1 |
| B9 | Reserved | 1 | Reserved and set to 1 |
| B10-B17 | CRC | 8 | CRC calculated as in Section 20.3.9.4.4 with C7 in B10, etc. |
| B18-B23 | Tail | 6 | Used to terminate the trellis of the convolutional decoder. Set to 0. |

NOTE 1—Integer fields are represented by unsigned binary format, with the least significant bit in the lowest numbered bit position.

The VHT-SIG-A is composed of two symbols, VHT-SIG-A1 and VHT-SIG-A2, each containing 24 bits, as shown in Figure[TBD]. For fields consisting of multiple bits, the LSB of the field is mapped to the lowest bit among the corresponding VHT-SIG-A bits. For example, for a group ID of 11 (0b001011), B4=1, B5=1, B6=0, B7=1, B8=0 and B9=0 in VHT-SIG-A1. VHT-SIG-A1 is transmitted before VHT-SIG-A2. The VHT-SIG-A parts shall be BCC encoded at rate, R = 1/2, interleaved, mapped to a BPSK constellation, and have pilots inserted following the steps described in 17.3.5.5, 17.3.5.6, 17.3.5.7, and 17.3.5.8, respectively. The BPSK constellation for VHT-SIG-A2 is rotated by 90° relative to VHT-SIG-A1 field in order to accommodate differentiation of the VHT format PPDU from a non-HT and HT PPDU. The stream of 96 complex numbers generated by these steps is divided into two groups of 48 complex numbers  . The time domain waveform for the VHT-SIG-A field in a VHT format packet shall be:

|  |  |
| --- | --- |
|  |  |

where

 and  are defined in 22.3.9.1.4



|  |  |
| --- | --- |
|  |  |

 is defined in 22.3.9.1.4

 and  are defined in 17.3.5.9

 has the value given in Table 22‑6

is defined in Equations , , and



 represents the cyclic shift for transmitter chain  with a value given in Table 22‑7.

NOTE—This definition results in a QBPSK modulation on the second symbol of VHT-SIG-A where the constellation of the data tones is rotated by 90º relative to the first symbol of VHT-SIG-A and relative to the non-HT signal field in VHT format PPDUs (Figure 22‑8). In VHT format PPDUs, the VHT-SIG-A is transmitted with the same number of subcarriers and the same cyclic shifts as the preceding non-HT portion of the preamble. This is done to accommodate the estimation of channel parameters needed to robustly demodulate and decode the information contained in VHT-SIG-A.

For non-contiguous transmissions using two 80 MHz frequency segments, each frequency segment shall use the time domain waveform for 80 MHz transmissions.

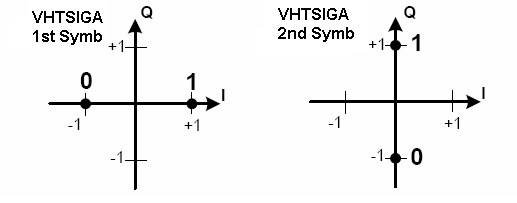
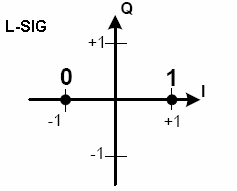


Figure 22‑10--Data constellation in the VHT format PPDU

##### VHT-STF definition

The purpose of the VHT-STF is to improve automatic gain control estimation in a MIMO transmission. The duration of the VHT-STF is 4 μs. The frequency domain sequence used to construct the VHT-STF in 20 MHz transmission is identical to the L-STF. In 40 and 80 MHz transmissions, the VHT-STF is constructed from the 20 MHz version by replicating it in each 20 MHz band, frequency shifting, and applying appropriate phase rotations for each 20MHz sub-band.

For 20 MHz, the frequency domain sequence is given by Equation .

|  |  |
| --- | --- |
|  |  |

where  is defined in Equation (20-19).

For 40 MHz, the frequency domain sequence is given by Equation .

|  |  |
| --- | --- |
|  |  |

where  is defined in Equation (20-20).

For 80 MHz, the frequency domain sequence is given by Equation .

|  |  |
| --- | --- |
|  |  |

where  is given in Equation .

For 160 MHz, the frequency domain sequence is given by Equation .

|  |  |
| --- | --- |
|  |  |

where  is given in Equation .

Note that Equations , , and do not include the phase rotation per 20 MHz subchannel.

For non-contiguous transmissions using two 80 MHz frequency segments, each 80 MHz frequency segment shall use the VHT-STF pattern for the 80 MHz () defined in Equation .

The time domain representation of the signal on frequency segment  of transmit chain  shall be:

|  |  |
| --- | --- |
|  |  |

where

|  |  |
| --- | --- |
|  | is defined in Table 22‑5, |
|  | has the value given in Table 22‑6, |
|  | is defined in , |
|  | is defined in , |
|  | is given in Table 22‑6, |
|  | is given by with , |
|  | is defined in , and |
|  | is defined in Equations , , and . |

VHT-STF shall use the 800 ns GI regardless of the Short GI Field setting in VHT-SIG-A.

##### VHT-LTF definition

The VHT long training field (VHT-LTF) provides a means for the receiver to estimate the MIMO channel between the set of QAM mapper outputs (or, if STBC is applied, the STBC encoder outputs) and the receive chains. The transmitter provides training for the space time streams (spatial mapper inputs) used for the transmission of the PSDU. All VHT transmissions have a preamble that contains a single section of VHT-LTFs, where the data tones of each VHT-LTF are multiplied by entries belonging to a matrix P, to enable channel estimation at the receiver. The pilot tones of each VHT-LTF are multiplied by the entries of a matrix R defined in the following text. The multiplication of the pilot tones in the VHT-LTF symbol by the R matrix instead of the P matrix is to allow receivers to track phase and frequency offset during MIMO channel estimation using the VHT-LTF. The number of VHT-LTF symbols is a function of the total number of space-time streams  as shown in Table 22‑10. As a result, the single section of LTFs consists of one, two, four, six or eight VHT-LTF that are necessary for demodulation of the VHT-Data portion of the PPDU or for channel estimation in an NDP packet.



Table 22‑10 -- Number of LTFs required for different numbers of space time streams

|  |  |
| --- | --- |
|  |  |
| 1 | 1 |
| 2 | 2 |
| 3 | 4 |
| 4 | 4 |
| 5 | 6 |
| 6 | 6 |
| 7 | 8 |
| 8 | 8 |

Let  and  be sequences defined by Equations and respectively.





The following VHT-LTF sequence is transmitted in the case of 20MHz operation:



where  is defined in Equation (20-23).

In a 40MHz transmission the sequence to be transmitted is:



where  is defined in Equation (20-24).

In an 80 MHz transmission the sequence to be transmitted is:



For 160 MHz, VHT-LTF is given by Equation .



where  is given in Equation .

For non-contiguous transmissions using two 80 MHz frequency segments, each 80 MHz frequency segment shall use the VHT-LTF pattern for the 80 MHz () defined in Equation .

The generation of the time domain VHT-LTFs is shown in Figure 22‑11 where  is given in Equation .

|  |  |
| --- | --- |
|  |  |

where

|  |  |
| --- | --- |
|  | is the subcarrier indices for the pilot tones. For 20 MHz transmissions, . For 40 MHz transmissions, . For 80 MHz transmissions, . For 160 MHz transmissions, .  For noncontiguous 80+80 MHz transmissions,  for each 80 MHz frequency segment is identical to  of 80 MHz transmissions. |
|  | is a matrix whose elements are defined in Equation . |
|  |  |

|  |  |
| --- | --- |
|  |  |



Figure 22‑11 -- Generation of VHT-LTFs

The time domain representation of the waveform transmitted on frequency segment  of transmit chain  during VHT-LTF  shall be as described by Equation .

|  |  |
| --- | --- |
|  |  |

where

 is defined in Table 22‑5,

 has the value given in Table 22‑6,

 is defined in Table 22‑5,

 is the number of space-time streams for user *u*,

 is given in Table 22‑8,

 is defined in 22.3.11.10.1,

 is defined in Equations , , and ,

 is defined in Equation , and

|  |  |
| --- | --- |
|  |  |

where is defined in Equation (20-27).

The VHT-LTF mapping matrix for six VHT-LTFs,  is defined in Equation .

|  |  |
| --- | --- |
|  |  |

The VHT-LTF mapping matrix for eight VHT-LTFs,  is defined in Equation .

|  |  |
| --- | --- |
|  |  |

where *P4x4* is defined in Equation 20-27.

VHT-LTF shall use the 800 ns GI regardless of the Short GI Field setting in VHT-SIG-A.

##### VHT-SIG-B definition

The VHT-SIG-B is one symbol and contains 26 bits in a 20 MHz PPDU, 27 bits in a 40 MHz PPDU and 29 bits in 80 MHz, 160 MHz and 80+80 MHz PPDUs. The VHT-SIG-B fields are listed in Table 22‑11. For fields consisting of multiple bits, the LSB of the field is mapped to the lowest bit among the corresponding VHT-SIG-B bits. For example, for an MCS of 5 (0b0101) in case of MU transmissions using 20 MHz bandwidth, B16=1, B17=0, B18=1 and B19=0 in VHT-SIG-B.

Table 22‑11--VHT-SIG-B fields

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Field** | **MU Allocation (bits)** | | | **SU Allocation (bits)** | | | **Description** |
|  | **20 MHz** | **40 MHz** | **80 MHz 160 MHz**  **80+80 MHz** | **20 MHz** | **40 MHz** | **80 MHz**  **160 MHz**  **80+80 MHz** |  |
| Length | B0-B15  (16) | B0-B16  (17) | B0-B18  (19) | B0-B16  (17) | B0-B18  (19) | B0-B20  (21) | length of useful data in PSDU in units of 4 octets |
| MCS | B16-B19  (4) | B17-B20  (4) | B19-B22  (4) | N/A | N/A | N/A |  |
| Reserved | N/A | N/A | N/A | B17-B19  (3) | B19-B20  (2) | B21-B22  (2) | All ones |
| Tail | B20-B25  (6) | B21-B26  (6) | B23-B28  (6) | B20-B25  (6) | B21-B26  (6) | B23-B28  (6) | All zeros |
| **Total # bits** | 26 | 27 | 29 | 26 | 27 | 29 |  |

NOTE–varying the Length field size ensures that a consistent maximum packet duration of approximately 5.46 ms (the max packet duration from L-SIG) is maintained across all channel widths with both SU and MU formats.

The Length field in VHT-SIG-B shall be set using Equation .

|  |  |
| --- | --- |
|  |  |

where

LENGTH is the TXVECTOR LENGTH parameter.

NOTE--The number of octets represented by VHT-SIG-B Length field will not exceed the PSDU\_LENGTH determined by Equations , and by more than 3 octets.

For an NDP with the TXVECTOR parameter CH\_BANDWIDTH set to HT\_CBW20, the VHT-SIG-B bits shall be:

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| B0 | B1 | B2 | B3 | B4 | B5 | B6 | B7 | B8 | B9 | B10 | B11 | B12 | B13 | B14 | B15 | B16 | B17 | B18 | B19 |
| 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 |

For an NDP with the TXVECTOR parameter CH\_BANDWIDTH set to HT\_CBW40, the VHT-SIG-B bits shall be:

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| B0 | B1 | B2 | B3 | B4 | B5 | B6 | B7 | B8 | B9 | B10 | B11 | B12 | B13 | B14 | B15 | B16 | B17 | B18 | B19 | B20 |
| 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |

For an NDP with the TXVECTOR parameter CH\_BANDWIDTH set to HT\_CBW80, HT\_CBW160, or HT\_CBW80+80, the VHT-SIG-B bits shall be:

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| B0 | B1 | B2 | B3 | B4 | B5 | B6 | B7 | B8 | B9 | B10 | B11 | B12 | B13 | B14 | B15 | B16 | B17 | B18 | B19 | B20 | B21 | B22 |
| 0 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 |

In a 40 MHz PPDU, VHT-SIG-B bits are repeated twice. In an 80 MHz PPDU, VHT-SIG-B bits are repeated four times and the pad bit is set to zero. In a 160 MHz and 80+80 MHz PPDU, VHT-SIG-B is first repeated four times and a pad bit set to zero as in the 80 MHz PPDU case. Then, the resulting 117 bits is repeated again to fill the 234 available bits. The repetition of VHT-SIG-B for various channel width PPDUs is shown in Figure 22‑12.



Figure 22‑12--VHT-SIG-B in 20, 40, 80, 160 and 80+80 MHz PPDUs

The VHT-SIG-B parts shall be BCC encoded at rate R = 1/2, interleaved, mapped to a BPSK constellation, and have pilots inserted following the steps described in 22.3.11.9. The VHT-SIG-B constellation points are mapped to NSTS space-time streams by the first column of the PVHTLTF matrix as defined in clause 22.3.9.2.5. The total number of data subcarriers and pilot subcarriers are the same as in the Data field. The remaining transmission flow of VHT-SIG-B is the same as the Data field. The 800ns guard interval is always applied to the VHT-SIG-B symbol, regardless of the Short GI field setting in VHT-SIG-A. The time domain waveform for the VHT-SIG-B field in a VHT format packet shall be:

|  |  |
| --- | --- |
|  |  |

where

 is defined in Table 22‑5,

 has the value given in Table 22‑6,

 is the number of space-time streams for user *u*,

 is given in Table 22‑8,

 is given by  (note that ),

 is defined in Section 22.3.11.10.1,

*z* is 3,

*pn* is defined in Section 17.3.5.9,

 is defined in Section 22.3.11.9,

 is defined in Equations , , and ,

 is given by Equation .

For 20 MHz VHT transmissions,





For 40 MHz VHT transmissions,





For 80 MHz VHT transmissions,





For 160 MHz VHT transmissions





For non-contiguous VHT transmissions using two 80 MHz frequency segments, each frequency segment shall follow the 80 MHz VHT transmission format as specified in Equations and .

In Equations , , and ,  is the constellation of VHT-SIG B (prior to multiplication by ) for user  at subcarrier .

### Transmission of NON\_HT format PPDUs with more than one antenna

When a VHT device transmits a NON\_HT format PPDU with the MODULATION parameter set to OFDM it shall apply the cyclic shifts defined in Table 22‑7.

### Data field

The number of OFDM symbols in the Data field is determined by the Length field in L-SIG (see 22.3.9.1.4), the preamble duration and the setting of the Short GI field in VHT-SIG-A (see 0).

For both BCC and LDPC, all bits (including the PHY pad bits) shall be encoded.

When BCC encoding is used, the Data field shall consist of the 16-bit SERVICE field, the PSDU, the PHY pad bits and the tail bits (6NES bits). When LDPC encoding is used, the Data field shall consist of the 16-bit SERVICE field, the PSDU and the PHY pad bits. No tail bits are present when LDPC encoding is used.

The padding flow is as follows. The MAC delivers a PSDU that fills the available octets in the data portion of the PPDU for each user *u*. In the case of BCC, the PHY determines the number of pad bits to add using Equation and appends them to the PSDU. The number of pad bits added will always be between 0 and 7 inclusive.

|  |  |
| --- | --- |
|  |  |

where

 is the number of octets delivered by the MAC for user *u* and is given by Equation ,

 is the number of symbols in the Data field and is the same for all users,

** is the number of tail bits for user *u*,

 is the number of BCC encodes for user *u*.

In case of MU LDPC encoding, the PHY padding bits are calculated using Equation .



where

 is the number of octets delivered by the MAC for user *u* and is given by Equation , and

 is given by Equation

The data field of the VHT PPDU contains data for one (SU transmission) or more users (MU transmission). In case of an MU transmission, the encoding process shall happen on a per-user basis. In the following sections, we describe this process from a single user’s point of view.

#### SERVICE field

The SERVICE field is as shown in Table 22‑12.

Table 22‑12--SERVICE field

|  |  |  |
| --- | --- | --- |
| **Bits** | **Field** | **Description** |
| B0-B6 | Scrambler Initialization |  |
| B7 | Reserved | Set to 0 |
| B8-B15 | CRC | CRC calculated over VHT-SIG-B (excluding tail bits) |

The Reserved and CRC fields shall be scrambled.

#### CRC calculation for VHT-SIG-B

The CRC calculation and insertion is illustrated in Figure 22‑13.

20 bits in 20MHz

21

(40MHz) / 23(80MHz) bits

Tail

(6bit)

Scrambler

Seed (7bit)

Rsvd

(1bit)

CRC

(8bit)

VHT-SIGB

Service Field

Figure 22‑13--VHT-SIG-B and SERVICE field relationship

The value of the CRC field shall be the ones complement of

|  |  |
| --- | --- |
|  |  |

where



and

*N* is the number of bits over which the CRC is generated; 20 for 20 MHz, 21 for 40 MHz and 23 for 80 MHz/160 MHz/80+80 MHz,

** is bit *i* of VHT-SIG-B,

 are initialized values that are added modulo 2 to the first 8 bits of VHT-SIG-B,

 is the CRC generating polynomial, and



Figure 20-8 shows the operation of the CRC. First, the shift register is reset to all ones. The bits are then passed through the XOR operation at the input. When the last bit has entered, the output is generated by shifting the bits out of the shift register, *c7* first, through an inverter.

As an example, if bits {*m0*, … *m22*} are given by {1 0 0 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1}, the CRC bits {c7, … c0} are {0 0 0 1 1 1 0 0}.

#### Scrambler

The SERVICE, PSDU and pad parts of the DATA field shall be scrambled by the scrambler defined in 17.3.5.4 (PLCP DATA scrambler and descrambler) and initialized with a pseudo-random nonzero seed.

#### Coding

The Data field shall be encoded using either the binary convolutional code (BCC) defined in 22.3.11.4.1, or the low density parity check (LDPC) code defined in 22.3.11.6. The encoder is selected by the Coding field in VHT-SIG-A, as defined in 22.3.9.2.3. When BCC FEC encoding is used, the number of encoders is determined by rate-dependent parameters as defined in 22.5. The operation of the BCC FEC is described in 22.3.11.4.1.1. The operation of the LDPC coder is described in 22.3.11.4.2. Support for the reception of BCC-encoded Data field frames is mandatory.

##### Binary convolutional coding

###### Encoder parsing operation

If multiple encoders are used, the scrambled SERVICE, PSDU and pad bits are divided between the encoders by sending bits to different encoders in a round robin manner. The bit to the  encoder, denoted , is:



Following the parsing operation, 6 zero tail bits are appended in each FEC input sequence.

Encoder parsing is omitted in case of LDPC coding.

###### Binary convolutional coding and puncturing

The encoder parser output sequences ,  ,will each be encoded by a rate R = ½ convolutional encoder defined in section 17.3.5.5. After encoding, the encoded data will be punctured by the method defined in section 17.3.5.6 (except for rate 5/6), to achieve the rate selected by the modulation and coding scheme. In the case that rate 5/6 coding is selected, the puncturing scheme will be same as described in section 20.3.11.5.

##### LDPC coding

For SU packets using LDPC code to encode the Data field, the LDPC code and encoding process described in Section 20.3.11.6 shall be used with the following modifications. First, all bits in the Data field including the scrambled SERVICE, PSDU and pad bits are encoded. Thus,  for VHT packets shall be computed using Equation instead of Equation (20-35).



where

 is equal to 2 when STBC is used, and 1 otherwise

 is defined in Table 22-5

 is given by Equation



where

 is LENGTH parameter in the TXVECTOR

In addition, if  computed in Equation (20-41) in step (d) of Section 20.3.11.6.5 is greater than , then B3 of VHT-SIG-A2 should be set to 1. Otherwise, B3 of VHT-SIG-A2 shall be set to 0.

LDPC codes used in MU packets shall also follow the definitions in Section 20.3.11.6. Refer to Section 22.3.11.8 for LDPC encoding process in case of MU packets.

##### Encoding process for MU transmissions

In case of MU transmission, the transmitter first computes the initial number of OFDM symbols using Equation .



where

 is the LENGTH parameter for user *u* in the TXVECTOR.

 is equal to 2 when STBC is used, and 1 otherwise

 is  for user *u*, where is defined in

 is  for user *u*, where  is defined in

Based on the above equation, the initial estimate of the longest symbol length can be obtained by:



Then, for each LDPC user in the MU packet, compute the LDPC encoding parameters based on steps (a) through (d) in Section 20.3.11.6, with the exception that Equation is used to compute  instead of Equation (20-35). Let  be the  computed by Equation (20-41) in step (d) of Section 20.3.11.6.5 for user .

Note – The purpose of going through steps (a) to (d) in Section 20.3.11.6 in the above paragraph is to compute . Thus, it is not necessary to actually encode the data using LDPC at this stage.

For BCC users, .

Then, compute the packet length using Equation .



When constructing the Data field for users encoded using LDPC code, PHY padding shall be added to fill up  symbols computed in Equation . Then, for each user, all bits in the Data field including the scrambled SERVICE, PSDU and pad bits shall be encoded using the LDPC encoding process specified in Section 20.3.11.6.5 with the following modifications. First,  shall be computed using Equation instead of Equation (20-35). Next, for MU transmissions, step (d) in Section 20.3.11.6.5 is replaced with step (d) below.

d) If  computed in Equation is equal to , then the number of bits to be punctured, , from the codewords after encoding is computed as shown in Equation (20-38).  
If  computed in Equation is greater than , then the number of bits to be punctured, , from the codewords after encoding is computed using Equations (20-39) and (20-40).  
The punctured bits shall be equally distributed over all  codewords with the first  codewords punctured 1 bit more than the remaining codewords. Define . When , the puncturing is performed by discarding parity bits  of the first  codewords and discarding parity bits  of the remaining codewords after encoding.

When constructing the Data field for users encoded using BCC, PHY padding shall be added to fill up  symbols computed in Equation . Then, for each user, all bits in the Data field including the scrambled SERVICE, PSDU and pad bits shall be encoded using the BCC encoding process specified in Sections 22.3.11.5 and 22.3.11.6. Note that this process ensures that the BCC tail bits are placed at the very end of the packet.

In addition, if  computed in Equation is greater than  computed in Equation , then B3 of VHT-SIG-A2 should be set to 1. Otherwise, B3 of VHT-SIG-A2 should be set to 0.

#### Stream parser

After coding and puncturing, the data bit streams at the output of the FEC encoders are re-arranged into  blocks of  bits. This operation is referred to as “stream parsing” and is described in this section.

The number of bits assigned to a single axis (real or imaginary) in a constellation point in a spatial stream is denoted by Equation .



The sum of these over all streams is: 

Consecutive blocks of  bits are assigned to different spatial streams in a round robin fashion.

If multiple encoders are present, the output of a different encoder is used for each round robin cycle, i.e. at the beginning,  bits from the output of first encoder are fed into all spatial streams, and then  bits from the output of next encoder are used, and so on.

Input to spatial stream  is , which is the output bit  of encoder :



and



where

 is the largest integer less than or equal to 

 is the remainder resulting from the division of integer  by integer 

For , the first term in Equation has a value of 0.

For 160 MHz MCSs, if each BCC encoder does not generate integer blocks of *S* coded bits in each OFDM symbol, then apply the same stream parsing method above until the last integer block (floor(*NCBPS/NES/S*)) of S bits at each encoder. Assuming that at this point in each OFDM symbol each BCC has *M.s* (*M<NSS*) residue bits, take the last *M.s* bits in the current OFDM symbol from the first encoder and allocate them to the first *M* spatial streams (s bits to each stream); then take the last *M.s* bits in the current OFDM symbol from the second encoder and distribute these among *M* spatial streams, starting from spatial stream *M+1*, and so on. Note that upon reaching the spatial stream NSS, cycle back to the 1st spatial stream. Repeat till all bits are distributed in the current OFDM symbol.

#### Segment parser

In case of contiguous 160 MHz or non-contiguous 80+80 MHz VHT PPDU transmissions, the output bits of each stream parser are first divided into blocks of  bits. Then, each block is further divided into two subblocks of  bits as shown in Equation .

where

 is the largest integer less than or equal to 

 is the remainder resulting from the division of integer  by integer 

 is the th bit of a block of  bits, = 0 to 

 is the subblock index, 

 is the th bit of the subblock 

 is defined in Equation

 is defined in

If  is not divisible by , then apply the segment parsing method described in Equation for  blocks of  segment parser input bits. At this point, each stream parser output has   residue bits. Then, the residue bits are divided into blocks of  bits, with each block being assigned to different subblock () in a round robin fashion. The first  bits are assigned to the subblock with index . Repeat  times until all bits are distributed to the two subblocks.

Segment parser is bypassed in case of 20, 40 and 80 MHz VHT PPDU transmissions.

#### BCC interleaver

This section describes the interleaver used in case of BCC encoding. Interleaver described in this section shall be bypassed in case of LDPC encoding.

In case of 20, 40 or 80 MHz VHT PPDU transmissions, the bits at the output of the stream parser are divided into  blocks of  bits and each block shall be interleaved by an interleaver based on the Clause 17 interleaver. In case of contiguous 160 MHz or non-contiguous 80+80 MHz VHT PPDU transmissions, each subblock of *NCBPSS*/2 output bits from the segment parser is interleaved by the interleaver for 80 MHz defined in this section. This interleaver, which is based on entering the data in rows, and reading it out in columns, has a different number of columns **** and rows **** for different bandwidths. The values of and are given in the table below.



Table 22‑13 -- Number of rows and columns in the interleaver

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **20 MHz** | **40 MHz** | **80 MHz** |
|  | 13 | 18 | 26 |
|  |  |  |  |
| (*NSS* ≤ 4) | 11 | 29 | 58 |
| (*NSS* > 4) | 6 | 13 | 28 |

After the operations based on the Clause 17 interleaver have been applied, if more than one spatial stream exists, a third operation called frequency rotation is applied to the additional spatial streams. The parameter for the frequency rotation is . The values of  are given in Table 22‑13.



An additional parameter is the spatial stream index . The output of the third permutation is a function of the spatial stream index.

The interleaving is defined using three permutations. The first permutation is given by the rule shown in Equation .



where

 is the largest integer less than or equal to 

The second permutation is defined by the rule shown in Equation .



where

 is defined in Equation .

If , a frequency rotation is applied to the output of the second permutation as shown in Equation .



where

 is the index of the spatial steam on which this interleaver is operating.

If , a frequency rotation is applied to the output of the second permutation as shown in Equation .



where  is the index of the spatial steam on which this interleaver is operating, and  is an integer as define in Table 22‑14.

Table ‑-- values

|  |  |
| --- | --- |
|  |  |
| 1 | 0 |
| 2 | 5 |
| 3 | 2 |
| 4 | 7 |
| 5 | 3 |
| 6 | 6 |
| 7 | 1 |
| 8 | 4 |

The deinterleaver uses the following three operations to perform the inverse permutations. Let *r* denote the index of the bit in the received block (per spatial stream). The first operationreverses the third (frequency rotation) permutation of the interleaver. When , this reversal is performed by *j* = *r* (*r* = 0, 1, …, *NCBPSS*-1). When , this reversal is performed by as shown in Equation .



When , this reversal is performed by Equation .



where  is defined in Table 22‑14.

The second operation defined by Equation reverses the second permutation in the interleaver.



where

 is defined in Equation .

The third operation defined in Equation reversed the first permutation of the interleaver.



#### Constellation mapping

##### General

The mapping between bits at the output of the interleaver and complex constellation points for BPSK, QPSK, 16-QAM and 64-QAM follows the rules defined in 17.3.5.7. For 256-QAM, the mapping is shown below:



Figure 22‑14--Constellation bit encoding for 256 QAM

The bit-string convention in Figure 22‑14 follows the bit-string convention outlined in Section 17.3.5.7.

The streams of complex numbers are denoted 

In case of contiguous 160 MHz VHT PPDU transmissions, the output bits of the interleaver corresponding to the subblock *l*=0 is used to form the complex numbers *dk,l,n*, *k* = 0,1,...,*NSD*/2-1, while the output bits of the interleaver corresponding to the subblock *l*=1 is used to form the complex numbers *dk,l,n*, *k* = *NSD*/2,*NSD*/2+1,...,*NSD*-1.

In case of non-contiguous 80+80 MHz VHT PPDU transmissions, the output bits of the interleaver corresponding to the subblock l=0 is used to form the complex numbers *dk,l,n* transmitted in the frequency segment lower in frequency, while the output bits of the interleaver corresponding to the subblock *l*=1 is used to form the complex numbers transmitted in the frequency segment higher in frequency.

The normalization factor for 256-QAM is .

##### LDPC tone mapping

If LDPC coding is used in the streams corresponding to a user *u*, at some rates the number of bits in each LDPC codeword may be smaller than the number of coded bits per OFDM symbols for user *u* (which, in the SU case, is equal to ). The LDPC tone mapping shall be performed on all LDPC coded streams as described in this subclause and using an LDPC tone-mapping distance parameter .  is constant for each bandwidth and its value for different bandwidths is given in Table 22‑15. LDPC tone mapping shall not be performed on streams that are encoded using BCC.

Table ‑--LDPC tone mapping distance for each bandwidth

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Parameter** | **20 MHz** | **40 MHz** | **80 MHz** | **160, 80+80 MHz** |
| *DTM* | 4 | 6 | 9 | 9 |

In cases of 20 MHz, 40 MHz, and 80 MHz VHT PPDU transmissions, the LDPC tone mapping for LDPC-coded streams corresponding to user *u* is done by permuting the stream of complex numbers



generated by the constellation mappers, to obtain



where



As a result of the LDPC tone mapping operation above, each two consecutively-generated complex constellation numbers  and  will be transmitted through two data tones that are separated by at least  other data tones. Note that the operation above is equivalent to block-interleaving the complex numbers ,..., for each *l*, *n* using a matrix with  rows and  columns, where ,..., are written row-wise into the matrix, and ,..., are read column-wise from the matrix.

In case of 160 MHz VHT PPDU transmissions, the LDPC tone mapping for LDPC-coded streams is performed separately for the upper and lower 80 MHz frequency segments, and the LDPC tone mapper treats each segment as an independent 80 MHz transmission. Hence, the overall LDPC tone mapping for 160 MHz will be equivalent to using the Equations and except that the index mapping function *t*(*k*) is changed to



Since LDPC tone mapping is not performed on BCC-coded streams, for BCC-coded streams, we have



##### Space-time block coding

This subclause defines a set of optional robust transmission formats that are applicable only when using STBC coding. In this case, NSS spatial streams are mapped to NSTS space-time streams, which are mapped to NTX transmit chains. These formats are based on STBC. When the VHT-SIG-A STBC field is set to 1, a symbol operation shall occur between the constellation mapper and the spatial mapper as defined in this subclause.

If STBC is applied, the stream of complex numbers, , generated by the constellation mapper, is the input of the STBC encoder, which produces as output the stream of complex numbers . For given values of *k* *a*nd *i*, STBC processing operates on the complex modulation symbols in sequential pairs of OFDM symbols so that the value of depends on and and also depends on and , as defined in Table 22‑16.

Table ‑--Constellation mapper output to spatial mapper input for STBC

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| ***NSTS*** | ***NSS*** | ***iSTS*** |  |  |
| 2 | 1 | 1 |  |  |
| 2 |  |  |
| 4 | 2 | 1 |  |  |
| 2 |  |  |
| 3 |  |  |
| 4 |  |  |
| 6 | 3 | 1 |  |  |
| 2 |  |  |
| 3 |  |  |
| 4 |  |  |
| 5 |  |  |
| 6 |  |  |
| 8 | 4 | 1 |  |  |
| 2 |  |  |
| 3 |  |  |
| 4 |  |  |
| 5 |  |  |
| 6 |  |  |
| 7 |  |  |
| 8 |  |  |

If STBC is not applied, and .

*NOTE--When STBC is applied, an odd number of space time streams per user is not allowed, and .*

#### Pilot subcarriers

For a 20 MHz transmission, four pilot tones shall be inserted in subcarriers –21, –7, 7, and 21. The pilot mapping  for subcarrier *k* for symbol *n* shall be as follows

|  |  |
| --- | --- |
|  |  |

where  is given by the *NSTS =* 1 row of Table 20-18 of Clause 20.

For a 40 MHz transmission, six pilot tones shall be inserted in subcarriers –53, –25, –11, 11, 25, and 53. The pilot mapping for subcarrier *k* for symbol *n* shall be as follows



|  |  |
| --- | --- |
|  |  |

where is given by the *NSTS =* 1 row of Table 20-19 of Clause 20.



For an 80 MHz transmission, eight pilot tones shall be inserted in subcarriers –103, –75, –39, –11, 11, 39, 75, and 103. The pilot mapping for subcarrier *k* for symbol *n* shall be as follows



|  |  |
| --- | --- |
|  |  |

where  is defined in Table 22‑17.

Table 22‑17 – Pilot values for 80 MHz transmission

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Ψ0 | Ψ1 | Ψ2 | Ψ3 | Ψ4 | Ψ5 | Ψ6 | Ψ7 |
| 1 | 1 | 1 | -1 | -1 | 1 | 1 | 1 |

For a 160 MHz transmission, the 80 MHz pilot mapping is replicated in the two 80 MHz subbands of the 160 MHz transmission. Specifically, 16 pilot tones shall be inserted in subcarriers -231, -203, -167, -139, -117, -89, -53, -25, 25, 53, 89, 117, 139, 167, 203 and 231. The pilot mapping  for subcarrier *k* for symbol *n* shall be as follows

|  |  |
| --- | --- |
|  |  |

where  is given in Table 22‑17.

For a non-contiguous transmission using two 80 MHz frequency segments, each frequency segment shall follow the 80 MHz pilot tone allocation and values defined for 80 MHz transmission as specified in Equation and Table 22‑17.

The above pilot mapping shall be copied on all space-time streams before the space-time stream cyclic shifts are applied.

#### OFDM modulation

##### Transmission in VHT format

For VHT transmissions, the signal from transmit chain *iTX*, 1 ≤ *iTX* ≤ *NTX* shall be as follows

|  |  |
| --- | --- |
|  |  |

where

*z* is 4,

*pn* is defined in 17.3.5.9,

is defined in Section 22.3.11.9,



 is defined in Equations , , and ,

 is the transmitted constellation for user *u* at subcarrier *k*, space-time stream  and Data field OFDM symbol *n*,

 is defined in Table 22‑5,

 has the value given in Table 22‑6,

 is defined in Table 22‑5,

 is given in Table 22‑8, and

 is given by (note that )

For 20 MHz VHT transmissions

|  |  |
| --- | --- |
|  |  |

where  is defined in Equation .

For 40 MHz VHT transmissions

|  |  |
| --- | --- |
|  |  |

where  is defined in Equation .

For 80 MHz VHT transmissions

|  |  |
| --- | --- |
|  |  |

where  is defined in Equation .

For 160 MHz VHT transmissions

|  |  |
| --- | --- |
|  |  |

where  is defined in Equation .

For non-contiguous VHT transmissions using two 80 MHz frequency segments, each frequency segment shall follow the 80 MHz VHT transmission format as specified in Equations and .

 is a spatial mapping matrix with  rows and  columns for subcarrier  in frequency segment .  may be frequency dependent. Refer to the examples of  listed in Section 20.3.11.10.1 for examples of  that could be used for SU packets. Note that implementations are not restricted to the spatial mapping matrix examples listed in Section 20.3.11.10.1. For MU packets,  is the MU-MIMO steering matrix which is implementation specific.

#### Non-HT duplicate transmission

Non-HT duplicate transmission is used to transmit to non-HT OFDM STAs, HT STAs, or VHT STAs that may be present in a part of a 40 MHz, 80 MHz or 160 MHz channel. The VHT-SIG-A, VHT-STF, VHT-LTF and VHT-SIG-B are not transmitted. The L-STF, L-LTF, and L-SIG shall be transmitted in the same way as in the VHT transmission. Note that for the non-HT duplicate transmission, the length field in L-SIG doesn’t include VHT-SIG-A, VHT-STF, VHT-LTF and VHT-SIG-B.

For 40 MHz non-HT duplicate, data transmission shall be as defined by Equation (20-61).

For 80 MHz and 160 MHz non-HT duplicate, data transmission shall be as defined by Equation .



where

*Pk* and *pn* are defined in 17.3.5.9,

*Dk*,*n* is defined in 20.3.9.4.3,

*M* is *BW*/20 – 1 (with *BW* in MHz),

 is defined in Equations and ,

 represents the cyclic shift for transmitter chain  with a value given in Table 20-8 (Cyclic shift for non-HT portion of packet) for up to 4 antennas. For more than 4 antennas, the cyclic shifts are TBD.

 has the value given in Table 22‑6.

For non-contiguous 80+80 MHz non-HT duplicate, data transmission in each frequency segment shall be as defined for 80 MHz non-HT duplicate transmission in Equation .

### SU-MIMO and MU-MIMO Beamforming

#### General

SU-MIMO and MU-MIMO beamforming are techniques used by a STA (the beamformer) to steer signals using knowledge of the channel to improve packet reception at another STA (the beamformee). With SU-MIMO beamforming, all spatial streams in the transmitted signal are intended for reception at a single STA. With MU-MIMO beamforming, subsets of the spatial streams are intended for reception at two or more STAs.

For SU-MIMO beamforming, mathematical equations describing the steering matrix *Qk* are given in 20.3.12.0a, where the subscript *k* denotes a subcarrier index. Typically, the steering matrix *Qk* is the same as the beamforming feedback matrix *Vk* that is sent back to beamformer by beamformee using compressed beamforming matrix format as in 20.3.12.2.5 (Compressed Beamforming Feedback Matrix). The feedback report format is described in 7.3.1.32 (VHT Compressed Beamforming Report Field).

For MU-MIMO beamforming, the receive signal vector in subcarrier *k* at beamformee *i*, , is shown in Equation , when a transmit signal vector for multiple users up to the *Nu* beamformee is with for beamformee *i*.

|  |  |
| --- | --- |
|  |  |

where

***H****k,i* is the channel matrix from the beamformer to beamformee *i* with dimensions in subcarrier *k*

is the number of receive antennas at beamformee *i*

is the number of space-time streams of signal that is transmitted to beamformee *i*

is a steering matrix for beamformee *i* with dimensions in subcarrier *k*

*Nu* is the number of MU-MIMO packet recipients. (see 22.3.7)

***n*** is white complex Gaussian noise

The MU-MIMO steering matrix can be found by the beamformer using the beamforming feedback matrices *Vk,j* and *SNRj* information from beamformee, where *j=1,2,…,Nu*. The steering matrix that is computed (or updated) using new beamforming feedback matrices and new SNR information from some or all of participating beamformees may replace the existing steering matrix for the next MU-MIMO data transmission. When there is feedback information from more than *Nu* STAs available at the beamformer, the beamformer may choose a beamformee group of *Nu* STAs for a MU-MIMO transmission with which the steering matrix can be designed to reduce crosstalk interference between the beamformees. The beamformee group for the MU-MIMO transmission is signaled using the Group ID field in VHT-SIG-A (see 22.3.9.2.3 (VHT-SIG-A definition) and 22.3.12.3 (Group ID)).

#### Beamforming Feedback Matrix *V*

Upon receipt of an NDP sounding PPDU, the beamformee shall remove the space-time stream CSD in Table 22‑8 (Cyclic shift values of VHT portion of packet) from the measured channel before computing a set of matrices for feedback to the beamformer. The beamforming feedback matrix, *Vk*, found by the beamformee shall be compressed in the form of angles using the method described in 20.3.12.2.5 (Compressed Beamforming Feedback Matrix). The angles, *k* and *k*, are quantized according to Table 7-25j. The number of bits for quantization may be chosen by beamformee, upon the indication from the beamformer whether the feedback is requested for SU-MIMO beamforming or MU-MIMO beamforming. The compressed beamforming feedback using 20.3.12.2.5 (Compressed Beamforming Feedback Matrix) is the only beamforming feedback format and no other feedback format is allowed for interoperability.

After receiving the angle information, *k* and *k*, the beamformer reconstructs *Vk* using Equation (20-79). For SU-MIMO beamforming, the beamformer uses this *Vk* matrix as a steering matrix *Qk*. For MU-MIMO beamforming, the beamformer may calculate a steering matrix using *Vk,j* and *SNRj* () in order to suppress crosstalk between participating beamformees. The method used by the beamformer to calculate the steering matrix *Qk* is implementation specific.

#### Group ID

The Group ID field in VHT-SIG-A (see 22.3.9.2.3) identifies the recipients of an MU-MIMO transmission, where the group definition information is informed by AP to MU-MIMO capable STAs using the Group ID Management frame as defined in 7.4.12.3, before an MU-MIMO data packet is sent to them. The group definition also determines the position of space-time streams of a user within the total space-time streams being transmitted in an MU transmission. When an MU-MIMO data packet is received, each STA identifies whether it is a member of the group for this packet by detecting the Group ID field in VHT-SIG-A. If an STA finds it is a member of the group for the MU-MIMO data packet, the STA reads its own number of space-time streams in the NSTS field by locating its STA position within the group as fixed by the group definition of the corresponding Group ID. At this point, a STA is also able to identify which streams correspond to its own signals and which streams correspond to interference. For an MU-MIMO transmission, VHT-LTFs are used to measure not only the channel for the designated signals but also to suppress the interference at a beamformee. While receiving an MU-MIMO transmission, it is recommended that the receiver use the channel knowledge to all spatial streams (including those which are interference) to do receive processing, in order to avoid interference on the eigenmodes that were not part of the beam-forming done at the AP.

If an STA finds it is not a member of the group, or it is a member of the group but assigned NSTS indicates there is no space-time streams for it in the packet, the STA may drop the packet before processing the VHT-LTFs.

### VHT preamble format for sounding PPDUs

NDP shall be the only VHT sounding format.

The VHT NDP format is shown in Figure 22‑15 and has the following properties:

* it has the same the VHT PPDU format but with no data portion
* has a VHT-SIG-A indicating a SU packet
* and has VHT-SIG-B carrying a fixed bit pattern (see 22.3.9.2.6)



Figure ‑—VHT NDP format

### Regulatory requirements

### Channelization

A VHT STA may operate in the 5 GHz band.

A VHT channel is specified by the four PLME MIB fields specified in Table 22‑18.

Table ‑--Fields to specify VHT channels

|  |  |
| --- | --- |
| **Field** | **Meaning** |
| dot11CurrentChannelBandwidth | Channel bandwidth. Possible values are 20 MHz, 40 MHz, 80 MHz, 160 MHz and 80+80 MHz. |
| dot11CurrentChannelCenterFrequencyIndex1 | In case of 20 MHz, 40 MHz, 80 MHz and 160 MHz channels, denotes the channel center frequency.  In case of 80+80 MHz channels, denotes the center frequency of the primary segment.  Valid range = 0, 1, … , 200.  See Equation . |
| dot11CurrentChannelCenterFrequencyIndex2 | In case of 80+80 MHz channels, denotes the center frequency of the secondary segment.  Valid range = 0, 1, … , 200.  See Equation .  Undefined for 20 MHz, 40 MHz, 80 MHz and 160 MHz channels. |
| dot11CurrentPrimary20MHzChannel | Denotes the location of the primary 20 MHz channel.  Valid range = 0, 1, … , 200.  See Equation . |

Given dot11CurrentChannelCenterFrequencyIndex1 and dot11CurrentChannelCenterFrequencyIndex2, the respective center frequency is given by Equation .



where channel starting frequency is given in the operating class (Annex J) and dot11CurrentChannelCenterFrequencyIndex is either dot11CurrentChannelCenterFrequencyIndex1 or dot11CurrentChannelCenterFrequencyIndex2.

The center frequency of the primary 20 MHz channel is given by Equation .



channel starting frequency is given in the operating class (Annex J).

For 80+80 MHz channels, any two channels that would each be allowed as 80 MHz channels and whose center frequencies are separated by greater than 80 MHz (difference between dot11CurrentChannelCenterFrequencyIndex1 and dot11CurrentChannelCenterFrequencyIndex2 corresponds to frequency difference greater than 80 MHz) may used.

For example, a channel specified by

dot11CurrentChannelBandwidth = 80 MHz

dot11CurrentChannelCenterFrequencyIndex1 = 42

dot11CurrentPrimary20MHzChannel = 36

is an 80 MHz channel with a center frequency of 5210 MHz and the primary 20 MHz channel centered at 5180 MHz.

A channel specified by

dot11CurrentChannelBandwidth = 160 MHz

dot11CurrentChannelCenterFrequencyIndex1 = 50

dot11CurrentPrimary20MHzChannel = 56

is a 160 MHz channel with a center frequency of 5250 MHz and the primary 20 MHz channel centered at 5280 MHz.

A channel specified by

dot11CurrentChannelBandwidth = 80+80 MHz

dot11CurrentChannelCenterFrequencyIndex1 = 155

dot11CurrentChannelCenterFrequencyIndex2 = 106

dot11CurrentPrimary20MHzChannel = 161

is an 80+80 MHz channel in which the primary segment has 80 MHz bandwidth and center frequency of 5775 MHz. The secondary segment also has 80 MHz bandwidth and center frequency of 5530 MHz. The primary 20 MHz channel is centered at 5805 MHz.

### Transmit RF delay

The transmitter RF delay shall follow 17.3.8.5.

### Slot time

The slot time is defined in 17.3.8.6.

### Transmit and receive port impedance

Transmit and receive antenna port impedance for each transmit and receive antenna is defined in 17.3.8.7.

### PMD transmit specification

#### Transmit spectrum mask

NOTE 1 – In the presence of additional regulatory restrictions, the device has to meet both the regulatory requirements and the mask defined here – i.e., its emissions can be no higher at any frequency offset than the minimum of the values specified in the regulatory and default masks.

NOTE 2 – Transmit spectral mask figures in this subclause are not drawn to scale.

For transmissions using a 20 MHz channel, the transmit spectrum shall have a 0 dBr (dB relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, -20 dBr at 11 MHz frequency offset, -28 dBr at 20 MHz frequency offset and the maximum of -40 dBr and -53 dBm/MHz at 30 MHz frequency offset and above. The spectral density of the transmitted signal shall fall within the spectral mask shown in Figure 22‑16.



Figure ‑--Transmit spectral mask for a 20 MHz channel

For transmissions using a 40 MHz channel, the transmit spectrum shall have a 0 dBr (dB relative to the maximum spectral density of the signal) bandwidth not exceeding 38 MHz, -20 dBr at 21 MHz frequency offset, -28 dBr at 40 MHz frequency offset and the maximum of -40 dBr and -56 dBm/MHz at 60 MHz frequency offset and above. The spectral density of the transmitted signal shall fall within the spectral mask shown in Figure 22‑17.



Figure ‑--Transmit spectral mask for a 40 MHz channel

For transmissions using a 80 MHz channel, the transmit spectrum shall have a 0 dBr (dB relative to the maximum spectral density of the signal) bandwidth not exceeding 78 MHz, -20 dBr at 41 MHz frequency offset, -28 dBr at 80 MHz frequency offset and the maximum of -40 dBr and -59 dBm/MHz at 120 MHz frequency offset and above. The spectral density of the transmitted signal shall fall within the spectral mask shown in Figure 22‑18.



Figure 22‑18 -- Transmit spectral mask for 80 MHz channel

For transmissions using a 160 MHz channel, the transmit spectrum shall have a 0 dBr (dB relative to the maximum spectral density of the signal) bandwidth not exceeding 158 MHz, -20 dBr at 81 MHz frequency offset, -28 dBr at 160 MHz frequency offset and the maximum of -40 dBr and -59 dBm/MHz at 240 MHz frequency offset and above. The spectral density of the transmitted signal shall fall within the spectral mask shown in Figure 22‑19.



Figure 22‑19 -- Transmit spectral mask for 160 MHz channel

For non-contiguous transmissions using two nonadjacent 80 MHz channels, the overall transmit spectral mask is constructed in the following manner. First, the 80 MHz spectral mask shown in Figure 22‑18 is placed on each of the two 80 MHz segments. Then, for each frequency at which both of the 80 MHz spectral masks have values in between -40 dBr and -20 dBr, the sum of the two mask values (summed in linear domain) shall be taken as the overall spectral mask value. Next, for each frequency at which neither of the two 80 MHz masks have values in between -20 dBr and 0 dBr, the higher value of the two masks shall be taken as the overall spectral value. Finally, for any frequency region where the mask value has not been defined yet, linear interpolation (in dB domain) between the nearest two frequency points with the spectral mask value defined shall be used to define the spectral mask value. The spectral density of the transmitted signal shall fall within the spectral mask constructed in this manner. Figure 22‑20 shows an example of transmit spectral mask for a non-contiguous transmission using two 80 MHz channels where the center frequency of the two 80 MHz channels are separated by 160 MHz. If the transmit spectral mask specified in dBr, in conjunction with the transmit power, results in a transmit spectral mask requirement of less than -59 dBm/MHz at a given frequency offset, then the transmit spectral mask requirement at that frequency offset shall be -59 dBm/MHz.



Figure ‑-- Example of transmit spectral mask for a non-contiguous transmission using two 80 MHz channels where the center frequency of the two 80 MHz channels are separated by 160 MHz

Measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.

#### Spectral flatness

Let  denote the average constellation energy of the subcarrier *i* averaged over TBD VHT data symbols.

In a 20 MHz transmission,  of each of the subcarriers with indices –16 to –1 and +1 to +16 shall not deviate by more than ± 4 dB from the average of  over subcarrier indices -16 to -1 and +1 to +16.  in each of the subcarriers with indices –28 to –17 and +17 to +28 shall not deviate more than +4/–6 dB from the average of  over subcarriers with indices –16 to –1 and +1 to +16.

In a 40 MHz transmission,  of each of the subcarriers with indices –42 to –2 and +2 to +42 shall not deviate by more than ± 4 dB from the average of  over subcarrier indices -42 to -2 and +2 to +42. of each of the subcarriers with indices –43 to –58 and +43 to +58 shall not deviate more than +4/–6 dB from the average of  over subcarriers with indices –42 to –2 and +2 to +42.

In a 80 MHz transmission,  of each of the subcarriers with indices –84 to –2 and +2 to +84 shall not deviate by more than ± 4 dB from the average of  over subcarrier indices -84 to -2 and +2 to +84.  of each of the subcarriers with indices –122 to –85 and +85 to +122 shall not deviate more than +4/–6 dB from the average of  over subcarriers with indices –84 to –2 and +2 to +84.

In a 160 MHz transmission,  of each of the subcarriers with indices –250 to –6 and +6 to +250 shall not deviate by more than +4/–6 dB from the average  over subcarriers with indices -250 to -6 and +6 to +250.

In a non-contiguous transmission consisting of two 80 MHz frequency segments nonadjacent in frequency, each segment shall meet the spectral flatness requirement for an 80 MHz transmission.

All averaging performed in this section is performed in TBD domain ***[Editor’s note: TBD domain is either linear domain or dB domain]***.

The tests for the spectral flatness requirements can be performed with spatial mapping  (see 22.3.11.10).

#### Transmit center frequency tolerance

The transmitter center frequency tolerance shall be ±20 ppm maximum. Carrier (LO) and symbol clock frequencies for the all transmit chains and frequency segments shall be derived from the same reference oscillator.

The phase of LO shall not be required to be correlated between the lower and upper 80 MHz frequency portions of the signal at the transmitter if the CH\_BANDWIDTH parameter in the TXVECTOR is HT\_CBW160, HT\_CBW80+80, NON\_HT\_CBW160 or NON\_HT\_CBW80+80.

#### Packet alignment

Packet alignment shall be done as described in 20.3.21.5.

#### Symbol clock frequency tolerance

The symbol clock frequency tolerance shall be maximum ±20 ppm. The transmit center frequency and the symbol clock frequency for all transmit antennas and frequency segments shall be derived from the same reference oscillator.

#### Modulation accuracy

##### Introduction to modulation accuracy tests

Transmit modulation accuracy specifications are described in 22.3.19.6.2 and 22.3.19.6.3. The test method is described in 22.3.19.6.4.

##### Transmit center frequency leakage

Requirements for transmit center frequency leakage are TBD.

##### Transmitter constellation error

The relative constellation RMS error, calculated by first averaging over subcarriers, frequency segments, OFDM frames and spatial streams (see Equation (20-89)) shall not exceed a data-rate dependent value according to Table 22‑19. The number of spatial streams under test shall be equal to the number of utilized transmitting STA antenna (output) ports and also equal to the number of utilized testing instrumentation input ports. In the test,  shall be used. Each output port of the transmitting STA shall be connected through a cable to one input port of the testing instrumentation. The same requirement applies 20, 40, 80 and 160 MHz transmissions, as well as non-contiguous transmissions.

Table 22‑19 -- Allowed relative constellation error versus constellation size and coding rate

|  |  |  |
| --- | --- | --- |
| **Modulation** | **Coding rate** | **Relative constellation error (dB)** |
| BPSK | 1/2 | -5 |
| QPSK | 1/2 | -10 |
| QPSK | 3/4 | -13 |
| 16-QAM | 1/2 | -16 |
| 16-QAM | 3/4 | -19 |
| 64-QAM | 2/3 | -22 |
| 64-QAM | 3/4 | -25 |
| 64-QAM | 5/6 | -28 |
| 256-QAM | 3/4 | -30 |
| 256-QAM | 5/6 | -32 |

##### Transmitter modulation accuracy (EVM) test

The transmit modulation accuracy test shall be performed by instrumentation capable of converting the transmitted signals into a streams of complex samples at sampling rate greater than or equal to the bandwidth of the signal being transmitted.

For non-contiguous transmissions, each frequency segment may be tested independently with both segments being transmitted. In this case, transmit modulation accuracy of each segment shall meet the required value in Table 22‑19 using only the subcarriers within the corresponding segment.

The instrument shall have sufficient accuracy in terms of I/Q arm amplitude and phase balance, dc offsets, phase noise, and analog to digital quantization noise. A possible embodiment of such a setup is converting the signals to a low IF frequency with a microwave synthesizer, sampling the signal with a digital oscilloscope and decomposing it digitally into quadrature components. The sampled signal shall be processed in a manner similar to an actual receiver, according to the following steps, or equivalent procedure:

1. Start of frame shall be detected.
2. Transition from L-STF to L-LTF shall be detected, and fine timing (with one sample resolution) shall be established.
3. Coarse and fine frequency offsets shall be estimated.
4. For each VHT-LTF symbol, transform the symbol into subcarrier received values, estimate the phase from the pilot subcarriers, and derotate the subcarrier values according to estimated phase.
5. Estimate the complex channel response coefficient for each of the subcarriers and each of the transmit streams.
6. For each of the data OFDM symbols: transform the symbol into subcarrier received values, estimate the phase from the pilot subcarriers, derotate the subcarrier values according to estimated phase, group the results from all the receiver chains in each subcarrier to a vector, multiply the vector by a zero-forcing equalization matrix generated from the estimated channel. Data OFDM symbols may be used to update or recompute the channel estimate.
7. For each data-carrying subcarrier in each spatial stream, find the closest constellation point and compute the Euclidean distance from it.
8. Compute the average of the RMS of all errors in a frame as given by Equation (20-89).

The test shall be performed over at least 20 frames , and the average of the RMS shall be taken. The frames under test shall be at least 16 symbols long. Random data shall be used for the symbols.

### VHT PMD receiver specification

For tests in this subclause, the input levels are measured at the antenna connectors and are referenced as the average power per receive antenna. The number of spatial streams under test shall be equal to the number of utilized transmitting STA antenna (output) ports and also equal to the number of utilized Device Under Test input ports. Each output port of the transmitting STA shall be connected through a cable to one input port of the Device Under Test.

#### Receiver minimum input sensitivity

The packet error rate (PER) shall be less than 10% for a PSDU length of 4096 octets with the rate-dependent input levels listed in Table 22‑20 or less. The test in this subclause and the minimum sensitivity levels specified in Table 22‑20 only apply to non-STBC modes, 800 ns GI and BCC.

Table 22‑20--Receive minimum input level sensitivity

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Modulation** | **Rate (R)** | **Minimum sensitivity (20 MHz PPDU)**  **(dBm)** | **Minimum sensitivity (40 MHz PPDU)**  **(dBm)** | **Minimum sensitivity (80 MHz PPDU)**  **(dBm)** | **Minimum sensitivity (160 MHz or**  **80+80 MHz PPDU)**  **(dBm)** |
| BPSK | 1/2 | -82 | -79 | -76 | -73 |
| QPSK | 1/2 | -79 | -76 | -73 | -70 |
| QPSK | 3/4 | -77 | -74 | -71 | -68 |
| 16-QAM | 1/2 | -74 | -71 | -68 | -65 |
| 16-QAM | 3/4 | -70 | -67 | -64 | -61 |
| 64-QAM | 2/3 | -66 | -63 | -60 | -57 |
| 64-QAM | 3/4 | -65 | -62 | -59 | -56 |
| 64-QAM | 5/6 | -64 | -61 | -58 | -55 |
| 256-QAM | 3/4 | -59 | -56 | -53 | -50 |
| 256-QAM | 5/6 | -57 | -54 | -51 | -48 |

#### Adjacent channel rejection

Adjacent channel rejection for *W* MHz channels (where *W* is 20, 40, 80 or 160) shall be measured by setting the desired signal’s strength 3 dB above the rate dependent sensitivity specified in Table 22‑20 and raising the power of the interfering signal of *W* MHz bandwidth until 10% PER is caused for a PSDU length of 4096 octets. The power difference between the interfering and desired channel is the corresponding adjacent channel rejection. The center frequency of the adjacent channel shall be placed *W* MHz away from the center frequency of the desired signal.

Adjacent channel rejection for 80+80 MHz channels shall be measured by setting the desired signal’s strength 3 dB above the rate dependent sensitivity specified in Table 22‑20. Then, an interfering signal of 80 MHz bandwidth is introduced, where the center frequency of the interfering signal is placed 80 MHz away from the center frequency of one of the frequency segments of the desired signal. The power of the interfering signal is raised until 10% PER is caused for a PSDU length of 4096 octets. The power difference between the interfering and desired channel is the corresponding adjacent channel rejection.

The interfering signal in the adjacent channel shall be a conformant OFDM signal, unsynchronized with the signal in the channel under test. For a conforming OFDM PHY, the corresponding rejection shall be no less than specified in Table 22‑21. The interference signal shall have a minimum duty cycle of 50%.

The test in this subclause and the adjacent sensitivity levels specified in Table 22‑21 only apply to non-STBC modes, 800 ns GI and BCC.

Table ‑--Minimum required adjacent and nonadjacent channel rejection levels

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Modulation** | **Rate (R)** | **Adjacent channel rejection (dB)** | | **Nonadjacent channel rejection (dB)** | |
| 20/40/80/160 MHz Channel | 80+80 MHz Channel | 20/40/80/160 MHz Channel | 80+80 MHz Channel |
| BPSK | 1/2 | 16 | 13 | 32 | 29 |
| QPSK | 1/2 | 13 | 10 | 29 | 26 |
| QPSK | 3/4 | 11 | 8 | 27 | 24 |
| 16-QAM | 1/2 | 8 | 5 | 24 | 21 |
| 16-QAM | 3/4 | 4 | 1 | 20 | 17 |
| 64-QAM | 2/3 | 0 | -3 | 16 | 13 |
| 64-QAM | 3/4 | -1 | -4 | 15 | 12 |
| 64-QAM | 5/6 | -2 | -5 | 14 | 11 |
| 256-QAM | 3/4 | -7 | -10 | 9 | 6 |
| 256-QAM | 5/6 | -9 | -12 | 7 | 4 |

#### Nonadjacent channel rejection

Nonadjacent channel rejection for *W* MHz channels (where *W* is 20, 40, 80 or 160) shall be measured by setting the desired signal’s strength 3 dB above the rate-dependent sensitivity specified in Table 22‑20, and raising the power of the interfering signal of *W* MHz bandwidth until a 10% PER occurs for a PSDU length of 4096 octets. The power difference between the interfering and desired channel is the corresponding nonadjacent channel rejection. The center frequency of the nonadjacent channel shall be placed 2×*W* MHz or more away from the center frequency of the desired signal.

Nonadjacent channel rejection for 80+80 MHz channels shall be measured by setting the desired signal’s strength 3 dB above the rate dependent sensitivity specified in Table 22‑20. Then, an interfering signal of 80 MHz bandwidth is introduced, where the center frequency of the interfering signal is placed at least 160 MHz away from the center frequency of each frequency segment of the desired signal. The power of the interfering signal is raised until 10% PER is caused for a PSDU length of 4096 octets. The power difference between the interfering and desired channel is the corresponding nonadjacent channel rejection.

The interfering signal in the nonadjacent channel shall be a conformant OFDM signal, unsynchronized with the signal in the channel under test. For a conforming OFDM PHY, the corresponding rejection shall be no less than specified in Table 22‑21. The interference signal shall have a minimum duty cycle of 50%.

The test in this subclause and the adjacent sensitivity levels specified in Table 22‑21 only apply to non-STBC modes, 800 ns GI and BCC.

#### Receiver maximum input level

The receiver shall provide a maximum PER of 10% at a PSDU length of 4096 octets, for a maximum input level of –30 dBm, measured at each antenna for any baseband modulation.

#### CCA sensitivity

CCA sensitivity requirements for non-HT PPDUs in the primary 20 MHz channel are described in 17.3.10.5 and 19.4.6. CCA sensitivity requirements for HT PPDUs are described in 20.3.22.5.

The CCA sensitivity requirements for all other signals are defined in the remainder of this clause.

##### CCA sensitivity for signals occupying the primary 20 MHz channel

The PHY shall issue a PHY-CCA.indication(BUSY, {primary}) if one of the conditions listed in Table Table 22‑22 are met in an otherwise idle 20 MHz, 40 MHz, 80 MHz, 160 MHz or 80+80 MHz operating channel width. The start of a PPDU that occupies at least the primary 20 MHz channel under the conditions listed in Table 22‑22 shall be detected with >90% probability within a period of aCCATime (< 4μs).

Table ‑--Conditions for CCA BUSY on the primary 20 MHz

|  |  |
| --- | --- |
| **Operating Channel Width** | **Conditions** |
| 20 MHz, 40 MHz, 80 MHz, 160 MHz or 80+80 MHz | * Any signal within the primary 20 MHz channel at or above -62 dBm * The start of a 20 MHz NON\_HT or VHT format PPDU in the primary 20 MHz channel at or above -82 dBm * The start of an HT format PPDU under the conditions defined in 20. 3.22.5 |
| 40 MHz, 80 MHz, 160 MHz or 80+80 MHz | * The start of a 40 MHz NON\_HT duplicate or VHT format PPDU in the primary 40 MHz channel at or above -79 dBm * The start of an HT format PPDU under the conditions defined in 20.3.22.5 |
| 80 MHz, 160 MHz or 80+80 MHz | * The start of an 80 MHz NON\_HT duplicate or VHT format PPDU in the primary 80 MHz channel at or above -76 dBm |
| 160 MHz or 80+80 MHz | * The start of a 160 MHz or 80+80 MHz NON\_HT duplicate or VHT format PPDU at or above -73 dBm |

##### CCA sensitivity for signals not occupying the primary 20 MHz channel

The PHY shall issue a PHY-CCA.indication(BUSY, {secondary}) if the conditions for issuing PHY-CCA.indication(BUSY, {primary}) are not present and one of the following conditions are present in an otherwise idle 40 MHz, 80 MHz, 160 MHz or 80+80 MHz operating channel width:

* Any signal within the secondary 20 MHz channel at or above -62 dBm.
* A 20 MHz NON\_HT, HT\_MF, HT\_GF or VHT format signal in the secondary 20 MHz channel at or above -72 dBm.

The PHY shall issue a PHY-CCA.indication(BUSY, {secondary40}) if the conditions for issuing PHY-CCA.indication(BUSY, {primary}) and PHY-CCA.indication(BUSY, {secondary}) are not present and one of the following conditions are present in an otherwise idle 80 MHz, 160 MHz or 80+80 MHz operating channel width:

* Any signal within the secondary 40 MHz channel at or above -59 dBm.
* A 40 MHz NON\_HT duplicate, HT\_MF, HT\_GF or VHT format signal in the secondary 40 MHz channel at or above -72 dBm.
* A 20 MHz NON\_HT, HT\_MF, HT\_GF or VHT format signal in any 20 MHz sub-channel of the secondary 40 MHz channel at or above -72 dBm.

The PHY shall issue a PHY-CCA.indication(BUSY, {secondary80}) if the conditions for PHY-CCA.indication(BUSY, {primary}), PHY-CCA.indication(BUSY, {secondary}) and PHY-CCA.indication(BUSY, {secondary40}) are not present and one of the following conditions are present in an otherwise idle 160 MHz or 80+80 MHz operating channel width:

* Any signal within the secondary 80 MHz channel at or above -56 dBm.
* An 80 MHz NON\_HT duplicate or VHT format signal in the secondary 80 MHz channel at or above -69 dBm.
* A 40 MHz NON\_HT duplicate, HT\_MF, HT\_GF or VHT format signal in any 40 MHz sub-channel of the secondary 80 MHz channel at or above -69 dBm.
* A 20 MHz NON\_HT, HT\_MF, HT\_GF or VHT format signal in any 20 MHz sub-channel of the secondary 80 MHz channel at or above -69 dBm.

The presence of a signal that occupies one or more secondary channels under the conditions listed in this section shall be detected with >90% probability within a period aCCAMidTime (< 25μs).

### PLCP transmit procedure

There are two options for transmit PLCP procedure. The first option, for which typical transmit procedures are shown in Figure 22‑21, is selected if the FORMAT field of PHY-TXSTART.request(TXVECTOR) is set to VHT. These transmit procedures do not describe the operation of optional features, such as LDPC or STBC. The other option is selected if the FORMAT field of PHY-TXSTART.request(TXVECTOR) is set to HT\_MF or HT\_GF or NON\_HT, respectively. And furthermore, if the FORMAT field is set to NON\_HT and CH\_BANDWIDTH indicates NON\_HT\_CBW80, NON\_HT\_CBW160 or NON\_HT\_CBW80+80, follow the transmit procedure as in Clause 17, except that the signal in Clause 17 is generated simultaneously on each of the 20 MHz channels that comprise the 80 or 160 MHz channel as defined in 22.3.8 and 22.3.11.11. In all these options, in order to transmit data, PHY-TXSTART.request shall be enabled so that the PHY entity will be in the transmit state. Further, the PHY is set to operate at the appropriate frequency through station management via the PLME, as specified in 20.4. Other transmit parameters, such as MCS Coding types and transmit power, are set via the PHY-SAP with the PHY-TXSTART.request(TXVECTOR), as described in 22.2.2.

A clear channel shall be indicated by PHY-CCA.indication(IDLE). Note that under some circumstances, the MAC uses the latest value of PHY-CCA.indication before issuing the PHY-TXSTART.request. Transmission of the PPDU shall be initiated after receiving the PHYTXSTART.request(TXVECTOR) primitive. The TXVECTOR elements for the PHY-TXSTART.request are specified in Table 22‑1.

The PLCP shall issue the parameters in the following PMD primitives to configure the PHY:

— PMD\_TXPWRLVL

— PMD\_TX\_PARAMETERS

The PLCP shall then issue a PMD\_TXSTART.request, and transmission of the PLCP preamble may start, based on the parameters passed in the PHY-TXSTART.request primitive. The data shall then be exchanged between the MAC and the PHY through a series of PHY-DATA.request(DATA) primitives issued by the MAC, and PHY-DATA.confirm primitives issued by the PHY. Once PLCP preamble transmission is started, the PHY entity immediately initiates data scrambling and data encoding. The encoding method is based on the FEC\_CODING, CH\_BANDWIDTH, NUM\_STS, STBC, MCS, and NUM\_USERS parameter of the TXVECTOR. A modulation rate change, if any, is initiated starting with the SERVICE field data, as described in 22.3.2.

The PHY proceeds with PSDU transmission through a series of data octet transfers from the MAC. The SERVICE field and PSDU are encoded by the encoder selected by the FEC\_CODING, CH\_BANDWIDTH, NUM\_STS, MCS, and NUM\_USERS parameters of the TXVECTOR as described in 22.3.3. At the PMD layer, the data octets are sent in bit 0–7 order and presented to the PHY through PMD\_DATA.request primitives. Transmission can be prematurely terminated by the MAC through the primitive PHY-TXEND.request. PHY-TXSTART is disabled by receiving a PHY-TXEND.request. In single user transmission, normal termination occurs after the transmission of the final bit of the last PSDU octet, according to the number OFDM symbols indicated supplied in the N\_SYM field. Zero to seven bits are stuffed to make the C-PSDU length an integral multiple of the OFDM symbol length.

The packet transmission is completed and the PHY entity enters the receive state (i.e., PHYTXSTART is disabled). Each PHY-TXEND.request is acknowledged with a PHY-TXEND.confirm primitive from the PHY.

In the PMD, the GI or short GI is inserted in every OFDM symbol as a countermeasure against delay spread.

A typical state machine implementation of the transmit PLCP for single user is provided in Figure 22‑22. Requests (.request) and confirmations (.confirm) are issued once per state as shown. This state machine does not describe the operation of optional features, such as multi-user, LDPC or STBC.



Figure 22‑21 -- PLCP transmit procedure



Figure 22‑22 -- PLCP transmit state machine

### PLCP receive procedure

A typical PLCP receive procedure is shown in Figure 22‑23 for VHT format. A typical state machine implementation of the receive PLCP is given in Figure 22‑24. This receive procedure and state machine do not describe the operation of optional features, such as STBC. If the detected format indicates a non-HT PPDU format, refer to the receive procedure and state machine in Clause 17. If the detected format indicates an HT PPDU format, refer to the receive procedure and state machine in Clause 20. Further, through station management (via the PLME) the PHY is set to the appropriate frequency, as specified in 22.4. Other receive parameters, such as RSSI and indicated DATARATE, may be accessed via the PHY-SAP.

Upon receiving the transmitted PLCP preamble, PMD\_RSSI.indication shall report a receive signal strength to the PLCP. This activity is indicated to the MAC via a PHY-CCA.indication. A PHY-CCA.indication(BUSY, channel-list) shall also be issued as an initial indication of reception of a signal. The channel-list parameter of the PHY-CCA.indication is absent when the operating channel width is 20 MHz and includes the element “primary” when the operating channel width is 40 MHz, 80 MHz, 160 MHz or 80+80 MHz.

The PMD primitive PMD\_RSSI is issued to update the RSSI and parameter reported to the MAC.

After the PHY-CCA.indication(BUSY, channel-list) is issued, the PHY entity shall begin receiving the training symbols and searching for L-SIG and VHT-SIG-A in order to set the maximum duration of the data stream. If signal loss occurs before validating L-SIG, the VHT PHY shall maintain PHY-CCA.indication(BUSY, channel-list) until the received level drops below the CCA sensitivity level (for a missed preamble) specified in 22.3.20.5. If the check of the L-SIG parity bit is not valid, a PHY-RXSTART.indication is not issued. The PHY shall issue the error condition PHY-RXEND.indication(FormatViolation). The VHT PHY shall maintain PHY-CCA.indication(BUSY, channel-list) until the received level drops below the CCA sensitivity level (for a missed preamble) specified in 22.3.20.5. If a valid L-SIG parity bit is indicated, the VHT PHY shall maintain PHY-CCA.indication(BUSY, channel-list) for the predicted duration of the transmitted frame, as defined by RXTIME in Equation , for all supported modes, unsupported modes, Reserved VHT-SIG-A Indication, and invalid VHT-SIG-A CRC. Reserved VHT-SIG-A Indication is defined as a VHT-SIG-A with Reserved bits equal to 0 or NSTS per user for MU set to 5-7 or Short GI set to 01 or the combination of MCS and NSTS not included in 22.6 or any other VHT-SIG-A field bit combinations that do not correspond to modes of PHY operation defined in Clause 22. If the VHT-SIG-A indicates an unsupported mode, the PHY shall issue the error condition PHY-RXEND.indication(UnsupportedRate). If the VHT-SIG-A indicates an invalid CRC or Reserved VHT-SIG-A Indication, the PHY shall issue the error condition PHY-RXEND.indication(FormatViolation).

|  |  |
| --- | --- |
|  |  |

After receiving a valid L-SIG and VHT-SIG-A and supported mode, the PHY entity shall begin receiving the VHT training symbols and VHT-SIG-B. If the received Group ID in VHT-SIG-A has a value of 63 (indicating a SU transmission), the PHY entity may choose not to decode VHT-SIG-B. If VHT-SIG-B is not decoded, subsequent to an indication of a valid VHT-SIG-A CRC, a PHY-RXSTART.indication(RXVECTOR) shall be issued. The RXVECTOR associated with this primitive includes the parameters specified in Table 22-1.

If Group ID in VHT-SIG-A has a value other than 63 (indicating a MU transmission), the PHY shall decode VHT-SIG-B. If the VHT-SIG-B indicates an unsupported mode, the PHY shall issue the error condition PHY-RXEND.indication(UnsupportedRate).

If VHT-SIG-B was decoded the PHY may check the VHT-SIG-B CRC in the SERVICE field. If the VHT-SIG-B CRC in the SERVICE field is not checked a PHY-RXSTART.indication(RXVECTOR) shall be issued. The RXVECTOR associated with this primitive includes the parameters specified in Table 22-1.

Following training and signal fields, the coded PSDU (C-PSDU) (which comprises the coded PLCP SERVICE field and scrambled and coded PSDU) shall be received. The number of symbols in the C-PSDU is determined by Equation .



where



In case of SU transmissions, B2 of VHT-SIG-A2 is the coding bit. In case of MU transmissions, B2, B4, B5 and B6 of VHT-SIG-A2 are the coding bits for user 1, 2, 3 and 4, respectively. The PHY entity shall use an LDPC decoder to decode the C-PSDU if the coding bit for its C-PSDU is set to 1. BCC decoder shall be used otherwise. When an LDPC decoder is to be used,  can be computed by Equation using  obtained from Equation .



If VHT-SIG-B is decoded and the VHT-SIG-B CRC in the SERVICE field is checked and not valid, the PHY shall issue the error condition PHY-RXEND.indication(FormatViolation). Subsequent to an indication of a valid VHT-SIG-B CRC in the SERVICE field, a PHY-RXSTART.indication(RXVECTOR) shall be issued. The RXVECTOR associated with this primitive includes the parameters specified in Table 22-1.

If signal loss occurs during reception prior to completion of the PSDU reception, the error condition PHY-RXEND.indication(CarrierLost) shall be reported to the MAC. After waiting for the intended end of the PSDU, the PHY shall set PHY-CCA.indication(IDLE) and return to RX IDLE state.

The received PSDU bits are assembled into octets, decoded, and presented to the MAC using a series of PHY-DATA.indication(DATA) primitive exchanges. Any final bits that cannot be assembled into a complete octet are considered pad bits and should be discarded. After the reception of the final bit of the last PSDU octet, and possible tail and padding bits, the receiver shall be returned to the RX IDLE state, as shown in Figure 22-24.



Figure 22‑23 -- PLCP receive procedure



Figure 22‑24 -- PLCP receive state machine

## VHT PLME

### PLME\_SAP sublayer management primitives

Table 22‑23 lists the MIB attributes that may be accessed by the PHY entities and the intralayer of higher level LMEs. These attributes are accessed via the PLME-GET, PLME-SET, PLMERESET, and PLME-CHARACTERISTICS primitives defined in 10.4.

### PHY MIB

VHT PHY MIB attributes are defined in TBD with specific values defined in Table 22‑23. The “Operational semantics” column in Table 22-xx contains two types: static and dynamic.

- Static MIB attributes are fixed and cannot be modified for a given PHY implementation.

- Dynamic MIB attributes are interpreted according the MAX-ACCESS field of the MID attribute. When MAX-ACCESS is set to read-only, the MIB attribute value may be updated by the PLME and read from the MIB attribute by management entities. When MAX-ACCESS is set to read-write, the MIB attribute may be read and written by management entities.

Table ‑--VHT PHY MIB attributes

|  |  |  |
| --- | --- | --- |
| **Managed Object** | **Default value/range** | **Operational Semantics** |
| dot11PHYOperationTable | | |
| dot11PHYType | VHT (TBD) | Static |
| dot11PHYVHTTable | | |
| dot11CurrentChannelBandwidth | Implementation dependent | Dynamic |
| dot11CurrentChannelCenterFrequencyIndex1 | Implementation dependent | Dynamic |
| dot11CurrentChannelCenterFrequencyIndex2 | Implementation dependent | Dynamic |
| dot11CurrentPrimary20MHzChannel | Implementation dependent | Dynamic |

### TXTIME and PSDU\_LENGTH calculation

The value of the TXTIME parameter returned by the PLME-TXTIME.confirm primitive shall be calculated for a VHT format PPDU using Equation for short GI and Equation for regular GI.

|  |  |  |
| --- | --- | --- |
|  |  |  |

|  |  |  |
| --- | --- | --- |
|  |  |  |

where

 denotes the smallest integer greater than or equal to 

 is the duration of the non-HT preamble

 is the duration of the VHT preamble in VHT format, given by 

are defined in Table 22‑4

 is defined in Table 22‑10

The total number of data symbols in the data portion of the packet, , for a SU packet using BCC encoding is given by Equation .



where

 is passed as the LENGTH parameter for user *u* in the TXVECTOR.

 is equal to 2 when STBC is used, and 1 otherwise

 is defined in Table 22‑5

 is defined in Table 22‑5

The total number of data symbols in the data portion of the packet, , for a SU packet using LDPC encoding is given in Section 22.3.11.4.2 (computed using Equation (20-41) in step (d) of Section 20.3.11.6.5).

The total number of data symbols in the data portion of the packet, , for a MU packet using is given by Equation .

The value of the PSDU\_LENGTH parameter returned in the PLME-TXTIME.confirm primitive and in the RXVECTOR for a SU packet using BCC encoding is calculated using Equation .



where

 is given by Equation ,

 denotes the largest integer smaller than or equal to ,

is defined in Table 22‑5,



is defined in Table 22‑5



The value of the PSDU\_LENGTH parameter returned in the PLME-TXTIME.confirm primitive and in the RXVECTOR for a SU packet using LDPC encoding is calculated using Equation .



where

 is given by Equation

is defined in Table 22‑5



The value of the PSDU\_LENGTH parameter for user *u* returned in the PLME-TXTIME.confirm primitive and in the RXVECTOR for a MU packet is calculated using Equation .



where

 denotes the largest integer smaller than or equal to ,

 is given by Equation ,

 is given by Equation ,

 is  for user *u*, where is defined in Table 22‑5

 is  for user *u*, where  is defined in Table 22‑5

### PHY characteristics

The static VHT PHY characteristics, provided through the PLME-CHARACTERISTICS service primitive, shall be as shown in Table 20-24 unless otherwise listed in Table 22‑24. The definitions for these characteristics are given in 10.4.

Table 22‑24--VHT PHY characteristics

|  |  |
| --- | --- |
| **Characteristics** | **Value** |
| aPSDUMaxLength | TBD octets |
| aCCAMidTime | < 25 µs |

## Parameters for VHT MCSs

The rate-dependent parameters for 20 MHz, 40 MHz, 80 MHz and 160 MHz *NSS*=1,…,8 are given in Table 22-18 through Table 22-49. Support for 400 ns GI is optional in all cases. Support for MCS 8 and 9 (when valid) is optional in all cases. Support for MCS 1 through 7 (when listed as valid in the associated table) is mandatory. Support for 20 MHz, 40 MHz and 80 MHz with *NSS*=1 is mandatory. Support for 20 MHz, 40 MHz and 80 MHz with *NSS*=2,…,8 is optional. Support for 160 MHz with *NSS*=1,…,8 is optional.

Table 22‑25--VHT MCSs for mandatory 20 MHz, *NSS* = 1

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| MCS Index | Modulation | R | NBPSCS | NSD | NSP | NCBPS | NDBPS | NES | Data rate (Mb/s) | |
| 800ns GI | 400ns GI |
| 0 | BPSK | 1/2 | 1 | 52 | 4 | 52 | 26 | 1 | 6.5 | 7.2 |
| 1 | QPSK | 1/2 | 2 | 52 | 4 | 104 | 52 | 1 | 13.0 | 14.4 |
| 2 | QPSK | 3/4 | 2 | 52 | 4 | 104 | 78 | 1 | 19.5 | 21.7 |
| 3 | 16-QAM | 1/2 | 4 | 52 | 4 | 208 | 104 | 1 | 26.0 | 28.9 |
| 4 | 16-QAM | 3/4 | 4 | 52 | 4 | 208 | 156 | 1 | 39.0 | 43.3 |
| 5 | 64-QAM | 2/3 | 6 | 52 | 4 | 312 | 208 | 1 | 52.0 | 57.8 |
| 6 | 64-QAM | 3/4 | 6 | 52 | 4 | 312 | 234 | 1 | 58.5 | 65.0 |
| 7 | 64-QAM | 5/6 | 6 | 52 | 4 | 312 | 260 | 1 | 65.0 | 72.2 |
| 8 | 256-QAM | 3/4 | 8 | 52 | 4 | 416 | 312 | 1 | 78.0 | 86.7 |
| 9 |  |  |  |  |  |  |  |  |  |  |
| NOTE: MCS 9 is invalid due to mod(NCBPS/NES, DR) not being equal to 0. | | | | | | | | | | |

Table 22‑26--VHT MCSs for optional 20 MHz, *NSS* = 2

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| MCS Index | Modulation | R | NBPSCS | NSD | NSP | NCBPS | NDBPS | NES | Data rate (Mb/s) | |
| 800ns GI | 400ns GI |
| 0 | BPSK | 1/2 | 1 | 52 | 4 | 104 | 52 | 1 | 13.0 | 14.4 |
| 1 | QPSK | 1/2 | 2 | 52 | 4 | 208 | 104 | 1 | 26.0 | 28.9 |
| 2 | QPSK | 3/4 | 2 | 52 | 4 | 208 | 156 | 1 | 39.0 | 43.3 |
| 3 | 16-QAM | 1/2 | 4 | 52 | 4 | 416 | 208 | 1 | 52.0 | 57.8 |
| 4 | 16-QAM | 3/4 | 4 | 52 | 4 | 416 | 312 | 1 | 78.0 | 86.7 |
| 5 | 64-QAM | 2/3 | 6 | 52 | 4 | 624 | 416 | 1 | 104.0 | 115.6 |
| 6 | 64-QAM | 3/4 | 6 | 52 | 4 | 624 | 468 | 1 | 117.0 | 130.0 |
| 7 | 64-QAM | 5/6 | 6 | 52 | 4 | 624 | 520 | 1 | 130.0 | 144.4 |
| 8 | 256-QAM | 3/4 | 8 | 52 | 4 | 832 | 624 | 1 | 156.0 | 173.3 |
| 9 |  |  |  |  |  |  |  |  |  |  |
| NOTE: MCS 9 is invalid due to mod(NCBPS/NES, DR) not being equal to 0. | | | | | | | | | | |

Table 22‑27--VHT MCSs for optional 20 MHz, *NSS* = 3

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| MCS Index | Modulation | R | NBPSCS | NSD | NSP | NCBPS | NDBPS | NES | Data rate (Mb/s) | |
| 800ns GI | 400ns GI |
| 0 | BPSK | 1/2 | 1 | 52 | 4 | 156 | 78 | 1 | 19.5 | 21.7 |
| 1 | QPSK | 1/2 | 2 | 52 | 4 | 312 | 156 | 1 | 39.0 | 43.3 |
| 2 | QPSK | 3/4 | 2 | 52 | 4 | 312 | 234 | 1 | 58.5 | 65.0 |
| 3 | 16-QAM | 1/2 | 4 | 52 | 4 | 624 | 312 | 1 | 78.0 | 86.7 |
| 4 | 16-QAM | 3/4 | 4 | 52 | 4 | 624 | 468 | 1 | 117.0 | 130.0 |
| 5 | 64-QAM | 2/3 | 6 | 52 | 4 | 936 | 624 | 1 | 156.0 | 173.3 |
| 6 | 64-QAM | 3/4 | 6 | 52 | 4 | 936 | 702 | 1 | 175.5 | 195.0 |
| 7 | 64-QAM | 5/6 | 6 | 52 | 4 | 936 | 780 | 1 | 195.0 | 216.7 |
| 8 | 256-QAM | 3/4 | 8 | 52 | 4 | 1248 | 936 | 1 | 234.0 | 260.0 |
| 9 | 256-QAM | 5/6 | 8 | 52 | 4 | 1248 | 1040 | 1 | 260.0 | 288.9 |

Table 22‑28--VHT MCSs for optional 20 MHz, *NSS* = 4

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| MCS Index | Modulation | R | NBPSCS | NSD | NSP | NCBPS | NDBPS | NES | Data rate (Mb/s) | |
| 800ns GI | 400ns GI |
| 0 | BPSK | 1/2 | 1 | 52 | 4 | 208 | 104 | 1 | 26.0 | 28.9 |
| 1 | QPSK | 1/2 | 2 | 52 | 4 | 416 | 208 | 1 | 52.0 | 57.8 |
| 2 | QPSK | 3/4 | 2 | 52 | 4 | 416 | 312 | 1 | 78.0 | 86.7 |
| 3 | 16-QAM | 1/2 | 4 | 52 | 4 | 832 | 416 | 1 | 104.0 | 115.6 |
| 4 | 16-QAM | 3/4 | 4 | 52 | 4 | 832 | 624 | 1 | 156.0 | 173.3 |
| 5 | 64-QAM | 2/3 | 6 | 52 | 4 | 1248 | 832 | 1 | 208.0 | 231.1 |
| 6 | 64-QAM | 3/4 | 6 | 52 | 4 | 1248 | 936 | 1 | 234.0 | 260.0 |
| 7 | 64-QAM | 5/6 | 6 | 52 | 4 | 1248 | 1040 | 1 | 260.0 | 288.9 |
| 8 | 256-QAM | 3/4 | 8 | 52 | 4 | 1664 | 1248 | 1 | 312.0 | 346.7 |
| 9 |  |  |  |  |  |  |  |  |  |  |
| NOTE: MCS 9 is invalid due to mod(NCBPS/NES, DR) not being equal to 0. | | | | | | | | | | |

Table 22‑29--VHT MCSs for optional 20 MHz, *NSS* = 5

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| MCS Index | Modulation | R | NBPSCS | NSD | NSP | NCBPS | NDBPS | NES | Data rate (Mb/s) | |
| 800ns GI | 400ns GI |
| 0 | BPSK | 1/2 | 1 | 52 | 4 | 260 | 130 | 1 | 32.5 | 36.1 |
| 1 | QPSK | 1/2 | 2 | 52 | 4 | 520 | 260 | 1 | 65.0 | 72.2 |
| 2 | QPSK | 3/4 | 2 | 52 | 4 | 520 | 390 | 1 | 97.5 | 108.3 |
| 3 | 16-QAM | 1/2 | 4 | 52 | 4 | 1040 | 520 | 1 | 130.0 | 144.4 |
| 4 | 16-QAM | 3/4 | 4 | 52 | 4 | 1040 | 780 | 1 | 195.0 | 216.7 |
| 5 | 64-QAM | 2/3 | 6 | 52 | 4 | 1560 | 1040 | 1 | 260.0 | 288.9 |
| 6 | 64-QAM | 3/4 | 6 | 52 | 4 | 1560 | 1170 | 1 | 292.5 | 325.0 |
| 7 | 64-QAM | 5/6 | 6 | 52 | 4 | 1560 | 1300 | 1 | 325.0 | 361.1 |
| 8 | 256-QAM | 3/4 | 8 | 52 | 4 | 2080 | 1560 | 1 | 390.0 | 433.3 |
| 9 |  |  |  |  |  |  |  |  |  |  |
| NOTE: MCS 9 is invalid due to mod(NCBPS/NES, DR) not being equal to 0. | | | | | | | | | | |

Table 22‑30--VHT MCSs for optional 20 MHz, *NSS* = 6

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| MCS Index | Modulation | R | NBPSCS | NSD | NSP | NCBPS | NDBPS | NES | Data rate (Mb/s) | |
| 800ns GI | 400ns GI |
| 0 | BPSK | 1/2 | 1 | 52 | 4 | 312 | 156 | 1 | 39.0 | 43.3 |
| 1 | QPSK | 1/2 | 2 | 52 | 4 | 624 | 312 | 1 | 78.0 | 86.7 |
| 2 | QPSK | 3/4 | 2 | 52 | 4 | 624 | 468 | 1 | 117.0 | 130.0 |
| 3 | 16-QAM | 1/2 | 4 | 52 | 4 | 1248 | 624 | 1 | 156.0 | 173.3 |
| 4 | 16-QAM | 3/4 | 4 | 52 | 4 | 1248 | 936 | 1 | 234.0 | 260.0 |
| 5 | 64-QAM | 2/3 | 6 | 52 | 4 | 1872 | 1248 | 1 | 312.0 | 346.7 |
| 6 | 64-QAM | 3/4 | 6 | 52 | 4 | 1872 | 1404 | 1 | 351.0 | 390.0 |
| 7 | 64-QAM | 5/6 | 6 | 52 | 4 | 1872 | 1560 | 1 | 390.0 | 433.3 |
| 8 | 256-QAM | 3/4 | 8 | 52 | 4 | 2496 | 1872 | 1 | 468.0 | 520.0 |
| 9 | 256-QAM | 5/6 | 8 | 52 | 4 | 2496 | 2080 | 1 | 520.0 | 577.8 |

Table 22‑31--VHT MCSs for optional 20 MHz, *NSS* = 7

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| MCS Index | Modulation | R | NBPSCS | NSD | NSP | NCBPS | NDBPS | NES | Data rate (Mb/s) | |
| 800ns GI | 400ns GI |
| 0 | BPSK | 1/2 | 1 | 52 | 4 | 364 | 182 | 1 | 45.5 | 50.6 |
| 1 | QPSK | 1/2 | 2 | 52 | 4 | 728 | 364 | 1 | 91.0 | 101.1 |
| 2 | QPSK | 3/4 | 2 | 52 | 4 | 728 | 546 | 1 | 136.5 | 151.7 |
| 3 | 16-QAM | 1/2 | 4 | 52 | 4 | 1456 | 728 | 1 | 182.0 | 202.2 |
| 4 | 16-QAM | 3/4 | 4 | 52 | 4 | 1456 | 1092 | 1 | 273.0 | 303.3 |
| 5 | 64-QAM | 2/3 | 6 | 52 | 4 | 2184 | 1456 | 1 | 364.0 | 404.4 |
| 6 | 64-QAM | 3/4 | 6 | 52 | 4 | 2184 | 1638 | 1 | 409.5 | 455.0 |
| 7 | 64-QAM | 5/6 | 6 | 52 | 4 | 2184 | 1820 | 1 | 455.0 | 505.6 |
| 8 | 256-QAM | 3/4 | 8 | 52 | 4 | 2912 | 2184 | 2 | 546.0 | 606.7 |
| 9 |  |  |  |  |  |  |  |  |  |  |
| NOTE: MCS 9 is invalid due to mod(NCBPS/NES, DR) not being equal to 0. | | | | | | | | | | |

Table 22‑32--VHT MCSs for optional 20 MHz, *NSS* = 8

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| MCS Index | Modulation | R | NBPSCS | NSD | NSP | NCBPS | NDBPS | NES | Data rate (Mb/s) | |
| 800ns GI | 400ns GI |
| 0 | BPSK | 1/2 | 1 | 52 | 4 | 416 | 208 | 1 | 52.0 | 57.8 |
| 1 | QPSK | 1/2 | 2 | 52 | 4 | 832 | 416 | 1 | 104.0 | 115.6 |
| 2 | QPSK | 3/4 | 2 | 52 | 4 | 832 | 624 | 1 | 156.0 | 173.3 |
| 3 | 16-QAM | 1/2 | 4 | 52 | 4 | 1664 | 832 | 1 | 208.0 | 231.1 |
| 4 | 16-QAM | 3/4 | 4 | 52 | 4 | 1664 | 1248 | 1 | 312.0 | 346.7 |
| 5 | 64-QAM | 2/3 | 6 | 52 | 4 | 2496 | 1664 | 1 | 416.0 | 462.2 |
| 6 | 64-QAM | 3/4 | 6 | 52 | 4 | 2496 | 1872 | 1 | 468.0 | 520.0 |
| 7 | 64-QAM | 5/6 | 6 | 52 | 4 | 2496 | 2080 | 1 | 520.0 | 577.8 |
| 8 | 256-QAM | 3/4 | 8 | 52 | 4 | 3328 | 2496 | 2 | 624.0 | 693.3 |
| 9 |  |  |  |  |  |  |  |  |  |  |
| NOTE: MCS 9 is invalid due to mod(NCBPS/NES, DR) not being equal to 0. | | | | | | | | | | |

Table 22‑33--VHT MCSs for mandatory 40 MHz, *NSS* = 1

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| MCS Index | Modulation | R | NBPSCS | NSD | NSP | NCBPS | NDBPS | NES | Data rate (Mb/s) | |
| 800ns GI | 400ns GI |
| 0 | BPSK | 1/2 | 1 | 108 | 6 | 108 | 54 | 1 | 13.5 | 15.0 |
| 1 | QPSK | 1/2 | 2 | 108 | 6 | 216 | 108 | 1 | 27.0 | 30.0 |
| 2 | QPSK | 3/4 | 2 | 108 | 6 | 216 | 162 | 1 | 40.5 | 45.0 |
| 3 | 16-QAM | 1/2 | 4 | 108 | 6 | 432 | 216 | 1 | 54.0 | 60.0 |
| 4 | 16-QAM | 3/4 | 4 | 108 | 6 | 432 | 324 | 1 | 81.0 | 90.0 |
| 5 | 64-QAM | 2/3 | 6 | 108 | 6 | 648 | 432 | 1 | 108.0 | 120.0 |
| 6 | 64-QAM | 3/4 | 6 | 108 | 6 | 648 | 486 | 1 | 121.5 | 135.0 |
| 7 | 64-QAM | 5/6 | 6 | 108 | 6 | 648 | 540 | 1 | 135.0 | 150.0 |
| 8 | 256-QAM | 3/4 | 8 | 108 | 6 | 864 | 648 | 1 | 162.0 | 180.0 |
| 9 | 256-QAM | 5/6 | 8 | 108 | 6 | 864 | 720 | 1 | 180.0 | 200.0 |

Table 22‑34--VHT MCSs for optional 40 MHz, *NSS* = 2

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| MCS Index | Modulation | R | NBPSCS | NSD | NSP | NCBPS | NDBPS | NES | Data rate (Mb/s) | |
| 800ns GI | 400ns GI |
| 0 | BPSK | 1/2 | 1 | 108 | 6 | 216 | 108 | 1 | 27.0 | 30.0 |
| 1 | QPSK | 1/2 | 2 | 108 | 6 | 432 | 216 | 1 | 54.0 | 60.0 |
| 2 | QPSK | 3/4 | 2 | 108 | 6 | 432 | 324 | 1 | 81.0 | 90.0 |
| 3 | 16-QAM | 1/2 | 4 | 108 | 6 | 864 | 432 | 1 | 108.0 | 120.0 |
| 4 | 16-QAM | 3/4 | 4 | 108 | 6 | 864 | 648 | 1 | 162.0 | 180.0 |
| 5 | 64-QAM | 2/3 | 6 | 108 | 6 | 1296 | 864 | 1 | 216.0 | 240.0 |
| 6 | 64-QAM | 3/4 | 6 | 108 | 6 | 1296 | 972 | 1 | 243.0 | 270.0 |
| 7 | 64-QAM | 5/6 | 6 | 108 | 6 | 1296 | 1080 | 1 | 270.0 | 300.0 |
| 8 | 256-QAM | 3/4 | 8 | 108 | 6 | 1728 | 1296 | 1 | 324.0 | 360.0 |
| 9 | 256-QAM | 5/6 | 8 | 108 | 6 | 1728 | 1440 | 1 | 360.0 | 400.0 |

Table 22‑35--VHT MCSs for optional 40 MHz, *NSS* = 3

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| MCS Index | Modulation | R | NBPSCS | NSD | NSP | NCBPS | NDBPS | NES | Data rate (Mb/s) | |
| 800ns GI | 400ns GI |
| 0 | BPSK | 1/2 | 1 | 108 | 6 | 324 | 162 | 1 | 40.5 | 45.0 |
| 1 | QPSK | 1/2 | 2 | 108 | 6 | 648 | 324 | 1 | 81.0 | 90.0 |
| 2 | QPSK | 3/4 | 2 | 108 | 6 | 648 | 486 | 1 | 121.5 | 135.0 |
| 3 | 16-QAM | 1/2 | 4 | 108 | 6 | 1296 | 648 | 1 | 162.0 | 180.0 |
| 4 | 16-QAM | 3/4 | 4 | 108 | 6 | 1296 | 972 | 1 | 243.0 | 270.0 |
| 5 | 64-QAM | 2/3 | 6 | 108 | 6 | 1944 | 1296 | 1 | 324.0 | 360.0 |
| 6 | 64-QAM | 3/4 | 6 | 108 | 6 | 1944 | 1458 | 1 | 364.5 | 405.0 |
| 7 | 64-QAM | 5/6 | 6 | 108 | 6 | 1944 | 1620 | 1 | 405.0 | 450.0 |
| 8 | 256-QAM | 3/4 | 8 | 108 | 6 | 2592 | 1944 | 1 | 486.0 | 540.0 |
| 9 | 256-QAM | 5/6 | 8 | 108 | 6 | 2592 | 2160 | 1 | 540.0 | 600.0 |

Table 22‑36--VHT MCSs for optional 40 MHz, *NSS* = 4

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| MCS Index | Modulation | R | NBPSCS | NSD | NSP | NCBPS | NDBPS | NES | Data rate (Mb/s) | |
| 800ns GI | 400ns GI |
| 0 | BPSK | 1/2 | 1 | 108 | 6 | 432 | 216 | 1 | 54.0 | 60.0 |
| 1 | QPSK | 1/2 | 2 | 108 | 6 | 864 | 432 | 1 | 108.0 | 120.0 |
| 2 | QPSK | 3/4 | 2 | 108 | 6 | 864 | 648 | 1 | 162.0 | 180.0 |
| 3 | 16-QAM | 1/2 | 4 | 108 | 6 | 1728 | 864 | 1 | 216.0 | 240.0 |
| 4 | 16-QAM | 3/4 | 4 | 108 | 6 | 1728 | 1296 | 1 | 324.0 | 360.0 |
| 5 | 64-QAM | 2/3 | 6 | 108 | 6 | 2592 | 1728 | 1 | 432.0 | 480.0 |
| 6 | 64-QAM | 3/4 | 6 | 108 | 6 | 2592 | 1944 | 1 | 486.0 | 540.0 |
| 7 | 64-QAM | 5/6 | 6 | 108 | 6 | 2592 | 2160 | 1 | 540.0 | 600.0 |
| 8 | 256-QAM | 3/4 | 8 | 108 | 6 | 3456 | 2592 | 2 | 648.0 | 720.0 |
| 9 | 256-QAM | 5/6 | 8 | 108 | 6 | 3456 | 2880 | 2 | 720.0 | 800.0 |

Table 22‑37--VHT MCSs for optional 40 MHz, *NSS* = 5

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| MCS Index | Modulation | R | NBPSCS | NSD | NSP | NCBPS | NDBPS | NES | Data rate (Mb/s) | |
| 800ns GI | 400ns GI |
| 0 | BPSK | 1/2 | 1 | 108 | 6 | 540 | 270 | 1 | 67.5 | 75.0 |
| 1 | QPSK | 1/2 | 2 | 108 | 6 | 1080 | 540 | 1 | 135.0 | 150.0 |
| 2 | QPSK | 3/4 | 2 | 108 | 6 | 1080 | 810 | 1 | 202.5 | 225.0 |
| 3 | 16-QAM | 1/2 | 4 | 108 | 6 | 2160 | 1080 | 1 | 270.0 | 300.0 |
| 4 | 16-QAM | 3/4 | 4 | 108 | 6 | 2160 | 1620 | 1 | 405.0 | 450.0 |
| 5 | 64-QAM | 2/3 | 6 | 108 | 6 | 3240 | 2160 | 1 | 540.0 | 600.0 |
| 6 | 64-QAM | 3/4 | 6 | 108 | 6 | 3240 | 2430 | 2 | 607.5 | 675.0 |
| 7 | 64-QAM | 5/6 | 6 | 108 | 6 | 3240 | 2700 | 2 | 675.0 | 750.0 |
| 8 | 256-QAM | 3/4 | 8 | 108 | 6 | 4320 | 3240 | 2 | 810.0 | 900.0 |
| 9 | 256-QAM | 5/6 | 8 | 108 | 6 | 4320 | 3600 | 2 | 900.0 | 1000.0 |

Table 22‑38--VHT MCSs for optional 40 MHz, *NSS* = 6

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| MCS Index | Modulation | R | NBPSCS | NSD | NSP | NCBPS | NDBPS | NES | Data rate (Mb/s) | |
| 800ns GI | 400ns GI |
| 0 | BPSK | 1/2 | 1 | 108 | 6 | 648 | 324 | 1 | 81.0 | 90.0 |
| 1 | QPSK | 1/2 | 2 | 108 | 6 | 1296 | 648 | 1 | 162.0 | 180.0 |
| 2 | QPSK | 3/4 | 2 | 108 | 6 | 1296 | 972 | 1 | 243.0 | 270.0 |
| 3 | 16-QAM | 1/2 | 4 | 108 | 6 | 2592 | 1296 | 1 | 324.0 | 360.0 |
| 4 | 16-QAM | 3/4 | 4 | 108 | 6 | 2592 | 1944 | 1 | 486.0 | 540.0 |
| 5 | 64-QAM | 2/3 | 6 | 108 | 6 | 3888 | 2592 | 2 | 648.0 | 720.0 |
| 6 | 64-QAM | 3/4 | 6 | 108 | 6 | 3888 | 2916 | 2 | 729.0 | 810.0 |
| 7 | 64-QAM | 5/6 | 6 | 108 | 6 | 3888 | 3240 | 2 | 810.0 | 900.0 |
| 8 | 256-QAM | 3/4 | 8 | 108 | 6 | 5184 | 3888 | 2 | 972.0 | 1080.0 |
| 9 | 256-QAM | 5/6 | 8 | 108 | 6 | 5184 | 4320 | 2 | 1080.0 | 1200.0 |

Table 22‑39--VHT MCSs for optional 40 MHz, *NSS* = 7

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| MCS Index | Modulation | R | NBPSCS | NSD | NSP | NCBPS | NDBPS | NES | Data rate (Mb/s) | |
| 800ns GI | 400ns GI |
| 0 | BPSK | 1/2 | 1 | 108 | 6 | 756 | 378 | 1 | 94.5 | 105.0 |
| 1 | QPSK | 1/2 | 2 | 108 | 6 | 1512 | 756 | 1 | 189.0 | 210.0 |
| 2 | QPSK | 3/4 | 2 | 108 | 6 | 1512 | 1134 | 1 | 283.5 | 315.0 |
| 3 | 16-QAM | 1/2 | 4 | 108 | 6 | 3024 | 1512 | 1 | 378.0 | 420.0 |
| 4 | 16-QAM | 3/4 | 4 | 108 | 6 | 3024 | 2268 | 2 | 567.0 | 630.0 |
| 5 | 64-QAM | 2/3 | 6 | 108 | 6 | 4536 | 3024 | 2 | 756.0 | 840.0 |
| 6 | 64-QAM | 3/4 | 6 | 108 | 6 | 4536 | 3402 | 2 | 850.5 | 945.0 |
| 7 | 64-QAM | 5/6 | 6 | 108 | 6 | 4536 | 3780 | 2 | 945.0 | 1050.0 |
| 8 | 256-QAM | 3/4 | 8 | 108 | 6 | 6048 | 4536 | 3 | 1134.0 | 1260.0 |
| 9 | 256-QAM | 5/6 | 8 | 108 | 6 | 6048 | 5040 | 3 | 1260.0 | 1400.0 |

Table 22‑40--VHT MCSs for optional 40 MHz, *NSS* = 8

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| MCS Index | Modulation | R | NBPSCS | NSD | NSP | NCBPS | NDBPS | NES | Data rate (Mb/s) | |
| 800ns GI | 400ns GI |
| 0 | BPSK | 1/2 | 1 | 108 | 6 | 864 | 432 | 1 | 108.0 | 120.0 |
| 1 | QPSK | 1/2 | 2 | 108 | 6 | 1728 | 864 | 1 | 216.0 | 240.0 |
| 2 | QPSK | 3/4 | 2 | 108 | 6 | 1728 | 1296 | 1 | 324.0 | 360.0 |
| 3 | 16-QAM | 1/2 | 4 | 108 | 6 | 3456 | 1728 | 1 | 432.0 | 480.0 |
| 4 | 16-QAM | 3/4 | 4 | 108 | 6 | 3456 | 2592 | 2 | 648.0 | 720.0 |
| 5 | 64-QAM | 2/3 | 6 | 108 | 6 | 5184 | 3456 | 2 | 864.0 | 960.0 |
| 6 | 64-QAM | 3/4 | 6 | 108 | 6 | 5184 | 3888 | 2 | 972.0 | 1080.0 |
| 7 | 64-QAM | 5/6 | 6 | 108 | 6 | 5184 | 4320 | 2 | 1080.0 | 1200.0 |
| 8 | 256-QAM | 3/4 | 8 | 108 | 6 | 6912 | 5184 | 3 | 1296.0 | 1440.0 |
| 9 | 256-QAM | 5/6 | 8 | 108 | 6 | 6912 | 5760 | 3 | 1440.0 | 1600.0 |

Table 22‑41--VHT MCSs for mandatory 80 MHz, *NSS* = 1

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| MCS Index | Modulation | R | NBPSCS | NSD | NSP | NCBPS | NDBPS | NES | Data rate (Mb/s) | |
| 800ns GI | 400ns GI |
| 0 | BPSK | 1/2 | 1 | 234 | 8 | 234 | 117 | 1 | 29.3 | 32.5 |
| 1 | QPSK | 1/2 | 2 | 234 | 8 | 468 | 234 | 1 | 58.5 | 65.0 |
| 2 | QPSK | 3/4 | 2 | 234 | 8 | 468 | 351 | 1 | 87.8 | 97.5 |
| 3 | 16-QAM | 1/2 | 4 | 234 | 8 | 936 | 468 | 1 | 117.0 | 130.0 |
| 4 | 16-QAM | 3/4 | 4 | 234 | 8 | 936 | 702 | 1 | 175.5 | 195.0 |
| 5 | 64-QAM | 2/3 | 6 | 234 | 8 | 1404 | 936 | 1 | 234.0 | 260.0 |
| 6 | 64-QAM | 3/4 | 6 | 234 | 8 | 1404 | 1053 | 1 | 263.3 | 292.5 |
| 7 | 64-QAM | 5/6 | 6 | 234 | 8 | 1404 | 1170 | 1 | 292.5 | 325.0 |
| 8 | 256-QAM | 3/4 | 8 | 234 | 8 | 1872 | 1404 | 1 | 351.0 | 390.0 |
| 9 | 256-QAM | 5/6 | 8 | 234 | 8 | 1872 | 1560 | 1 | 390.0 | 433.3 |

Table 22‑42--VHT MCSs for optional 80 MHz, *NSS* = 2

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| MCS Index | Modulation | R | NBPSCS | NSD | NSP | NCBPS | NDBPS | NES | Data rate (Mb/s) | |
| 800ns GI | 400ns GI |
| 0 | BPSK | 1/2 | 1 | 234 | 8 | 468 | 234 | 1 | 58.5 | 65.0 |
| 1 | QPSK | 1/2 | 2 | 234 | 8 | 936 | 468 | 1 | 117.0 | 130.0 |
| 2 | QPSK | 3/4 | 2 | 234 | 8 | 936 | 702 | 1 | 175.5 | 195.0 |
| 3 | 16-QAM | 1/2 | 4 | 234 | 8 | 1872 | 936 | 1 | 234.0 | 260.0 |
| 4 | 16-QAM | 3/4 | 4 | 234 | 8 | 1872 | 1404 | 1 | 351.0 | 390.0 |
| 5 | 64-QAM | 2/3 | 6 | 234 | 8 | 2808 | 1872 | 1 | 468.0 | 520.0 |
| 6 | 64-QAM | 3/4 | 6 | 234 | 8 | 2808 | 2106 | 1 | 526.5 | 585.0 |
| 7 | 64-QAM | 5/6 | 6 | 234 | 8 | 2808 | 2340 | 2 | 585.0 | 650.0 |
| 8 | 256-QAM | 3/4 | 8 | 234 | 8 | 3744 | 2808 | 2 | 702.0 | 780.0 |
| 9 | 256-QAM | 5/6 | 8 | 234 | 8 | 3744 | 3120 | 2 | 780.0 | 866.7 |

Table 22‑43--VHT MCSs for optional 80 MHz, *NSS* = 3

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| MCS Index | Modulation | R | NBPSCS | NSD | NSP | NCBPS | NDBPS | NES | Data rate (Mb/s) | |
| 800ns GI | 400ns GI |
| 0 | BPSK | 1/2 | 1 | 234 | 8 | 702 | 351 | 1 | 87.8 | 97.5 |
| 1 | QPSK | 1/2 | 2 | 234 | 8 | 1404 | 702 | 1 | 175.5 | 195.0 |
| 2 | QPSK | 3/4 | 2 | 234 | 8 | 1404 | 1053 | 1 | 263.3 | 292.5 |
| 3 | 16-QAM | 1/2 | 4 | 234 | 8 | 2808 | 1404 | 1 | 351.0 | 390.0 |
| 4 | 16-QAM | 3/4 | 4 | 234 | 8 | 2808 | 2106 | 1 | 526.5 | 585.0 |
| 5 | 64-QAM | 2/3 | 6 | 234 | 8 | 4212 | 2808 | 2 | 702.0 | 780.0 |
| 6 |  |  |  |  |  |  |  |  |  |  |
| 7 | 64-QAM | 5/6 | 6 | 234 | 8 | 4212 | 3510 | 2 | 877.5 | 975.0 |
| 8 | 256-QAM | 3/4 | 8 | 234 | 8 | 5616 | 4212 | 2 | 1053.0 | 1170.0 |
| 9 | 256-QAM | 5/6 | 8 | 234 | 8 | 5616 | 4680 | 3 | 1170.0 | 1300.0 |
| NOTE: MCS 6 is invalid due to mod(NCBPS/NES, DR) not being equal to 0. | | | | | | | | | | |

Table 22‑44--VHT MCSs for optional 80 MHz, *NSS* = 4

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| MCS Index | Modulation | R | NBPSCS | NSD | NSP | NCBPS | NDBPS | NES | Data rate (Mb/s) | |
| 800ns GI | 400ns GI |
| 0 | BPSK | ½ | 1 | 234 | 8 | 936 | 468 | 1 | 117.0 | 130.0 |
| 1 | QPSK | 1/2 | 2 | 234 | 8 | 1872 | 936 | 1 | 234.0 | 260.0 |
| 2 | QPSK | 3/4 | 2 | 234 | 8 | 1872 | 1404 | 1 | 351.0 | 390.0 |
| 3 | 16-QAM | 1/2 | 4 | 234 | 8 | 3744 | 1872 | 1 | 468.0 | 520.0 |
| 4 | 16-QAM | 3/4 | 4 | 234 | 8 | 3744 | 2808 | 2 | 702.0 | 780.0 |
| 5 | 64-QAM | 2/3 | 6 | 234 | 8 | 5616 | 3744 | 2 | 936.0 | 1040.0 |
| 6 | 64-QAM | 3/4 | 6 | 234 | 8 | 5616 | 4212 | 2 | 1053.0 | 1170.0 |
| 7 | 64-QAM | 5/6 | 6 | 234 | 8 | 5616 | 4680 | 3 | 1170.0 | 1300.0 |
| 8 | 256-QAM | 3/4 | 8 | 234 | 8 | 7488 | 5616 | 3 | 1404.0 | 1560.0 |
| 9 | 256-QAM | 5/6 | 8 | 234 | 8 | 7488 | 6240 | 3 | 1560.0 | 1733.3 |

Table 22‑45--VHT MCSs for optional 80 MHz, *NSS* = 5

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| MCS Index | Modulation | R | NBPSCS | NSD | NSP | NCBPS | NDBPS | NES | Data rate (Mb/s) | |
| 800ns GI | 400ns GI |
| 0 | BPSK | 1/2 | 1 | 234 | 8 | 1170 | 585 | 1 | 146.3 | 162.5 |
| 1 | QPSK | 1/2 | 2 | 234 | 8 | 2340 | 1170 | 1 | 292.5 | 325.0 |
| 2 | QPSK | 3/4 | 2 | 234 | 8 | 2340 | 1755 | 1 | 438.8 | 487.5 |
| 3 | 16-QAM | 1/2 | 4 | 234 | 8 | 4680 | 2340 | 2 | 585.0 | 650.0 |
| 4 | 16-QAM | 3/4 | 4 | 234 | 8 | 4680 | 3510 | 2 | 877.5 | 975.0 |
| 5 | 64-QAM | 2/3 | 6 | 234 | 8 | 7020 | 4680 | 3 | 1170.0 | 1300.0 |
| 6 | 64-QAM | 3/4 | 6 | 234 | 8 | 7020 | 5265 | 3 | 1316.3 | 1462.5 |
| 7 | 64-QAM | 5/6 | 6 | 234 | 8 | 7020 | 5850 | 3 | 1462.5 | 1625.0 |
| 8 | 256-QAM | 3/4 | 8 | 234 | 8 | 9360 | 7020 | 4 | 1755.0 | 1950.0 |
| 9 | 256-QAM | 5/6 | 8 | 234 | 8 | 9360 | 7800 | 4 | 1950.0 | 2166.7 |

Table 22‑46--VHT MCSs for optional 80 MHz, *NSS* = 6

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| MCS Index | Modulation | R | NBPSCS | NSD | NSP | NCBPS | NDBPS | NES | Data rate (Mb/s) | |
| 800ns GI | 400ns GI |
| 0 | BPSK | 1/2 | 1 | 234 | 8 | 1404 | 702 | 1 | 175.5 | 195.0 |
| 1 | QPSK | 1/2 | 2 | 234 | 8 | 2808 | 1404 | 1 | 351.0 | 390.0 |
| 2 | QPSK | 3/4 | 2 | 234 | 8 | 2808 | 2106 | 1 | 526.5 | 585.0 |
| 3 | 16-QAM | 1/2 | 4 | 234 | 8 | 5616 | 2808 | 2 | 702.0 | 780.0 |
| 4 | 16-QAM | 3/4 | 4 | 234 | 8 | 5616 | 4212 | 2 | 1053.0 | 1170.0 |
| 5 | 64-QAM | 2/3 | 6 | 234 | 8 | 8424 | 5616 | 3 | 1404.0 | 1560.0 |
| 6 | 64-QAM | 3/4 | 6 | 234 | 8 | 8424 | 6318 | 3 | 1579.5 | 1755.0 |
| 7 | 64-QAM | 5/6 | 6 | 234 | 8 | 8424 | 7020 | 4 | 1755.0 | 1950.0 |
| 8 | 256-QAM | 3/4 | 8 | 234 | 8 | 11232 | 8424 | 4 | 2106.0 | 2340.0 |
| 9 |  |  |  |  |  |  |  |  |  |  |
| NOTE: MCS 9 is invalid due to mod(NCBPS/NES, DR) not being equal to 0. | | | | | | | | | | |

Table 22‑47--VHT MCSs for optional 80 MHz, *NSS* = 7

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| MCS Index | Modulation | R | NBPSCS | NSD | NSP | NCBPS | NDBPS | NES | Data rate (Mb/s) | |
| 800ns GI | 400ns GI |
| 0 | BPSK | ½ | 1 | 234 | 8 | 1638 | 819 | 1 | 204.8 | 227.5 |
| 1 | QPSK | ½ | 2 | 234 | 8 | 3276 | 1638 | 1 | 409.5 | 455.0 |
| 2 |  |  |  |  |  |  |  |  |  |  |
| 3 | 16-QAM | ½ | 4 | 234 | 8 | 6552 | 3276 | 2 | 819.0 | 910.0 |
| 4 | 16-QAM | 3/4 | 4 | 234 | 8 | 6552 | 4914 | 3 | 1228.5 | 1365.0 |
| 5 | 64-QAM | 2/3 | 6 | 234 | 8 | 9828 | 6552 | 4 | 1638.0 | 1820.0 |
| 6 |  |  |  |  |  |  |  |  |  |  |
| 7 |  |  |  |  |  |  |  |  |  |  |
| 8 |  |  |  |  |  |  |  |  |  |  |
| 9 | 256-QAM | 5/6 | 8 | 234 | 8 | 13104 | 10920 | 6 | 2730 | 3033.3 |
| NOTE: MCSs 2, 6, 7 and 8 are invalid for BCC due to mod(NCBPS/NES, DR) not being equal to 0. | | | | | | | | | | |

Table 22‑48--VHT MCSs for optional 80 MHz, *NSS* = 8

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| MCS Index | Modulation | R | NBPSCS | NSD | NSP | NCBPS | NDBPS | NES | Data rate (Mb/s) | |
| 800ns GI | 400ns GI |
| 0 | BPSK | 1/2 | 1 | 234 | 8 | 1872 | 936 | 1 | 234.0 | 260.0 |
| 1 | QPSK | 1/2 | 2 | 234 | 8 | 3744 | 1872 | 1 | 468.0 | 520.0 |
| 2 | QPSK | 3/4 | 2 | 234 | 8 | 3744 | 2808 | 2 | 702.0 | 780.0 |
| 3 | 16-QAM | 1/2 | 4 | 234 | 8 | 7488 | 3744 | 2 | 936.0 | 1040.0 |
| 4 | 16-QAM | 3/4 | 4 | 234 | 8 | 7488 | 5616 | 3 | 1404.0 | 1560.0 |
| 5 | 64-QAM | 2/3 | 6 | 234 | 8 | 11232 | 7488 | 4 | 1872.0 | 2080.0 |
| 6 | 64-QAM | 3/4 | 6 | 234 | 8 | 11232 | 8424 | 4 | 2106.0 | 2340.0 |
| 7 |  |  |  |  |  |  |  |  |  |  |
| 8 | 256-QAM | 3/4 | 8 | 234 | 8 | 14976 | 11232 | 6 | 2808.0 | 3120.0 |
| 9 | 256-QAM | 5/6 | 8 | 234 | 8 | 14976 | 11232 | 6 | 3120.0 | 3466.7 |
| NOTE: MCS 7 is invalid for BCC due to mod(NCBPS/NES, DR) not being equal to 0. | | | | | | | | | | |

Table 22‑49--VHT MCSs for optional 160 MHz, *NSS* = 1

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| MCS Index | Modulation | R | NBPSCS | NSD | NSP | NCBPS | NDBPS | NES | Data rate (Mb/s) | |
| 800ns GI | 400ns GI |
| 0 | BPSK | 1/2 | 1 | 468 | 16 | 468 | 234 | 1 | 58.5 | 65.0 |
| 1 | QPSK | 1/2 | 2 | 468 | 16 | 936 | 468 | 1 | 117.0 | 130.0 |
| 2 | QPSK | 3/4 | 2 | 468 | 16 | 936 | 702 | 1 | 175.5 | 195.0 |
| 3 | 16-QAM | 1/2 | 4 | 468 | 16 | 1872 | 936 | 1 | 234.0 | 260.0 |
| 4 | 16-QAM | 3/4 | 4 | 468 | 16 | 1872 | 1404 | 1 | 351.0 | 390.0 |
| 5 | 64-QAM | 2/3 | 6 | 468 | 16 | 2808 | 1872 | 1 | 468.0 | 520.0 |
| 6 | 64-QAM | 3/4 | 6 | 468 | 16 | 2808 | 2106 | 1 | 526.5 | 585.0 |
| 7 | 64-QAM | 5/6 | 6 | 468 | 16 | 2808 | 2340 | 2 | 585.0 | 650.0 |
| 8 | 256-QAM | 3/4 | 8 | 468 | 16 | 3744 | 2808 | 2 | 702.0 | 780.0 |
| 9 | 256-QAM | 5/6 | 8 | 468 | 16 | 3744 | 3120 | 2 | 780.0 | 866.7 |

Table 22‑50--VHT MCSs for optional 160 MHz, *NSS* = 2

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| MCS Index | Modulation | R | NBPSCS | NSD | NSP | NCBPS | NDBPS | NES | Data rate (Mb/s) | |
| 800ns GI | 400ns GI |
| 0 | BPSK | 1/2 | 1 | 468 | 16 | 936 | 468 | 1 | 117.0 | 130.0 |
| 1 | QPSK | 1/2 | 2 | 468 | 16 | 1872 | 936 | 1 | 234.0 | 260.0 |
| 2 | QPSK | 3/4 | 2 | 468 | 16 | 1872 | 1404 | 1 | 351.0 | 390.0 |
| 3 | 16-QAM | 1/2 | 4 | 468 | 16 | 3744 | 1872 | 1 | 468.0 | 520.0 |
| 4 | 16-QAM | 3/4 | 4 | 468 | 16 | 3744 | 2808 | 2 | 702.0 | 780.0 |
| 5 | 64-QAM | 2/3 | 6 | 468 | 16 | 5616 | 3744 | 2 | 936.0 | 1040.0 |
| 6 | 64-QAM | 3/4 | 6 | 468 | 16 | 5616 | 4212 | 2 | 1053.0 | 1170.0 |
| 7 | 64-QAM | 5/6 | 6 | 468 | 16 | 5616 | 4680 | 3 | 1170.0 | 1300.0 |
| 8 | 256-QAM | 3/4 | 8 | 468 | 16 | 7488 | 5616 | 3 | 1404.0 | 1560.0 |
| 9 | 256-QAM | 5/6 | 8 | 468 | 16 | 7488 | 6240 | 3 | 1560.0 | 1733.3 |

Table 22‑51--VHT MCSs for optional 160 MHz, *NSS* = 3

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| MCS Index | Modulation | R | NBPSCS | NSD | NSP | NCBPS | NDBPS | NES | Data rate (Mb/s) | |
| 800ns GI | 400ns GI |
| 0 | BPSK | 1/2 | 1 | 468 | 16 | 1404 | 702 | 1 | 175.5 | 195.0 |
| 1 | QPSK | 1/2 | 2 | 468 | 16 | 2808 | 1404 | 1 | 351.0 | 390.0 |
| 2 | QPSK | 3/4 | 2 | 468 | 16 | 2808 | 2106 | 1 | 526.5 | 585.0 |
| 3 | 16-QAM | 1/2 | 4 | 468 | 16 | 5616 | 2808 | 2 | 702.0 | 780.0 |
| 4 | 16-QAM | 3/4 | 4 | 468 | 16 | 5616 | 4212 | 2 | 1053.0 | 1170.0 |
| 5 | 64-QAM | 2/3 | 6 | 468 | 16 | 8424 | 5616 | 3 | 1404.0 | 1560.0 |
| 6 | 64-QAM | 3/4 | 6 | 468 | 16 | 8424 | 6318 | 3 | 1579.5 | 1755.0 |
| 7 | 64-QAM | 5/6 | 6 | 468 | 16 | 8424 | 7020 | 4 | 1755.0 | 1950.0 |
| 8 | 256-QAM | 3/4 | 8 | 468 | 16 | 11232 | 8424 | 4 | 2106.0 | 2340.0 |
| 9 |  |  |  |  |  |  |  |  |  |  |
| NOTE: MCS 9 invalid due for BCC due to mod(NCBPS/NES, DR) not being equal to 0. | | | | | | | | | | |

Table 22‑52--VHT MCSs for optional 160 MHz, *NSS* = 4

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| MCS Index | Modulation | R | NBPSCS | NSD | NSP | NCBPS | NDBPS | NES | Data rate (Mb/s) | |
| 800ns GI | 400ns GI |
| 0 | BPSK | 1/2 | 1 | 468 | 16 | 1872 | 936 | 1 | 234.0 | 260.0 |
| 1 | QPSK | 1/2 | 2 | 468 | 16 | 3744 | 1872 | 1 | 468.0 | 520.0 |
| 2 | QPSK | 3/4 | 2 | 468 | 16 | 3744 | 2808 | 2 | 702.0 | 780.0 |
| 3 | 16-QAM | 1/2 | 4 | 468 | 16 | 7488 | 3744 | 2 | 936.0 | 1040.0 |
| 4 | 16-QAM | 3/4 | 4 | 468 | 16 | 7488 | 5616 | 3 | 1404.0 | 1560.0 |
| 5 | 64-QAM | 2/3 | 6 | 468 | 16 | 11232 | 7488 | 4 | 1872.0 | 2080.0 |
| 6 | 64-QAM | 3/4 | 6 | 468 | 16 | 11232 | 8424 | 4 | 2106.0 | 2340.0 |
| 7 |  |  |  |  |  |  |  |  |  |  |
| 8 | 256-QAM | 3/4 | 8 | 468 | 16 | 14976 | 11232 | 6 | 2808.0 | 3120.0 |
| 9 | 256-QAM | 5/6 | 8 | 468 | 16 | 14976 | 12480 | 6 | 3120.0 | 3466.7 |
| NOTE: MCS 7 is invalid for BCC due to mod(NCBPS/NES, DR) not being equal to 0. | | | | | | | | | | |

Table 22‑53--VHT MCSs for optional 160 MHz, *NSS* = 5

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| MCS Index | Modulation | R | NBPSCS | NSD | NSP | NCBPS | NDBPS | NES | Data rate (Mb/s) | |
| 800ns GI | 400ns GI |
| 0 | BPSK | 1/2 | 1 | 468 | 16 | 2340 | 1170 | 1 | 292.5 | 325.0 |
| 1 | QPSK | 1/2 | 2 | 468 | 16 | 4680 | 2340 | 2 | 585.0 | 650.0 |
| 2 | QPSK | 3/4 | 2 | 468 | 16 | 4680 | 3510 | 2 | 877.5 | 975.0 |
| 3 | 16-QAM | 1/2 | 4 | 468 | 16 | 9360 | 4680 | 3 | 1170.0 | 1300.0 |
| 4 | 16-QAM | 3/4 | 4 | 468 | 16 | 9360 | 7020 | 4 | 1755.0 | 1950.0 |
| 5 | 64-QAM | 2/3 | 6 | 468 | 16 | 14040 | 9360 | 5 | 2340.0 | 2600.0 |
| 6 | 64-QAM | 3/4 | 6 | 468 | 16 | 14040 | 10530 | 5 | 2632.5 | 2925.0 |
| 7 | 64-QAM | 5/6 | 6 | 468 | 16 | 14040 | 11700 | 6 | 2925.0 | 3250.0 |
| 8 |  |  |  |  |  |  |  |  |  |  |
| 9 | 256-QAM | 5/6 | 8 | 468 | 16 | 18720 | 15600 | 8 | 3900.0 | 4333.3 |
| NOTE: MCS 8 is invalid for BCC due to mod(NCBPS/NES, DR) not being equal to 0. | | | | | | | | | | |

Table 22‑54--VHT MCSs for optional 160 MHz, *NSS* = 6

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| MCS Index | Modulation | R | NBPSCS | NSD | NSP | NCBPS | NDBPS | NES | Data rate (Mb/s) | |
| 800ns GI | 400ns GI |
| 0 | BPSK | 1/2 | 1 | 468 | 16 | 2808 | 1404 | 1 | 351.0 | 390.0 |
| 1 | QPSK | 1/2 | 2 | 468 | 16 | 5616 | 2808 | 2 | 702.0 | 780.0 |
| 2 | QPSK | 3/4 | 2 | 468 | 16 | 5616 | 4212 | 2 | 1053.0 | 1170.0 |
| 3 | 16-QAM | 1/2 | 4 | 468 | 16 | 11232 | 5616 | 3 | 1404.0 | 1560.0 |
| 4 | 16-QAM | 3/4 | 4 | 468 | 16 | 11232 | 8424 | 4 | 2106.0 | 2340.0 |
| 5 | 64-QAM | 2/3 | 6 | 468 | 16 | 16848 | 11232 | 6 | 2808.0 | 3120.0 |
| 6 | 64-QAM | 3/4 | 6 | 468 | 16 | 16848 | 12636 | 6 | 3159.0 | 3510.0 |
| 7 |  |  |  |  |  |  |  |  |  |  |
| 8 | 256-QAM | 3/4 | 8 | 468 | 16 | 22464 | 16848 | 8 | 4212.0 | 4680.0 |
| 9 | 256-QAM | 5/6 | 8 | 468 | 16 | 22464 | 18720 | 9 | 4680.0 | 5200.0 |
| NOTE: MCS 7 is invalid for BCC due to mod(NCBPS/NES, DR) not being equal to 0. | | | | | | | | | | |

Table 22‑55--VHT MCSs for optional 160 MHz, *NSS* = 7

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| MCS Index | Modulation | R | NBPSCS | NSD | NSP | NCBPS | NDBPS | NES | Data rate (Mb/s) | |
| 800ns GI | 400ns GI |
| 0 | BPSK | 1/2 | 1 | 468 | 16 | 3276 | 1638 | 1 | 409.5 | 455.0 |
| 1 | QPSK | 1/2 | 2 | 468 | 16 | 6552 | 3276 | 2 | 819.0 | 910.0 |
| 2 | QPSK | 3/4 | 2 | 468 | 16 | 6552 | 4914 | 3 | 1228.5 | 1365.0 |
| 3 | 16-QAM | 1/2 | 4 | 468 | 16 | 13104 | 6552 | 4 | 1638.0 | 1820.0 |
| 4 |  |  |  |  |  |  |  |  |  |  |
| 5 | 64-QAM | 2/3 | 6 | 468 | 16 | 19656 | 13104 | 7 | 3276.0 | 3640.0 |
| 6 | 64-QAM | 3/4 | 6 | 468 | 16 | 19656 | 14742 | 7 | 3685.5 | 4095.0 |
| 7 |  |  |  |  |  |  |  |  |  |  |
| 8 |  |  |  |  |  |  |  |  |  |  |
| 9 |  |  |  |  |  |  |  |  |  |  |
| NOTE: MCS 4, 7, 8 and 9 are invalid for BCC due to mod(NCBPS/NES, DR) not being equal to 0. | | | | | | | | | | |

Table 22‑56--VHT MCSs for optional 160 MHz, *NSS* = 8

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| MCS Index | Modulation | R | NBPSCS | NSD | NSP | NCBPS | NDBPS | NES | Data rate (Mb/s) | |
| 800ns GI | 400ns GI |
| 0 | BPSK | 1/2 | 1 | 468 | 16 | 3744 | 1872 | 1 | 468.0 | 520.0 |
| 1 | QPSK | 1/2 | 2 | 468 | 16 | 7488 | 3744 | 2 | 936.0 | 1040.0 |
| 2 | QPSK | 3/4 | 2 | 468 | 16 | 7488 | 5616 | 3 | 1404.0 | 1560.0 |
| 3 | 16-QAM | 1/2 | 4 | 468 | 16 | 14976 | 7488 | 4 | 1872.0 | 2080.0 |
| 4 | 16-QAM | 3/4 | 4 | 468 | 16 | 14976 | 11232 | 6 | NA | 3120.0 |
| 5 |  |  |  |  |  |  |  |  |  |  |
| 6 | 64-QAM | 3/4 | 6 | 468 | 16 | 22464 | 16848 | 8 | 4212.0 | 4680.0 |
| 7 | 64-QAM | 5/6 | 6 | 468 | 16 | 22464 | 18720 | 9 | 4680.0 | 5200.0 |
| 8 |  |  |  |  |  |  |  |  |  |  |
| 9 | 256-QAM | 5/6 | 8 | 468 | 16 | 29952 | 24960 | 12 | 6240.0 | 6933.3 |
| NOTE: MCS 5 and 8 are invalid for BCC due to mod(NCBPS/NES, DR) not being equal to 0. | | | | | | | | | | |

**Annex I**

**I.1 External regulatory references**

***Editor’s note: Modify Table I-2 by insert rows as shown below, change the reserved rows, and insert the note:***

***Editor’s note: The <ANA> flags will be replaced with values assigned by the 802.11 ANA.***

**Table I-2 – Behavior limit sets**

|  |  |  |
| --- | --- | --- |
| **Encoding** | **Behavior limit sets** | **Description** |
| <ANA> | VHT80MHzBehavior | Can be used as the 80 MHz channel for a VHT80 BSS, or as either the primary or secondary 80 MHz frequency segment for an VHT80+80 BSS. |
| <ANA> | VHT160MHzBehavior | Can be used as the 160 MHz channel for a VHT160 BSS. |
| <ANA>-255 | Reserved |  |
| NOTE – The fields that specify the 80 MHz, 160 MHz and 80+80 MHz channels are described in 22.3.15. | | |

**Annex J**

**J.1 Country information and regulatory classes**

***Editor’s note: Modify rows for regulatory classes 4, 24 and 29, insert rows for regulatory classes shown as <ANA>, change the reserved rows as appropriate, and insert the note in Table J-1 as follows (note that the entire table is not shown):***

***Editor’s note: The <ANA> flags will be replaced with values assigned by the 802.11 ANA.***

Table J-1 – Operating classes in the United States

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Operating class** | **Global operating class (see Table J-5 (DSE timer limits))** | **Channel starting frequency (GHz)** | **Channel spacing (MHz)** | **Channel set** | **Channel center frequency index** | **Behavior limits set** |
| 4 | 121 | 5 | 20 | 100, 104, 108, 112, 116, 120, 124, 128, 132, 136, 140, 144 | - | NomadicBehavior,  DynamicFrequencySelectionBehavior,  DFS\_50\_100\_Behavior |
| 24 | 122 | 5 | 40 | 100, 108, 116, 124,  132, 140 | - | NomadicBehavior,  DynamicFrequencySelectionBehavior,  PrimaryChannelLowerBehavior,  DFS\_50\_100\_Behavior |
| 29 | 128 | 5 | 40 | 104, 112, 120, 128,  136, 144 | - | NomadicBehavior,  DynamicFrequencySelectionBehavior,  PrimaryChannelUpperBehavior,  DFS\_50\_100\_Behavior |
|  |  |  |  |  |  |  |
| <ANA> | TBD | 5 | 80 | - | 42 | VHT80MHzBehavior,  NomadicBehavior,  IndoorOnlyBehavior |
| <ANA> | TBD | 5 | 80 | - | 58 | VHT80MHzBehavior,  NomadicBehavior,  DynamicFrequencySelectionBehavior, |
| <ANA> | TBD | 5 | 80 | - | 106, 122, 138 | VHT80MHzBehavior,  NomadicBehavior,  DynamicFrequencySelectionBehavior,  DFS\_50\_100\_Behavior |
| <ANA> | TBD | 5 | 80 | - | 155 | VHT80MHzBehavior,  NomadicBehavior,  IndoorOnlyBehavior,  DynamicFrequencySelectionBehavior |
| <ANA> | TBD | 5 | 160 | - | 50 | VHT160MHzBehavior,  NomadicBehavior,  IndoorOnlyBehavior,  DynamicFrequencySelectionBehavior |
| <ANA> | TBD | 5 | 160 | - | 114 | VHT160MHzBehavior,  NomadicBehavior,  IndoorOnlyBehavior,  DynamicFrequencySelectionBehavior,  DFS\_50\_100\_Behavior |
| <ANA>-255 | Reserved | Reserved | Reserved | Reserved |  | Reserved |
| NOTE—The channel spacing for operating classes <ANA> through <ANA> is for the supported bandwidth rather than the operating bandwidth. | | | | | | |

***Editor’s note: Modify Insert rows for regulatory classes <ANA> through <ANA>, change the reserved rows, and insert the note in Table J-2 as follows (note that the entire table is not shown):***

Table J-2 – Operating classes in Europe

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Operating class** | **Global operating class (see Table J.4)** | **Channel starting frequency (GHz)** | **Channel spacing (MHz)** | **Channel set** | **Channel center frequency index** | **Behavior limits set** |
| <ANA> | TBD | 5 | 80 | - | 42 | VHT80MHzBehavior,  IndoorOnlyBehavior, TransmitPowerControlBehavior |
| <ANA> | TBD | 5 | 80 | - | 58, 106, 122 | VHT80MHzBehavior, NomadicBehavior, TransmitPowerControlBehavior, DynamicFrequencySelectionBehavior |
| <ANA> | TBD | 5 | 160 | - | 50 | VHT160MHzBehavior, IndoorOnlyBehavior, NomadicBehavior, TransmitPowerControlBehavior, DynamicFrequencySelectionBehavior |
| <ANA> | TBD | 5 | 160 | - | 50 | VHT160MHzBehavior, NomadicBehavior, TransmitPowerControlBehavior, DynamicFrequencySelectionBehavior |
| <ANA>-255 | Reserved | Reserved | Reserved | Reserved |  | Reserved |
| NOTE—The channel spacing for operating classes <ANA> through <ANA> is for the supported bandwidth rather than the operating bandwidth. | | | | | | |

***Editor’s note: Modify Insert rows for regulatory classes <ANA> through <ANA>, change the reserved rows, and insert the note in Table J-3 as follows (note that the entire table is not shown):***

Table J-3 – Operating classes in Japan

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Operating class** | **Global operating class (see Table J.4)** | **Channel starting frequency (GHz)** | **Channel spacing (MHz)** | **Channel set** | **Channel center frequency index** | **Behavior limits set** | |
| <ANA> | TBD | 5 | 80 | - | 42 | VHT80MHzBehavior, IndoorsOnlyBehavior, CS4msBehavior | |
| <ANA> | TBD | 5 | 80 | - | 58 | VHT80MHzBehavior, IndoorsOnlyBehavior, TransmitPowerControlBehavior, DynamicFrequencySelectionBehavior, IBSSRestrictionsBehavior, CS4msBehavior | |
| <ANA> | TBD | 5 | 80 | - | 58 | VHT80MHzBehavior, IndoorsOnlyBehavior, DynamicFrequencySelectionBehavior, IBSSRestrictionsBehavior, CS4msBehavior | |
| <ANA> | TBD | 5 | 80 | - | 106, 122 | VHT80MHzBehavior, TransmitPowerControlBehavior, DynamicFrequencySelectionBehavior, IBSSRestrictionsBehavior, CS4msBehavior, DFS\_50\_100\_Behavior | |
| <ANA> | TBD | 5 | 80 | - | 106, 122 | VHT80MHzBehavior, DynamicFrequencySelectionBehavior, IBSSRestrictionsBehavior, CS4msBehavior, DFS\_50\_100\_Behavior | |
| <ANA> | TBD | 5 | 160 | - | 50 | VHT160MHzBehavior IndoorsOnlyBehavior, TransmitPowerControlBehavior, DynamicFrequencySelectionBehavior, IBSSRestrictionsBehavior, CS4msBehavior | |
| <ANA> | TBD | 5 | 160 | - | 50 | VHT160MHzBehavior IndoorsOnlyBehavior, DynamicFrequencySelectionBehavior, IBSSRestrictionsBehavior, CS4msBehavior | |
| <ANA> | TBD | 5 | 160 | - | 114 | VHT160MHzBehavior TransmitPowerControlBehavior, DynamicFrequencySelectionBehavior, IBSSRestrictionsBehavior, CS4msBehavior | |
| <ANA> | TBD | 5 | 160 | - | 114 | VHT160MHzBehavior TransmitPowerControlBehavior, DynamicFrequencySelectionBehavior, IBSSRestrictionsBehavior, CS4msBehavior | |
| <ANA>-255 | Reserved | Reserved | Reserved | Reserved |  | Reserved | |
| NOTE—The channel spacing for operating classes <ANA> through <ANA> is for the supported bandwidth rather than the operating bandwidth. | | | | | | |

***Editor’s note: Modify Insert rows for regulatory classes <ANA> through <ANA> and change the reserved rows in Table J-4 as follows (note that the entire table is not shown):***

Table J-4 – Global Operating classes

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Operating class** | **Global operating class (see Table J.4)** | **Channel starting frequency (GHz)** | **Channel spacing (MHz)** | **Channel set** | **Channel center frequency index** | **Behavior limits set** |
| <ANA> | TBD | 5 | 80 | - | 42 | VHT80MHzBehavior, IndoorOnlyBehavior |
| <ANA> | TBD | 5 | 80 | - | 58, 106, 122 | VHT80MHzBehavior, TransmitPowerControlBehavior, DynamicFrequencySelectionBehavior, DFS\_50\_100\_Behavior |
| <ANA> | TBD | 5 | 160 | - | 50 | VHT160MHzBehavior, IndoorOnlyBehavior, TransmitPowerControlBehavior, DynamicFrequencySelectionBehavior, DFS\_50\_100\_Behavior |
| <ANA> | TBD | 5 | 160 | - | 114 | VHT160MHzBehavior, TransmitPowerControlBehavior, DynamicFrequencySelectionBehavior, DFS\_50\_100\_Behavior |
| <ANA>-191 | Reserved | Reserved | Reserved | Reserved |  | Reserved |