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Wireless LANs

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 9
1.1 Revision History 9
1.2 Notation 9
1.3 Baseline document 9
2 Normative references 9
3 Definitions, acronyms and abbreviations 9
3.1 Definitions 9
3.2 Definitions specific to IEEE 802.11 10
3.3 Abbreviations and acronyms 10
7 Frame formats 12
7.1 MAC frame formats 12
7.1.1 Conventions 12
7.1.2 General frame format 12
7.1.3 Frame fields 12
7.1.4 Duration/ID field 14
7.2 Format of individual frame types 14
7.2.1 Control frames 14
7.3 Management frame body components 15
7.3.1 Fields that are not information elements 15
7.3.2 Information elements 24
7.4 Action frame format details 26
7.4.1 26
7.4.2 26
7.4.3 DLS Action frame details 26
7.4.4 27
7.4.5 27
7.4.6 27
7.4.7 27
7.4.8 27
7.4.9 27
7.4.10 27
7.4.11 TDLS Action frame details 27
7.4.12 VHT Action frame details 27
7.4a Aggregate MPDU (A-MPDU) 29
7.4a.1 A-MPDU format 29

7.4a.3 A-MPDU contents 30
9 MAC sublayer functional description 33
9.2 DCF 33
9.2.0a General 33
9.2.0b Procedures common to both DCF and EDCAF 33
9.6 Multirate support 34
9.7d A-MPDU operation 34
9.7d.1 A-MPDU contents 34
9.7d.2 A-MPDU length limit rules 34
9.7d.3 Minimum MPDU Start Spacing field 34
9.7d.4 A-MPDU aggregation of group addressed data frames 34
9.7d.5 Transport of A-MPDU by the PHY data service 34
9.7d.6 A-MPDU padding for VHT format PPDU 34
9.7d.7 Transport of VHT single MPDUs 35
9.7x Partial AID in VHT PPDUs 35
9.9 HCF 36
9.9.1 HCF contention-based channel access (EDCA) 36
9.21 Null data packet (NDP) sounding 38
9.21.1 38
9.21.2 38
9.21.3 38
9.21.4 38
9.21.5 VHT sounding protocol 38
10 Layer Management 40
10.1 Overview of management model 40
10.2 Generic management primitives 40
10.3 MLME SAP interface 40
10.4 PLME SAP interface 40
10.4.1 40
10.4.2 40
10.4.3 40
10.4.4 40
10.4.5 40
10.4.6 40
10.4.7 PLME-TXTIME.confirm 40
11 MLME 41
11.2 Power management 41
11.2.1 Power management in an infrastructure network 41
11.20 VHT BSS operation 42

11.20.1 AID assignment by VHT AP 42
11.20.2 Rules for operation in a VHT BSS 42
11.20.3 Basic VHT BSS functionality....42
11.20.4 STA CCA sensing in a VHT BSS 42
12 PHY service specification 44
12.3 Detailed PHY service specifications 44
12.3.1....44
12.3.2....44
12.3.3....44
12.3.4....44
12.3.5 PHY-SAP detailed service specification 44
17 Orthogonal frequency division multiplexing (OFDM) PHY specification 46
17.2 OFDM PHY specific service parameter list....46
17.2.1....46
17.2.2 TXVECTOR parameters 46
17.2.3 RXVECTOR parameters....46
17.3 OFDM PLCP sublayer 47
17.3.1 Introduction 47
17.3.2 PLCP frame format....47
17.3.3....47
17.3.4....47
17.3.5....47
18....48
19....48
22 Very High Throughput (VHT) PHY specification....49
22.1 Introduction 49
22.1.1 Introduction to the VHT PHY 49
22.1.2 Scope 49
22.1.3 VHT PHY functions....49
22.1.4 PPDU formats....49
22.2 VHT PHY service interface....49
22.2.1 Introduction 49
22.2.2 TXVECTOR and RXVECTOR parameters....50
22.2.3 Effects of CH_BANDWIDTH, CH_OFFSET, MCS and NUM_STREAMS parameters on PPDU format 56
22.2.4 Support for NON_HT formats....57
22.2.5 Support for HT formats 57
22.3 VHT PLCP sublayer....57
22.3.1 Introduction 57

22.3.2 VHT PPDU format ... 57
22.3.3 Transmitter block diagram ... 58
22.3.4 Overview of the PPDU encoding process ... 61
22.3.5 Modulation and coding scheme (MCS) ... 61
22.3.6 Timing-related parameters ... 62
22.3.7 Mathematical description of signals ... 64
22.3.8 Transmission of PPDU with bandwidth less than the BSS bandwidth ... 67
22.3.9 VHT preamble ... 67
22.3.10 Transmission of NON_HT format PPDUs with more than one antenna ... 83
22.3.11 Data field ... 83
22.3.12 Beamforming and MU-MIMO ... 96
22.3.13 VHT preamble format for sounding PPDUs ... 97
22.3.14 Regulatory requirements ... 97
22.3.15 Channel numbering and channelization ... 97
22.3.16 Transmit and receive in-band and out-of-band spurious transmissions ... 99
22.3.17 Transmit RF delay ... 99
22.3.18 Slot time ... 99
22.3.19 Transmit and receive port impedance ... 99
22.3.20 PMD transmit specification ... 99
22.3.21 VHT PMD receiver specification ... 105
22.3.22 PLCP transmit procedure ... 109
22.3.23 PLCP receive procedure ... 111
22.4 VHT PLME ... 116
22.4.1 PLME_SAP sublayer management primitives ... 116
22.4.2 PHY MIB ... 116
22.4.3 TXTIME and PSDU_LENGTH calculation ... 116
22.4.4 PHY characteristics ... 117
22.5 VHT PMD sublayer ... 118
22.6 Parameters for VHT MCSs ... 118

1 Preface

1.1 Revision History

Revision	Date	Comments
r0	11/10/2010	First draft

1.2 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.

1.3 Baseline document

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

2 Normative references

3 Definitions, acronyms and abbreviations

3.1 Definitions

Change the following definitions:

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 channel to receive the transmission.

non-high-throughput (non-HT) duplicate frame: A frame transmitted in a non-HT duplicate physical layer convergence procedure (PLCP) protocol data unit (PPDU).

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 or NON_HT_CBW80 or NON_HT_CBW160.

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 with a single transmitting STA and multiple receiving 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.

3.2 Definitions specific to IEEE 802.11

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 which 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 which 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 which 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 which 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, which 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.

primary segment: the frequency segment that includes the primary 20 MHz channel

secondary segment: the frequency segment that does not include the primary 20 MHz channel

3.3 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

7 Frame formats

7.1 MAC frame formats

7.1.1 Conventions

7.1.2 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 11,414 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 7-1--MAC frame format

NOTE--the maximum A-MSDU size (11,414 octets) is arrived at by subtracting the length of the longest QoS Data frame MAC header 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.

7.1.3 Frame fields

7.1.3.1 Frame Control field

7.1.3.2 Duration/ID field

7.1.3.3 Address fields

7.1.3.3.7 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 duplicate format and set to zero otherwise.

7.1.3.4 Sequence Control field

7.1.3.5 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 [TBD] 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, <u>if the HT/VHT subfield is set to the value 0,</u> this subfield contains recommended MFB <u>expressed as an HT MCS</u>, <u>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 N_{STS}</u>. A value of 127 indicates that no feedback is present.

7.1.3.5.1 TID subfield

7.1.3.5.2 EOSP (end of service period) subfield

7.1.3.5.3 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~~ <u>When not carried in an A-MPDU subframe or carried in an A-MPDU subframe with EOF set to 1</u>: 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~~ <u>When carried in</u> an A-MPDU <u>subframe with EOF set to 0</u>:

		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).

7.1.4 Duration/ID field

7.2 Format of individual frame types

7.2.1 Control frames

7.2.1.1 RTS frame format

Change the third paragraph as follows:

The TA field is the address of the STA transmitting the RTS frame. For non-VHT STAs, the Individual/Group bit in the TA field is set to 0. For VHT STAs, the Individual/Group bit in the TA field is set to 1 to indicate that the frame carries a BW indication as defined in section 17.3.2.1 and set to 0 otherwise.

7.2.1.2 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. When the CTS is the first frame in a frame exchange, the RA field is set to the MAC address of the transmitter. For VHT STAs, a CTS frame contains one more field: the two-bit bandwidth indication field, which is carried in the scrambling sequence (section 17.3.2.1).

Insert sections 7.2.1.11 and 7.2.1.12:

7.2.1.11 NDPA

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

Frame Control	Duration	RA	TA	Sounding Sequence	STA Info	FCS
Octets: 2	2	6	6	1	Variable	4

Figure 7-16e—NDPA

The Duration field is set to TBD
The RA field is set as described in 9.21.x
The TA field is the address of the STA transmitting the NDPA
The Sounding Sequence field indicates a sequence number associated to the current sounding sequence
The STA Info field includes a list of STAs IDs (TBD), according to the protocol described in 9.21.5 and may include other information TBD
The NDPA frame may include additional fields TBD

7.2.1.12 Sounding Poll

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

	Frame Control	Duration	RA	TA	FCS
Octets:	2	2	6	6	4

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

7.3 Management frame body components

7.3.1 Fields that are not information elements

7.3.1.11 Action field

Add the following row to Table 7-24:

Table 7-24— Category values

Code	Meaning	See subclause	Robust
TBD	VHT	7.4.11	TBD

Insert section 7.3.1.60:

7.3.1.60 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-B24
Nc Index	Nr Index	Channel Width	Grouping (Ng)	Codebook Information	MU-type	Reserved	Sounding Sequence

Figure 7-2--VHT MIMO Control field

The subfields of the VHT MIMO Control field are defined in Table 7-1.

Table 7-1--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 Nc=1 Set to 1 for Nc=2 … Set to 7 for Nc=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 (Ng)	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
MU-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 7.3.1.62) 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 MU-type is set to 0 (SU-BF) Set to 0 for 2 bit for ψ, 4 bits for ϕ Set to 1 for 4 bit for ψ, 6 bits for ϕ If MU-type is set to 1 (MU-BF) Set to 0 for 5 bit for ψ, 7 bits for ϕ Set to 1 for 7 bit for ψ, 9 bits for ϕ
Sounding Sequence	Sequence number from the NDPA soliciting feedback

Insert section 7.3.1.61:

7.3.1.61 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 Compressed Beamforming Report field depends on the values in the MIMO Control field.

The Compressed Beamforming Report field contains the channel matrix elements indexed, first, by matrix angles in the order shown in Table 7-2 to Table 7-6 (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 7-2--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	ϕ11, ψ21
2x2	2	ϕ11, ψ21
3x1	4	ϕ11, ϕ21, ψ21, ψ31,
3x2	6	ϕ11, ϕ21, ψ21, ψ31, ϕ22, ψ32
3x3	6	ϕ11, ϕ21, ψ21, ψ31, ϕ22, ψ32

4x1	6	ϕ11, ϕ21, ϕ31, ψ21, ψ31, ψ41
4x2	10	ϕ11, ϕ21, ϕ31, ψ21, ψ31, ψ41, ϕ22, ϕ32, ψ32, ψ42
4x3	12	ϕ11, ϕ21, ϕ31, ψ21, ψ31, ψ41, ϕ22, ϕ32, ψ32, ψ42, ϕ33, ψ43
4x4	12	ϕ11, ϕ21, ϕ31, ψ21, ψ31, ψ41, ϕ22, ϕ32, ψ32, ψ42, ϕ33, ψ43

Table 7-3-- 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	ϕ11, ϕ21, ϕ31, ϕ41, ψ21, ψ31, ψ41, ψ51
5×2	14	ϕ11, ϕ21, ϕ31, ϕ41, ψ21, ψ31, ψ41, ψ51, ϕ22, ϕ32, ϕ42, ψ32, ψ42, ψ52
5×3	18	ϕ11, ϕ21, ϕ31, ϕ41, ψ21, ψ31, ψ41, ψ51, ϕ22, ϕ32, ϕ42, ψ32, ψ42, ψ52, ϕ33, ϕ43, ψ43, ψ53
5×4	20	ϕ11, ϕ21, ϕ31, ϕ41, ψ21, ψ31, ψ41, ψ51, ϕ22, ϕ32, ϕ42, ψ32, ψ42, ψ52, ϕ33, ϕ43, ψ43, ψ53, ϕ44, ψ54
5×5	20	ϕ11, ϕ21, ϕ31, ϕ41, ψ21, ψ31, ψ41, ψ51, ϕ22, ϕ32, ϕ42, ψ32, ψ42, ψ52, ϕ33, ϕ43, ψ43, ψ53, ϕ44, ψ54

Table 7-4-- 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	ϕ11, ϕ21, ϕ31, ϕ41, ϕ51, ψ21, ψ31, ψ41, ψ51, ψ61
6×2	18	ϕ11, ϕ21, ϕ31, ϕ41, ϕ51, ψ21, ψ31, ψ41, ψ51, ψ61, ϕ22, ϕ32, ϕ42, ϕ52, ψ32, ψ42, ψ52, ψ62
6×3	24	ϕ11, ϕ21, ϕ31, ϕ41, ϕ51, ψ21, ψ31, ψ41, ψ51, ψ61, ϕ22, ϕ32, ϕ42, ϕ52, ψ32, ψ42, ψ52, ψ62, ϕ33, ϕ43, ϕ53, ψ43, ψ53, ψ63
6×4	28	ϕ11, ϕ21, ϕ31, ϕ41, ϕ51, ψ21, ψ31, ψ41, ψ51, ψ61, ϕ22, ϕ32, ϕ42, ϕ52, ψ32, ψ42, ψ52, ψ62, ϕ33, ϕ43, ϕ53, ψ43, ψ53, ψ63, ϕ44, ϕ54, ψ54, ψ64
6×5	30	ϕ11, ϕ21, ϕ31, ϕ41, ϕ51, ψ21, ψ31, ψ41, ψ51, ψ61, ϕ22, ϕ32, ϕ42, ϕ52, ψ32, ψ42, ψ52, ψ62, ϕ33, ϕ43, ϕ53, ψ43, ψ53, ψ63, ϕ44, ϕ54, ψ54, ψ64, ϕ55, ψ65
6×6	30	ϕ11, ϕ21, ϕ31, ϕ41, ϕ51, ψ21, ψ31, ψ41, ψ51, ψ61, ϕ22, ϕ32, ϕ42, ϕ52, ψ32, ψ42, ψ52, ψ62, ϕ33, ϕ43, ϕ53, ψ43, ψ53, ψ63, ϕ44, ϕ54, ψ54, ψ64, ϕ55, ψ65

Table 7-5-- 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	ϕ11, ϕ21, ϕ31, ϕ41, ϕ51, ϕ61, ψ21, ψ31, ψ41, ψ51, ψ61, ψ71
7×2	22	ϕ11, ϕ21, ϕ31, ϕ41, ϕ51, ϕ61, ψ21, ψ31, ψ41, ψ51, ψ61, ψ71, ϕ22, ϕ32, ϕ42, ϕ52, ϕ62, ψ32, ψ42, ψ52, ψ62, ψ72
7×3	30	ϕ11, ϕ21, ϕ31, ϕ41, ϕ51, ϕ61, ψ21, ψ31, ψ41, ψ51, ψ61, ψ71, ϕ22, ϕ32, ϕ42, ϕ52, ϕ62, ψ32, ψ42, ψ52, ψ62, ψ72, ϕ33, ϕ43, ϕ53, ϕ63, ψ43, ψ53,

		ψ63, ψ73
7×4	36	ϕ11, ϕ21, ϕ31, ϕ41, ϕ51, ϕ61, ψ21, ψ31, ψ41, ψ51, ψ61, ψ71, ϕ22, ϕ32, ϕ42, ϕ52, ϕ62, ψ32, ψ42, ψ52, ψ62, ψ72, ϕ33, ϕ43, ϕ53, ϕ63, ψ43, ψ53, ψ63, ψ73, ϕ44, ϕ54, ϕ64, ψ54, ψ64, ψ74
7×5	40	ϕ11, ϕ21, ϕ31, ϕ41, ϕ51, ϕ61, ψ21, ψ31, ψ41, ψ51, ψ61, ψ71, ϕ22, ϕ32, ϕ42, ϕ52, ϕ62, ψ32, ψ42, ψ52, ψ62, ψ72, ϕ33, ϕ43, ϕ53, ϕ63, ψ43, ψ53, ψ63, ψ73, ϕ44, ϕ54, ϕ64, ψ54, ψ64, ψ74, ϕ55, ϕ65, ψ65, ψ75
7×6	42	ϕ11, ϕ21, ϕ31, ϕ41, ϕ51, ϕ61, ψ21, ψ31, ψ41, ψ51, ψ61, ψ71, ϕ22, ϕ32, ϕ42, ϕ52, ϕ62, ψ32, ψ42, ψ52, ψ62, ψ72, ϕ33, ϕ43, ϕ53, ϕ63, ψ43, ψ53, ψ63, ψ73, ϕ44, ϕ54, ϕ64, ψ54, ψ64, ψ74, ϕ55, ϕ65, ψ65, ψ75, ϕ66, ψ76
7×7	42	ϕ11, ϕ21, ϕ31, ϕ41, ϕ51, ϕ61, ψ21, ψ31, ψ41, ψ51, ψ61, ψ71, ϕ22, ϕ32, ϕ42, ϕ52, ϕ62, ψ32, ψ42, ψ52, ψ62, ψ72, ϕ33, ϕ43, ϕ53, ϕ63, ψ43, ψ53, ψ63, ψ73, ϕ44, ϕ54, ϕ64, ψ54, ψ64, ψ74, ϕ55, ϕ65, ψ65, ψ75, ϕ66, ψ76

Table 7-6-- 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	ϕ11, ϕ21, ϕ31, ϕ41, ϕ51, ϕ61, ϕ71, ψ21, ψ31, ψ41, ψ51, ψ61, ψ71, ψ81
8×2	26	ϕ11, ϕ21, ϕ31, ϕ41, ϕ51, ϕ61, ϕ71, ψ21, ψ31, ψ41, ψ51, ψ61, ψ71, ψ81, ϕ22, ϕ32, ϕ42, ϕ52, ϕ62, ϕ72, ψ32, ψ42, ψ52, ψ62, ψ72, ψ82
8×3	36	ϕ11, ϕ21, ϕ31, ϕ41, ϕ51, ϕ61, ϕ71, ψ21, ψ31, ψ41, ψ51, ψ61, ψ71, ψ81, ϕ22, ϕ32, ϕ42, ϕ52, ϕ62, ϕ72, ψ32, ψ42, ψ52, ψ62, ψ72, ψ82, ϕ33, ϕ43, ϕ53, φ63, ϕ73, ψ43, ψ53, ψ63, ψ73, ψ83
8×4	44	ϕ11, ϕ21, ϕ31, ϕ41, ϕ51, ϕ61, ϕ71, ψ21, ψ31, ψ41, ψ51, ψ61, ψ71, ψ81, ϕ22, ϕ32, ϕ42, ϕ52, ϕ62, ϕ72, ψ32, ψ42, ψ52, ψ62, ψ72, ψ82, ϕ33, ϕ43, ϕ53, ϕ63, ϕ73, ψ43, ψ53, ψ63, ψ73, ψ83, ϕ44, ϕ54, ϕ64, ϕ74, ψ54, ψ64, ψ74, ψ84
8×5	50	ϕ11, ϕ21, ϕ31, ϕ41, ϕ51, ϕ61, ϕ71, ψ21, ψ31, ψ41, ψ51, ψ61, ψ71, ψ81, ϕ22, ϕ32, ϕ42, ϕ52, ϕ62, ϕ72, ψ32, ψ42, ψ52, ψ62, ψ72, ψ82, ϕ33, ϕ43, ϕ53, ϕ63, ϕ73, ψ43, ψ53, ψ63, ψ73, ψ83, ϕ44, ϕ54, ϕ64, ϕ74, ψ54, ψ64, ψ74, ψ84, ϕ55, ϕ65, ϕ75, ψ65, ψ75, ψ85
8×6	54	ϕ11, ϕ21, ϕ31, ϕ41, ϕ51, ϕ61, ϕ71, ψ21, ψ31, ψ41, ψ51, ψ61, ψ71, ψ81, ϕ22, ϕ32, ϕ42, ϕ52, ϕ62, ϕ72, ψ32, ψ42, ψ52, ψ62, ψ72, ψ82, ϕ33, ϕ43, ϕ53, ϕ63, ϕ73, ψ43, ψ53, ψ63, ψ73, ψ83, ϕ44, ϕ54, ϕ64, ϕ74, ψ54, ψ64, ψ74, ψ84, ϕ55, ϕ65, ϕ75, ψ65, ψ75, ψ85, ϕ66, ϕ76, ψ76, ψ86
8×7	56	ϕ11, ϕ21, ϕ31, ϕ41, ϕ51, ϕ61, ϕ71, ψ21, ψ31, ψ41, ψ51, ψ61, ψ71, ψ81, ϕ22, ϕ32, ϕ42, ϕ52, ϕ62, ϕ72, ψ32, ψ42, ψ52, ψ62, ψ72, ψ82, ϕ33, ϕ43, ϕ53, ϕ63, ϕ73, ψ43, ψ53, ψ63, ψ73, ψ83, ϕ44, ϕ54, ϕ64, ϕ74, ψ54, ψ64, ψ74, ψ84, ϕ55, ϕ65, ϕ75, ψ65, ψ75, ψ85, ϕ66, ϕ76, ψ76, ψ86, ϕ77, ψ87
8×8	56	ϕ11, ϕ21, ϕ31, ϕ41, ϕ51, ϕ61, ϕ71, ψ21, ψ31, ψ41, ψ51, ψ61, ψ71, ψ81, ϕ22, ϕ32, ϕ42, ϕ52, ϕ62, ϕ72, ψ32, ψ42, ψ52, ψ62, ψ72, ψ82, ϕ33, ϕ43, ϕ53, ϕ63, ϕ73, ψ43, ψ53, ψ63, ψ73, ψ83, ϕ44, ϕ54, ϕ64, ϕ74, ψ54, ψ64, ψ74, ψ84, ϕ55, ϕ65, ϕ75, ψ65, ψ75, ψ85, ϕ66, ϕ76, ψ76, ψ86, ϕ77, ψ87

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

Table 7-7--Quantization of angles

Quantized ψ	Quantized ϕ
$\psi = \frac{k\pi}{2^{b_\psi+1}} + \frac{\pi}{2^{b_\psi+2}}$ radians where $k = 0,1,\dots,2^{b_\psi-1}$ b_ψ is the number of bits used to quantize ψ (defined by the Codebook Information field of the VHT MIMO Control field (see 7.3.1.60)	$\phi = \frac{k\pi}{2^{b_\phi-1}} + \frac{\pi}{2^{b_\phi}}$ radians where $k = 0,1,\dots,2^{b_\phi-1}$ b_ϕ is the number of bits used to quantize ϕ (defined by the Codebook Information field of the VHT MIMO Control field (see 7.3.1.60)

The Compressed Beamforming Report field for 20 MHz has the structure defined in Table 7-8 (Compressed Beamforming Report field (20 MHz)), where *Na* is the number of angles used for beamforming feedback matrix *V* (see Table 7-2 to Table 7-6).

Table 7-8--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	$Na\times(b_\psi+b_\phi)/2$	Beamforming feedback matrix *V*
Beamforming Feedback Matrix *V* for carrier –28+Ng	$Na\times(b_\psi+b_\phi)/2$	Beamforming feedback matrix *V*
Beamforming Feedback Matrix *V* for carrier –28+2Ng	$Na\times(b_\psi+b_\phi)/2$	Beamforming feedback matrix *V*
...		
Beamforming Feedback Matrix *V* for carrier –1	$Na\times(b_\psi+b_\phi)/2$	Beamforming feedback matrix *V*
Beamforming Feedback Matrix *V* for carrier 1	$Na\times(b_\psi+b_\phi)/2$	Beamforming feedback matrix *V*
Beamforming Feedback Matrix *V* for carrier 2	$Na\times(b_\psi+b_\phi)/2$	Beamforming feedback matrix *V*
Beamforming Feedback Matrix *V* for carrier 2+Ng	$Na\times(b_\psi+b_\phi)/2$	Beamforming feedback matrix *V*
Beamforming Feedback Matrix *V* for carrier 2+2Ng	$Na\times(b_\psi+b_\phi)/2$	Beamforming feedback matrix *V*
...		
Beamforming Feedback Matrix *V* for carrier 28	$Na\times(b_\psi+b_\phi)/2$	Beamforming feedback matrix *V*

The Compressed Beamforming Report field for 40 MHz has the structure defined in Table 7-9 (Compressed Beamforming Report field (40 MHz)), where *Na* is the number of angles used for beamforming feedback matrix *V* (see Table 7-2 to Table 7-6).

Table 7-9--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	$Na\times(b_\psi+b_\phi)/2$	Beamforming feedback matrix *V*
Beamforming Feedback Matrix *V* for carrier –58+Ng	$Na\times(b_\psi+b_\phi)/2$	Beamforming feedback matrix *V*
Beamforming Feedback Matrix *V* for carrier –58+2Ng	$Na\times(b_\psi+b_\phi)/2$	Beamforming feedback matrix *V*
...		
Beamforming Feedback Matrix *V* for carrier –2	$Na\times(b_\psi+b_\phi)/2$	Beamforming feedback matrix *V*
Beamforming Feedback Matrix *V* for carrier 2	$Na\times(b_\psi+b_\phi)/2$	Beamforming feedback matrix *V*
Beamforming Feedback Matrix *V* for carrier 2+Ng	$Na\times(b_\psi+b_\phi)/2$	Beamforming feedback matrix *V*
Beamforming Feedback Matrix *V* for carrier 2+2Ng	$Na\times(b_\psi+b_\phi)/2$	Beamforming feedback matrix *V*
...		
Beamforming Feedback Matrix *V* for carrier 58	$Na\times(b_\psi+b_\phi)/2$	Beamforming feedback matrix *V*

The Compressed Beamforming Report field for 80 MHz has the structure defined in Table 7-10(Compressed Beamforming Report field (80 MHz)), where *Na* is the number of angles used for beamforming feedback matrix *V* (see Table 7-2 to Table 7-6).

Table 7-10--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	$Na\times(b_\psi+b_\phi)/2$	Beamforming feedback matrix *V*
Beamforming Feedback Matrix *V* for carrier –122+Ng	$Na\times(b_\psi+b_\phi)/2$	Beamforming feedback matrix *V*
Beamforming Feedback Matrix *V* for carrier –122+2Ng	$Na\times(b_\psi+b_\phi)/2$	Beamforming feedback matrix *V*
...		
Beamforming Feedback Matrix *V* for carrier –2	$Na\times(b_\psi+b_\phi)/2$	Beamforming feedback matrix *V*
Beamforming Feedback Matrix *V* for carrier 2	$Na\times(b_\psi+b_\phi)/2$	Beamforming feedback matrix *V*
Beamforming Feedback Matrix *V* for carrier 2+Ng	$Na\times(b_\psi+b_\phi)/2$	Beamforming feedback matrix *V*
Beamforming Feedback Matrix *V* for carrier 2+2Ng	$Na\times(b_\psi+b_\phi)/2$	Beamforming feedback matrix *V*
...		

Beamforming Feedback Matrix *V* for carrier 122	$Na\times(b_\psi+b_\phi)/2$	Beamforming feedback matrix *V*

The Compressed Beamforming Report field for non-contiguous 80+80 MHz has the structure defined in Table 7-10 (Compressed Beamforming Report field (80 MHz)) for each frequency segment. For contiguous 160MHz, the Compressed Beamforming Report field has the structure defined in Table 7-10 (Compressed Beamforming Report field (80 MHz)) with tone shifting ±256. *Na* is the number of angles used for beamforming feedback matrix *V* (see Table 7-2 to Table 7-6).

The SNR values in Table 7-8 (Compressed Beamforming Report field (20 MHz)), Table 7-9 (Compressed Beamforming Report field (40 MHz)) and Table 7-10 (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 Compressed Beamforming Report field by reporting a single value for each group of *Ng* adjacent subcarriers. With grouping, the size of the Compressed Beamforming Report field is $Nc\times8+Ns\times(Na\times(b_\psi+b_\phi)/2)$ 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 7.3.1.29). The value of *Ns* and the specific carriers for which matrices are sent is defined in Table 7-11 (Number of subcarriers and tone mapping). If the size of the 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 7-11--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	-58:2:58 (same as 11n)
	4	30	-58:4:58 (same as 11n)
80 MHz	1	234	All subcarriers -122 to 122 except ±103, ±75, ±39, ±11, ±1 and 0.
	2	122	-122:2:122
	4	62	-122:4:122

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 7.3.1.62:

7.3.1.62 MU Exclusive Beamforming Report field

The MU Exclusive Beamforming Report field is used by the VHT Compressed Beamforming frame to carry additional information for MU-type feedback. The MU Exclusive Beamforming Report field shall be included in the feedback report field only if MU-type bit in VHT MIMO Control field is set to 1 (see 7.3.1.29).

The MU Exclusive Beamforming Report field contains the SNR information for each subcarrier, from the lowest frequency subcarrier to the highest frequency subcarrier, as shown in Table 7-12. At each subcarrier, it reports SNR that corresponds to the columns of V, in the order of the first to Nc^{th} column of V, where each SNR is represented by Nd bits (Nd is TBD). The SNR of space-time stream i for each subcarrier k is found by Equation (7-1).

$$SNR_{k,i} = 10\log_{10}\left(\frac{\left\|H_k V_{k,i}\right\|^2}{N}\right) \qquad (7\text{-}1)$$

where $V_{k,i}$ is the i^{th} column of the feedback beamforming matrix at subcarrier k, and N is the noise plus interference power measured at the beamformee. $SNR_{k,i}$ is reported in Per-Tone-SNR subfield in Table 7-2 as the deviation in dB at each tone relative to the fed back average_SNR per space-time-stream,1 to Nc (reported in Compressed Beamforming Report field), from -8 dB to 7 dB with 1 dB granularity. The value of grouping of Per-Tone-SNR (Ng') is two times the value of the grouping of the Compressed V matrix (Ng), i.e. Ng'=2xNg.

Table 7-12—Per-Tone-SNR subfields

Field	Size	Meaning
Delta-SNR for carrier at negative band edge	4 x Nc	The deviation in dB relative to the fed back average_SNR per space-time-stream,1 to Nc, from -8 dB to 7 dB with 1 dB granularity
Delta-SNR for carrier at negative band edge + Ng'	4 x Nc	The deviation in dB relative to the fed back average_SNR per space-time-stream,1 to Nc, from -8 dB to 7 dB with 1 dB granularity
…		
Delta-SNR for carrier at negative band edge + m Ng'	4 x Nc	The deviation in dB relative to the fed back average_SNR per space-time-stream,1 to Nc, from -8 dB to 7 dB with 1 dB granularity
Delta-SNR for carrier at negative DC edge	4 x Nc	The deviation in dB relative to the fed back average_SNR per space-time-stream,1 to Nc, from -8 dB to 7 dB with 1 dB granularity
Delta-SNR for carrier at positive DC edge	4 x Nc	The deviation in dB relative to the fed back average_SNR per space-time-stream,1 to Nc, from

		-8 dB to 7 dB with 1 dB granularity
Delta-SNR for carrier at positive band edge - m Ng’	4 x Nc	The deviation in dB relative to the fed back average_SNR per space-time-stream,1 to Nc, from -8 dB to 7 dB with 1 dB granularity
…		
Delta-SNR for carrier at positive DC edge + Ng’	4 x Nc	The deviation in dB relative to the fed back average_SNR per space-time-stream,1 to Nc, from -8 dB to 7 dB with 1 dB granularity
Delta-SNR for carrier at positive band edge	4 x Nc	The deviation in dB relative to the fed back average_SNR per space-time-stream,1 to Nc, from -8 dB to 7 dB with 1 dB granularity

In Table 7.12, $m = \left\lfloor \frac{\text{positive band edge} - \text{positiveDC edge}}{Ng'} \right\rfloor$ where $\lfloor . \rfloor$ is a function to find the maximum integer that does not exceed the argument.

Insert section 7.3.1.63:

7.3.1.63 Operating Mode field

The Operating Mode field is used in a Notify Operating Mode frame (see 7.4.12.4) to indicate the operating channel width and/or 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 7-3.

B0-B1	B2-B3	B4-B6	B7
Channel Width	Reserved	Rx Nss	Reserved

Figure 7-3--Operating Mode field

If a STA transmitting or receiving this field is operating in a regulatory class that includes a value of TBD in the behavior limits as specified in Annex J, then the values of the Channel Width field are defined in Table 7-13. If a STA transmitting or receiving this field is operating in a regulatory class that does not include a value of TBD in the behavior limits as specified in Annex J, then the Channel Width field is reserved.

Table 7-13--Subfields of the Operating Mode field

Subfield	Description
Channel Width	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
Rx Nss	Indicates the supported number of spatial streams: Set to 0 for Nss=1

	Set to 1 for Nss=2 … Set to 7 for Nss=8

7.3.2 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:

7.3.2.61 VHT Capabilities element

7.3.2.61.1 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 7-4.

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

Figure 7-4--VHT Capabilities element format

7.3.2.61.2 VHT Capabilities Info field

The subfields of the VHT Capabilities Info field are defined in Table 7-14.

Table 7-14--Subfields of the VHT Capabilities Info field

Subfield	Definition	Encoding
Maximum A-MSDU Length	Indicates maximum A-MSDU length. See 9.7c.	Set to 0 for 3839 octets Set to 1 for 7935 octets Set to 2 for 11414 octets 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	Indicates support for	TBD

20/40/80/160	receiving packets using the short guard interval in various bandwidths	
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
Tx MU-MIMO	TBD	TBD
Rx MU-MIMO	TBD	TBD
Tx BF	TBD	TBD

7.3.2.61.3 VHT A-MPDU Parameters field

The structure of the A-MPDU Parameters field of the VHT Capabilities element is shown in Figure 7-5.

B0-B2	B3-B5	B6-B7
Maximum A-MPDU Length Exponent	Minimum MPDU Start Spacing	Reserved

Figure 7-5--VHT A-MPDU Parameters field

The subfields of the A-MPDU Parameters field are defined in Table 7-15.

Table 7-15--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 $2^{(13+\text{Maximum A-MPDU Length Exponent})} - 1$ octets.
Minimum MPDU Start Spacing	Determines the minimum time between the start of adjacent MPDUs within an A-MPDU that the STA can receive, measured at the PHY-SAP. See 9.7d.3.	Set to 0 for no restriction Set to 1 for 1/4 µs Set to 2 for 1/2 µs Set to 3 for 1 µs Set to 4 for 2 µs Set to 5 for 4 µs Set to 6 for 8 µs Set to 7 for 16 µs

Insert section 7.3.2.62:

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 7-6.

	Element ID	Length	VHT Operational Information	Basic MCS Set
Octets:	1	2	TBD	TBD

Figure 7-6--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 7-7.

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

Figure 7-7--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 7-16.

Table 7-16--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. Set to 0 for STA Channel Width of 20, 40, 80 and 160 MHz.

Insert section 7.3.2.63:

7.3.2.63 VHT BSS Load element

The VHT BSS Load element contains additional load information target for MU-MIMO capable STA in VHT BSS. The element information format is defined in Figure 7-8 (VHT BSS Load element format). The element may be used by the STA for vendor-specific AP selection algorithm.

Element ID	Length	TBD
Octets: 1	1	N

Figure 7-8--VHT BSS Load element format

7.4 Action frame format details

7.4.3 DLS Action frame details

7.4.3.1 DLS Setup Request frame format

Change Table 7-51, inserting the row for order 10:

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

7.4.3.2 DLS Setup Response frame format

Change Table 7-52, inserting the row for order 10:

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

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.

7.4.11 TDLS Action frame details

7.4.11.1 TDLS Setup Request frame format

Change Table 7-57v2, appending the row for order 18:

Table 7-52v2—DLS Response frame Action field format

Order	Information	Notes
18	Source Association ID	The Association ID as specified in 7.3.1.8

7.4.11.2 TDLS Setup Response frame format

Change Table 7-57v3, appending the row for order 19:

Table 7-52—DLS Response frame Action field format

Order	Information	Notes
19	Destination Association ID	The Association ID as specified in 7.3.1.8

Insert section 7.4.12:

7.4.12 VHT Action frame details

7.4.12.1 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 7-17.

Table 7-17--VHT Action field values

Value	Meaning
0	VHT Compressed Beamforming
1	Group ID Management
2	Notify Operating Mode

7.4.12.2 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 7-18.

Table 7-18--VHT Conpressed Beamforming frame body

Order	Information

1	Category
2	Action
3	VHT MIMO Control (see 7.3.1.60)
4	VHT Compressed Beamforming Report (see 7.3.1.61)
5	MU Exclusive Beamforming Report (see 7.3.1.62)

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 7-17.

The MU Exclusive Beamforming Report field is only present when the MU-type field in the VHT MIMO Control field is set to 1.

7.4.12.3 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, which 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" which specifies whether or not the STA is a member of the corresponding group ID
- 2 bit STA position which 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.

7.4.12.4 Notify Operating Mode

The Notify Operating Mode frame is used to notify peers STAs that the 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 Notify Operating Mode Action frame body is defined in Table 7-19.

Table 7-19--Notify Operating Mode

Order	Information
1	Category
2	Action
3	Operating Mode (see 7.3.1.63)

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

The Action field is set to the value for Notify Operating Mode, specified in Table 7-17.

Editor's note: the following note should be moved to a more appropriate section.

NOTE--It may take long for a STA to switch its operating mode and during the switching a STA may not be able to receive any frames. If a STA cannot tolerate frame loss during that period, the Power Management subfield in the Frame Control field may be set to 1 to indicate that the STA has entered power save. This is followed by a later frame, following the completion of the mode switch, to indicate that the STA has exited power save.

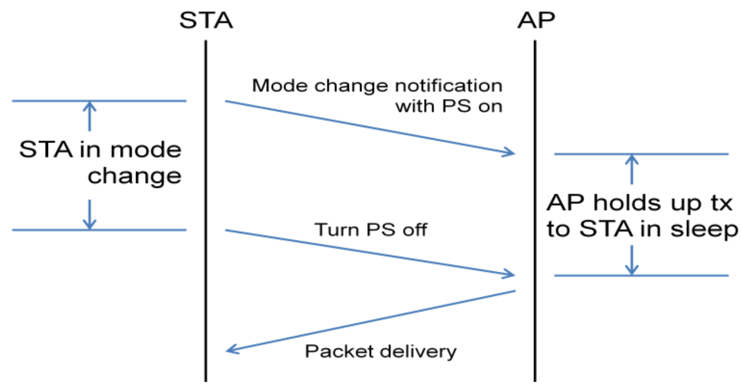

Figure 7-9—Suggested frame exchange to prevent frame loss with operating mode change

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 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).

	MPDU delimiter	MPDU	Pad
Octets:	4	Variable	0–3

Figure 7-101p—A-MPDU subframe format

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 7-10**. 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 7-10--MPDU Length field

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 A-MPDU Contexts. Ordering of MPDUs within an A-MPDU is not constrained, except where noted in these tables. See 9.7d.1 (A-MPDU contents).

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.

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:

Table 7-57x—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	Table 7-57ab1--A-MPDU contents MPDUs in
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

9 MAC sublayer functional description

9.2 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.7 CTS procedure

Insert the following as the first two paragraph of this section:

A VHT STA transmitting a RTS frame carried in a non-HT duplicate format packet and addressed to a VHT STA shall set the bandwidth indication bits in the RTS frame to indicate the channel width occupied by the frame and shall set the Individual/Group bit in the TA field to 1. If the VHT STA originating the RTS frame is using dynamic bandwidth operation, it shall set the dynamic bandwidth operation bit to one. Otherwise, the STA shall set the dynamic bandwidth operation bit to zero.

The RTS frame shall be transmitted by the VHT STA using non-HT duplicate format over all 20MHz channels indicated in the channel bandwidth indication field of the RTS frame.

Change the remainder of the section 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 a VHT STA receives a RTS frame with the Individual/Group bit in the TA field set to1, it shall process the TBD parameter in RXVECTOR to obtain the dynamic bandwidth operation field and the channel bandwidth indication field. If the dynamic bandwidth operation field in a RTS frame is set to 0, a VHT STA that is addressed by the RTS frame shall not respond if PHY-CCA.indication primitive shows that at least one secondary channel lies within the bandwidth indicated in the RTS frame has been detected busy during an interval of PIFS before the RTS frame is received. If the dynamic bandwidth operation field in a RTS frame is set to 1, a VHT STA that is addressed by the RTS frame shall respond a CTS frame over the primary channel and may respond a CTS frame over the secondary channels that have been indicated in 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, 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 CTS frame that contains the bandwidth indication field shall be transmitted by the VHT STA using non-HT duplicate format over all 20MHz channels indicated in the bandwidth indication field of the CTS frame.

9.6 Multirate support

9.6.0e.6 Channel Width selection for control frames

Change section 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_CBW20 or NON_HT_CBW40
NON_HT_CBW80	HT_CBW80 or NON_HT_CBW20 or NON_HT_CBW40 or NON_HT_CBW80
NON_HT_CBW160	HT_CBW160 or NON_HT_CBW20 or NON_HT_CBW40 or NON_HT_CBW80 or NON_HT_CBW160

For a VHT STA, a non-HT duplicate CTS frame transmitted in response to a non-HT duplicate RTS frame may use a channel bandwidth that is narrower than what was indicated in the RTS frame (section 9.2.0b.7). All other control response frames shall use the same bandwidth as the preceding PPDU.

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.

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

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

The A-MPDU delivered to the PHY (using PHY-DATA.request primitives) as the PSDU for a VHT format PPDU shall fill the available whole octets remaining in the data symbols of the PPDU after subtracting the space needed to accommodate the SERVICE field and tail bits (if present). To achieve this, the following procedure is used. 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 (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 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 Partial AID parameter is set to 0.

In a VHT PPDU that carries MPDUs addressed to a single STA, the Partial AID parameter is set to the low order 9 bits of the AID assigned to that STA. In the case that the STA is the AP, the Partial AID parameter is set to a special value(s) that is/are TBD.

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.

9.9 HCF

9.9.1 HCF contention-based channel access (EDCA)

9.9.1.1 Reference implementation

9.9.1.2 EDCA TXOPs

Change the first paragraph 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 STA has obtained the right to access to the medium and decided to share the TXOP with other ACs (secondary ACs) in the same AP STA. 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.

Insert section 9.9.1.2a

9.9.1.2a Sharing an EDCA TXOP

This mode only applies to an AP STA when it 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. In this case, up to four STAs can be selected as destinations and each data frame can be carried by up to four spatial streams (i.e. a stream set). 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. The secondary destinations are necessarily different from each other and from the primary destination. 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 transmitted first. The decision of which secondary AC, primary destination and secondary destination shall be 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 determined by the TXOP limit of the primary AC. In addition, at least one stream set in each DL MU-MIMO PPDU shall contain only MSDU(s) corresponding to the primary AC.

NOTE—A stream set is a group of spatial streams of a DL MU-MIMO PPDU that are all intended for reception by a single recipient.

9.9.1.3 Obtaining an EDCA TXOP

9.9.1.4 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 to a secondary destination as part of a MU-MIMO transmission. 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/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 first 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, traffic from secondary ACs may be piggy-backed on MU-MIMO transmissions carying traffic from the primary AC.

9.9.1.5 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 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 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 ~~the initial frame~~ one or more MPDUs in the initial PPDU or MU PPDU of a TXOP of that AC fails,

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.

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 PPDU by the TXOP holder fails.

9.21 Null data packet (NDP) sounding

Insert section 9.21.5 as shown below:

9.21.5 VHT sounding protocol

Transmit Beamforming and DL MU-MIMO both require feedback to compute the beamformer steering matrix. The device requesting the feedback response and computing the steering matrix is called the “beamformer” and the device providing the feedback response is called the “beamformee”. Explicit feedback mechanism is used to provide the feedback where the beamformee directly estimates the channel from the training symbols sent by the beamformee and feeds back estimated channel to the beamformer. The beamformer then uses the feedback to determine the transmit vectors.

The beamformer and beamformee shall advertise support for the VHT sounding protocol in its VHT Capabilities element carried in the Beacon, Probe Request, Probe Response, Association Request, Association Response, Action and Action No Ack frames.

The general sounding and feedback protocol is shown in Figure 9.37b

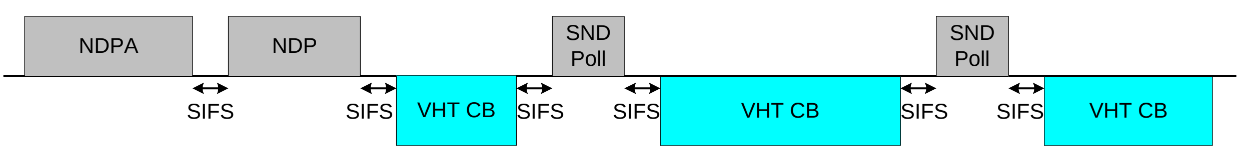

Figure 9.37b

The sounding feedback sequence starts with the beamformer sending an NDPA frame followed by an NDP after SIFS. The NDPA identifies the first beamformee whose response shall follow SIFS after the NDP and may identify other beamformees which will be polled subsequently. The beamformee identified as the first beamformee by the NDPA shall send the VHT Compressed Beamforming frame (VHT-CB) SIFS time after the NDP. The beamformee identified by a Sounding Poll frame (SND Poll) shall send the VHT Compressed Beamforming frame SIFS time after the Sounding Poll frame.

Sounding feedback sequence for the case a single beamformee is requested to send feedback is shown in Figure 9.37c

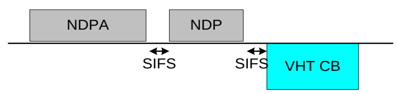

Figure 9.37c

The sounding feedback sequence in this case starts with the beamformer sending an NDPA frame with unicast MAC address and only one beamformee identified in the in the Multi STA Info field. This is followed by the NDP packet sent SIFS after the NDPA frame. The beamformee identified in the NDPA then sends the VHT Compressed Beamforming frame SIFS time after the NDP.

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 may use the information to compute the delay in receiving the feedback. If this delay is greater than the channel coherence time, the beamformer may discard the response

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 address of the beamformee when sounding feedback is requested from one beamformee.

The RA field in the NDPA frame shall be set to the broadcast address when more than one beamformee is supposed to compute the sounding feedback.
The first beamformee in the Multi STA info shall respond within SIFS on receiving the NDP packet.
Beamformees other than the first one may be polled later.
Beamformees not included in the Multi STA info field may ignore the NDP.

When allowed by rules in section 9.9.1.4 (Multiple frame transmission in an EDCA TXOP), the AP shall request the sounding feedback referred to an NDP from all the beamformees listed in the Multi STA info field, within the same 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 SIFS separation. It also defines the recovery procedure in case of a missing response to NDPA or Sounding Poll

10 Layer Management

10.1 Overview of management model

10.2 Generic management primitives

10.3 MLME SAP interface

10.4 PLME SAP interface

10.4.7 PLME-TXTIME.confirm

Change section 10.4.7 as follows:

10.4.7.1 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.

10.4.7.2 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.

10.4.7.3 When generated

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

10.4.7.4 Effect of receipt

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

11 MLME

11.2 Power management

11.2.1 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 MU-MIMO transmissions

The power management scheme described in this section is applicable only when VHT AP allows TXOP power save mode (see section 11.2.1.4b) at non-AP VHT STAs. A VHT AP that obtains TXOP for MU-MIMO transmissions shall indicate non-AP VHT STAs at the beginning of TXOP whether or not they are allowed to enter Doze state.

Editor's note: Exact frame and bit that is used by VHT AP for this is TBD.

If non-AP VHT STAs are allowed to enter Doze state during a TXOP, then the non-AP VHT STA that is in TXOP power save mode shall 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 receives RXVECTOR with NUM_STS parameter set to 0.
- 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. A non-AP VHT STA learns the end of TXOP from Duration/ID value included in this NAV-set sequence. VHT AP shall buffer frames addressed to non-AP VHT STA in Doze state till the end of TXOP.

10.2.1.4b VHT STA TXOP power management modes

A non-AP VHT STA may be either in Awake or Doze state during a TXOP obtained by VHT AP for MU-MIMO transmissions. The manner in which non-AP VHT STA switches between these two states shall be determined by TXOP power management modes (see Table 10-x).

Table 10-x—TXOP power Management modes

TXOP power save mode	Non-AP VHT STA shall enter Doze state as mentioned in 10.2.1.4a during a TXOP and shall enter Awake state when the TXOP ends. VHT AP shall not transmit to non-AP VHT STA that is in Doze state till the end of TXOP.
TXOP non-power save mode	Non-AP VHT STA shall be in Awake state to receive MU-MIMO frame during a TXOP.

Note that, only the non-AP VHT STAs that are in Active mode (see Table 10-1) shall operate TXOP power save mode. The operation of non-AP VHT STA in TXOP non-power save mode is same as that of STA in Active power management mode.
To switch from TXOP power save mode to TXOP non-power save mode or vice-versa, non-AP VHT STA shall inform VHT AP through a successful frame exchange as described in Annex Q initiated by non-AP VHT STA and appropriately acknowledged by VHT AP.

Editor's note: Exact bit that is used by VHT STA to indicate the change in TXOP power management mode is TBD (a TBD bit either VHT control field or a reserved bit in HT control field can be used)

If the TXOP truncates, then VHT AP shall not transmit frames to non-AP VHT STAs in Doze state for the duration of TXOP that was carried in NAV set sequence.

Insert the new section 11.20 below following section 11.19:

11.20 VHT BSS operation

11.20.1 AID assignment by VHT AP

The PHY header of a unicast SU VHT format packet may contain the low order 9 bits of the AID assigned to STA addressed in MPDUs carried in the frame body. A VHT AP should assign AID values in manner which optimizes the power saving opportunities for STAs in the BSS and different BSSs.

A VHT AP should choose AID values that reduce the probability of overlap of AID numbers assigned in different BSSs.

A VHT AP should not assign AID values where the low order 9 bits are all zeros.

A VHT STA shall set the Partial AID field in VHT-SIG-A to a special value(s) (TBD) for STA-to-AP packets.

11.20.2 Rules for operation in a VHT BSS

11.20.3 Basic VHT BSS functionality

A VHT STA which is a member of a VHT BSS shall not transmit a 20 MHz VHT PPDU which does not use the primary 20 MHz channel of the BSS. A VHT STA shall not transmit a 20 MHz VHT PPDU using a 20 MHz channel which cannot be used to setup a VHT 20 MHz BSS.

A VHT STA which is a member of a VHT 40 MHz, 80 MHz, 160 MHz or 80+80 MHz BSS shall not transmit a 40 MHz PPDU which does not use the primary 20 MHz channel of the BSS. A VHT STA shall not transmit a 40 MHz VHT PPDU using a 40 MHz channel which cannot be used to setup a VHT 40 MHz BSS.

A VHT STA which is part of a VHT 80 MHz, 160 MHz or 80+80 MHz BSS shall not transmit a 80 MHz PPDU which does not use the primary 20 MHz channel of the BSS. A VHT STA shall not transmit an 80 MHz VHT PPDU using an 80 MHz channel which cannot be used to setup a VHT 80 MHz BSS.

A VHT STA shall not transmit a 160 MHz VHT PPDU using a 160 MHz channel which 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 Notify Operating Mode 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.

11.20.4 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 before the 40 MHz mask PPDU transmission starts.

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 and contains secondary as an element and the STA is transmitting a 20 MHz mask PPDU on the primary 20 MHz channel, or
— If the channel-list parameter is present and contains secondary40 as an element and the STA is transmitting a 20 MHz mask PPDU on the primary 20 MHz channel or the STA is transmitting a 40 MHz mask PPDU on the primary 40 MHz channel, or
— If the channel-list parameter is present and contains secondary80 as an element and the STA is transmitting a 20 MHz mask PPDU on the primary 20 MHz channel or the STA is transmitting a 40 MHz mask PPDU on the primary 40 MHz channel, or the STA is transmitting an 80 MHz mask PPDU on the primary 80 MHz channel.

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:

a) 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.
b) Transmit a 40 MHz mask PPDU on the primary 40 MHz channel if the secondary channel was idle during this interval.
c) Transmit a 20 MHz mask PPDU on the primary 20 MHz channel
d) 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.

The rules for obtaining a greater than 20 MHz TXOP are still TBD.

12 PHY service specification

12.3 Detailed PHY service specifications

12.3.5 PHY-SAP detailed service specification

12.3.5.10 PHY-CCA.indication

12.3.5.10.2 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 12-1—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, that 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.

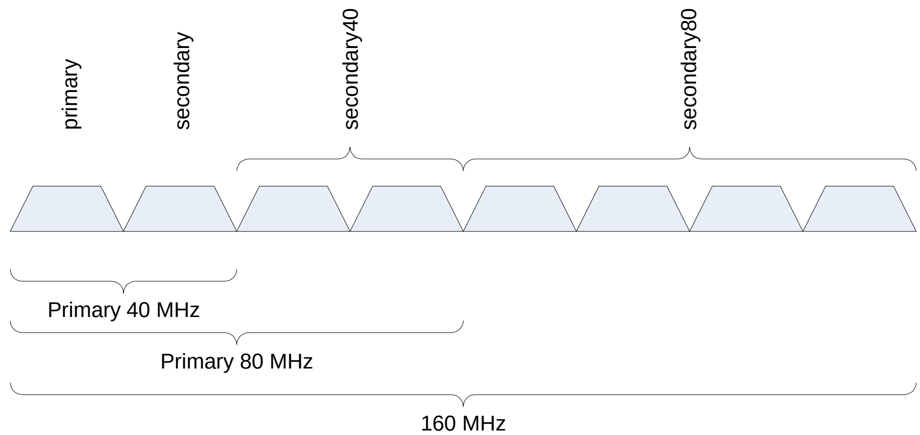

Figure 12-1—Relationship between the channel-list elements and the operating channel bandwidth

12.3.5.10.3 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 or VHT

— In a valid HT-SIG field if the format of the PPDU is HT_MF or HT_GF

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

17 Orthogonal frequency division multiplexing (OFDM) PHY specification

17.2 OFDM PHY specific service parameter list

17.2.2 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:

17.2.2.5 TXVECTOR 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.

17.2.2.6 TXVECTOR 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.

17.2.3 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

17.2.3.6 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.

17.2.3.7 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 CH_BANDWIDTH is also present.

NOTE--The INDICATED_DYN_BANDWIDTH parameter is not present when the frame is received by a non-VHT STA.

17.3 OFDM PLCP sublayer

17.3.1 Introduction

17.3.2 PLCP frame format

17.3.2.1 Overview of the PPDU encoding process

Modify step e) as follows:

e) 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.

17.3.5.4 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):

$$S(x) = x^7 + x^4 + 1 \qquad (17\text{-}14)$$

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

<table>
<tr><td>INDICATED_CH_ BANDWIDTH</td><td>INDICATED_DYN_ BANDWIDTH</td><td colspan="3">First 7 Bits of Scrambling Sequence</td></tr>
<tr><td>Not present</td><td>-</td><td colspan="3">Unused</td></tr>
<tr><td>Present</td><td>Not present</td><td colspan="2">5 bit pseudo-random nonzero integer</td><td rowspan="2">00 (NON_HT_CBW20),
01 (NON_HT_CBW40),
10 (NON_HT_CBW80),
11 (NON_HT_CBW160)</td></tr>
<tr><td>Present</td><td>Present</td><td>4 bit pseudo-random nonzero integer</td><td>0 (Static)
1 (Dynamic)</td></tr>
<tr><td></td><td></td><td>B0 B3</td><td>B4</td><td>B5 B6</td></tr>
</table>

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:

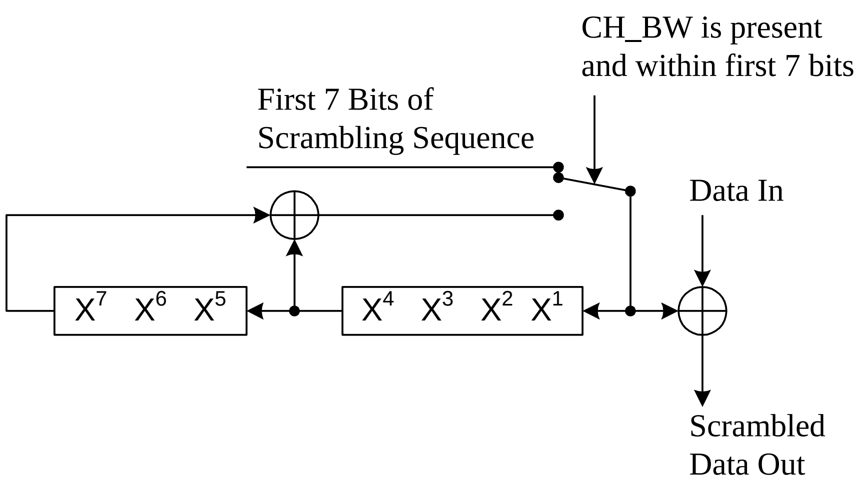

Figure 17-7—Data scrambler

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

19

22 Very High Throughput (VHT) PHY specification

22.1 Introduction

22.1.1 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 coding) 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)

22.1.2 Scope

22.1.3 VHT PHY functions

22.1.4 PPDU formats

22.2 VHT PHY service interface

22.2.1 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).

22.2.2 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	Y	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	See corresponding entry in Table 20-1			
FEC_CODING	FORMAT is HT_MF, HT_GF or VHT	Indicates which FEC encoding is used. Enumerated type: BCC_CODING indicates binary convolutional code. LDPC_CODING indicates low-density parity check code.	Y	Y
	Otherwise	Not present	N	N
STBC	FORMAT is HT_MF or HT_GF	Indicates the difference between the number of space-time streams (N_{STS}) and the number of spatial streams (N_{SS}) indicated by the MCS as follows: 0 indicates no STBC ($N_{STS}=N_{SS}$). 1 indicates $N_{STS}-N_{SS}=1$. 2 indicates $N_{STS}-N_{SS}=2$. Value of 3 is reserved.	Y	Y
	FORMAT is VHT	Indicates whether or not STBC is used. 0 indicates no STBC ($N_{STS}=N_{SS}$). 1 indicates $N_{STS}=2N_{SS}$	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 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 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_LENGT	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	Y	N
	Otherwise	Not present	N	N
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.				

22.2.3 Effects of CH_BANDWIDTH, CH_OFFSET, MCS and NUM_STREAMS parameters on PPDU format

TBD

22.2.4 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

22.2.5 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.

22.3 VHT PLCP sublayer

22.3.1 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.

22.3.2 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.

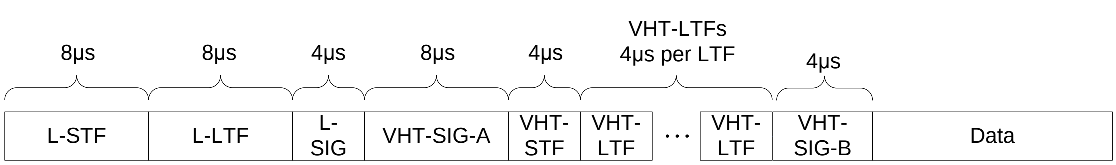

Figure 22-1 -- VHT PPDU format

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, N_{VHTLTF} , 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).

22.3.3 Transmitter block diagram

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

a) PHY Padding
b) Scrambler
c) Encoder parser
d) FEC encoders
e) Stream parser
f) Segment parser (for non-contiguous transmission)
g) BCC Interleaver
h) Constellation mapper
i) LDPC tone mapper
j) Space time block encoder
k) Spatial mapper
l) Inverse discrete Fourier transform (IDFT)
m) Cyclic shift (CSD) insertion
n) Guard interval (GI) insertion
o) Windowing

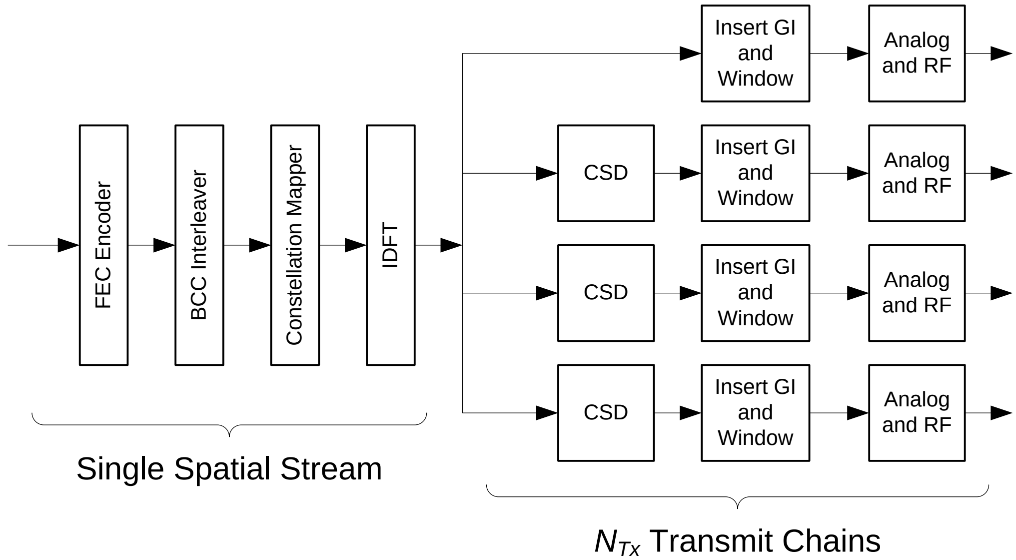

Figure 22-2 -- Transmitter block diagram 1 (L-SIG and VHT-SIG-A)

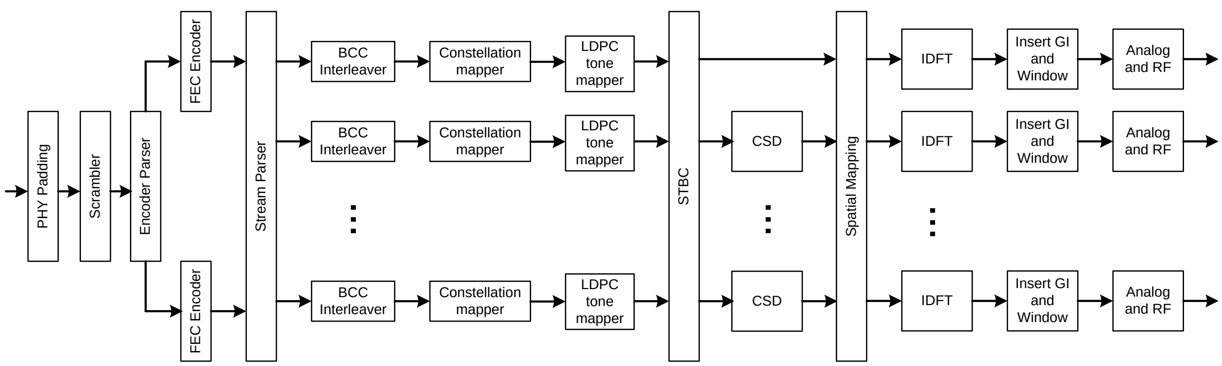

Figure 22-3 -- Transmitter block diagram 2 (Data field in SU packet)

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.

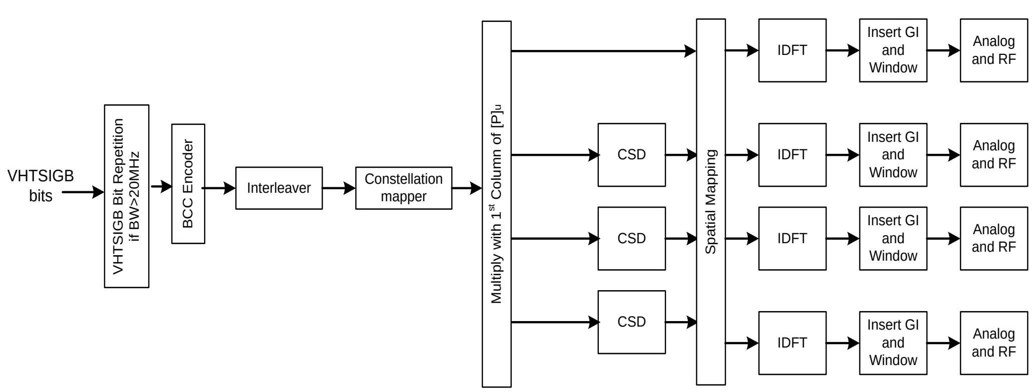

Figure 22-4 -- Transmitter block diagram 3 (VHT-SIG-B)

Editor's note: "Interleaver" in the above figure should be renamed "BCC Interleaver".

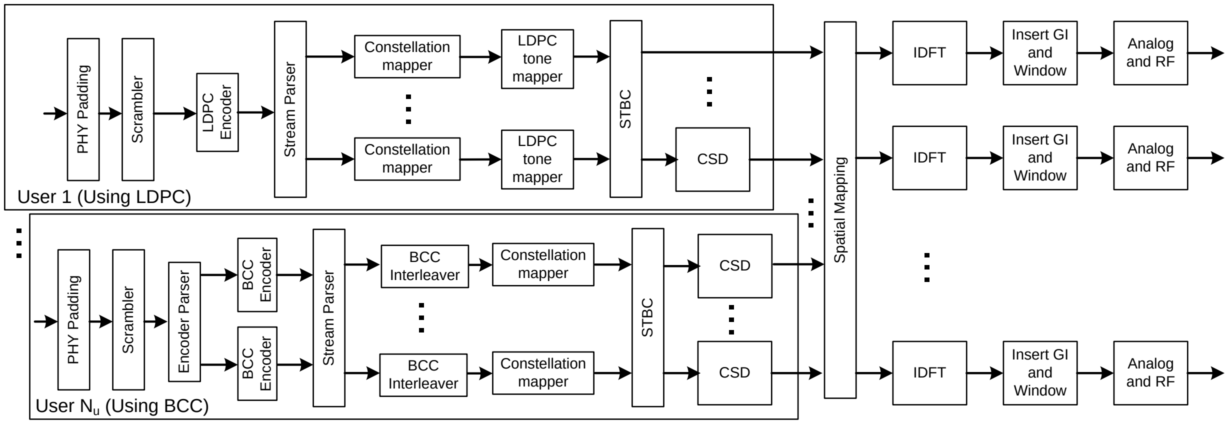

Figure 22-5 -- Transmitter block diagram 4 (Data field in MU Packet, with LDPC and BCC encoding)

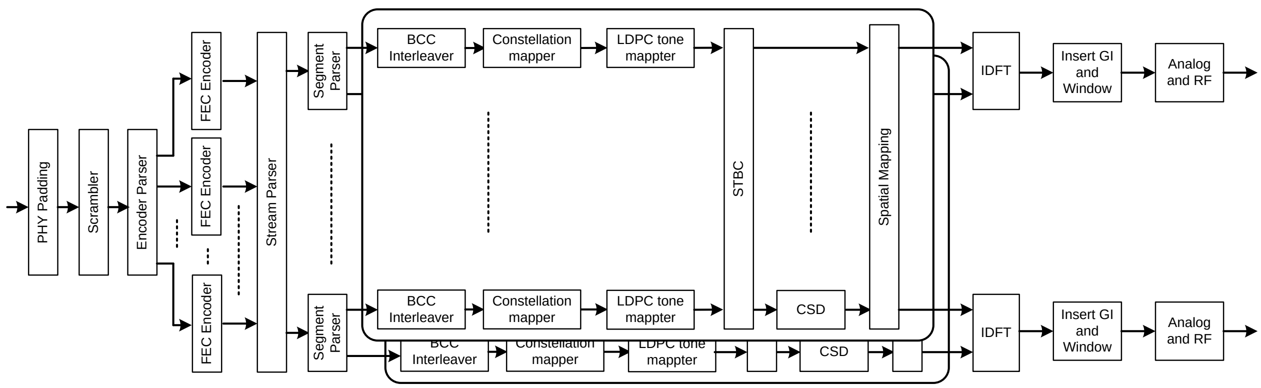

Figure 22-6 -- Transmitter block diagram 5 (contiguous 160 MHz)

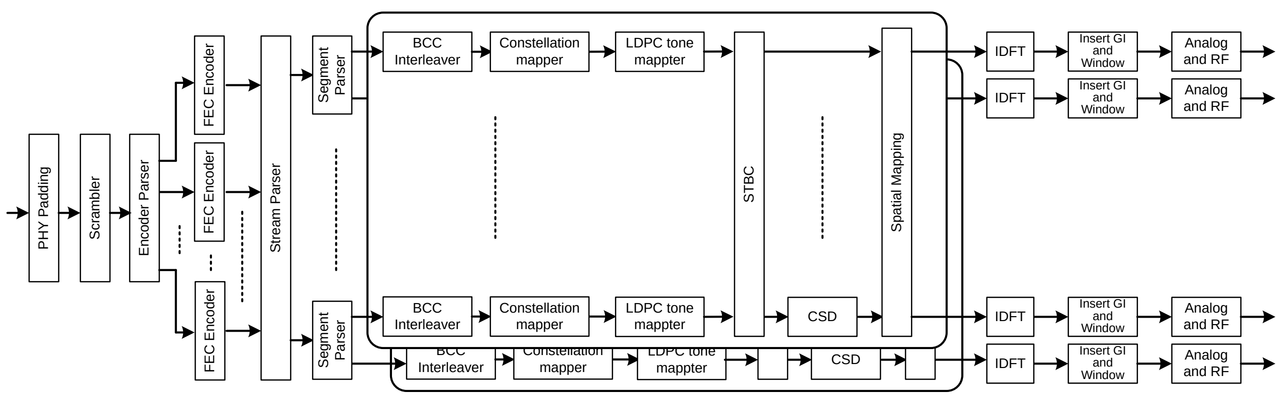

Figure 22-7--Transmitter block diagram 6 (non-contiguous 80+80 MHz)

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 22-3 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 22-4 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.

22.3.4 Overview of the PPDU encoding process

The VHT-PPDU encoding process is described below

a) Construction of L_STF and L_LTF: Construct the L-STF and L-LTF as defined by Clause 17. From the TXVECTOR determine the CH_BANDWIDTH. Duplicate the L_STF and L_LTF over each 20 MHz of the CH_BANDWIDTH. Apply appropriate phase rotation for each 20MHz sub-band. Apply CSD for each transmit chain, compute the Inverse Fourier Transmit and prepend a GI..

b) Construction of L_SIGNAL: Construct the L_SIGNAL as defined by Clause 17. For VHT PPDU set the RATE in the SIGNAL field to 6 Mbps. Set the LENGTH in the SIGNAL field according to section 9.3.16. Add 6 tail bits into the L_SIGNAL symbol. Encode the RATE and the LENGTH fields of the PLCP header by a convolution code at the rate of R=1/2 and then interleave, BPSK modulate and insert pilots. Duplicate the L_SIGNAL over each 20 MHz of the CH_BANDWIDTH. Apply appropriate phase rotation for each 20MHz sub-band. Apply CSD for each transmit chain, compute the Inverse Fourier Transmit and prepend a GI. Refer to section 17.3.4 for details.

c) Construction of VHT-SIG-A: The VHT-SIG-A consists of two symbols VHT-SIG-A1 and VHT-SIG-A2 as defined in sections 0. Obtain the CH_BANDWIDTH, STBC, GROUP_ID, N_STS, SGI, CODING, MCS (for SU only), [SU-Beamformed] from the TX_VECTOR. Add the appropriate reserved bits and 6 tail bits as shown in section 0. 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. Encode the data by a convolution coder at the rate of R=1/2. Then interleave, BPSK modulate and insert pilot 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, apply CSD for each transmit chain, and prepend a GI.

d) Construction of VHT-STF: Construct the VHT-STF according to section 22.3.9.2.4.

e) 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. The Pilot tones in the VHT-LTF are multiplied by the entries of the matrix R as defined in section 22.3.9.2.5.

f) Construction of VHT-SIG-B: The fields in VHT-SIG-B are shown in 22.3.9.2.6. The VHT-SIG-B is encoded using BCC at rate R=1/2, interleaved, mapped to a BPSK constellation, and have pilots inserted. The total number of data and pilot subcarriers is same as the data PSDU. The 800ns guard interval is always applied for VHT-SIG-B symbol. Apply CSD for each space-time stream, compute the Inverse Fourier transform and prepend a GI.

g) Append the PSDU to the SERVICE field (see 22.3.11.1).

h) 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 for details.

22.3.5 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 22-19 through Table 22-50 (in 22.6). 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.

Table 22-19 through Table 22-26 show rate-dependent parameters for MCSs for one through eight streams for 20 MHz operation. Table 22-27 through Table 22-34 show rate-dependent parameters for MCSs for one through eight streams for 40 MHz operation. Table 22-35 through Table 22-42 show rate-dependent parameters for MCSs for one through eight streams for 80 MHz operation. Table 22-43 through Table 22-50 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 AP 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.

22.3.6 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**
N_{SD}: Number of complex data numbers per frequency segment	52	108	234	234	468
N_{SP}: Number of pilot values per frequency segment	4	6	8	8	16
N_{ST}: Total number of subcarriers per frequency segment See NOTE 1	56	114	242	242	484
N_{SR}: Highest data subcarrier index per frequency segment	28	58	122	122	250
N_{Seg}: Number of frequency segments	1	1	1	2	1
Δ_F: Subcarrier frequency spacing	312.5 kHz				
T_{DFT}: IDFT/DFT period	3.2 µs				
T_{GI}: Guard interval	0.8 µs = T_{DFT} /4				

duration	
T_{GI2}: Double guard interval	1.6 µs
T_{GIS}: Short guard interval duration	0.4 µs = T_{DFT} /8
$T_{L\text{-}STF}$: Legacy short training sequence duration	8 µs = 10 x T_{DFT} /4
$T_{L\text{-}STF}$: Legacy long training sequence duration	8 µs = 2 x T_{DFT} + T_{GIS}
T_{SYM}: Symbol interval	4 µs = T_{DFT} + T_{GI}
T_{SYMS}: Short GI symbol interval	3.6 µs = T_{DFT} + T_{GIS}
$T_{L\text{-}SIG}$: Legacy SIGNAL field duration	4 µs
$T_{VHT\text{-}SIG\text{-}A}$: VHT SIGNAL A field duration	8 µs = 2T_{SYM}
$T_{VHT\text{-}STF}$: VHT short training field duration	4 µs
$T_{VHT\text{-}LTF}$: Duration of each VHT LTF training field	4 µs
$T_{VHT\text{-}SIG\text{-}B}$: VHT SIGNAL B field duration	4 µs = T_{SYM}
	NOTE 1 – $N_{ST} = N_{SD} + N_{SP}$

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

Table 22-5 – Frequently used parameters

Symbol	**Explanation**
N_{CBPS}	Number of coded bits per symbol
N_{CBPSS}	Number of coded bits per symbol per spatial stream
N_{DBPS}	Number of data bits per symbol
N_{BPSC}	Number of coded bits per subcarrier over all spatial streams

N_{BPSCS}	Number of coded bits per subcarrier per spatial stream
N_{RX}	Number of receive chains
N_u	Number of users in a transmission. N_u = 1 for SU transmission.
N_{STS}, $N_{\mathrm{STS},u}$	$N_{\mathrm{STS},u}$ is the number of space-time streams for user *u*, *u*=0,1,2,3. For SU packets, $N_{\mathrm{STS}} = N_{\mathrm{STS},0}$. For MU packets, N_{STS} is undefined.
$N_{\mathrm{STS,total}}$	Total number of space-time streams in a packet. $N_{\mathrm{STS,total}} = \sum_{u=0}^{N_u-1} N_{\mathrm{STS},u}$ Note that $N_{\mathrm{STS,total}} = N_{\mathrm{STS}}$ for SU packets.
N_{SS}, $N_{SS,u}$	$N_{SS,u}$ is the number of spatial streams for user *u*, *u*=0,1,2,3. For SU packets, $N_{SS} = N_{SS,0}$. For MU packets, N_{SS} is undefined.
N_{TX}	Number of transmit chains
N_{ES}, $N_{ES,u}$	$N_{ES,u}$ is the number of BCC encoders for the Data field for user *u*, *u*=0,1,2,3. For SU packets, $N_{ES} = N_{ES,0}$. For MU packets, N_{ES} is undefined.
N_{VHTLTF}	Number of VHT long training fields (see 22.3.9.2.5)
R	Coding rate

22.3.7 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 (22-0).

$$r_{\mathrm{RF}}(t) = \mathrm{Re}\left\{ \frac{1}{\sqrt{N_{\mathrm{Seg}}}} \sum_{i_{\mathrm{seg}}=0}^{N_{\mathrm{Seg}}-1} r^{(i_{\mathrm{Seg}})}(t) \exp\left(j2\pi f_c^{(i_{\mathrm{Seg}})} t \right) \right\} \qquad (22\text{-}0)$$

where

$\mathrm{Re}\{\cdot\}$	represents the real part of a complex variable;
N_{Seg}	represents the number of frequency segments the transmit signal consists of. $N_{\mathrm{Seg}} = 1$ for contiguous transmissions and $N_{\mathrm{Seg}} = 2$ for non-contiguous transmissions;
$r^{(i_{\mathrm{Seg}})}(t)$	represents the complex baseband signal of frequency segment i_{Seg};
$f_c^{(i_{\mathrm{Seg}})}$	represents the carrier center frequency of frequency segment i_{Seg}.

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.

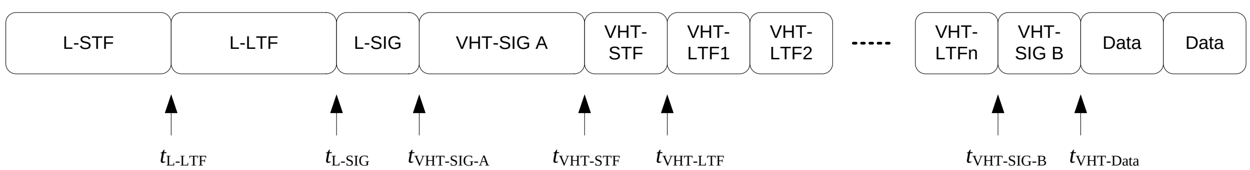

Figure 22-8 -- Timing boundaries for VHT PPDU fields

The time offset, t_{Field}, determines the starting time of the corresponding field.

The signal transmitted on frequency segment i_{Seg} of transmit chain i_{TX} shall be as shown in Equation (22-1).

$$\begin{aligned} r_{\mathrm{PPDU}}^{(i_{\mathrm{Seg}},i_{\mathrm{TX}})}(t) &= r_{\mathrm{L-STF}}^{(i_{\mathrm{Seg}},i_{\mathrm{TX}})}(t) + r_{\mathrm{L-LTF}}^{(i_{\mathrm{Seg}},i_{\mathrm{TX}})}(t - t_{\mathrm{L-LTF}}) \\ &+ r_{\mathrm{L-SIG}}^{(i_{\mathrm{Seg}},i_{\mathrm{TX}})}(t - t_{\mathrm{L-SIG}}) + r_{\mathrm{VHT-SIG-A}}^{(i_{\mathrm{Seg}},i_{\mathrm{TX}})}(t - t_{\mathrm{VHT-SIG-A}}) + r_{\mathrm{VHT-STF}}^{(i_{\mathrm{Seg}},i_{\mathrm{TX}})}(t - t_{\mathrm{VHT-STF}}) \\ &+ \sum_{i_{\mathrm{LTF}}=1}^{N_{\mathrm{VHT-LTF}}} r_{\mathrm{VHT-LTF}}^{(i_{\mathrm{Seg}},i_{\mathrm{TX}},i_{\mathrm{LTF}})}\left(t - t_{\mathrm{VHT-LTF}} - (i_{\mathrm{LTF}}-1)T_{\mathrm{VHT-LTFs}}\right) + r_{\mathrm{VHT-SIG-B}}^{(i_{\mathrm{Seg}},i_{\mathrm{TX}})}(t - t_{\mathrm{VHT-SIG-B}}) + r_{\mathrm{VHT-Data}}^{(i_{\mathrm{Seg}},i_{\mathrm{TX}})}(t - t_{\mathrm{VHT-Data}}) \end{aligned} \qquad (22\text{-}1)$$

where

$$\begin{aligned} t_{\mathrm{L-LTF}} &= T_{\mathrm{L-STF}} \\ t_{\mathrm{L-SIG}} &= t_{\mathrm{L-LTF}} + T_{\mathrm{L-LTF}} \\ t_{\mathrm{VHT-SIG-A}} &= t_{\mathrm{L-SIG}} + T_{\mathrm{L-SIG}} \\ t_{\mathrm{VHT-STF}} &= t_{\mathrm{VHT-SIG-A}} + T_{\mathrm{VHT-SIG-A}} \\ t_{\mathrm{VHT-LTF}} &= t_{\mathrm{VHT-STF}} + T_{\mathrm{VHT-STF}} \\ t_{\mathrm{VHT-SIG-B}} &= t_{\mathrm{VHT-LTF}} + N_{\mathrm{VHT-LTF}} T_{\mathrm{VHT-LTFs}} \\ t_{\mathrm{VHT-Data}} &= t_{\mathrm{VHT-SIG-B}} + T_{\mathrm{VHT-SIG-B}}. \end{aligned}$$

Each baseband waveform, $r_{Field}^{(i_{\mathrm{Seg}},i_{\mathrm{TX}})}(t)$, is defined via the discrete Fourier transform per OFDM symbol as

$$r_{\mathrm{Field}}^{(i_{\mathrm{Seg}},i_{\mathrm{TX}})}(t)=\frac{1}{\sqrt{N_{\mathrm{Field}}^{\mathrm{Tone}}N_{\mathrm{TX}}}}w_{T_{\mathrm{Field}}}(t)\sum_{u=0}^{N_u-1}\sum_{k}\Upsilon_{k,\mathrm{BW}}X_{k,u}^{(i_{\mathrm{Seg}},i_{\mathrm{TX}})}\exp\left(j2\pi k\Delta_F t\right). \quad (22\text{-}2)$$

This general representation holds for all fields. An example definition of the windowing function, $w_{T_{\mathrm{Field}}}(t)$, is given in 17.3.2.4. N_u represents the number of users in the transmission, and u is the user index. For SU transmissions, $N_u=1$. The non-VHT portion (consisting of L-STF, L-LTF, L-SIG and VHT-SIG-A) of MU transmissions are common to all users, and thus shall also use $N_u=1$ in Equation (22-2). For MU transmissions, the VHT portion starting from the VHT-STF shall have $1\le N_u\le 4$ depending on the number of users in the transmission. The frequency-domain symbols $X_k^{(i_{\mathrm{Seg}},i_{\mathrm{TX}})}$ represents the output of any spatial processing in subcarrier k of user u for frequency segment i_{Seg} of transmit chain i_{TX} required for the field.

The function $\Upsilon_{k,\mathrm{BW}}$ is used to represent a rotation of the tones. For 20 MHz PPDU transmissions,

$$\Upsilon_{k,20}=1. \quad (22\text{-}3)$$

For 40 MHz PPDU transmissions,

$$\Upsilon_{k,40}=\begin{cases}1 & , \quad k<0\\ j & , \quad k\ge 0.\end{cases} \quad (22\text{-}4)$$

For 80 MHz PPDU transmissions,

$$\Upsilon_{k,80}=\begin{cases}1 & , \quad k<-64\\ -1 & , \quad k\ge -64.\end{cases} \quad (22\text{-}5)$$

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 (22-5).

For contiguous 160 MHz PPDU transmissions,

$$\Upsilon_{k,160}=\begin{cases}1 & , \quad k<-192\\ -1 & , \quad -192\le k<0\\ 1 & , \quad 0\le k<64\\ -1 & , \quad 64\le k.\end{cases} \quad (22\text{-}6)$$

The $1\big/\sqrt{N_{\mathrm{Field}}^{\mathrm{Tone}}N_{\mathrm{TX}}}$ scale factor in Equation (22-2) 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 $N_{\mathrm{Field}}^{\mathrm{Tone}}$ as a function of bandwidth per frequency segment.

Table 22-6 -- Value of tone scaling factor $N_{\mathrm{Field}}^{\mathrm{Tone}}$

Field	$N_{\mathrm{Field}}^{\mathrm{Tone}}$ **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

22.3.8 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 $f_c^{(i_{\mathrm{Seg}})}$ in Equation (22-2) replaced by $f_c^{(i_{\mathrm{Seg}})} \pm 10$ 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 $f_c^{(i_{\mathrm{Seg}})}$ in Equation (22-2) replaced by $f_c^{(i_{\mathrm{Seg}})} \pm 10$ MHz or $f_c^{(i_{\mathrm{Seg}})} \pm 30$ 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 $f_c^{(i_{\mathrm{Seg}})}$ in Equation (22-2) replaced by $f_c^{(i_{\mathrm{Seg}})} \pm 10$ MHz, $f_c^{(i_{\mathrm{Seg}})} \pm 30$ MHz, $f_c^{(i_{\mathrm{Seg}})} \pm 50$ MHz or $f_c^{(i_{\mathrm{Seg}})} \pm 70$ 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 $f_c^{(i_{\mathrm{Seg}})}$ in Equation (22-2) replaced by $f_c^{(i_{\mathrm{Seg}})} \pm 20$ 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 $f_c^{(i_{\mathrm{Seg}})}$ in Equation (22-2) replaced by $f_c^{(i_{\mathrm{Seg}})} \pm 20$ MHz or $f_c^{(i_{\mathrm{Seg}})} \pm 60$ 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 $f_c^{(i_{\mathrm{Seg}})}$ in Equation (22-2) replaced by $f_c^{(i_{\mathrm{Seg}})} \pm 40$ MHz.

22.3.9 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.

22.3.9.1 Non-VHT portion of VHT format preamble

22.3.9.1.1 Cyclic shift definition

The cyclic shift value $T_{CS}^{i_{TX}}$ for the L-STF, L-LTF, L-SIG and VHT-SIG-A portions of the packet for transmitter i_{TX} out of total N_{TX} are defined in Table 22-7.

Table 22-7--Cyclic shift values for L-STF, L-LTF, L-SIG and VHT-SIG-A portions of the packet

$T_{CS}^{i_{TX}}$ 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	-150	-25	-100	-50	-200

22.3.9.1.2 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 (22-7), which does not include the phase rotation per 20 MHz subchannel.

$$S_{-122,122} = \{S_{-58,58}, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, S_{-58,58}\} \tag{22-7}$$

where $S_{-58,58}$ is define in Equation (20-9).

For 160 MHz, the L-STF is defined by Equation (22-8).

$$S_{-250,250} = \{S_{-122,122}, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, S_{-122,122}\} \tag{22-8}$$

where $S_{-122,122}$ is defined in Equation (22-7).

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 ($S_{-122,122}$) defined in Equation (22-7).

The time domain representation of the signal on frequency segment i_{Seg} in transmit chain i_{TX} shall be:

$$r_{\text{L-STF}}^{(i_{\text{Seg}},i_{\text{TX}})}(t) = \frac{1}{\sqrt{N_{\text{L-STF}}^{\text{Tones}} N_{\text{TX}}}} w_{T_{\text{L-STF}}}(t) \sum_{k=-N_{SR}}^{N_{SR}} \Upsilon_{k,\text{BW}} S_k \exp\left(j2\pi k\Delta_F \left(t - T_{\text{CS}}^{i_{\text{TX}}}\right)\right) \tag{22-9}$$

where

$T_{\text{CS}}^{i_{\text{TX}}}$ represents the cyclic shift for transmit chain i_{TX} with a value given in Table 20-8 for up to 4 antennas. For more than 4 antennas, refer to Table 22-X (in clause 22.3.9.1.1).

$\Upsilon_{k,BW}$ is defined by Equations (22-3), (22-4), (22-5) and (22-6).

22.3.9.1.3 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 (22-10), which does not include the phase rotations per 20 MHz subchannel.

$$L_{-122,122} = \left\{L_{-58,58},\ 0,\ 0,\ 0,\ 0,\ 0,\ 0,\ 0,\ 0,\ 0,\ 0,\ 0,\ L_{-58,58}\right\} \tag{22-10}$$

where $L_{-58,58}$ is define in Equation (20-9).

For 160 MHz, L-LTF is defined by Equation (22-11), which does not include the phase rotations per 20 MHz subchannel.

$$L_{-250,250} = \left\{L_{-122,122},\ 0,\ 0,\ 0,\ 0,\ 0,\ 0,\ 0,\ 0,\ 0,\ 0,\ 0,\ L_{-122,122}\right\} \tag{22-11}$$

Where $L_{-122,122}$ is given by Equation (22-10).

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 ($L_{-122,122}$) defined in Equation (22-10).

The time domain representation of the signal on transmit chain i_{TX} shall be as defined in Equation (22-12).

$$r_{\text{L-LTF}}^{(i_{\mathrm{Seg}},i_{\mathrm{TX}})}(t) = \frac{1}{\sqrt{N_{\text{L-LTF}}^{\mathrm{Tones}} N_{\mathrm{TX}}}} w_{T_{\text{VHT-LTF}}}(t) \sum_{k=-N_{SR}}^{N_{SR}} \Upsilon_{k,\mathrm{BW}} L_k \exp\left(j2\pi k\Delta_F\left(t - T_{\mathrm{GI2}} - T_{\mathrm{CS}}^{i_{\mathrm{TX}}}\right)\right) \tag{22-12}$$

where

$T_{\mathrm{CS}}^{i_{\mathrm{TX}}}$ represents the cyclic shift for transmitter chain i_{TX} with a value given in Table 20-8 for up to 4 antennas. For more than 4 antennas, the cyclic shifts are TBD.

$\Upsilon_{k,BW}$ is defined by Equations (22-3), (22-4), (22-5) and (22-6).

22.3.9.1.4 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.

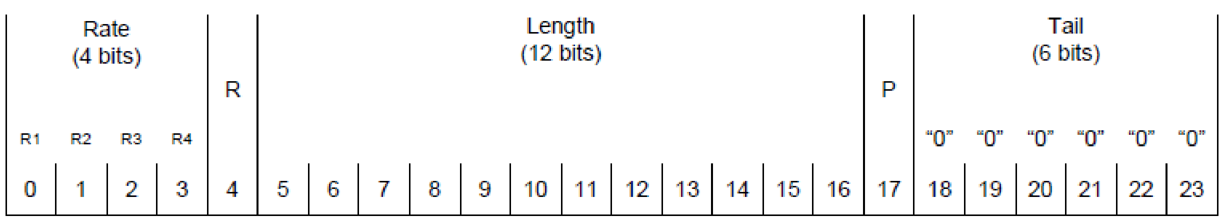

Figure 22-9--L-SIG structure

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

$$\text{Length} = \left\lceil \frac{\text{TXTIME} - 20}{4} \right\rceil \times 3 - 3 \tag{22-13}$$

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 (22-13) 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 d_k, k=0..47. The time domain waveform of the L-SIG shall be as given by Equation (22-14).

$$r_{\text{L-SIG}}^{(i_{\text{Seg}},i_{\text{TX}})}(t) = \frac{1}{\sqrt{N_{\text{L-SIG}}^{\text{Tone}} N_{\text{TX}}}} w_{T_{\text{SYM}}}(t) \cdot \sum_{i_{\text{BW}}=0}^{N_{20\text{MHz}}-1} \sum_{k=-26}^{26} \left(\Upsilon_{(k-K_{\text{Shift}}(i_{\text{BW}})),\text{BW}} \left(D_k + p_0 P_k\right) \exp\left(j2\pi\left(k - K_{\text{Shift}}\left(i_{\text{BW}}\right)\right)\Delta_F \left(t - T_{\text{GI}} - T_{\text{CS}}^{i_{\text{TX}}}\right)\right) \right) \tag{22-14}$$

where

$N_{20\text{MHz}}$ 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

$K_{\text{Shift}}(i) = \left(N_{20\text{MHz}} - 1 - 2i\right) \cdot 32$

$$D_k = \begin{cases} 0, & k = 0, \pm 7, \pm 21 \\ d_{M^r(k)}, & \text{otherwise} \end{cases}$$

$$M^r(k) = \begin{cases} k+26 & -26 \le k \le -22 \\ k+25 & -20 \le k \le -8 \\ k+24 & -6 \le k \le -1 \\ k+23 & 1 \le k \le 6 \\ k+22 & 8 \le k \le 20 \\ k+21 & 22 \le k \le 26 \end{cases}$$

P_k is defined in 17.3.5.9

p_0 is the first pilot value in the sequence defined in 17.3.5.9

$N_{\text{L-SIG}}^{\text{Tone}}$ has the value given in Table 22-6

$\Upsilon_{k,BW}$ is defined in Equations (22-3), (22-4), (22-5) and (22-6)

$T_{\text{CS}}^{i_{\text{TX}}}$ represents the cyclic shift for transmitter chain i_{TX} with a value given in Table 20-8 for up to 4 antennas. For more than 4 antennas, the cyclic shifts are TBD.

22.3.9.2 VHT portion of VHT format preamble

22.3.9.2.1 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:

- $[Q]_{m,n}$ indicates the element in row m and column n of matrix Q
- $[Q]_N$ indicates a matrix consisting of the first N columns of matrix Q

- $[Q]_{M:N}$ indicates a matrix consisting of columns M through N of matrix Q

22.3.9.2.2 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 $T_{\text{CS,VHT}}(n)$ for the portion of the packet following VHT-SIG-A for the n-th space-time stream out of $N_{\text{STS,total}}$ total space-time streams is shown in Table 22-8.

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

$T_{\text{CS,VHT}}(n)$ values for VHT portion of packet								
Total number of space-time streams $(N_{\text{STS,total}})$	**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 is applied continuously across the space-time streams as defined in Equation (22-15).

$$T_{CS,u}^{i_{STS,u}} = T_{CS,VHT}\left(i_{STS,u} + \sum_{k=1}^{u-1} N_{STS,k}\right), \qquad \text{where } N_{\text{STS,total}} = \sum_{k=1}^{N_u} N_{STS,k} \tag{22-15}$$

22.3.9.2.3 VHT-SIG-A definition

The VHT-SIG-A field carries information required to interpret VHT format packets. VHT-SIG-A contains the fields listed in Table 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	N_{STS}	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-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 N_{SYM} mod 10 = 9, otherwise set to 0. N_{SYM} 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 N_{STS} 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 N_{STS} 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 N_{STS} field for user 2 is non-zero, then B4 indicates coding for user 2: set to 0 for BCC, 1 for LDPC. If N_{STS} for user 2 is set to 0, then B4 is reserved and set to 1. If the N_{STS} field for user 3 is non-zero, then B5 indicates coding for user 3: set to 0 for BCC, 1 for LDPC. If N_{STS} for user 3 is set to 0, then B5 is reserved and set to 1. If the N_{STS} field for user 4 is non-zero, then B6 indicates coding for user 4: set to 0 for BCC, 1 for LDPC. If N_{STS} 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]. All the fields in the VHT-SIG-A are transmitted LSB first, and 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 $d_{k,n}, \quad k = 0 \ldots 47, n = 0,1$. The time domain waveform for the VHT-SIG-A field in a VHT format packet shall be:

$$\begin{aligned} r^{(i_{\text{Seg}},i_{\text{TX}})}_{\text{VHT-SIG\_A}}(t) &= \frac{1}{\sqrt{N^{\text{Tone}}_{\text{VHT-SIG-A}} N_{\text{TX}}}} \sum_{n=0}^{1} w_{T_{\text{SYM}}}\left(t - nT_{\text{SYM}}\right) \\ &\cdot \sum_{i_{\text{BW}}=0}^{N_{20\text{MHz}}-1} \left[\Upsilon_{\left(k-K_{\text{Shift}}\left(i_{\text{BW}}\right)\right),\text{BW}} \sum_{k=-26}^{26} \left(j^n D_{k,n} + p_{n+1} P_k \right) \right. \\ &\left. \cdot \exp\left(j2\pi \left(k - K_{\text{Shift}}\left(i_{\text{BW}}\right)\right) \Delta_F \left(t - nT_{\text{SYM}} - T_{\text{GI}} - T_{\text{CS}}^{i_{\text{TX}}}\right)\right)\right] \end{aligned} \tag{22-16}$$

where

N_{20MHz} and $K_{\text{Shift}}(i)$ are defined in 22.3.9.1.4

$$D_{k,n} = \begin{cases} 0, & k = 0, \pm 7, \pm 21 \\ d_{M^r(k),n}, & \text{otherwise} \end{cases}$$

$M^r(k)$ is defined in 22.3.9.1.4

P_k and p_n are defined in 17.3.5.9

$N_{\text{VHT-SIG-A}}^{\text{Tone}}$ has the value given in Table 22-6

$\Upsilon_{k,BW}$ is defined in Equations (22-3), (22-4), (22-5) and (22-6)

$T_{\text{CS}}^{i_{\text{TX}}}$ represents the cyclic shift for transmitter chain i_{TX} with a value given in Table 20-8 for up to 4 antennas. For more than 4 antennas, the cyclic shifts are TBD.

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.

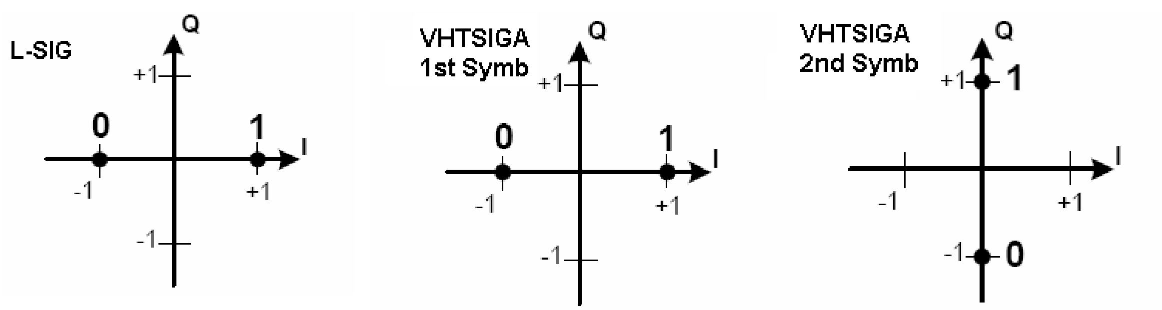

Figure 22-10 -- Data constellation in the VHT format PPDU

22.3.9.2.4 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 (22-17).

$$VHTS_{-28,28} = HTS_{-28,28} \tag{22-17}$$

where $HTS_{-28,28}$ is defined in Equation (20-19).

For 40 MHz, the frequency domain sequence is given by Equation (22-18).

$$VHTS_{-58,58} = HTS_{-58,58} \tag{22-18}$$

where $HTS_{-58,58}$ is defined in Equation (20-20).

For 80 MHz, the frequency domain sequence is given by Equation (22-19).

$$VHTS_{-122,122} = \{VHTS_{-58,58}, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, VHTS_{-58,58}\} \quad (22\text{-}19)$$

where $VHTS_{-58,58}$ is given in Equation (22-18).

For 160 MHz, the frequency domain sequence is given by Equation (22-20).

$$VHTS_{-250,250} = \left\{VHTS_{-122,122}, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, VHTS_{-122,122}\right\} \quad (22\text{-}20)$$

where $VHTS_{-122,122}$ is given in Equation (22-19).

Note that Equations (22-17), (22-18), (22-19) and (22-20) 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 ($VHTS_{-122,122}$) defined in Equation (22-19).

The time domain representation of the signal on frequency segment i_{Seg} of transmit chain i_{TX} shall be:

$$\begin{aligned} r_{\text{VHT-STF}}^{(i_{\text{Seg}},i_{\text{TX}})}(t) &= \frac{1}{\sqrt{N_{\text{VHT-STF}}^{\text{Tones}} N_{\text{STS,total}}}} w_{T_{\text{VHT-STF}}}(t) \\ &\cdot \sum_{k=-N_{SR}}^{N_{SR}} \sum_{u=0}^{N_u-1} \sum_{m=1}^{N_{\text{STS},u}} \left[Q_k^{(i_{\text{Seg}})} \right]_{i_{\text{TX}},(M_u+m)} \Upsilon_{k,\text{BW}} VHTS_k \\ &\cdot \exp\left(j2\pi k \Delta_F \left(t - T_{\text{CS,VHT}}\left(M_u + m\right)\right)\right) \end{aligned} \quad (22\text{-}21)$$

where

N_u	is defined in Table 22-5,
$N_{\text{VHT-STF}}^{\text{Tone}}$	has the value given in Table 22-6,
$N_{\text{STS,total}}$	is defined in Table 22-5,
$N_{\text{STS},u}$	is defined in Table 22-5,
$T_{\text{CS,VHT}}(n)$	is given in Table 22-6,
M_u	is given by $M_u = \sum_{u'=0}^{u-1} N_{\text{STS},u'}$ with $M_0 = 0$,
$Q_k^{(i_{\text{Seg}})}$	is defined in 22.3.11.10.1, and
$\Upsilon_{k,BW}$	is defined in Equations (22-3), (22-4), (22-5) and (22-6).

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

22.3.9.2.5 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 which 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 which is 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 N_{VHTLTF} is a function of the total number of space-time streams $N_{STS,total}$ 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

$N_{\mathrm{STS,total}}$	N_{VHTLTF}
1	1
2	2
3	4
4	4
5	6
6	6
7	8
8	8

Let LTF_{left} and LTF_{right} be sequences defined by Equations (22-22) and (22-23) respectively.

$$LTF_{\mathrm{left}} = \{1,1,-1,-1,1,1,-1,1,-1,1,1,1,1,1,1,-1,-1,1,1,-1,1,-1,1,1,1,1\} \quad (22\text{-}22)$$

$$LTF_{\mathrm{right}} = \{1,-1,-1,1,1,-1,1,-1,1,-1,-1,-1,-1,-1,1,1,-1,-1,1,-1,1,-1,1,1,1,1\} \quad (22\text{-}23)$$

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

$$\begin{aligned} VHTLTF_{-28:28} &= \{1,1,LTF_{\mathrm{left}},0,LTF_{\mathrm{right}},-1,-1\} \\ &= HTLTF_{-28,28} \end{aligned} \quad (22\text{-}24)$$

where $HTLTF_{-28,28}$ is defined in Equation (20-23).

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

$$\begin{aligned} VHTLTF_{-58,58} &= \{LTF_{\mathrm{left}},1,LTF_{\mathrm{right}},-1,-1,-1,1,0,0,0,-1,1,1,-1,LTF_{\mathrm{left}},1,LTF_{\mathrm{right}}\} \\ &= HTLTF_{-58,58} \end{aligned} \quad (22\text{-}25)$$

where $HTLTF_{-58,58}$ is defined in Equation (20-24).

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

$$\begin{aligned} VHTLTF_{-122,122} = \{ & LTF_{\mathrm{left}},1,LTF_{\mathrm{right}},-1,-1,-1,1,1,-1,1,-1,1,1,-1,LTF_{\mathrm{left}},1,LTF_{\mathrm{right}}, \\ & 1, -1, 1, -1, 0, 0, 0, 1, -1, -1, 1, \\ & LTF_{\mathrm{left}},1,LTF_{\mathrm{right}},-1,-1,-1,1,1,-1,1,-1,1,1,-1,LTF_{\mathrm{left}},1,LTF_{\mathrm{right}}\} \end{aligned} \quad (22\text{-}26)$$

For 160 MHz, VHT-LTF is given by Equation (22-27).

$$VHTLTF_{-250,250} = \{VHTLTF_{-122,122}, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, VHTLTF_{-122,122}\} \quad (22\text{-}27)$$

where $VHTLTF_{-122,122}$ is given in Equation (22-26).

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 ($VHTLTF_{-122,122}$) defined in Equation (22-26).

The generation of the time domain VHT-LTFs is shown in Figure 22-11 where A_{VHTLTF}^{k} is given in Equation (22-28).

$$A_{VHTLTF}^{k} = \begin{cases} R_{VHTLTF} & , \text{ if } k \in K_{\text{Pilot}} \\ P_{VHTLTF} & , \text{ otherwise} \end{cases} \quad (22\text{-}28)$$

where

K_{Pilot} is the subcarrier indices for the pilot tones.
For 20 MHz transmissions, $K_{\text{Pilot}} = \{\pm 7, \pm 21\}$.
For 40 MHz transmissions, $K_{\text{Pilot}} = \{\pm 11, \pm 25, \pm 53\}$.
For 80 MHz transmissions, $K_{\text{Pilot}} = \{\pm 11, \pm 39, \pm 75, \pm 103\}$.
For 160 MHz transmissions,
$K_{\text{Pilot}} = \{\pm 25, \pm 53, \pm 89, \pm 117, \pm 139, \pm 167, \pm 203, \pm 231\}$.
For noncontiguous 80+80 MHz transmissions, K_{Pilot} for each 80 MHz frequency segment is identical to K_{Pilot} of 80 MHz transmissions.

R_{VHTLTF} is a $N_{VHTLTF} \times N_{VHTLTF}$ matrix whose elements are defined in Equation (22-29).

$$[R_{VHTLTF}]_{m,n} = [P_{VHTLTF}]_{1,n} \qquad \forall\ 1 \le m, n \le N_{VHTLTF} \quad (22\text{-}29)$$

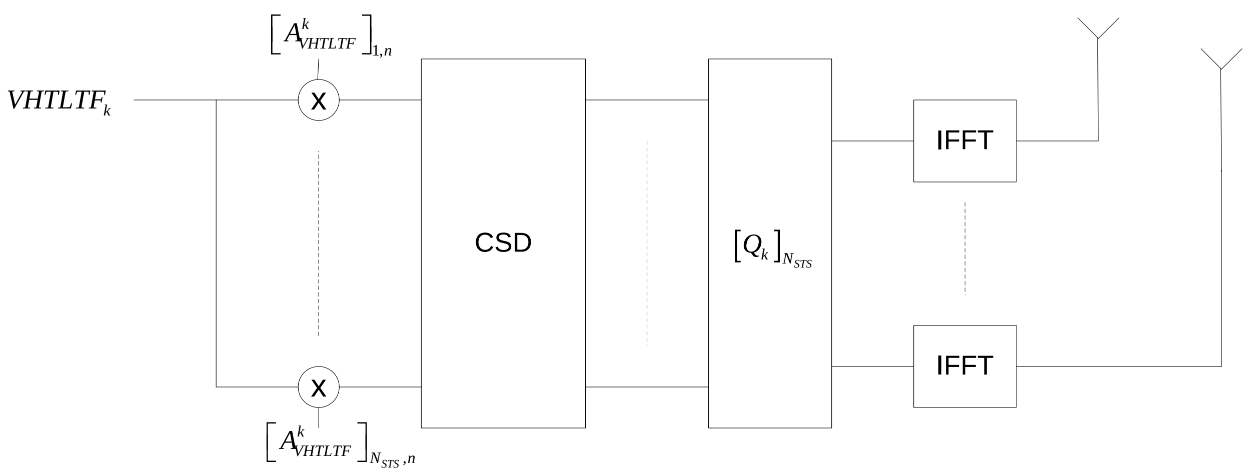

Figure 22-11 -- Generation of VHT-LTFs

The time domain representation of the waveform transmitted on frequency segment i_{Seg} of transmit chain i_{TX} during VHT-LTF n, $1 \le n \le N_{VHTLTF}$ shall be as described by Equation (22-30).

$$r_{\text{VHT-LTF}}^{(i_{\text{Seg}},i_{\text{TX}},n)}(t)=\frac{1}{\sqrt{N_{\text{VHT-LTF}}^{\text{Tones}}N_{\text{STS,total}}}}w_{T_{\text{VHT-LTFs}}}(t)$$
$$\cdot\sum_{k=-N_{SR}}^{N_{SR}}\sum_{u=0}^{N_u-1}\sum_{m=1}^{N_{\text{STS},u}}\left[Q_k^{(i_{\text{Seg}})}\right]_{i_{\text{TX}},(M_u+m)}\Upsilon_{k,\text{BW}}\left[A_{VHTLTF}^{k}\right]_{(M_u+m),n}VHTLTF_k$$
$$\cdot\exp\left(j2\pi k\Delta_F\left(t-T_{\text{GI}}-T_{\text{CS,VHT}}\left(M_u+m\right)\right)\right) \quad (22\text{-}30)$$

where

N_u is defined in Table 22-5,

$N_{\text{VHT-LTF}}^{\text{Tone}}$ has the value given in Table 22-6,

$N_{\text{STS,total}}$ is defined in Table 22-5,

$N_{\text{STS},u}$ is the number of space-time streams for user u,

$T_{\text{CS,VHT}}(n)$ is given in Table 22-8,

$Q_k^{(i_{\text{Seg}})}$ is defined in 22.3.11.10.1,

$\Upsilon_{k,BW}$ is defined in Equations (22-3), (22-4), (22-5) and (22-6),

A_{VHTLTF}^{k} is defined in Equation (22-28), and

$$P_{VHTLTF}=\begin{cases}P_{4\times4}, N_{STS}\le 4\\ P_{6\times6}, N_{STS}=5,6\\ P_{8\times8}, N_{STS}=7,8\end{cases} \quad (22\text{-}31)$$

where $P_{4\times4}$ is defined in Equation (20-27).

The VHT-LTF mapping matrix for six VHT-LTFs, $P_{6\times6}$ is defined in Equation (22-32).

$$P_{6x6}=\begin{bmatrix}1 & -1 & 1 & 1 & 1 & -1\\ 1 & -w^1 & w^2 & w^3 & w^4 & -w^5\\ 1 & -w^2 & w^4 & w^6 & w^8 & -w^{10}\\ 1 & -w^3 & w^6 & w^9 & w^{12} & -w^{15}\\ 1 & -w^4 & w^8 & w^{12} & w^{16} & -w^{20}\\ 1 & -w^5 & w^{10} & w^{15} & w^{20} & -w^{25}\end{bmatrix} \quad (22\text{-}32)$$

where $w=\exp(-j2\pi/6)$

The VHT-LTF mapping matrix for eight VHT-LTFs, $P_{8\times8}$ is defined in Equation (22-33).

$$P_{8x8}=\begin{bmatrix}P_{4x4} & P_{4x4}\\ P_{4x4} & -P_{4x4}\end{bmatrix} \quad (22\text{-}33)$$

where P_{4x4} 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.

22.3.9.2.6 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. All the fields in the VHT-SIG-B are transmitted LSB first.

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 (22-34).

$$\text{VHT-SIG-B Length}=\left\lceil \frac{\text{LENGTH}}{4} \right\rceil \tag{22-34}$$

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 (22-78), (22-79) and (22-80) 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 remaining information 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.

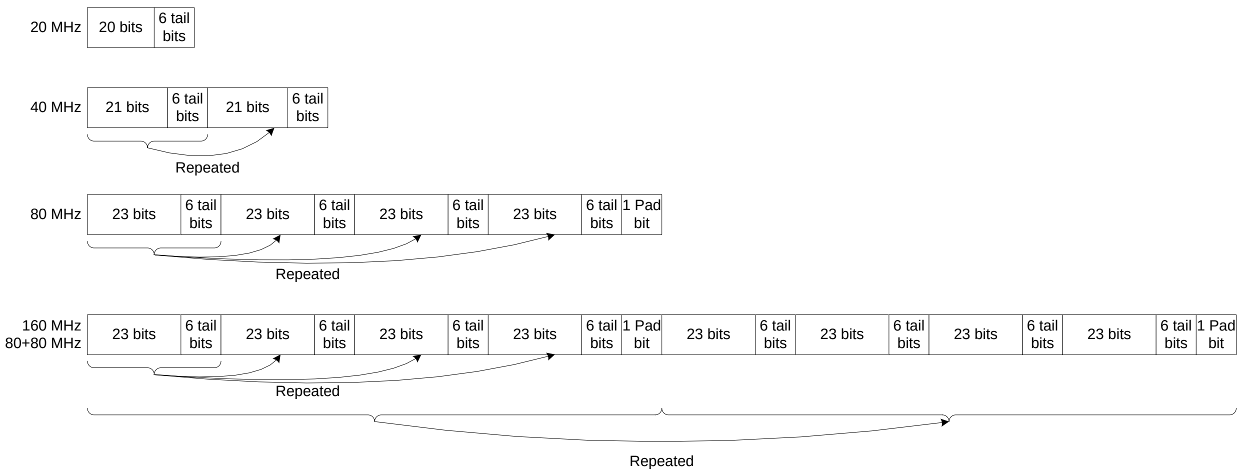

Figure 22-12--VHT-SIG-B in 20, 40, 80, 160 and 80+80 MHz PPDUs

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 N_{STS} space-time streams by the first column of P_{VHTLTF} matrix as defined in clause 22.3.9.2.5. The total number of data subcarriers and pilot subcarriers are the same as in data field. The remaining transmission flow of VHT-SIG-B is the same as Data field. The 800ns guard interval is always applied for VHT-SIG-B symbol, regardless 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:

$$r_{\text{VHT-SIG-B}}^{(i_{\text{Seg}},i_{\text{TX}})}(t)=\frac{1}{\sqrt{N_{\text{VHT-SIG-B}}^{\text{Tones}}N_{\text{STS,total}}}}w_{T_{\text{SYM}}}(t) \cdot\sum_{u=0}^{N_u-1}\sum_{k=-N_{SR}}^{N_{SR}}\sum_{m=1}^{N_{\text{STS},u}}\left[Q_k^{(i_{\text{Seg}})}\right]_{i_{\text{TX}},(M_u+m)}\Upsilon_{k,\text{BW}}\left(\left[P_{VHTLTF}\right]_{(M_u+m),1}D_k^{(u)}+p_{0+z}P_0^k\right) \cdot\exp\left(j2\pi k\Delta_F\left(t-T_{\text{GI}}-T_{\text{CS,VHT}}\left(M_u+m\right)\right)\right) \quad (22\text{-}35)$$

where

N_u is defined in Table 22-5,

$N_{\text{VHT-SIG-B}}^{\text{Tone}}$ has the value given in Table 22-6,

$N_{\text{STS},u}$ is the number of space-time streams for user u,

$T_{\text{CS,VHT}}(n)$ is given in Table 22-8,

M_u is given by $M_u=\sum_{u'=0}^{u-1}N_{\text{STS},u'}$ (note that $M_0=0$),

$Q_k^{(i_{\text{Seg}})}$ is defined in Section 22.3.11.10.1,

z is 3,

p_n is defined in Section 17.3.5.9,

P_n^k is defined in Section 22.3.11.9,

$\Upsilon_{k,BW}$ is defined in Equations (22-3), (22-4), (22-5) and (22-6),

P_{VHTLTF} is given by Equation (22-31).

For 20 MHz VHT transmissions,

$$D_k^{(u)} = \begin{cases} 0, & k = 0, \pm 7, \pm 21 \\ d_{M^r(k)}^{(u)}, & \text{otherwise} \end{cases} \tag{22-36}$$

$$M^r(k) = \begin{cases} k+28, & -28 \le k \le -22 \\ k+27, & -20 \le k \le -8 \\ k+26, & -6 \le k \le -1 \\ k+25, & 1 \le k \le 6 \\ k+24, & 8 \le k \le 20 \\ k+23, & 22 \le k \le 28 \end{cases} \tag{22-37}$$

For 40 MHz VHT transmissions,

$$D_k^{(u)} = \begin{cases} 0, & k = 0, \pm 1, \pm 11, \pm 25, \pm 53 \\ d_{M^r(k)}^{(u)}, & \text{otherwise} \end{cases} \tag{22-38}$$

$$M^r(k) = \begin{cases} k+58, & -58 \le k \le -54 \\ k+57, & -52 \le k \le -26 \\ k+56, & -24 \le k \le -12 \\ k+55, & -10 \le k \le -2 \\ k+52, & 2 \le k \le 10 \\ k+51, & 12 \le k \le 24 \\ k+50, & 26 \le k \le 52 \\ k+49, & 54 \le k \le 58 \end{cases} \tag{22-39}$$

For 80 MHz VHT transmissions,

$$D_k^{(u)} = \begin{cases} 0, & k = 0, \pm 1, \pm 11, \pm 39, \pm 75, \pm 103 \\ d_{M^r(k)}^{(u)}, & \text{otherwise} \end{cases} \tag{22-40}$$

$$M^r(k) = \begin{cases} k+122, & -122 \le k \le -104 \\ k+121, & -102 \le k \le -76 \\ k+120, & -74 \le k \le -40 \\ k+119, & -38 \le k \le -12 \\ k+118, & -10 \le k \le -2 \\ k+115, & 2 \le k \le 10 \\ k+114, & 12 \le k \le 38 \\ k+113, & 40 \le k \le 74 \\ k+112, & 76 \le k \le 102 \\ k+111, & 104 \le k \le 122 \end{cases} \quad (22\text{-}41)$$

For 160 MHz VHT transmissions

$$D_k^{(u)} = \begin{cases} 0, & k = 0, \pm\{1,2,3,4,5\}, \pm25, \pm53, \pm89, \pm117, \pm127, \pm128, \pm129, \pm139, \pm167, \pm203, \pm231 \\ d_{M^r(k)}^{(u)}, & \text{otherwise} \end{cases} \quad (22\text{-}42)$$

$$M^r(k) = \begin{cases} k+250, & -250 \le k \le -232 \\ k+249, & -230 \le k \le -204 \\ k+248, & -202 \le k \le -168 \\ k+247, & -166 \le k \le -140 \\ k+246, & -138 \le k \le -130 \\ k+243, & -126 \le k \le -118 \\ k+242, & -116 \le k \le -90 \\ k+241, & -88 \le k \le -54 \\ k+240, & -52 \le k \le -26 \\ k+239, & -24 \le k \le -6 \\ k+228, & 6 \le k \le 24 \\ k+227, & 26 \le k \le 52 \\ k+226, & 54 \le k \le 88 \\ k+225, & 90 \le k \le 116 \\ k+224, & 118 \le k \le 126 \\ k+221, & 130 \le k \le 138 \\ k+220, & 140 \le k \le 166 \\ k+219, & 168 \le k \le 202 \\ k+218, & 204 \le k \le 230 \\ k+217, & 232 \le k \le 250 \end{cases} \quad (22\text{-}43)$$

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 (22-40) and (22-41).

In Equations (22-36), (22-38), (22-40) and (22-42), $d_k^{(u)}$ is the constellation of VHT-SIG B (prior to multiplication by P_{VHTLTF}) for user u at the k-th subcarrier.

22.3.10 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 using up to four transmit chains, it shall apply the cyclic shifts defined in Table 20-8 to the transmission in each chain. Note >4 transmit chains is TBD.

22.3.11 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 MAC and 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 ($6N_{ES}$ bits), in that order as shown in Figure 22-13. 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.

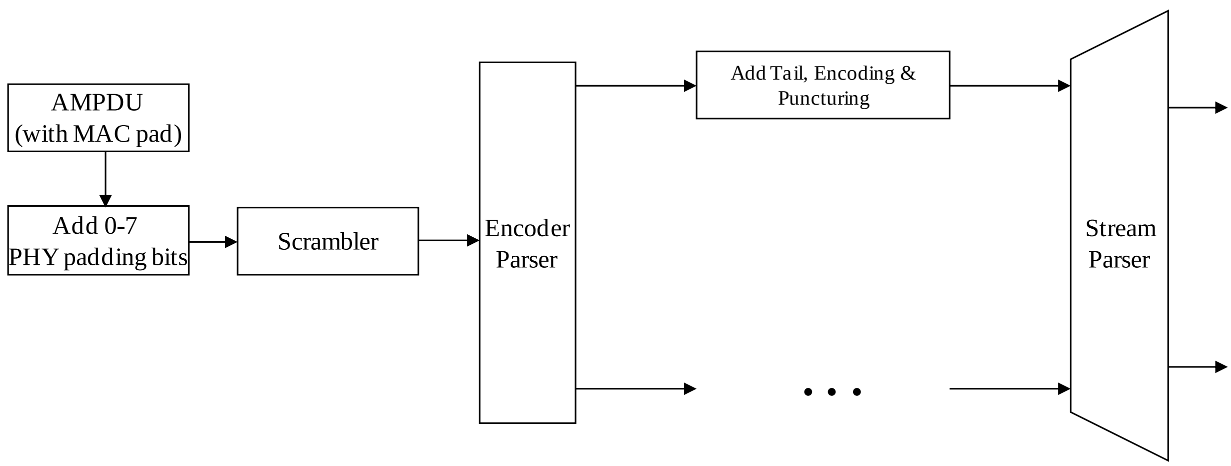

Figure 22-13—Per user Data field encoding with BCC

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*. The PHY determines the number of pad bits to add using Equation (22-44) and appends them to the PSDU. The number of pad bits added will always be between 0 and 7 inclusive.

$$N_{PAD,u} = N_{SYM} N_{DBPS,u} - 8 \cdot \mathrm{PSDU\_LENGTH}_u - N_{service} - N_{tail,u} N_{ES,u} \tag{22-44}$$

where

$\mathrm{PSDU\_LENGTH}_u$ is the number of octets delivered by the MAC for user *u* and is given by Equation (22-80),

N_{SYM} is the number of symbols in the Data field and is the same for all users,

$N_{tail,u}$ is the number of tail bits for user *u*,

$N_{ES,u}$ is the number of BCC encodes for user *u*.

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.

22.3.11.1 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.

22.3.11.2 CRC calculation for VHT-SIG-B

The CRC calculation and insertion is illustrated in Figure 22-14.

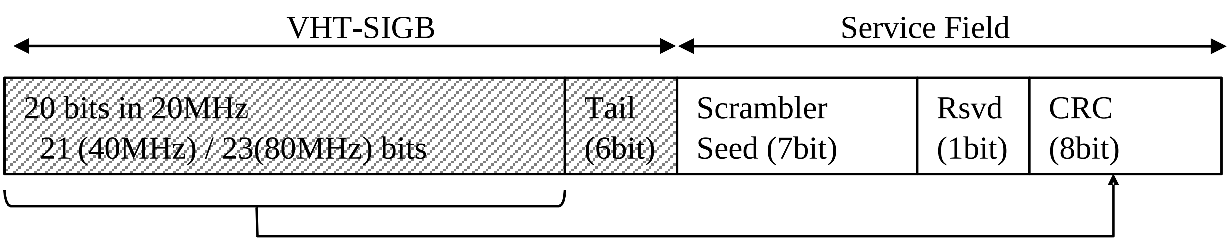

Figure 22-14--VHT-SIG-B and SERVICE field relationship

The value of the CRC field shall be the ones complement of

$$crc(D) = (M(D) \oplus I(D))D^8 \bmod G(D) \tag{22-45}$$

where

$$M(D) = m_0 D^{N-1} + m_1 D^{N-2} + \ldots + m_{N-2} D + m_{N-1}$$

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,

m_i is bit i of VHT-SIG-B,

$I(D) = \sum_{i=N-8}^{N-1} D^i$ are initialized values that are added modulo 2 to the first 8 bits of VHT-SIG-B,

$G(D) = D^8 + D^2 + D + 1$ is the CRC generating polynomial, and

$crc(D) = c_0 D^7 + c_1 D^6 + \ldots + c_6 D + c_7$

The CRC field is transmitted with c_7 first.

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, c_7 first, through an inverter.

As an example, if bits $\{m_0, \ldots m_{22}\}$ 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}.

22.3.11.3 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.

22.3.11.4 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 0. When BCC FEC encoding is used, the number of encoders is determined by rate-dependent parameters as defined in 22.6. 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.

22.3.11.4.1 Binary convolutional coding

22.3.11.4.1.1 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 i^{th} bit to the j^{th} encoder, denoted $x_i^{(j)}$, is:

$$x_i^{(j)} = b_{N_{ES} \cdot i + j} \quad ; \quad 0 \le j \le N_{ES} - 1$$

Following the parsing operation, 6 zero tail bits are appended in each FEC input sequence.

Encoder parsing is omitted in case of LDPC coding.

22.3.11.4.1.2 Binary convolutional coding and puncturing

The encoder parser output sequences $\left\{x_i^j\right\}$, $0 \le j \le N_{ES} - 1$,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, 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.

22.3.11.4.2 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, N_{pld} for VHT packets shall be computed using Equation (22-46) instead of Equation (20-35).

$$N_{pld} = \frac{N_{SYM,init}}{m_{\mathrm{STBC}}} N_{DBPS} \qquad (22\text{-}46)$$

where

m_{STBC} is equal to 2 when STBC is used, and 1 otherwise

N_{DBPS} is defined in Table 22-5

$N_{SYM,init}$ is given by Equation (22-47)

$$N_{SYM,init} = m_{\mathrm{STBC}} \times \left\lceil \frac{8 \cdot \mathrm{LENGTH} + 16}{m_{\mathrm{STBC}} \cdot N_{DBPS}} \right\rceil \qquad (22\text{-}47)$$

where

LENGTH is LENGTH parameter in the TXVECTOR

In addition, if N_{SYM} computed in Equation (20-41) in step (d) of Section 20.3.11.6.5 is greater than $N_{SYM,init}$, then B3 of VHT-SIG-A2 should be set to 1. Otherwise, B3 of VHT-SIG-A2 should be set to 0.

LDPC codes defined in Section 20.3.11.6 shall also be used for MU packets. Refer to Section 22.3.11.8 for LDPC encoding process in case of MU packets.

22.3.11.4.3 Encoding process for MU transmissions

In case of MU transmission, the transmitter first computes the initial number of OFDM symbols using Equation (22-48).

$$N_{\mathrm{SYM\_init},u} = \begin{cases} m_{\mathrm{STBC}} \times \left\lceil \dfrac{8 \cdot \mathrm{LENGTH}_u + 16 + 6 \cdot N_{\mathrm{ES},u}}{m_{\mathrm{STBC}} \cdot N_{\mathrm{DBPS},u}} \right\rceil & \text{when user } u \text{ uses BCC} \\ m_{\mathrm{STBC}} \times \left\lceil \dfrac{8 \cdot \mathrm{LENGTH}_u + 16}{m_{\mathrm{STBC}} \cdot N_{\mathrm{DBPS},u}} \right\rceil & \text{when user } u \text{ uses LDPC} \end{cases} \qquad (22\text{-}48)$$

where

LENGTH_u is the LENGTH parameter for user *u* in the TXVECTOR.

m_{STBC} is equal to 2 when STBC is used, and 1 otherwise

$N_{ES,u}$ is N_{ES} for user *u*, where N_{ES} is defined in Table 22-5

$N_{DBPS,u}$ is N_{DBPS} for user *u*, where N_{DBPS} is defined in Table 22-5

Based on the above equation, the initial estimate of the longest symbol length can be obtained by:

$$N_{\mathrm{SYM\_max\_init}} = \max\left\{N_{\mathrm{SYM\_init},u}\right\}_{u=0}^{u=N_u-1} \qquad (22\text{-}49)$$

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 (22-46) is used to compute N_{pld} instead of Equation (20-35). Let $N_{SYM,u}$ be the N_{SYM} computed by Equation (20-41) in step (d) of Section 20.3.11.6.5 for user u.

Note – The purpose of going through steps (a) to (d) in Section 20.3.11.6 in the above paragraph is to compute $N_{SYM,u}$. Thus, it is not necessary to actually encode the data using LDPC at this stage.

For BCC users, $N_{SYM,u} = N_{SYM\_init,u}$.

Then, compute the packet length using Equation (22-50).

$$N_{SYM} = \max\left\{N_{SYM,u}\right\}_{u=0}^{N_u-1} \qquad (22\text{-}50)$$

When constructing the Data field for users encoded using LDPC code, MAC and PHY padding shall be added to fill up $N_{\mathrm{SYM\_max\_init}}$ symbols computed in Equation (22-49). 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, N_{pld} shall be computed using Equation (22-46) instead of Equation (20-35). Next, step (d) in Section 20.3.11.6.5 is modified as shown below.

d) If N_{SYM} computed in Equation (22-50) is equal to $N_{\text{SYM\_max\_init}}$, then the number of bits to be punctured, N_{punc}, from the codewords after encoding is computed as shown in Equation (20-38).
If N_{SYM} computed in Equation (22-50) is greater than $N_{\text{SYM\_max\_init}}$, then the number of bits to be punctured, N_{punc}, from the codewords after encoding is computed using Equations (20-39) and (20-40).
The punctured bits shall be equally distributed over all N_{CW} codewords with the first $\text{rem}\left(N_{punc}, N_{CW}\right)$ codewords punctured 1 bit more than the remaining codewords. Define $N_{ppcw} = \left\lfloor N_{punc} / N_{CW} \right\rfloor$. When $N_{ppcw} > 0$, the puncturing is performed by discarding parity bits $p_{n-k-N_{ppcw}-1}, \cdots, p_{n-k-1}$ of the first $\text{rem}\left(N_{punc}, N_{CW}\right)$ codewords and discarding parity bits $p_{n-k-N_{ppcw}}, \cdots, p_{n-k-1}$ of the remaining codewords after encoding.

When constructing the Data field for users encoded using BCC, MAC and PHY padding shall be added to fill up N_{SYM} symbols computed in Equation (22-50). 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 N_{SYM} computed in Equation (22-50) is greater than $N_{\text{SYM\_max\_init}}$ computed in Equation (22-49), then B3 of VHT-SIG-A2 should be set to 1. Otherwise, B3 of VHT-SIG-A2 should be set to 0.

22.3.11.5 Stream parser

After coding and puncturing, the data bit streams at the output of the FEC encoders are re-arranged into N_{SS} blocks of N_{CBPSS} 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 (22-51).

$$s = \max\left\{1, \frac{N_{BPSCS}}{2}\right\} \qquad (22\text{-}51)$$

The sum of these over all streams is: $S = \sum_{i_{SS}=0}^{N_{SS}-1} s = N_{SS} \cdot s$

Consecutive blocks of s 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, S bits from the output of first encoder are fed into all spatial streams, and then S bits from the output of next encoder are used, and so on.

Input k to spatial stream i_{SS} is $y_i^{(j)}$, which is the output bit i of encoder j:

$$j = \left\lfloor \frac{k}{s} \right\rfloor \bmod N_{ES} \qquad (22\text{-}52)$$

and

$$i = \sum_{i'=1}^{i_{SS}-1} s + S \cdot \left\lfloor \frac{k}{N_{ES} \cdot s} \right\rfloor + k \bmod s \qquad (22\text{-}53)$$

where

$\lfloor x \rfloor$ is the largest integer less than or equal to x

$z \bmod t$ is the remainder resulting from the division of integer z by integer t

For $i_{SS} = 1$, the first term in Equation (22-53) has a value of 0.

For 160MHz 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(N_{CBPS}/N_{ES}/S)) of S bits at each encoder. Assuming that at this point in each OFDM symbol each BCC has M.s (M<N_{SS}) 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 the (M + 1)-th spatial stream, and so on. Note that upon reaching the N_{SS}-th spatial stream, we cycle back to the 1st spatial stream. Repeat till all bits are distributed in the current OFDM symbol.

22.3.11.6 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 N_{CBPSS} bits. Then, each block is further divided into two subblocks of $N_{CBPSS}/2$ bits as shown in Equation (22-54).

$$y_{k,l} = x_{2s \cdot N_{es} \left\lfloor \frac{k}{s \cdot N_{ES}} \right\rfloor + l \cdot s \cdot N_{ES} + k \bmod (s \cdot N_{ES})}, \qquad k = 0,1,\cdots,N_{CPBSS}/2 \qquad (22\text{-}54)$$

where

$\lfloor z \rfloor$ is the largest integer less than or equal to z

$z \bmod t$ is the remainder resulting from the division of integer z by integer t

x_m is the m th bit of a block of N_{CBPSS} bits, m = 0 to $N_{CBPSS} - 1$

l is the subblock index, $l = 0,1$

$y_{k,l}$ is the k th bit of of the subblock l

s is defined in Equation (22-51)

N_{ES} is defined in Table 22-5

If N_{CBPSS} is not divisible by $2s \cdot N_{\mathrm{ES}}$, then apply the segment parsing method described in Equation (22-54) for $\left\lfloor N_{CBPSS}/(2s \cdot N_{\mathrm{ES}}) \right\rfloor$ blocks of $2s \cdot N_{\mathrm{ES}}$ segment parser input bits. At this point, each stream parser output has $2s \cdot R$ $\left(R < N_{\mathrm{ES}},\ \text{integer}\right)$ residue bits. Then, the residue bits are divided into blocks of s bits, with each block being assigned to different subblock ($l = 0,1$) in a round robin fashion. The first s bits are assigned to the subblock with index $l = 0$. Repeat R 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.

22.3.11.7 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 N_{SS} blocks of N_{CBPSS} 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 $N_{CBPSS}/2$ 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 N_{COL} and rows N_{ROW} for different bandwidths. The values of N_{COL} and N_{ROW} are given in the table below.

Table 22-13 -- Number of rows and columns in the interleaver

Parameter	20 MHz	40 MHz	80 MHz
N_{COL}	13	18	26
N_{ROW}	$4 \times N_{BPSCS}$	$6 \times N_{BPSCS}$	$9 \times N_{BPSCS}$
N_{ROT}	11	29	58

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 N_{ROT}. The values of N_{ROT} are given in Table 22-13 for up to 4 spatial streams (N_{ROT} values for greater than 4 spatial streams are TBD).

An additional parameter is the spatial stream index $i_{SS} = 1, 2 \ldots N_{SS}$. 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 (22-55).

$$i = N_{ROW}\left(k \bmod N_{COL}\right) + \left\lfloor \frac{k}{N_{COL}} \right\rfloor, \qquad k = 0,\ 1,\ \cdots,\ N_{CBPSS} - 1 \qquad (22\text{-}55)$$

where

$\lfloor x \rfloor$ is the largest integer less than or equal to x

The second permutation is defined by the rule shown in Equation (22-56).

$$j = s\left\lfloor \frac{i}{s} \right\rfloor + \left(i + N_{CBPSS} - \left\lfloor \frac{N_{COL} \cdot i}{N_{CBPSS}} \right\rfloor\right) \bmod s, \qquad i = 0,\ 1,\ \cdots,\ N_{CBPSS} - 1 \qquad (22\text{-}56)$$

where

s is defined in Equation (22-51).

If more than one spatial stream exists, a frequency rotation is applied to the output of the second permutation as shown in Equation (22-57).

$$r = \left\{ j - \left[\left(2\left(i_{SS} - 1\right) \right) \bmod 3 + 3 \left\lfloor \frac{i_{SS} - 1}{3} \right\rfloor \right] N_{ROT} N_{BPSCS} \right\} \bmod N_{CBPSS}, \quad j = 0, 1, \cdots, N_{CBPSS} - 1 \tag{22-57}$$

where

$i_{SS} = 1, 2 \ldots N_{SS}$ is the index of the spatial steam on which this interleaver is operating.

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 operation reverses the third (frequency rotation) permutation of the interleaver as shown in Equation (22-58).

$$j = \left\{ r + \left[\left(2\left(i_{SS} - 1\right) \right) \bmod 3 + 3 \left\lfloor \frac{i_{SS} - 1}{3} \right\rfloor \right] N_{ROT} N_{BPSCS} \right\} \bmod N_{CBPSS}, \quad r = 0, 1, \cdots, N_{CBPSS} - 1 \tag{22-58}$$

Editor's note: The above 2 expressions need to be updated for greater than 4 spatial streams.

The second operation defined by Equation (22-59) reverses the second permutation in the interleaver.

$$i = s \left\lfloor \frac{j}{s} \right\rfloor + \left(j + \left\lfloor \frac{N_{COL} \cdot j}{N_{CBPSS}} \right\rfloor \right) \bmod s, \qquad j = 0, 1, \cdots, N_{CBPSS} - 1 \tag{22-59}$$

where

s is defined in Equation (22-51).

The third operation defined in Equation (22-60) reversed the first permutation of the interleaver.

$$k = N_{COL} \cdot i - \left(N_{CBPSS} - 1 \right) \left\lfloor \frac{i}{N_{ROW}} \right\rfloor, \qquad i = 0, 1, \cdots, N_{CBPSS} - 1 \tag{22-60}$$

22.3.11.8 Constellation mapping

22.3.11.8.1 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:

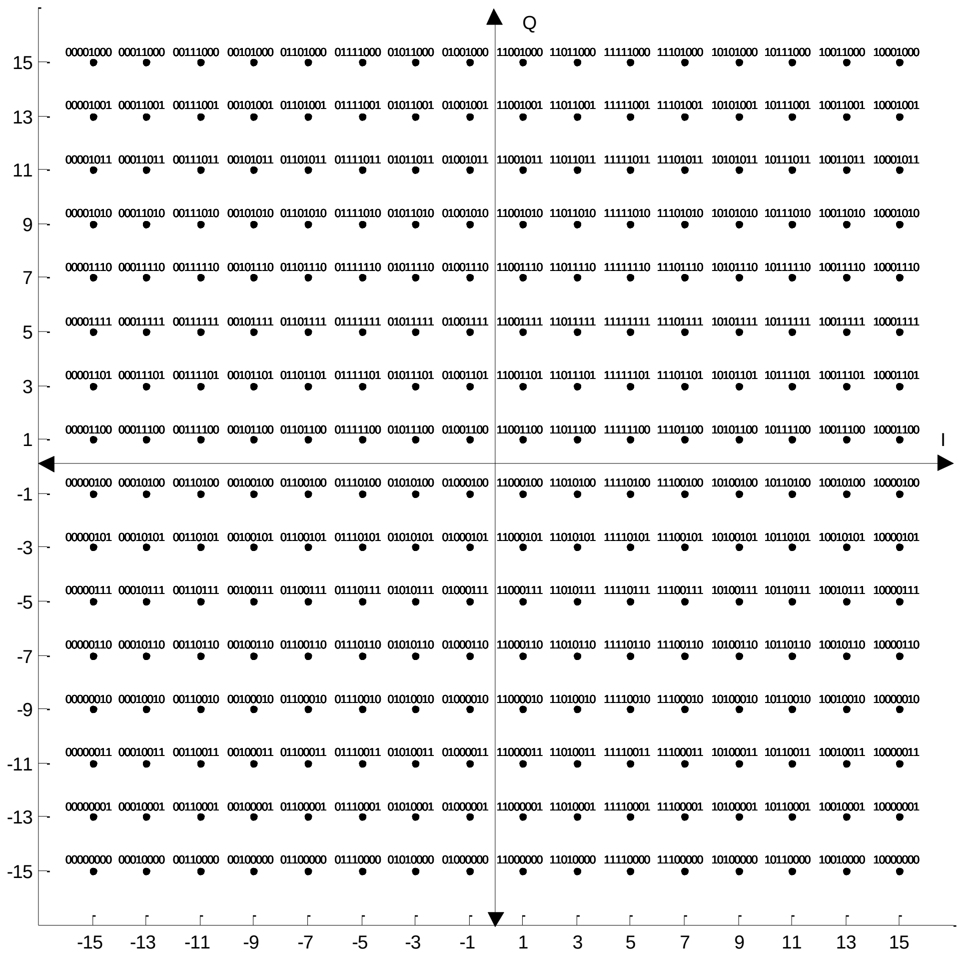

Figure 22-15 -- Constellation bit encoding for 256 QAM

The streams of complex numbers are denoted:

$$d_{k,l,n},\ k = 0,1,\ldots,N_{\mathrm{SD}}-1,\ l = 1,\ldots,N_{\mathrm{SS}},\ n = 0,1,\ldots,N_{\mathrm{SYM}}-1$$

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 $d_{k,l,n}$, k = 0,1,...,N_{SD}/2-1, while the output bits of the interleaver corresponding to the subblock l=1 is used to to form the complex numbers $d_{k,l,n}$, $k = N_{SD}/2, N_{SD}/2+1, \ldots, N_{SD}-1$.

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 $d_{k,l,n}$ 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 $K_{MOD} = 1/\sqrt{170}$.

22.3.11.8.2 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 N_{CBPS}). To achieve sufficient frequency diversity at all rates, LDPC tone mapping shall be performed on all LDPC-coded streams, as described in this subclause, using an LDPC tone-mapping distance parameter, D_{TM}. D_{TM} is constant for each bandwidth, and its values for different bandwidths are given in Table 22-14. LDPC tone mapping shall not be performed on streams that are encoded using BCC.

Table 22-14--LDPC tone mapping distance for each bandwidth

Parameter	20 MHz	40 MHz	80 MHz	160, 80+80 MHz
D_{TM}	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

$$d_{k,l,n},\ k = 0,1,\ldots,N_{\mathrm{SD}}-1,\ l = 1,\ldots,N_{\mathrm{SS},u},\ n = 0,1,\ldots,N_{\mathrm{SYM}}-1,$$

generated by the constellation mappers, to obtain

$$d'_{k,l,n} = d_{t(k),l,n},\ k = 0,1,\ldots,N_{\mathrm{SD}}-1,\ l = 1,\ldots,N_{\mathrm{SS},u},\ n = 0,1,\ldots,N_{\mathrm{SYM}}-1,$$

where

$$t(k) = D_{TM}.(k \bmod \frac{N_{SD}}{D_{TM}}) + \left\lfloor \frac{k.D_{TM}}{N_{SD}} \right\rfloor.$$

As a result of the LDPC tone mapping operation above, each two consecutively-generated complex constellation numbers $d_{k,l,n}$ and $d_{k+1,l,n}$ will be transmitted through two data tones which are separated by at least $D_{TM}-1$ other data tones.

Note that the operation above is equivalent to block-interleaving the complex numbers $d_{0,l,n},\ldots,d_{N_{SD}-1,l,n}$ for each *l*, *n* using a matrix with D_{TM} rows and $\frac{N_{SD}}{D_{TM}}$ columns, where $d_{0,l,n},\ldots,d_{N_{SD}-1,l,n}$ are written row-wise into the matrix, and $d'_{0,l,n},\ldots,d'_{N_{SD}-1,l,n}$ 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 same formulas as above, except that the index mapping function $t(k)$ is changed to

$$\left.\begin{array}{l} t(k) = D_{TM}.(k \bmod \dfrac{N_{SD}/2}{D_{TM}}) + \left\lfloor \dfrac{k.D_{TM}}{N_{SD}/2} \right\rfloor, \\ t(k+\dfrac{N_{SD}}{2}) = t(k) + \dfrac{N_{SD}}{2} \end{array}\right\} \text{for } k = 0,\ldots,\frac{N_{SD}}{2}-1.$$

Since LDPC tone mapping is not performed on BCC-coded streams, for BCC-coded streams, we have

$$d'_{k,l,n} = d_{k,l,n},\ k = 0,1,\ldots,N_{\mathrm{SD}}-1,\ l = 1,\ldots,N_{\mathrm{SS},u},\ n = 0,1,\ldots,N_{\mathrm{SYM}}-1.$$

22.3.11.8.3 Space-time block coding

TBD

22.3.11.9 Pilot subcarriers

For a 20 MHz transmission, four pilot tones shall be inserted in subcarriers –21, –7, 7, and 21. The pilot mapping P_n^k for the *k*th subcarrier for the *n*th symbol shall be as follows

$$P_n^{\{-21,-7,7,21\}} = \left\{\Psi^{(1)}_{1,n \bmod 4}, \Psi^{(1)}_{1,(n+1) \bmod 4}, \Psi^{(1)}_{1,(n+2) \bmod 4}, \Psi^{(1)}_{1,(n+3) \bmod 4}\right\}$$
$$P_n^{k \notin \{-21,-7,7,21\}} = 0 \qquad (22\text{-}61)$$

where $\Psi^{(1)}_{1,m}$ is given by the N_{STS} = 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 P_n^k for the *k*th subcarrier for the *n*th symbol shall be as follows

$$P_n^{\{-53,-25,-11,11,25,53\}} = \left\{\Psi^{(1)}_{1,n \bmod 6}, \Psi^{(1)}_{1,(n+1) \bmod 6}, \Psi^{(1)}_{1,(n+2) \bmod 6}, \Psi^{(1)}_{1,(n+3) \bmod 6}, \Psi^{(1)}_{1,(n+4) \bmod 6}, \Psi^{(1)}_{1,(n+5) \bmod}\right.$$
$$P_n^{k \notin \{-53,-25,-11,11,25,53\}} = 0 \qquad (22\text{-}62)$$

where $\Psi^{(1)}_{1,m}$ is given by the N_{STS} = 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 P_n^k for the *k*th subcarrier for the *n*th symbol shall be as follows

$$P_n^{\{-103,-75,-39,-11,11,39,75,103\}} = \{\Psi_{n \bmod 8}, \Psi_{(n+1) \bmod 8}, \Psi_{(n+2) \bmod 8}, \Psi_{(n+3) \bmod 8}, \ldots$$
$$\Psi_{(n+4) \bmod 8}, \Psi_{(n+5) \bmod 8}, \Psi_{(n+6) \bmod 8}, \Psi_{(n+7) \bmod 8}\} \qquad (22\text{-}63)$$
$$P_n^{k \notin \{-103,-75,-39,-11,11,39,75,103\}} = 0$$

where Ψ_m is defined in Table 22-15.

Table 22-15 – Pilot values for 80 MHz transmission

Ψ_0	Ψ_1	Ψ_2	Ψ_3	Ψ_4	Ψ_5	Ψ_6	Ψ_7
1	1	1	-1	-1	1	1	1

For a 160 MHz transmission, the 80 MHz pilot mapping shall be 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 P_n^k for the *k*th subcarrier for the *n*th symbol shall be as follows

$$P_n^{\{-231,-203,-167,-139,-117,-89,-53,-25,25,53,89,117,139,167,203,231\}}$$
$$= \left\{\Psi_{n \bmod 8}, \Psi_{(n+1) \bmod 8}, \Psi_{(n+2) \bmod 8}, \Psi_{(n+3) \bmod 8}, \Psi_{(n+4) \bmod 8}, \Psi_{(n+5) \bmod 8}, \Psi_{(n+6) \bmod 8}, \Psi_{(n+7)}\right. \qquad (22\text{-}64)$$
$$\Psi_{n \bmod 8}, \Psi_{(n+1) \bmod 8}, \Psi_{(n+2) \bmod 8}, \Psi_{(n+3) \bmod 8}, \Psi_{(n+4) \bmod 8}, \Psi_{(n+5) \bmod 8}, \Psi_{(n+6) \bmod 8}, \Psi_{(n+7}$$

where Ψ_m is given in Table 22-15.

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 (22-63) and Table 22-15.

The above pilot mapping shall be copied on all space-time streams before the space-time stream cyclic shifts are applied.

22.3.11.10 OFDM modulation

22.3.11.10.1 Transmission in VHT format

For VHT transmissions, the signal from transmit chain i_{TX}, $1 \le i_{TX} \le N_{TX}$ shall be as follows

$$
\begin{aligned}
r_{\text{VHT-DATA}}^{(i_{\text{Seg}},i_{\text{TX}})}(t) = {} & \frac{1}{\sqrt{N_{\text{VHT-DATA}}^{\text{Tones}} N_{\text{STS,total}}}} \sum_{n=0}^{N_{\text{SYM}}-1} w_{T_{\text{SYM}}}(t-nT_{\text{SYM}}) \\
& \cdot \sum_{u=0}^{N_u-1} \sum_{k=-N_{SR}}^{N_{SR}} \sum_{m=1}^{N_{\text{STS},u}} \left[Q_k^{(i_{\text{Seg}})} \right]_{i_{\text{TX}},(M_u+m)} \Upsilon_{k,\text{BW}} \left(\tilde{D}_{k,i_{\text{STS},u},n}^{(u)} + p_{n+z} P_n^k \right) \\
& \cdot \exp\left(j2\pi k \Delta_F \left(t - nT_{\text{SYM}} - T_{\text{GI}} - T_{\text{CS,VHT}}(M_u+m) \right) \right)
\end{aligned}
\qquad (22\text{-}65)
$$

where

z	is 4,
p_n	is defined in 17.3.5.9,
P_n^k	is defined in Section 22.3.11.9,
$\Upsilon_{k,\text{BW}}$	is defined in Equations (22-3), (22-4), (22-5) and (22-6),
$D_{k,i_{STS,u},n}^{(u)}$	is the transmitted constellation for user *u* at the *k*-th subcarrier, $i_{STS,u}$ -th space-time stream and the *n*-th Data field OFDM symbol,
N_u	is defined in Table 22-5,
$N_{\text{VHT-DATA}}^{\text{Tone}}$	has the value given in Table 22-6,
$N_{\text{STS},u}$	is defined in Table 22-5,
$T_{\text{CS,VHT}}(n)$	is given in Table 22-8, and
M_u	is given by $M_u = \sum_{u'=0}^{u-1} N_{\text{STS},u'}$ (note that $M_0 = 0$)

For 20 MHz VHT transmissions

$$
\tilde{D}_{k,i_{STS},n} = \begin{cases} 0, & k = 0, \pm 7, \pm 21 \\ \tilde{d}_{M^r(k),i_{STS},n} & \text{otherwise} \end{cases} \qquad (22\text{-}66)
$$

where $M^r(k)$ is defined in Equation (22-37).

For 40 MHz VHT transmissions

$$
\tilde{D}_{k,i_{STS},n} = \begin{cases} 0, & k = 0, \pm 1, \pm 11, \pm 25, \pm 53 \\ \tilde{d}_{M^r(k),i_{STS},n} & \text{otherwise} \end{cases} \qquad (22\text{-}67)
$$

where $M^r(k)$ is defined in Equation (22-39).

For 80 MHz VHT transmissions

$$
\tilde{D}_{k,i_{STS},n} = \begin{cases} 0, & k = 0, \pm 1, \pm 11, \pm 39, \pm 75, \pm 103 \\ \tilde{d}_{M^r(k),i_{STS},n} & \text{otherwise} \end{cases} \qquad (22\text{-}68)
$$

where $M^r(k)$ is defined in Equation (22-41).

For 160 MHz VHT transmissions

$$\tilde{D}_{k,i_{STS},n} = \begin{cases} 0, & k = 0, \pm\{1,2,3,4,5\}, \pm 25, \pm 53, \pm 89, \pm 117, \\ & \quad \pm 127, \pm 128, \pm 129, \pm 139, \pm 167, \pm 203, \pm 231 \\ \tilde{d}_{M^r(k), i_{STS}, n} & \text{otherwise} \end{cases} \quad (22\text{-}69)$$

where $M^r(k)$ is defined in Equation (22-43).

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 (22-68) and (22-43).

$Q_k^{(i_{\text{Seg}})}$ is a spatial mapping matrix with N_{TX} rows and $N_{\text{STS,total}}$ columns for the k th subcarrier in the frequency segment i_{Seg}. $Q_k^{(i_{\text{Seg}})}$ may be frequency dependent. Refer to the examples of Q_k listed in Section 20.3.11.10.1 for examples of $Q_k^{(i_{\text{Seg}})}$ 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, $Q_k^{(i_{\text{Seg}})}$ is the MU-MIMO steering matrix which is implementation specific.

22.3.11.11 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 (22-69).

$$\begin{aligned} r_{non-HT,BW}^{i_{TX}}(t) = {} & \frac{1}{\sqrt{N_{NON-HT-DUP}^{Tone}(BW)}} \sum_{n=0}^{N_{SYM}-1} w_{T_{SYM}}\left(t - nT_{SYM}\right) \\ & \cdot \left(\sum_{k=-26}^{26} \left(D_{k,n} + p_{n+1} P_k \right) \right. \\ & \left. \cdot \left(\sum_{m=0}^{M} \Upsilon_{k+64\left(m-\frac{M}{2}\right),BW} \exp\left(j2\pi \left(k + 64\left(m - \tfrac{M}{2}\right)\right) \Delta_F \left(t - nT_{SYM} - T_{GI} - T_{CS}^{i_{TX}} \right)\right)\right)\right) \end{aligned} \quad (22\text{-}69)$$

where

- P_k and p_n are defined in 17.3.5.9,
- $D_{k,n}$ is defined in 20.3.9.4.3,
- M is $BW/20 - 1$ (with BW in MHz),
- $\Upsilon_{k,BW}$ is defined in Equations (22-5) and (22-6),
- $T_{CS}^{i_{TX}}$ represents the cyclic shift for transmitter chain i_{TX} 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.
- $N_{NON-HT-DUP}^{Tone}(BW)$ 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 (22-69).

22.3.12 Beamforming and MU-MIMO

22.3.12.1 General

Beamforming is a technique at the beamformer to steer signals with a knowledge of the channel in order to improve the packet reception at the beamformee. Beamforming can be applied for SU-MIMO and MU-MIMO,using the feedback information from the beamformee.

For SU-MIMO beamforming, general description for mathematical equations with a steering matrix Q_k are in 20.3.12.0a, where subscript k denotes tone index. Typically, the steering matrix Q_k is the same as the beamforming feedback matrix V_k 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 7.3.1.61 (VHT Compressed Beamforming Report Field).

For MU-MIMO beamforming, the receive signal vector in subcarrier k at i^th beamformee, $\mathbf{y}_{\boldsymbol{k},\boldsymbol{i}} = [y_{k,1}, y_{k,2}, \dots, y_{k,N_{TX}}]^T$, is shown in Equation (22-70), when a transmit signal vector for multiple users up to the N_u beamformee is $\boldsymbol{x}_{\mathbf{k}} = [\boldsymbol{x}_{k,1}{}^T, \boldsymbol{x}_{k,2}{}^T, \dots \boldsymbol{x}_{k,N_u}{}^T]^T$ with $\mathbf{x}_{\boldsymbol{k},\boldsymbol{i}} = [x_{k,1}, x_{k,2}, \dots, x_{k,N_{STS,i}}]^T$ for the i^th beamformee.

$$\mathbf{y}_{k,i} = \mathbf{H}_{\mathrm{k,i}} \times [\boldsymbol{Q}_{k,1}, \boldsymbol{Q}_{k,2}, \dots, \boldsymbol{Q}_{k,N_u}] \times \boldsymbol{x}_{\mathbf{k}} + \mathbf{n} \quad (22\text{-}70)$$

where

$\mathbf{H}_{k,i}$	is the channel matrix from the beamformer to the i^th beamformee with dimensions $N_{RX_i} \times N_{TX}$ in subcarrier k
N_{RX_i}	is the number of receive antennas at the i^th beamformee
N_{STS_i}	is the number of space-time streams of signal that is transmitted to the i^th beamformee
$\boldsymbol{Q}_{k,i}$	is a steering matrix for the i^th beamformee with dimensions $N_{TX} \times N_{STS_i}$ in subcarrier k
N_u	is the number of MU-MIMO packet recipients. $1 \le N_u \le 4$ (see 22.3.7)
$\mathbf{n}$	is white complex Gaussian noise

The MU-MIMO steering matrix $\boldsymbol{Q}_{\boldsymbol{k}} = [\boldsymbol{Q}_{k,1}, \boldsymbol{Q}_{k,2}, \dots, \boldsymbol{Q}_{k,N_u}]$ can be found by the beamformer using the beamforming feedback matrices $V_{k,j}$ and SNR_j information from beamformee, where j=1,2,…,N_u. The steering matrix that is computed (or updated) using new beamforming feedback matrices and new SNR information from some or all of participating beamformee may replace the existing steering matrix $\boldsymbol{Q}_{\boldsymbol{k}}$ for the next MU-MIMO data transmission. When there are feedback information from more than N_u STAs available at the beamformer, the beamformer may choose a beamformee group with N_u STAs for MU-MIMO data transmission with which the steering matrix can be designed to easily reduce crosstalk interference between beamformee. The choice of beamformee group for MU-MIMO data transmission is signaled using Group ID field in VHT-SIG-A (see 0 and 22.3.12.3 (Group ID)).

22.3.12.2 Beamforming Feedback Matrix V

Upon reception of NDP sounding PPDU, the beamformee shall remove the space-time stream CSD in Table 22-7 (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, V_k, found by the beamformee shall be compressed in the form of angles which are sent to the beamformer. The way to find those angles is described in 20.3.12.2.5 (Compressed Beamforming Feedback Matrix). When beamformee finds the angles, $\phi(k)$ and $\psi(k)$, this angle information is quantized as in Table 7-25j to be included in the feedback report. 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.

When the beamformer receives the angle information, $\phi(k)$ and $\psi(k)$, from the beamformee, the beamformer can decompress it to reconstruct V_k matrix using Equation (20-79). For SU-MIMO beamforming, the beamformer can use this V_k matrix as a steering matrix Q_k. For MU-MIMO beamforming, the beamformer may recalculate a steering matrix $\boldsymbol{Q_k} = [\boldsymbol{Q}_{k,1}, \boldsymbol{Q}_{k,2}, \dots, \boldsymbol{Q}_{k,Nu}]$ to transmit MU-MIMO data packets, by using $V_{k,j}$ and SNR_j information from Nu beamformee ($1 \leq j \leq N_u$), in order to suppress crosstalk between participating beamformees. How to use $V_{k,i}$ and SNR_i information to find an MU-MIMO steering matrix Q_k is implementation specific.

22.3.12.3 Group ID

For an MU-MIMO data packet, VHT-LTFs are used to measure not only the channel for the designated signals but also to suppress the interference at a beamformee. In order to identify which streams are used to measure the channels to the designated signals and which streams are used to measure the channels to interference (during the VHT-LTFs), the beamformer uses Group ID field and Nsts field in VHT preamble (22.3.9.2.3 VHT-SIG-A definition).

Group ID defines the groups for MU-MIMO transmission, where the group definition information is informed by AP to all participating MU-MIMO capable STAs. 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 N_{STS} field by locating the order of itself within the group. If an STA finds it is not a member of the group, or it is a member of the group but assigned N_{STS} indicates there is no space-time streams for it in the packet, the STA may drop the packet before processing for channel estimation with VHT-LTFs.

22.3.13 VHT preamble format for sounding PPDUs

NDP shall be the only VHT sounding format.

The VHT NDP format is shown in Figure 22-16 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 TBD fixed bit pattern

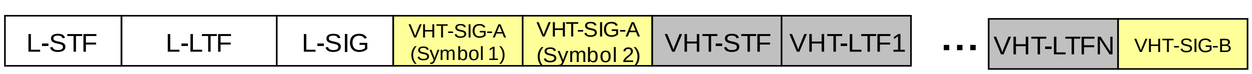

Figure 22-16—VHT NDP format

22.3.14 Regulatory requirements

22.3.15 Channel numbering and channelization

A STA may operate in any band below 6 GHz, except the 2.4 GHz band, contingent upon regulatory rules. Channel numbering in the 5 GHz band shall follow 20.3.15.2. When using 20 MHz channels in the 5 GHz band, the STA can operate in channels defined in 17.3.8.3. When using 40 MHz channels in the 5 GHz band, the STA can operate in channels defined in 20.3.15. When using 80 MHz or 160 MHz channels, the STA can operate in channels defined in 22.3.15.1. When using 80+80 MHz channels, the STA can operate in channels defined in 22.3.15.2.

22.3.15.1 80 MHz and 160 MHz channelization

The 80 MHz and 160 MHz channels are specified by three fields: (BW , $N_{\mathrm{CenterFreq}}$, $N_{\mathrm{Primary20MHz\_Ch}}$). The first field BW represents the bandwidth of the channel, and can be either 80 MHz or 160 MHz. The second field $N_{\mathrm{CenterFreq}}$ is used to represent the channel center frequency as given in Equation (22-71).

$$\text{Channel center frequency} = \text{Channel starting frequency} + 5 \times N_{\mathrm{CenterFreq}} \quad [\mathrm{MHz}] \qquad (22\text{-}71)$$

The channel starting frequency is defined as dot11ChannelStartingFactor × 500 kHz or is defined as 5 GHz for systems where dot11OperatingClassesRequired is false or not defined. The third field $N_{\mathrm{Primary20MHz\_Ch}}$ represents the channel number of the primary 20 MHz channel.

For example, an 80 MHz channel specified by $BW = 80$ MHz, $N_{\mathrm{CenterFreq}} = 42$ and $N_{\mathrm{Primary20MHz\_Ch}} = 36$ has center frequency of 5210 MHz, consists of four 20 MHz channels with channel numbers 36, 40, 44 and 48, and has the primary 20 MHz channel at channel 36.

A 160 MHz channel channel specified by $BW = 160$ MHz, $N_{\mathrm{CenterFreq}} = 50$ and $N_{\mathrm{Primary20MHz\_Ch}} = 56$ has center frequency of 5250 MHz, consists of eight 20 MHz channels with channel numbers 36, 40, 44, 48, 52, 56, 60 and 64, and has the primary 20 MHz channel at channel 56.

The set of valid operating channel numbers by regulatory domain is defined in Annex J.

22.3.15.2 80+80 MHz Channelization

Any two nonadjacent 80 MHz channels may be used in setting up an 80+80 MHz channel.

The 80+80 MHz channels are specified by four fields: (BW , $N_{\mathrm{CenterFreq,1}}$, $N_{\mathrm{CenterFreq,2}}$, $N_{\mathrm{Primary20MHz\_Ch}}$). The first field BW represents the bandwidth of the channel, and is set to 80+80 MHz for 80+80 MHz channels. The second field $N_{\mathrm{CenterFreq,1}}$ is used to represent the center frequency of the primary 80 MHz frequency segment as given in Equation (22-72).

$$\begin{aligned}&\text{Center frequency of the primary 80 MHz frequency segment}\\ &\qquad = \text{Channel starting frequency} + 5 \times N_{\mathrm{CenterFreq,1}} \quad [\mathrm{MHz}]\end{aligned} \qquad (22\text{-}72)$$

The channel starting frequency is defined as dot11ChannelStartingFactor × 500 kHz or is defined as 5 GHz for systems where dot11OperatingClassesRequired is false or not defined. The third field $N_{\mathrm{CenterFreq,2}}$ is used to represent the center frequency of the secondary 80 MHz frequency segment as given in Equation (22-73).

$$\begin{aligned}&\text{Center frequency of the secondary 80 MHz frequency segment}\\ &\qquad = \text{Channel starting frequency} + 5 \times N_{\mathrm{CenterFreq,2}} \quad [\mathrm{MHz}]\end{aligned} \qquad (22\text{-}73)$$

The fourth field $N_{\mathrm{Primary20MHz\_Ch}}$ represents the channel number of the primary 20 MHz channel.

For example, an 80+80 MHz channel specified by $BW = 80+80$ MHz, $N_{\mathrm{CenterFreq,1}} = 155$, $N_{\mathrm{CenterFreq,2}} = 106$ and $N_{\mathrm{Primary20MHz\_Ch}} = 161$ consists of two 80 MHz frequency segments. The primary frequency segment has center frequency of 5775 MHz and consists of four 20 MHz channels with channel numbers 149, 153, 157 and 161. The secondary frequency segment has center frequency of 5530 MHz and consists of four 20 MHz channels with channel numbers 100, 104, 108 and 112. Channel 161 is the primary 20 MHz channel.

22.3.16 Transmit and receive in-band and out-of-band spurious transmissions

The OFDM PHY shall conform to in-band and out-of-band spurious emissions as set by regulatory bodies.

22.3.17 Transmit RF delay

The transmitter RF delay shall follow 17.3.8.5.

22.3.18 Slot time

The slot time shall follow 17.3.8.6.

22.3.19 Transmit and receive port impedance

Transmit and receive antenna port impedance for each transmit and receive antenna shall follow 17.3.8.7.

22.3.20 PMD transmit specification

22.3.20.1 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 TBD dBm/MHz at 30 MHz frequency offset and above. Spectral density of the transmitted signal shall fall within the spectral mask shown in Figure 22-17.

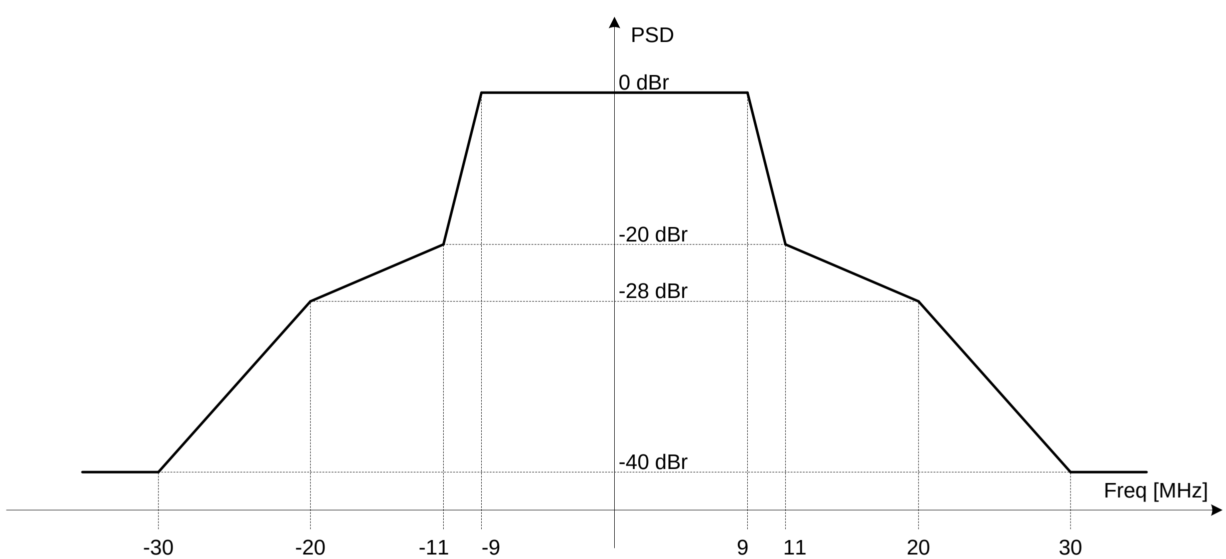

Figure 22-17--Transmit spectral mask for a 20 MHz channel

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 TBD dBm/MHz at 60 MHz frequency offset and above. Spectral density of the transmitted signal shall fall within the spectral mask shown in Figure 22-18.

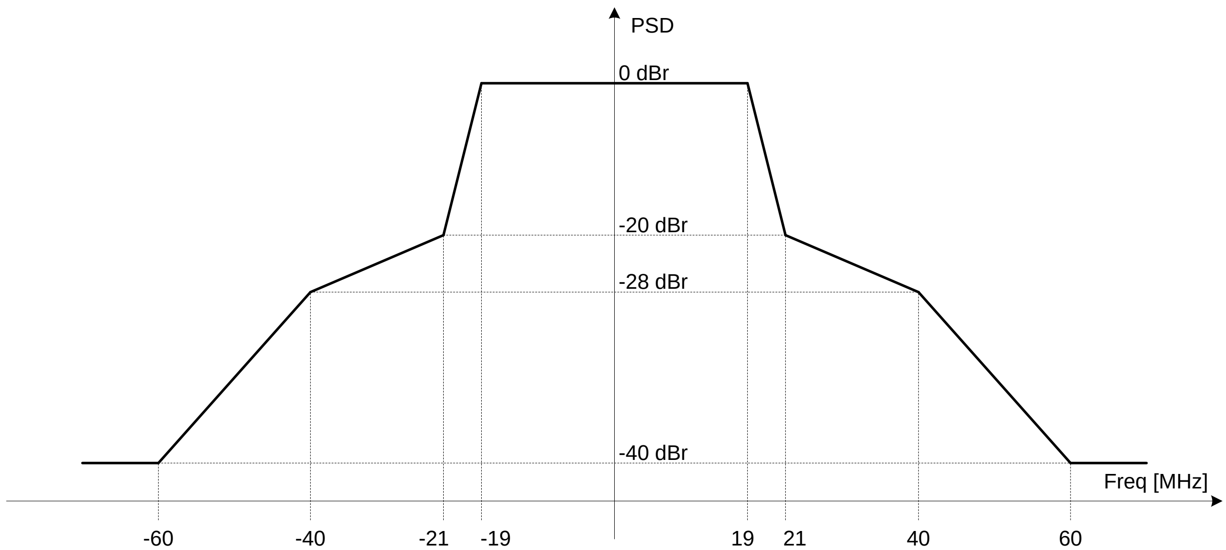

Figure 22-18--Transmit spectral mask for a 40 MHz channel

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 TBD dBm/MHz at 120 MHz frequency offset and above. Spectral density of the transmitted signal shall fall within the spectral mask shown in Figure 22-19.

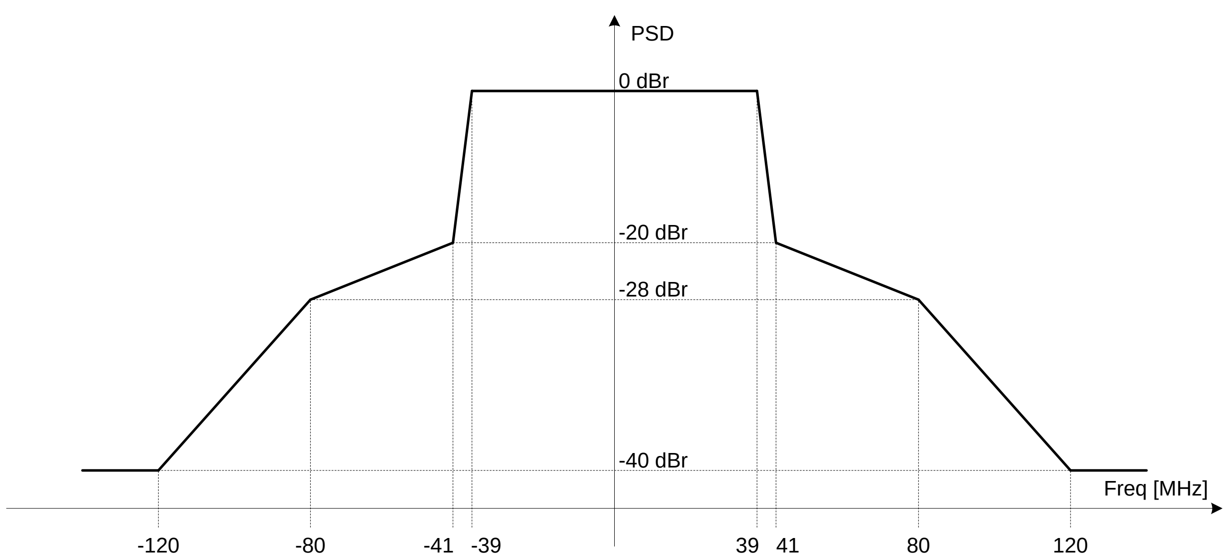

Figure 22-19 -- Transmit spectral mask for 80 MHz channel

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 TBD dBm/MHz at 240 MHz frequency offset and above. Spectral density of the transmitted signal shall fall within the spectral mask shown in Figure 22-20.

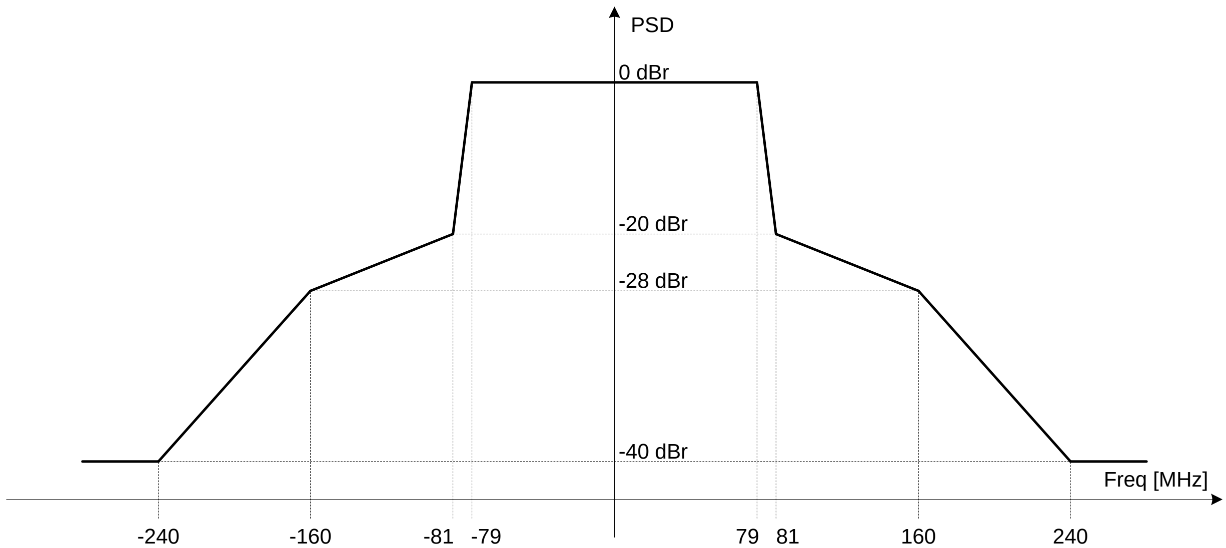

Figure 22-20 -- Transmit spectral mask for 160 MHz channel

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 22-19 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. Nex, 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. Spectral density of the transmitted signal shall fall within the spectral mask constructed in this manner. Figure 22-21 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.

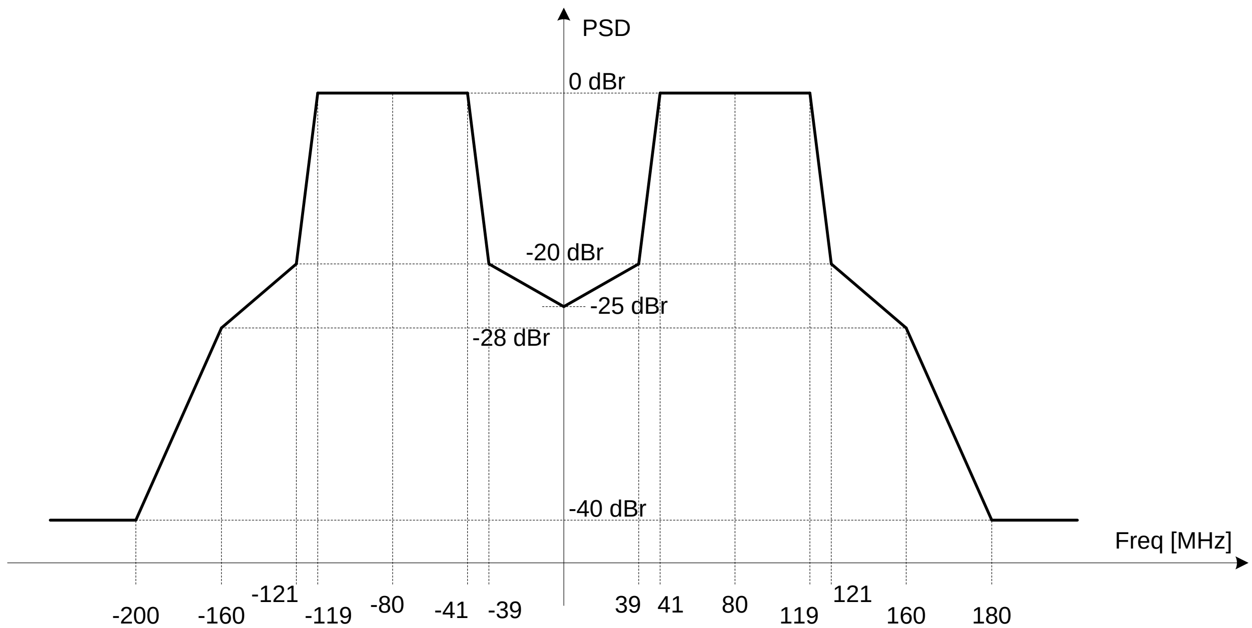

Figure 22-21-- Example of transmit spectral mask for a non-contiguous transmission using two 80 MHz channels where the center frequency of the two 80 MHz channels are separated by 160 MHz

Measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.

22.3.20.2 Spectral flatness

In a 20 MHz transmission, the average energy of the constellations in each of the subcarriers with indices –16 to –1 and +1 to +16 shall deviate by no more than ± 4 dB from their average energy. The average energy of the constellations in each of the subcarriers with indices –28 to –17 and +17 to +28 shall deviate no more than +4/–6 dB from the average energy of subcarriers with indices –16 to –1 and +1 to +16.

In a 40 MHz transmission, the average energy of the constellations in each of the subcarriers with indices –42 to –2 and +2 to +42 shall deviate by no more than ± 4 dB from their average energy. The average energy of the constellations in each of the subcarriers with indices –43 to –58 and +43 to +58 shall deviate no more than +4/–6 dB from the average energy of subcarriers with indices –42 to –2 and +2 to +42.

In a 80 MHz transmission, the average energy of the constellations in each of the subcarriers with indices –84 to –2 and +2 to +84 shall deviate by no more than ± 4 dB from their average energy. The average energy of the constellations in each of the subcarriers with indices –122 to –85 and +85 to +122 shall deviate no more than +4/–6 dB from the average energy of subcarriers with indices –84 to –2 and +2 to +84.

In a 160 MHz transmission, the average energy of the constellations in each of the subcarriers with indices –250 to –6 and +6 to +250 shall deviate by no more than +4/–6 dB from their average energy.

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.

The tests for the spectral flatness requirements can be performed with spatial mapping $Q_k = \mathbf{I}$ (see 22.3.11.10).

22.3.20.3 Transmit power

The maximum allowable output power is measured in accordance with practices specified by the appropriate regulatory bodies.

22.3.20.4 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 for 160 MHz PPDUs.

22.3.20.5 Packet alignment

Packet alignment shall be done as described in 20.3.21.5.

22.3.20.6 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.

22.3.20.7 Modulation accuracy

22.3.20.7.1 Introduction to modulation accuracy tests

Transmit modulation accuracy specifications are described in 22.3.20.7.2 and 22.3.20.7.3. The test method is described in 22.3.20.7.4.

22.3.20.7.2 Transmit center frequency leakage

Transmitter center frequency leakage shall follow 17.3.9.6.1 for all transmissions in a 20 MHz channel.

For transmissions in a 40 MHz channel, transmitter center frequency leakage shall follow 20.3.21.7.2.

Transmitter center frequency leakage for 20, 40 or 80 MHz transmissions in an 80 MHz channel shall not exceed TBD dB relative to the average energy of the rest of the subcarriers.

Transmitter center frequency leakage for 20, 40, 80 or 160 MHz transmissions in a 160 MHz channel shall not exceed TBD dB relative to the average energy of the rest of the subcarriers.

In non-contiguous transmissions consisting of two frequency segments, the transmitter center frequency leakage of each frequency segment shall not exceed TBD dB relative to the average energy of the rest of the subcarriers of the corresponding frequency segment.

22.3.20.7.3 Transmitter constellation error

The relative constellation RMS error, calculated by first averaging over subcarriers, frequency segments, OFDM frames and spatial streams shall not exceed a data-rate dependent value according to Table 22-16. 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, $N_{SS} = N_{STS}$ 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 22-16 -- 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	TBD
256-QAM	5/6	TBD

22.3.20.7.4 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 22-16 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:

a) Start of frame shall be detected.
b) Transition from L-STF to L-LTF shall be detected, and fine timing (with one sample resolution) shall be established.
c) Coarse and fine frequency offsets shall be estimated.
d) 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. After receiving all VHT-LTF symbols, multiply by the P-matrix to estimate complex channel response coefficient for each of the subcarriers and each of the transmit streams.
e) 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 channel estimated during the channel estimation phase.
f) For each data-carrying subcarrier in each spatial stream, find the closest constellation point and compute the Euclidean distance from it.
g) 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 (N_f), 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.

22.3.21 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.

22.3.21.1 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 22-17 or less. The test in this subclause and the minimum sensitivity levels specified in Table 22-17 only apply to non-STBC modes, 800 ns GI and BCC.

Table 22-17 -- Receive minimum input level sensitivity

Modulation	Rate (R)	Adjacent channel rejection (dB)	Non-adjacent channel rejection (dB)	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	16	32	-82	-79	-76	-73
QPSK	1/2	13	29	-79	-76	-73	-70
QPSK	3/4	11	27	-77	-74	-71	-68
16-QAM	1/2	8	24	-74	-71	-68	-65
16-QAM	3/4	4	20	-70	-67	-64	-61
64-QAM	2/3	0	16	-66	-63	-60	-57
64-QAM	3/4	-1	15	-65	-62	-59	-56
64-QAM	5/6	-2	14	-64	-61	-58	-55
256-QAM	3/4	TBD	TBD	TBD	TBD	TBD	TBD
256-QAM	5/6	TBD	TBD	TBD	TBD	TBD	TBD

22.3.21.2 Adjacent channel rejection

For all transmissions in a 20 MHz channel width, the adjacent channel rejection shall be measured by setting the desired signal's strength 3 dB above the rate dependent sensitivity specified in Table 22-17 and raising the power of the interfering signal with 20 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 20 MHz away from the center frequency of the desired signal.

For all transmissions in a 40 MHz channel width, the adjacent channel rejection shall be measured by setting the desired signal's strength 3 dB above the rate dependent sensitivity specified in Table 22-17 and raising the power of the interfering signal with 40 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 40 MHz away from the center frequency of the desired signal.

Adjacent channel rejection for 80 MHz, 160 MHz and 80+80 MHz channel width is TBD.
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 that specified in Table 22-17. The interference signal shall have a minimum duty cycle of 50%.

The test in this subclause and the adjacent sensitivity levels specified in Table 22-17 only apply to non-STBC modes, 800 ns GI and BCC.

22.3.21.3 Nonadjacent channel rejection

For all transmissions in a 20 MHz channel width, the nonadjacent channel rejection shall be measured by setting the desired signal's strength 3dB above the rate-dependent sensitivity specified in Table 22-17, and raising the power of the interfering signal 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 40 MHz or more away from the center frequency of the desired signal.

For all transmissions in a 40 MHz channel width, the nonadjacent channel rejection shall be measured by setting the desired signal's strength 3dB above the rate-dependent sensitivity specified in Table 22-17, and raising the power of the interfering signal 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 80 MHz or more away from the center frequency of the desired signal.

Non-adjacent channel rejection for 80 MHz, 160 MHz and 80+80 MHz channel width is TBD.

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 22-17. The interference signal shall have a minimum duty cycle of 50%.

The test in this subclause and the adjacent sensitivity levels specified in Table 22-17 only apply to non-STBC modes, 800 ns GI and BCC.

22.3.21.4 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.

22.3.21.5 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.

A PHY-CCA.indication(BUSY, channel-list) shall also be issued when the CCA sensitivity requirements are met on the primary and secondary channels. The channel-list parameter of the PHY-CCA.indication is absent when the operating channel width is 20 MHz. It includes one or more of the following elements when the operating channel width is 40 MHz, 80 MHz, 160 MHz or 80+80 MHz:

- "primary" when the operating channel width is 40 MHz, 80 MHz, 160 MHz or 80+80 MHz and a signal is present in the primary 20 MHz channel
- "secondary" when the operating channel width is 40 MHz, 80 MHz, 160 MHz or 80+80 MHz and a signal is present in the secondary 20 MHz channel
- "secondary40" when the operating channel width is 80 MHz, 160 MHz or 80+80 MHz and a signal is present in the secondary 40 MHz channel
- "secondary80" when the operating channel width is 160 MHz or 80+80 MHz and a signal is present in the secondary 80 MHz channel

22.3.21.5.1 CCA sensitivity for 20 MHz operating channel width

For a VHT STA with the operating channel width set to 20 MHz, the start of a valid 20 MHz VHT signal at a receive level greater than or equal –82 dBm (the minimum modulation and coding rate sensitivity for a 20 MHz PPDU) shall cause the PHY to set PHY-CCA.indicate(BUSY) with a probability > 90% within 4 μs. The receiver shall hold the CCA signal busy for any signal at or above -62 dBm (20 dB above the minimum modulation and coding rate sensitivity for a 20 MHz PPDU) in the 20 MHz channel.

22.3.21.5.2 CCA sensitivity for 40 MHz operating channel width

This subclause describes the CCA sensitivity requirements for a VHT STA with the operating channel width set to 40 MHz.

The receiver of a VHT STA with the operating channel width set to 40 MHz shall provide CCA on both the primary and secondary channels. When the secondary channel is idle, the start of a valid 20 MHz VHT signal in the primary 20 MHz channel at a receive signal level greater than or equal to -82 dBm (the minimum modulation and coding rate sensitivity for a 20 MHz PPDU) shall cause the PHY to set PHY-CCA.indicate(BUSY, {primary}) with a probability > 90% within 4 μs. The start of a valid 40 MHz VHT signal that occupies both the primary and secondary channels at a receive level greater than or equal to -79 dBm (the minimum modulation and coding rate sensitivity for a 40 MHz PPDU) shall cause the PHY to set PHY-CCA.indicate(BUSY, {primary, secondary}) for both the primary and secondary 20 MHz channels with a probability per channel > 90% within 4 μs.

The receiver shall hold the primary 20 MHz channel CCA signal busy for any signal at or above -62 dBm (20 dB above the minimum modulation and coding rate sensitivity for a 20 MHz PPDU) in the primary 20 MHz channel.

The receiver shall hold the secondary 20 MHz channel CCA signal busy for any signal at or above -62 dBm (20 dB above the minimum modulation and coding rate sensitivity for a 20 MHz PPDU) in the secondary 20 MHz channel.

CCA requirements on the secondary 20 MHz channel for any valid 802.11 OFDM signal is TBD.

22.3.21.5.3 CCA sensitivity for 80 MHz operating channel width

This subclause describes the CCA sensitivity requirements for a VHT STA with the operating channel width set to 80 MHz.

The receiver of a VHT STA with the operating channel width set to 80 MHz shall provide CCA on all 20 MHz channels constituting the 80 MHz channel. When all the non-primary channels are idle, start of a valid 20 MHz VHT signal in the primary 20 MHz channel at a receive signal level greater than or equal to -82 dBm (the minimum modulation and coding rate sensitivity for a 20 MHz PPDU) shall cause the PHY to set PHY-CCA.indicate(BUSY, {primary}) with a probability > 90% within 4 μs. When the secondary 40 MHz channel is idle, the start of a valid 40 MHz VHT signal that occupies the primary 40 MHz channel at a receive level greater than or equal to -79 dBm (the minimum modulation and coding rate sensitivity for a 40 MHz PPDU) shall cause the PHY to set PHY-CCA.indicate(BUSY, {primary, secondary}) with a probability per channel > 90% within 4 μs. The start of a valid 80 MHz VHT signal that occupies the primary 80 MHz channel at a receive signal level greater than or equal to -76 dBm (the minimum modulation and coding rate sensitivity for a 80 MHz PPDU) shall cause the PHY to set PHY-CCA.indicate(BUSY, {primary, secondary, secondary40}) with a probability per channel > 90% within 4 μs.

The receiver shall hold the primary 20 MHz channel CCA signal busy for any signal at or above TBD dBm (TBD dB above the minimum modulation and coding rate sensitivity for a 20 MHz PPDU) in the primary 20 MHz channel.

CCA requirements on the secondary 20 MHz channel and secondary 40 MHz channel for any valid 802.11 OFDM signal and any signal are TBD.

22.3.21.5.4 CCA sensitivity for 160 MHz operating channel width

This subclause describes the CCA sensitivity requirements for a VHT STA with the operating channel width set to 160 MHz.

The receiver of a VHT STA with the operating channel width set to 160 MHz shall provide CCA on all 20 MHz channels constituting the 160 MHz channel. When all other non-primary channels are idle, the start of a valid 20 MHz VHT signal in the primary 20 MHz channel at a receive signal level greater than or equal to -82 dBm (the minimum modulation and coding rate sensitivity for a 20 MHz PPDU) shall cause the PHY to set PHY-CCA.indicate(BUSY, {primary}) with a probability > 90% within 4 μs. When the secondary 40 MHz and secondary 80 MHZ channels are idle, the start of a valid 40 MHz VHT signal that occupies the primary 40 MHz channel at a receive level greater than or equal to -79 dBm (the minimum modulation and coding rate sensitivity for a 40 MHz PPDU) shall cause the PHY to set PHY-CCA.indicate(BUSY, {primary, secondary}) with a probability per channel > 90% within 4 μs. When the secondary 80 MHz channel is idle, the start of a valid 80 MHz VHT signal that occupies the primary 80 MHz channel at a receive signal level greater than or equal to -76 dBm (the minimum modulation and coding rate sensitivity for a 80 MHz PPDU) shall cause the PHY to set PHY-CCA.indicate(BUSY, {primary, secondary, secondary40}) with a probability per channel > 90% within 4 μs. The start of a valid 160 MHz VHT signal that occupies the entire 160 MHz channel at a receive signal level greater than or equal to -73 dBm (the minimum modulation and coding rate sensitivity for a 160 MHz PPDU) shall cause the PHY to set PHY-CCA.indicate(BUSY, {primary, secondary, secondary40, secondary80}) with a probability per channel > 90% within 4 μs.

The receiver shall hold the primary 20 MHz channel CCA signal busy for any signal at or above TBD dBm (TBD dB above the minimum modulation and coding rate sensitivity for a 20 MHz PPDU) in the primary 20 MHz channel.

CCA requirements on the secondary 20 MHz channel, secondary 40 MHz channel and secondary 80 MHz channel for any valid 802.11 OFDM signal and any signal are TBD.

22.3.21.5.5 CCA sensitivity for non-contiguous 80+80 MHz operating channel width

This subclause describes the CCA sensitivity requirements for a VHT STA with the operating channel width set to non-contiguous 80+80 MHz.

The receiver of a VHT STA with the operating channel width set to non-contiguous 80+80 MHz shall provide CCA on all 20 MHz channels constituting the two 80 MHz frequency segments. When all non-primary channels are idle, the start of a valid 20 MHz VHT signal in the primary 20 MHz channel at a receive signal level greater than or equal to -82 dBm (the minimum modulation and coding rate sensitivity for a 20 MHz PPDU) shall cause the PHY to set PHY-CCA.indicate(BUSY, {primary}) with a probability > 90% within 4 μs. When the secondary 40 MHz channel and secondary 80 MHz channel are idle, the start of a valid 40 MHz VHT signal that occupies the primary 40 MHz channel at a receive level greater than or equal to -79 dBm (the minimum modulation and coding rate sensitivity for a 40 MHz PPDU) shall cause the PHY to set PHY-CCA.indicate(BUSY, {primary, secondary}) with a probability per channel > 90% within 4 μs. When the secondary 80 MHz channel is idle, the start of a valid 80 MHz VHT signal that occupies the primary frequency segment (which is made up of the primary 80 MHz) at a receive signal level greater than or equal to -76 dBm (the minimum modulation and coding rate sensitivity for a 80 MHz PPDU) shall cause the PHY to set PHY-CCA.indicate(BUSY, {primary, secondary, secondary40}) with a probability per channel > 90% within 4 μs. The start of a valid 80+80 MHz VHT signal that occupies the 80+80 MHz channel at a receive signal level greater than or equal to -73 dBm (the minimum modulation and coding rate sensitivity for a 80+80 MHz PPDU) shall cause the PHY to set PHY-CCA.indicate(BUSY, {primary, secondary, secondary40, secondary80}) with a probability per channel > 90% within 4 μs.

The receiver shall hold the primary 20 MHz channel CCA signal busy for any signal at or above TBD dBm (TBD dB above the minimum modulation and coding rate sensitivity for a 20 MHz PPDU) in the primary 20 MHz channel.

CCA requirements on the secondary 20 MHz channel, secondary 40 MHz channel and secondary 80 MHz channel for any valid 802.11 OFDM signal and any signal are TBD.

22.3.22 PLCP transmit procedure

There are two options for transmit PLCP procedure. The first option, for which typical transmit procedures are shown in Figure 22-22, 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 shall be in the transmit state. Further, the PHY shall be 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 shall immediately initiate data scrambling and data encoding. The encoding method shall be based on the FEC_CODING, CH_BANDWIDTH, NUM_STS, STBC, MCS, and NUM_USERS parameter of the TXVECTOR. A modulation rate change, if any, shall be 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 shall be 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 shall be stuffed to make the C-PSDU length an integral multiple of the OFDM symbol length.

The packet transmission shall be completed and the PHY entity shall enter the receive state (i.e., PHYTXSTART shall be disabled). Each PHY-TXEND.request is acknowledged with a PHY-TXEND.confirm primitive from the PHY.

In the PMD, the GI or short GI shall be 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 22-23. 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.

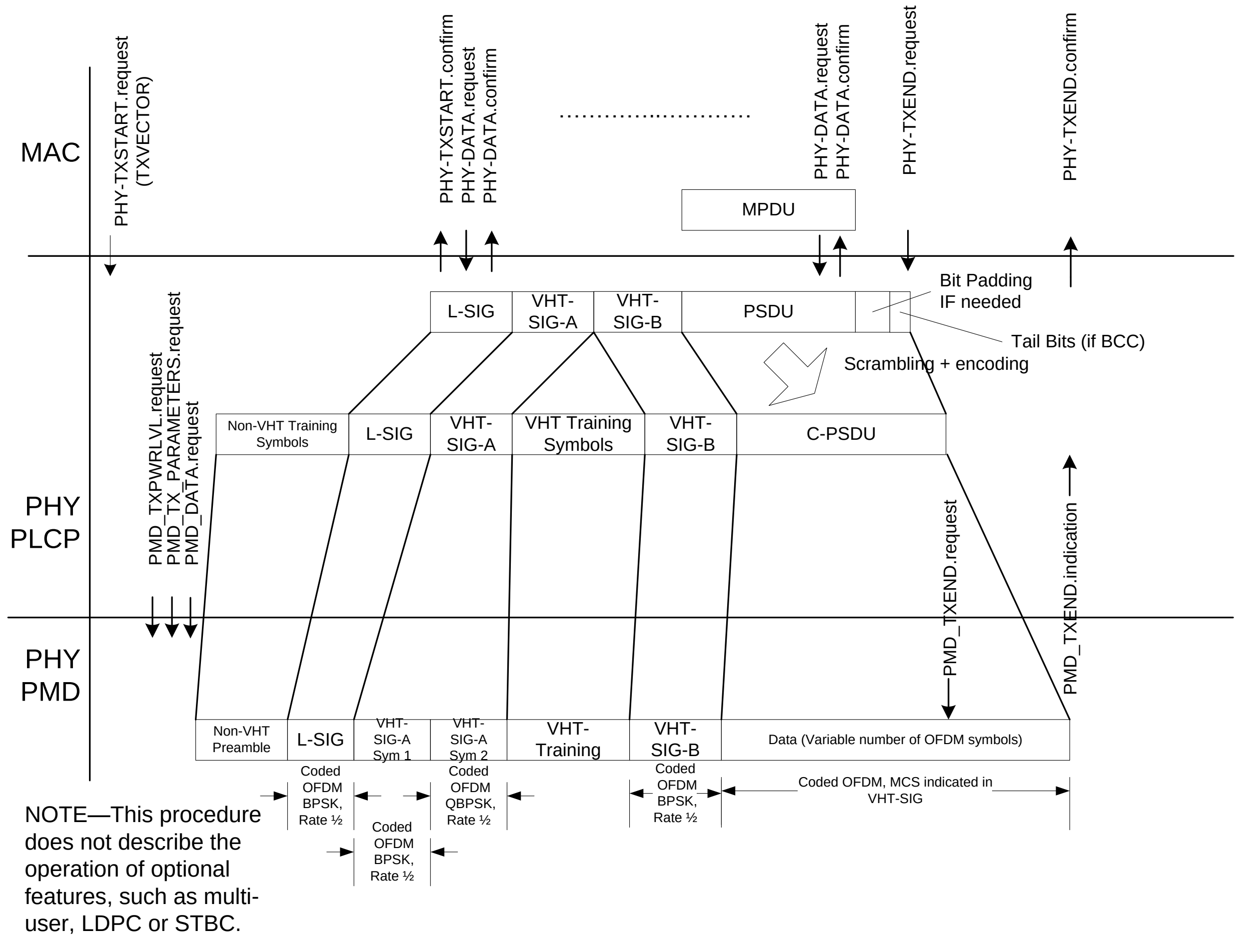

Figure 22-22 -- PLCP transmit procedure

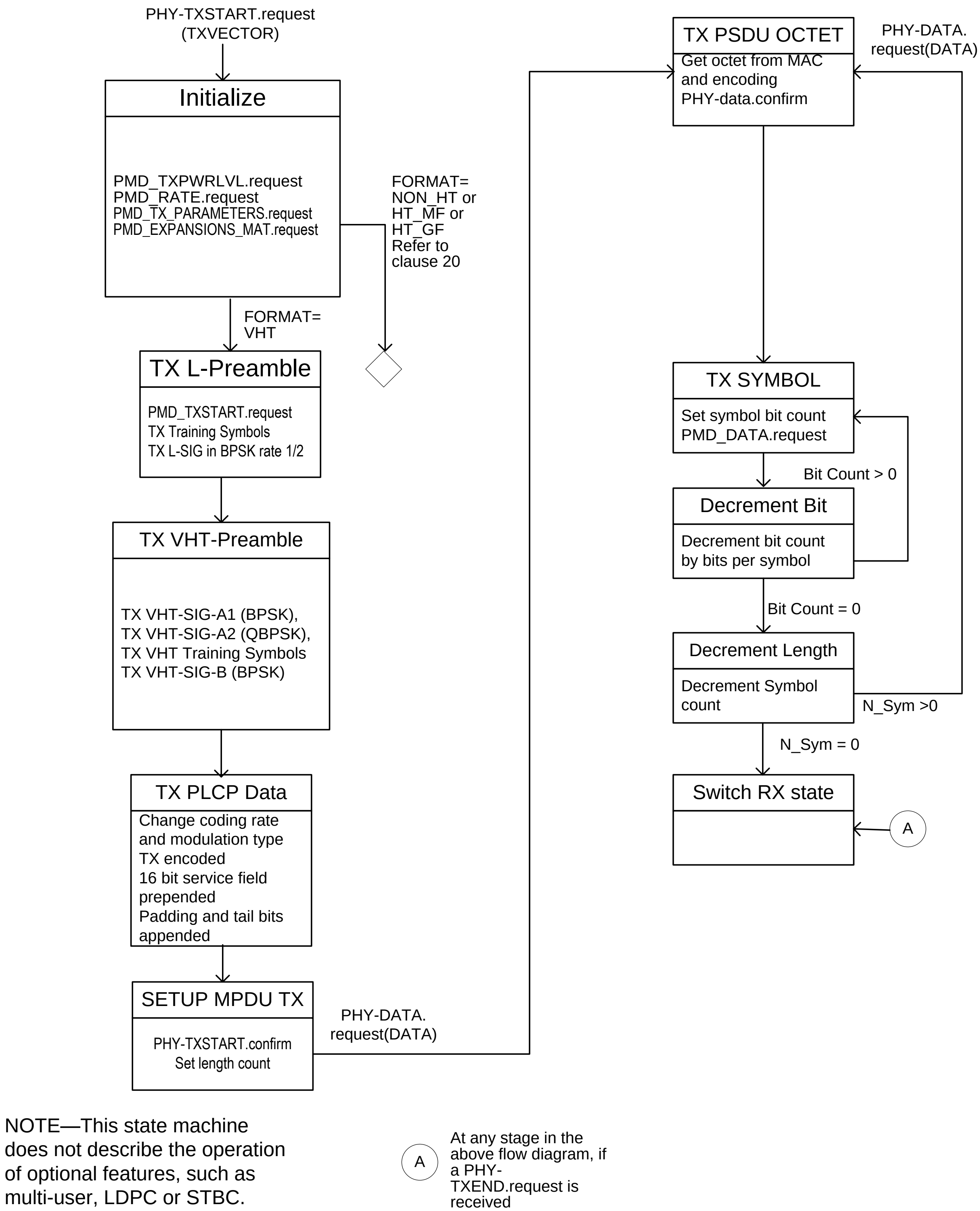

Figure 22-23 -- PLCP transmit state machine

22.3.23 PLCP receive procedure

A typical PLCP receive procedure is shown in Figure 22-24 for VHT format. A typical state machine implementation of the receive PLCP is given in Figure 22-25. This receive procedure and state machine do not describe the operation of optional features, such as LDPC or 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 indicates activity to the MAC via PHY-CCA.indication. 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 22.3.21.5. 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 22.3.21.5. 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 (22-74), 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, N_{STS} per user for MU set to 5-7, Short GI set to 01, the combination of MCS and N_{STS} not included in 22.6, and 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).

$$RXTIME(\mu s) = \frac{L\_LENGTH + 3}{3} * 4 + 20 \qquad (22\text{-}74)$$

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 (22-74).

$$N_{SYM} = \begin{cases} N'_{SYM} - 1, & \text{if Short GI} = 11\text{b} \\ N'_{SYM}, & \text{otherwise} \end{cases} \tag{22-74}$$

where

$$N'_{SYM} = \left\lfloor \frac{RXTIME - \begin{pmatrix} T_{L-STF} + T_{L-LTF} + T_{VHT-SIG-A} + \\ T_{VHT-STF} + N_{LTF} T_{VHT-LTF} + T_{VHT-SIG-B} \end{pmatrix}}{T_{SYM}} \right\rfloor$$

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.

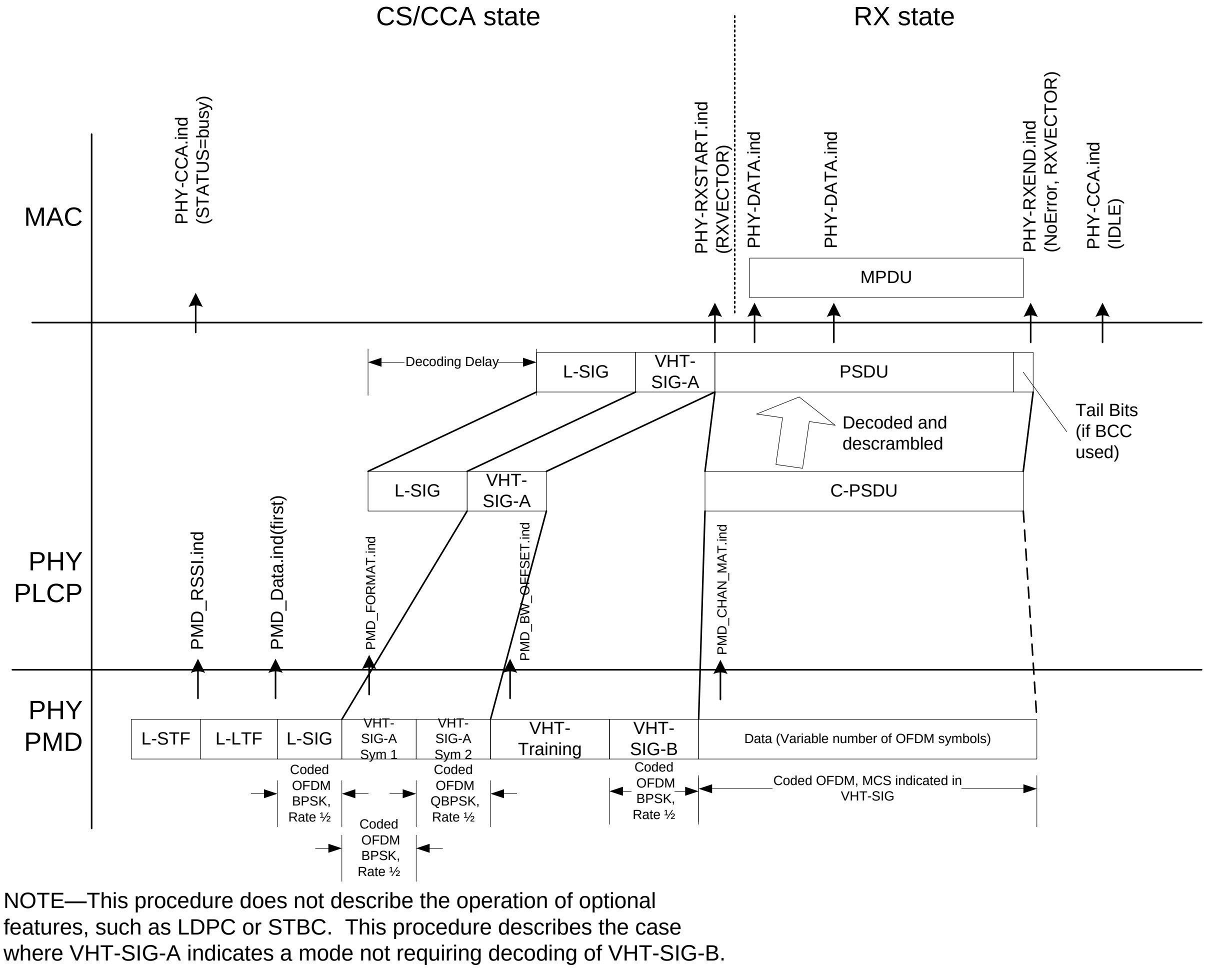

Figure 22-24 -- PLCP receive procedure

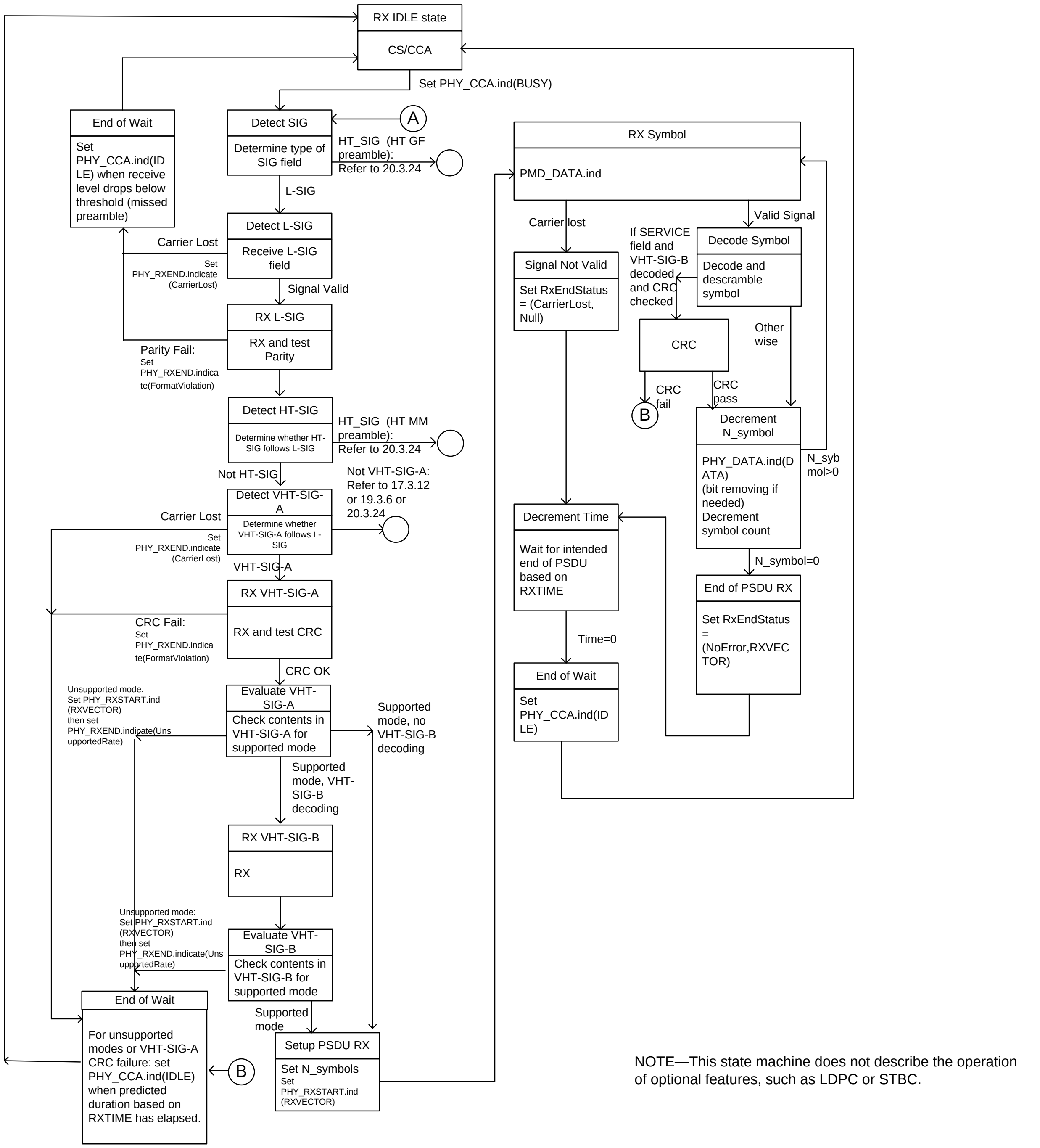

Figure 22-25 -- PLCP receive state machine

22.4 VHT PLME

22.4.1 PLME_SAP sublayer management primitives

22.4.2 PHY MIB

22.4.3 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 (22-75) for short GI and Equation (22-76) for regular GI.

$$\begin{aligned}\mathrm{TXTIME} = {} & T_{LEG\_PREAMBLE} + T_{L-SIG} + T_{VHT-SIG-A} + T_{VHT\_PREAMBLE} + T_{VHT-SIG-B} \\ & + T_{SYM} \times \left\lceil \frac{T_{SYMS} \times N_{SYM}}{T_{SYM}} \right\rceil \end{aligned} \quad (22\text{-}75)$$

$$\begin{aligned}\mathrm{TXTIME} = {} & T_{LEG\_PREAMBLE} + T_{L-SIG} + T_{VHT-SIG-A} + T_{VHT\_PREAMBLE} + T_{VHT-SIG-B} \\ & + T_{SYM} \times N_{SYM} \end{aligned} \quad (22\text{-}76)$$

where

$\lceil x \rceil$ denotes the smallest integer greater than or equal to x

$T_{LEG\_PREAMBLE} = T_{L-STF} + T_{L-LTF}$ is the duration of the non-HT preamble

$T_{VHT\_PREAMBLE}$ is the duration of the VHT preamble in VHT format, given by $T_{VHT-STF} + N_{VHTLTF} T_{VHT-LTF}$

$T_{SYM}, T_{SYMS}, T_{VHT-SIG-A}, T_{VHT-SIG-B}, T_{L-STF}, T_{VHT-STF}, T_{L-LTF}$ and $T_{VHT-LTF}$ are defined in Table 22-4

N_{VHTLTF} is defined in Table 22-10

The total number of data symbols in the data portion of the packet, N_{SYM}, for a SU packet using BCC encoding is given by Equation (22-77).

$$N_{SYM} = m_{STBC} \times \left\lceil \frac{8 \cdot \mathrm{LENGTH} + 16 + 6 \cdot N_{ES}}{m_{STBC} \cdot N_{DBPS}} \right\rceil \quad (22\text{-}77)$$

where

LENGTH_u is passed as the LENGTH parameter for user u in the TXVECTOR.

m_{STBC} is equal to 2 when STBC is used, and 1 otherwise

N_{ES} is defined in Table 22-5

N_{DBPS} is defined in Table 22-5

The total number of data symbols in the data portion of the packet, N_{SYM}, 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, N_{SYM}, for a MU packet using is given by Equation (22-50).

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 (22-78).

$$\mathrm{PSDU\_LENGTH} = \left\lfloor \frac{N_{SYM} N_{DBPS} - 16 - 6 \cdot N_{ES}}{8} \right\rfloor \quad (22\text{-}78)$$

where

N_{SYM} is given by Equation (22-77),

$\lfloor x \rfloor$ denotes the largest integer smaller than or equal to x,

N_{ES} is defined in Table 22-5,

N_{DBPS} 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 (22-79).

$$\mathrm{PSDU\_LENGTH} = \left\lfloor \frac{N_{SYM,init} N_{DBPS} - 16}{8} \right\rfloor \quad (22\text{-}79)$$

where

$N_{SYM,init}$ is given by Equation (22-47)

N_{DBPS} 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 (22-80).

$$\mathrm{PSDU\_LENGTH}_u = \begin{cases} \left\lfloor \dfrac{N_{\mathrm{SYM}} N_{DBPS,u} - 16 - 6 \cdot N_{ES,u}}{8} \right\rfloor & \text{when BCC is used} \\ \left\lfloor \dfrac{N_{\mathrm{SYM\_max\_init}} N_{DBPS,u} - 16}{8} \right\rfloor & \text{when LDPC is used} \end{cases} \quad (22\text{-}80)$$

where

$\lfloor x \rfloor$ denotes the largest integer smaller than or equal to x,

N_{SYM} is given by Equation (22-50),

$N_{\mathrm{SYM\_max\_init}}$ is given by Equation (22-49),

$N_{ES,u}$ is N_{ES} for user *u*, where N_{ES} is defined in Table 22-5

$N_{DBPS,u}$ is N_{DBPS} for user *u*, where N_{DBPS} is defined in Table 22-5

22.4.4 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 22-18**. The definitions for these characteristics are given in 10.4.

Table 22-18--VHT PHY characteristics

Characteristics	Value
aPSDUMaxLength	TBD octets

22.5 VHT PMD sublayer

22.6 Parameters for VHT MCSs

The rate-dependent parameters for 20 MHz, 40 MHz, 80 MHz and 160 MHz N_{SS}=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 valid) is mandatory. Support for 20 MHz, 40 MHz and 80 MHz with N_{SS}=1 is mandatory. Support for 20 MHz, 40 MHz and 80 MHz with N_{SS}=2,…,8 is optional. Support for 160 MHz with N_{SS}=1,…,8 is optional.

Table 22-19 -- VHT MCSs for mandatory 20 MHz, N_{SS} = 1

MCS Index	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	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(N_{CBPS}/N_{ES}, D_R) not being equal to 0.										

Table 22-20 -- VHT MCSs for optional 20 MHz, N_{SS} = 2

MCS Index	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	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(N_{CBPS}/N_{ES}, D_R) not being equal to 0.										

Table 22-21 -- VHT MCSs for optional 20 MHz, N_{SS} = 3

MCS Index	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	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 22-22 -- VHT MCSs for optional 20 MHz, N_{SS} = 4

MCS Index	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	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(N_{CBPS}/N_{ES}, D_R) not being equal to 0.										

Table 22-23 -- VHT MCSs for optional 20 MHz, N_{SS} = 5

MCS Index	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	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(N_{CBPS}/N_{ES}, D_R) not being equal to 0.										

Table 22-24 -- VHT MCSs for optional 20 MHz, N_{SS} = 6

MCS Index	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	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 22-25 -- VHT MCSs for optional 20 MHz, N_{SS} = 7

MCS	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)

Index									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(N_{CBPS}/N_{ES}, D_R) not being equal to 0.										

Table 22-26 -- VHT MCSs for optional 20 MHz, N_{SS} = 8

MCS Index	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	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(N_{CBPS}/N_{ES}, D_R) not being equal to 0.										

Table 22-27 -- VHT MCSs for mandatory 40 MHz, N_{SS} = 1

MCS Index	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	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 22-28 -- VHT MCSs for optional 40 MHz, N_{SS} = 2

MCS Index	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	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 22-29 -- VHT MCSs for optional 40 MHz, N_{SS} = 3

MCS Index	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	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 22-30 -- VHT MCSs for optional 40 MHz, N_{SS} = 4

MCS Index	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	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 22-31 -- VHT MCSs for optional 40 MHz, N_{SS} = 5

MCS Index	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	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 22-32 -- VHT MCSs for optional 40 MHz, N_{SS} = 6

MCS Index	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	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 22-33 -- VHT MCSs for optional 40 MHz, N_{SS} = 7

MCS Index	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	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 22-34 -- VHT MCSs for optional 40 MHz, N_{SS} = 8

MCS Index	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	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 22-35 -- VHT MCSs for mandatory 80 MHz, N_{SS} = 1

MCS Index	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	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 22-36 -- VHT MCSs for optional 80 MHz, N_{SS} = 2

MCS	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)

Index									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 22-37 -- VHT MCSs for optional 80 MHz, N_{SS} = 3

MCS Index	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	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(N_{CBPS}/N_{ES}, D_R) not being equal to 0.										

Table 22-38 -- VHT MCSs for optional 80 MHz, N_{SS} = 4

MCS Index	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	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 22-39 -- VHT MCSs for optional 80 MHz, N_{SS} = 5

MCS Index	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	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 22-40 -- VHT MCSs for optional 80 MHz, N_{SS} = 6

MCS Index	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	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(N_{CBPS}/N_{ES}, D_R) not being equal to 0.										

Table 22-41 -- VHT MCSs for optional 80 MHz, N_{SS} = 7

MCS Index	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	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(N_{CBPS}/N_{ES}, D_R) not being equal to 0.										

Table 22-42 -- VHT MCSs for optional 80 MHz, N_{SS} = 8

MCS Index	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	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(N_{CBPS}/N_{ES}, D_R) not being equal to 0.										

Table 22-43 -- VHT MCSs for optional 160 MHz, N_{SS} = 1

MCS Index	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	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 22-44 -- VHT MCSs for optional 160 MHz, N_{SS} = 2

MCS Index	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	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 22-45 -- VHT MCSs for optional 160 MHz, N_{SS} = 3

MCS Index	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	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(N_{CBPS}/N_{ES}, D_R) not being equal to 0.										

Table 22-46 -- VHT MCSs for optional 160 MHz, N_{SS} = 4

MCS Index	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	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(N_{CBPS}/N_{ES}, D_R) not being equal to 0.

Table 22-47 -- VHT MCSs for optional 160 MHz, N_{SS} = 5

MCS Index	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	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(N_{CBPS}/N_{ES}, D_R) not being equal to 0.										

Table 22-48 -- VHT MCSs for optional 160 MHz, N_{SS} = 6

MCS Index	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	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(N_{CBPS}/N_{ES}, D_R) not being equal to 0.										

Table 22-49 -- VHT MCSs for optional 160 MHz, N_{SS} = 7

MCS Index	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	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(N_{CBPS}/N_{ES}, D_R) not being equal to 0.										

Table 22-50 -- VHT MCSs for optional 160 MHz, N_{SS} = 8

MCS Index	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	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(N_{CBPS}/N_{ES}, D_R) 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 and 160 MHz channels are described in 22.3.15.1. NOTE – The fields that specify the 80+80 MHz channels are described in 22.3.15.2.		

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	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, 58, 106, 122, 138, 155	VHT80MHzBehavior
<ANA>	TBD	5	160	50, 114	VHT160MHzBehavior
<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	Behavior limits set
<ANA>	TBD	5	80	42, 58,	VHT80MHzBehavior

				106, 122	
<ANA>	TBD	5	160	50, 114	VHT160MHzBehavior
<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	Behavior limits set
<ANA>	TBD	5	80	42, 58, 106, 122	VHT80MHzBehavior
<ANA>	TBD	5	160	50, 114	VHT160MHzBehavior
<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	Behavior limits set
<ANA>	TBD	5	80	42, 58, 106, 122	VHT80MHzBehavior
<ANA>	TBD	5	160	50, 114	VHT160MHzBehavior
<ANA>-191	Reserved	Reserved	Reserved	Reserved	Reserved