

26. High Efficiency (HE) PHY specification

26.1 Introduction

26.1.1 Introduction to the HE PHY

High Efficiency (HE) PHY specification specifies the PHY entity for a high efficiency (HE) orthogonal frequency division multiplexing (OFDM) system. In addition to the requirements in High Efficiency (HE) PHY specification, an HE STA shall be capable of transmitting and receiving PPDU that are compliant with the mandatory requirements of the following PHY specifications: (#348)

- Clause 19 (High Throughput (HT) PHY specification) and Clause 21 (Very High Throughput (VHT) PHY specification) (#1021) when the HE STA with greater than or equal to 80 MHz capability is operating in the 5 GHz band (PHY Motion #163)
- Clause 19 (High Throughput (HT) PHY specification) when the 20 MHz only non-AP HE STA is operating in the 5 GHz band (PHY Motion #163)
- Clause 19 (High Throughput (HT) PHY specification) when the HE STA is operating in the 2.4 GHz band

The HE PHY with greater than or equal to 80 MHz capability is based on the VHT PHY defined in Clause 21 (Very High Throughput (VHT) PHY specification) (#1021), which in turn is based on the HT PHY defined in Clause 19 (High Throughput (HT) PHY specification) (#1021), which in turn is further based on the OFDM PHY defined in Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) (#1021). The HE PHY with 20 MHz only capability (see **Erreur ! Source du renvoi introuvable.**) is based on the HT PHY defined in Clause 19, which in turn is based on the OFDM PHY defined in Clause 17. (PHY Motion #163) The HE PHY extends the maximum number of users supported for downlink multi-user MIMO (MU-MIMO) transmissions to eight and provides support for downlink and uplink orthogonal frequency division (#1185) multiple access (OFDMA) as well as for uplink MU-MIMO. Both downlink and uplink MU-MIMO transmissions are supported on portions of the PPDU bandwidth (on resource units greater than or equal to 106 tones) and in an MU-MIMO resource unit, there is support for up to eight users with up to four space-time streams per user with the total number of space-time streams not exceeding eight.

The HE PHY provides support for 20 MHz, 40 MHz, 80 MHz and 160 MHz contiguous channel widths and support for 80+80 MHz non-contiguous channel width, depending on the frequency band and capability (PHY Motion #163). For channel widths greater than or equal to 80 MHz, the HE PHY supports channel puncturing (PHY Motion #161) transmissions where one or more of the non-primary 20 MHz channels in an HE MU PPDU with more than one RU is zeroed out. (#879)

The HE PHY provides support for 0.8 μ s, 1.6 μ s and 3.2 μ s (#1922) guard interval durations.

The HE PHY provides support for 3.2 μ s (1x LTF), 6.4 μ s (2x LTF), and 12.8 μ s (4x LTF) LTF symbol durations (symbol duration not including the guard interval). The HE PHY supports a single Data field OFDM symbol duration of 12.8 μ s (excluding guard interval). (#269)

The HE PHY data subcarrier frequency spacing is a quarter of VHT PHY and HT PHY subcarrier frequency spacing defined in Clause 21 (Very High Throughput (VHT) PHY specification) and Clause 19

(High Throughput (HT) PHY specification), respectively.(#1605) The HE PHY data subcarriers are modulated using binary phase shift keying (BPSK), quadrature phase shift keying (QPSK), 16-quadrature amplitude modulation (16-QAM), 64-QAM, 256-QAM and 1024-QAM. Forward error correction (FEC) coding (convolutional or LDPC coding) is used with coding rates of 1/2, 2/3, 3/4 and 5/6.

An HE STA shall support the following High Efficiency (HE) PHY specification features:(#351)

- Binary convolutional coding for 26-, 52-, 106- and 242-tone RUs (transmit and receive) when the number of spatial streams is less than or equal to 4
- Binary convolution coding for a 20 MHz HE SU PPDU (transmit and receive) when the number of spatial streams is less than or equal to 4
- LDPC as the only coding scheme for 484-, 996- and 2×996-tone RUs (transmit and receive)
- LDPC coding for 40 MHz, 80 MHz, 160 MHz and 80+80 MHz HE SU PPDU
- LDPC when declaring support for more than 4 spatial streams
- LDPC when declaring support for MCS10 and MCS11(PHY Motion #158)
- A combination of 2x LTF with 0.8 μ s GI duration on both LTF and data
- A combination of 2x LTF with 1.6 μ s GI duration on both LTF and data
- A combination of 4x LTF with 3.2 μ s GI duration on both LTF and data

An HE STA may support the following High Efficiency (HE) PHY specification features:(#351)

- Other combinations of LTF durations and GI durations
- LDPC coding for 26-, 52-, 106- and 242-tone RUs (transmit and receive) when the number of spatial streams is less than or equal to 4
- LDPC coding for a 20 MHz HE SU PPDU (transmit and receive) when the number of spatial streams is less than or equal to 4
- LDPC (transmit and receive) when declaring support for less than or equal to 4 spatial streams and when declaring not supporting MCS10 and MCS11(PHY Motion #158)
- Dual carrier modulation (transmit and receive)

Editor's Note: Once mandatory and optional TBUs are decided, the above text will be revised.(#1461)(#2352)

26.1.2 Scope

The services provided to the MAC by the HE PHY consist of the following protocol functions:

- a) A function that maps the PSDU received from the MAC into a PPDU for transmission to one or more receiving STAs.(#2354)
- b) A function that defines the characteristics and method of transmitting and receiving data through a wireless medium between two or more STAs. Depending on the PPDU format, these STAs support a mixture of HE, Clause 21 (Very High Throughput (VHT) PHY specification), Clause 19 (High Throughput (HT) PHY specification) and Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) PHYs.(#1021) A non-AP STA with 20 MHz only capability supports a mixture of HE, Clause 19 and Clause 17 PHYs.(PHY Motion #163)

26.1.3 HE PHY functions

26.1.3.1 General

The HE PHY contains two functional entities: the PHY function, and the physical layer management function (i.e., the PLME). Both of these functions are described in detail in HE PHY and HE PLME. The HE PHY service is provided to the MAC through the PHY service primitives defined in Clause 7 (PHY service specification). The HE PHY service interface is described in HE PHY service interface.

26.1.3.2 PHY management entity (PLME)

The PLME performs management of the local PHY functions in conjunction with the MLME.

26.1.3.3 Service specification method

The models represented by figures and state diagrams are intended to be illustrations of the functions provided. It is important to distinguish between a model and a real implementation. The models are optimized for simplicity and clarity of presentation; the actual method of implementation is left to the discretion of the HE-PHY-compliant developer.

The service of a layer is the set of capabilities that it offers to a user in the next higher layer. Abstract services are specified here by describing the service primitives and parameters that characterize each service. This definition is independent of any particular implementation.

26.1.4 PPDU formats

The structure of the PPDU transmitted by an HE STA is determined by the TXVECTOR parameters as defined in TXVECTOR and RXVECTOR parameters.

The FORMAT parameter determines the overall structure of the PPDU and can take on one of the following values:

- Non-HT format (NON_HT), based on Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) and including non-HT duplicate format.
- HT-mixed format (HT_MF) as specified in Clause 19 (High Throughput (HT) PHY specification).
- HT-greenfield format (HT_GF) as specified in Clause 19 (High Throughput (HT) PHY specification).
- VHT format (VHT) as defined in Clause 21 (Very High Throughput (VHT) PHY specification). (#468)
- HE SU PPDU format (HE_SU) carries a single PSDU. With this format the HE-SIG-A field is not repeated. Support for the HE SU PPDU format is mandatory.
- HE extended range SU PPDU format (HE_EXT_SU) carries a single PSDU. It is similar to the SU format, except that the HE-SIG-A field is repeated. Support for the HE extended range SU PPDU format is mandatory (#834).
- HE MU PPDU format (HE_MU) carries one or more PSDUs to one or more users. Support for the HE MU PPDU format is mandatory.

- HE trigger-based PPDU format (HE_TRIG) carries a single PSDU and is sent in response to a PPDU that carries a Trigger frame. The preamble format prior to the HE-STF field is identical to the HE SU PPDU. Support for the HE trigger-based PPDU format is mandatory(#834).

26.2 HE PHY service interface

26.2.1 Introduction

(#Ed)The PHY provides an interface to the MAC through an extension of the generic PHY service interface defined in 8.3.4 (Basic service and options). The interface includes TXVECTOR, RXVECTOR, and PHYCONFIG_VECTOR.

Using the TXVECTOR, the MAC supplies the PHY with per-PPDU transmit parameters. Using the RXVECTOR, the PHY informs the MAC of the received PPDU parameters. Using the PHYCONFIG_VECTOR, the MAC configures the PHY for operation, independent of frame transmission or reception.

26.2.2 TXVECTOR and RXVECTOR parameters

The parameters in TXVECTOR and RXVECTOR parameters 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 26-1—TXVECTOR and RXVECTOR parameters(#1780)

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 duplicate 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. HE_SU indicates HE SU PPDU format. HE_MU indicates HE MU PPDU format. HE_EXT_SU indicates HE extended range SU PPDU format. HE_TRIG indicates HE trigger-based PPDU format(#1029).	Y	Y

NON_HT_MODULATION	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).			
L_LENGTH	FORMAT is HE_SU or HE_MU or HE_EXT_SU	Not present. NOTE—The Length field of the L-SIG for HE PPDU is $\text{Length} = \left\lceil \frac{\text{TXTIME} - 20}{4} \right\rceil \times 3 - 3 - m$ defined in (#1 using the TXTIME value defined in TXTIME and PSDU_LENGTH calculation, which in turn depend on other parameters including the TXVECTOR parameter APEP_LENGTH).	N	N
	FORMAT is HE_TRIG	Indicates the value in the Length field of the L-SIG in the range of 1 to 4095. The value comes from the trigger frame which triggers the HE trigger-based PPDU.	Y	N
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
L_DATARATE	FORMAT is HE_SU or HE_MU or HE_EXT_SU or HE_TRIG	Not present NOTE—The RATE field in the L-SIG field in HE PPDU is set to the value representing 6 Mb/s in the 20 MHz channel spacing column of Table 17-6 (Contents of the SIGNAL field).	N	N
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
LSIGVALID	FORMAT is HE_SU or HE_MU or HE_EXT_SU or HE_TRIG	Not present	N	N
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
SERVICE	FORMAT is HE_SU or HE_MU or HE_EXT_SU or HE_TRIG	Not present	N	N

	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
SMOOTHING	FORMAT is HE_SU or HE_MU or HE_EXT_SU or HE_TRIG	Not present	N	N
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
AGGREGATION	FORMAT is HE_SU or HE_MU or HE_EXT_SU or HE_TRIG	Not present	N	N
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
NUM_EXTEN_SS	FORMAT is HE_SU or HE_MU or HE_EXT_SU or HE_TRIG	Not present	N	N
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
ANTENNA_SET	FORMAT is HE_SU or HE_MU or HE_EXT_SU or HE_TRIG	Not present	N	N
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
N_TX	FORMAT is HE_SU or HE_MU or HE_EXT_SU or HE_TRIG	Not present	N	N
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
EXPANSION_MAT_TABLE	FORMAT is HE_SU or HE_MU or HE_EXT_SU or HE_TRIG	Set to COMPRESSED_SV.	Y	N

	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
EXPANSION_MAT	FORMAT is HE_SU or IIE_EXT_SU or HE_TRIG	Contains a vector in the number of selected subcarriers containing feedback matrices as defined in Beamforming feedback matrix based on the channel measured during the training symbols of previous HE NDP PPDU or VHT NDP PPDU.	Y	N
	FORMAT is IIE_MU	For each user, contains a vector in the number of all the subcarriers within the RU which is assigned to this user. The vector for each subcarrier contains feedback matrices as defined in in Beamforming feedback matrix based on the channel measured during the training symbols of previous HE NDP PPDU or VHT NDP PPDU.	M U	N
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
CHAN_MAT_TYPE	FORMAT is HE_SU or HE_MU or HE_EXT_SU or HE_TRIG	Set to COMPRESSED_SV.	N	Y
	FORMAT is HE_MU or IIE_EXT_SU or HE_TRIG or (FORMAT is HE_SU and PSDU_LENGTH is greater than 0)	Not present.	N	N
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
CHAN_MAT	FORMAT is HE_SU and PSDU_LENGTH equals 0	Contains a vector in the number of selected subcarriers containing feedback matrices as defined in 26.3.12.3.2 (Beamforming Feedback) based on the channel measured during the training symbols of previous HE NDP PPDU.	N	Y
	FORMAT is HE_MU or IIE_EXT_SU or HE_TRIG or (FORMAT is HE_SU and PSDU_LENGTH is greater than 0)	Not present.	N	N

	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
DELTA_SNR	FORMAT is HE_SU or HE_MU or HE_EXT_SU or HE_TRIG	Contains an array of delta SNR values as defined in 9.4.1.64 (HE MU Exclusive Beamforming Report field) based on the channel measured during the training symbols of the received VHT NDP PPDU or HE NDP PPDU. NOTE—In the RXVECTOR this parameter is present only for HE NDP PPDU for MU sounding.	M U	Y
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
RCPI	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).			
SNR	FORMAT is HE_SU or HE_EXT_SU	Contains an array of received SNR measurements for each spatial stream. SNR indications of 8 bits are supported. SNR shall be the sum of the decibel values of SNR per tone divided by the number of tones represented in each stream as described in 9.4.1.63 (HE Compressed Beamforming Report field)	N	Y
	FORMAT is HE_MU	Contains an array of received SNR measurements for each spatial stream of the receiver. SNR indications of 8 bits are supported. SNR shall be the sum of the decibel values of SNR per tone divided by the number of tones which are assigned to the receiver in each stream as described in 9.4.1.63 (HE Compressed Beamforming Report field)	N	Y
	FORMAT is HE_TRIG	Contains an array of received SNR measurements for each spatial stream per user. SNR indications of 8 bits are supported. SNR shall be the sum of the decibel values of SNR per tone divided by the number of tones which are assigned to the user in each stream as described in 9.4.1.63 (HE Compressed Beamforming Report field)	N	Y
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
CQI	FORMAT is HE_SU and PSDU_LENGTH equals 0	Contains an array of received SNR measurements for each spatial stream per 26-tone RU. Each SNR is an absolute number represented by 6 bits, with 1 dB granularity and a range of -10 dB to 53 dB	N	Y

	FORMAT is HE_MU or HE_EXT_SU or HE_TRIG or (FORMAT is HE_SU and PSDU_LENGTH is greater than 0)	Not present.	N	N
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
NO_SIG_EXTN	FORMAT is HE_SU or HE_MU or HE_EXT_SU or HE_TRIG	Not present.	N	N
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
FEC_CODING	FORMAT is HE_SU or HE_MU or HE_EXT_SU or HE_TRIG	Indicates which FEC encoding is used. Enumerated type: BCC_CODING indicates binary convolutional code. LDPC_CODING indicates low-density parity check code.	M U	M U
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
STBC	FORMAT is HE_SU or HE_MU or HE_EXT_SU or HE_TRIG	Indicates if STBC is used. In an HE MU PPDU where each RU includes no more than 1 user: Set to 1 to indicate all RUs are STBC encoded in the payload Set to 0 to indicate all RUs are not STBC encoded in the payload In HE SU PPDU, HE extended range SU PPDU or HE trigger-based PPDU: Set to 1 to that indicate STBC is used in the payload Set to 0 to indicate that STBC is not used in the payload STBC is not applied in MU-MIMO RUs, in case of HE MU PPDU if any RU is assigned to more than 1 user, STBC is set to 0 to indicate all RUs are not STBC encoded in the payload.	Y	Y
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
GI_TYPE	FORMAT is HE_SU or HE_MU or HE_EXT_SU or HE_TRIG	Indicates the length of the GI for the HE-LTF and HE-Data fields. Enumerated type: 0.8 μ s 1.6 μ s 3.2 μ s NOTE—the length of GI for pre-HE modulated fields is 0.8 μ s.	Y	Y

	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
TXPWR_LEVEL_INDEX	FORMAT is HE_SU or HE_MU or HE_EXT_SU or HE_TRIG	The allowed values for the TXPWR_LEVEL_INDEX parameter are in the range from 1 to numberOFoctets (dot11TxPowerLevelExtended)/2. This parameter is used to indicate which of the available transmit output power levels defined in dot11TxPowerLevelExtended shall be used for the current transmission.	Y	N
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
RSSI	FORMAT is HE_SU or HE_EXT_SU	The allowed values for the RSSI parameter are in the range 0 to 255 inclusive. This parameter is a measure by the PHY of the power observed at the antennas used to receive the current PPDU measured during the reception of the HE-LTF field. RSSI is intended to be used in a relative manner, and it is a monotonically increasing function of the received power.	N	Y
	FORMAT is HE_MU	The allowed values for the RSSI parameter are in the range 0 to 255 inclusive. This parameter is a measure by the PHY of the power observed at the antennas used to receive the current PPDU measured during the reception of PHY legacy preamble. RSSI is intended to be used in a relative manner, and it is a monotonically increasing function of the received power.	N	Y
	FORMAT is HE_TRIG	Not present	N	N
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
MCS	FORMAT is HE_SU or HE_MU or HE_EXT_SU or HE_TRIG	Indicates the modulation and coding scheme used in the transmission of the PPDU. Integer: range 0 to 11	M U	M U
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		

DCM	FORMAT is HE_SU or HE_MU or HE_EXT_SU or HE_TRIG	Set to 1 to indicate that dual carrier modulation is used for the HE-Data field. Set to 0 to indicate that dual carrier modulation is not used for the HE-Data field. NOTE—DCM is only applied to MCS0, MCS1, MCS3 and MCS4. DCM is only applied to 1 and 2 spatial streams. DCM is only applied to HE SU PPDU, HE extend range SU PPDU, and SU RUs in HE MU PPDU. DCM is not applied to MU-MIMO. DCM is not applied to STBC.	M U	M U
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
MCS_SIG_B	FORMAT is HE_MU	Indicates the modulation and coding scheme used for HE-SIG-B field. Integer in the range 0 to 5	Y	Y
	Otherwise	Not present.	N	N
DCM_SIG_B	FORMAT is HE_MU	Set to 1 to indicate that dual carrier modulation is used for the HE-SIG-B field. Set to 0 to indicate that dual carrier modulation is not used for the HE-SIG-B field.	Y	Y
	Otherwise	Not present.	N	N
SIG_B_COMPRESSION_MODE	FORMAT is HE_MU	Used to differentiate full bandwidth MU-MIMO from OFDMA MU PPDU. In case of full bandwidth MU-MIMO set to 1, otherwise set to 0.	Y	N
	Otherwise	Not present.	N	N
REC_MCS	FORMAT is HE_SU or HE_MU or HE_EXT_SU	Indicates the MCS that the receiver recommends	N	O
	FORMAT is HE_TRIG	Not present.	N	N

	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
CH_BANDWIDTH	FORMAT is HE_SU or HE_EXT_SU or HE_TRIG	Indicates the channel width of the transmitted PPDU. Enumerated type: CBW20 for 20 MHz CBW40 for 40 MHz CBW80 for 80 MHz CBW160 for 160 MHz CBW80+80 for 80+80 MHz	Y	Y
	FORMAT is HE_MU	Indicates the channel occupied by the transmitted PPDU, supporting channel bonding. See the field of Bandwidth in Table 26-16 (Fields in the HE-SIG-A for an HE MU PPDU)	Y	Y
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
DYN_BANDWIDTH_IN_NON_HT	FORMAT is HE_SU or HE_MU or HE_EXT_SU or HE_TRIG	Not present.	N	N
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
CH_BANDWIDTH_IN_NON_HT	FORMAT is HE_SU or HE_MU or HE_EXT_SU or HE_TRIG	Not present.	N	N
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
LENGTH	FORMAT is HE_SU or HE_MU or HE_EXT_SU or HE_TRIG	Not present.	N	N
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		

APEP_LENGTH	FORMAT is HE_SU or HE_MU or HE_EXT_SU or HE_TRIG	If equal to 0, indicates an HE NDP PPDU. If greater than 0, indicates the number of octets in the range 1 to 1048575 in the A-MPDU pre-EOF padding (see 10.13.2 (A-MPDU length limit rules)) carried in the PSDU.	M U	N
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
PSDU_LENGTH	FORMAT is HE_SU or HE_MU or HE_EXT_SU or HE_TRIG	Indicates the number of octets in the HE PSDU in the range of 0 to aPSDUMaxLength octets (see HE PHY characteristics). A value of 0 indicates an HE NDP PPDU.	N	Y
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
USER_POSITION	FORMAT is HE_SU or HE_MU or HE_EXT_SU or HE_TRIG	Not present.	N	N
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters). (#1780)		
NUM_STS	FORMAT is HE_SU	Indicates the number of space-time streams. Integer in the range 1-8.	Y	Y
	FORMAT is HE_EXT_SU	Indicates the number of space-time streams. Integer in the range 1-2.	Y	Y
	FORMAT is HE_MU	Indicates the number of space-time streams. Integer in the range: 1-4 in the TXVECTOR per user 0-4 in the RXVECTOR per MU-MIMO RU 1-8 per non MU-MIMO RU in the TXVECTOR 0-8 per non MU-MIMO RU in the RXVECTOR NUM_STS summed over all users per RU is not greater than 8.	M U	M U
	FORMAT is HE_TRIG	Indicates the number of space-time streams. Integer in the range: 1-4 in the TXVECTOR for MU-MIMO RU 0-4 per user in the RXVECTOR per MU-MIMO RU 1-8 in the TXVECTOR for non MU-MIMO RU 0-8 per non MU-MIMO RU in the RXVECTOR NUM_STS summed over all users per RU is not greater than 8.	M U	M U

	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
GROUP_ID	FORMAT is HE_SU or HE_MU or HE_EXT_SU or HE_TRIG	Not present	N	N
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
PARTIAL_AID	FORMAT is HE_SU or HE_MU or HE_EXT_SU or HE_TRIG	Not present	N	N
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
TXOP_DURATION	FORMAT is HE_SU or HE_MU or HE_EXT_SU or HE_TRIG	Indicates a duration of time that is used to update the NAV for this TXOP (see 25.2.2 (Updating two NAVs)), except for a value of 127 (i.e., all 1s) which indicates an invalid value of TXOP duration in the HE-SIG-A field (see 25.12 (TXVECTOR parameter TXOP_DURATION for an HE PPDU(#2596))). B0 indicates whether the granularity is 8 μ s or 128 μ s. When B0 is 0, then B1 to B6 indicate a duration, in units of 8 μ s, starting from 0 to 504 μ s (i.e., duration = (8 μ s $\times$ value of (B1-B6)) μ s). When B0 is 1, then B1 to B6 indicate a duration, in units of 128 μ s, starting from 512 μ s until 8448 μ s (i.e., duration = (512 + 128 $\times$ value of (B1-B6)) μ s). See 25.12 (TXVECTOR parameter TXOP_DURATION for an HE PPDU(#2596)) for more details.(#783)	Y	Y
	Otherwise	Not present.	N	N
SPATIAL_REUSE	FORMAT is HE_SU or HE_MU or HE_EXT_SU or HE_TRIG	Indicates the spatial reuse parameter. There is only one value for an HE SU PPDU, HE extended range SU PPDU and HE MU PPDU. There might be one to four values for an HE trigger-based PPDU depending on the bandwidth of the PPDU. See the Spatial Reuse field definition in Content	Y	Y
	Otherwise	Not present	N	N
DOPPLER	FORMAT is HE_SU or HE_MU or HE_EXT_SU or HE_TRIG	Indicates whether the doppler effect should be considered for the PPDU. The value is 0 or 1	Y	N

	Otherwise	Not present	N	N
NUM_USERS	FORMAT is HE_SU or HE_MU or HE_EXT_SU or HE_TRIG	Not present. NOTE—number of users for an HE SU PPDU, HE extended range SU PPDU and HE trigger-based PPDU is always 1. The number of users for an HE MU PPDU is determined by RU_ALLOCATION.	N	N
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
RU_ALLOCATION	FORMAT is HE_MU	Each 8 bit per 20 MHz PPDU BW for signaling: The RU arrangement in frequency domain Number of MU-MIMO allocations See HE-SIG-B common content for details.	Y	Y
	FORMAT is HE_TRIG	8 bit for RU allocation in the whole bandwidth. See 9.3.1.23 (Trigger frame format) for details	Y	Y
	Otherwise	Not present	N	N
BEAMFORMED	FORMAT is HE_SU or HE_EXT_SU	Set to 1 if a beamforming steering matrix is applied to the waveform in an SU transmission. Set to 0 otherwise.	Y	Y
	FORMAT is HE_MU or HE_TRIG	For a single user allocation in an RU, set to 1 if a beamforming steering matrix is applied, and set to 0 otherwise. For each user in a multi-user allocation in an RU, always set to 0.	M U	O
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
HE_LTF_TYPE	FORMAT is HE_SU or HE_MU or HE_EXT_SU or HE_TRIG	Indicates the type of HE-LTF. Enumerated type: 1x HE-LTF 2x HE-LTF 4x HE-LTF See HE-LTF for details.	Y	Y
	Otherwise	Not present.	N	N

HE_LTF_MODE	FORMAT is HE_TRIG	Indicates whether the UL MU MIMO transmission uses single stream pilots or a mask on each spatial stream of the LTF sequence by a distinct orthogonal code. It is only present for full bandwidth MU-MIMO.	Y	N
	Otherwise	Not present.	N	N
STARTING_STS_NUM	FORMAT is HE_TRIG	Indicates the starting STS number in the global space-time streams for the UL MU MIMO.	Y	N
	Otherwise	Not present.	N	N
TXOP_PS_NOT_ALLOWED	FORMAT is HE_SU or HE_MU or HE_EXT_SU or HE_TRIG	Not present.	N	N
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
TIME_OF_DEPARTURE_REQUESTED	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).			
RX_START_OF_FRAME_OFFSET	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).			
PREAMBLE_TYPE	FORMAT is NON_HT and NON_HT_MODULATION is one of ERP-DSSS ERP-CCK	Enumerated type: SHORTPREAMBLE LONGPREAMBLE	Y	Y

	Otherwise	Not present	N	N
PE_DURATION	FORMAT is HE_SU or HE_MU or HE_EXT_SU or HE_TRIG.	Determines the duration of PE field in an HE PPDU. Possible values are 0 μ s, 4 μ s, 8 μ s, 12 μ s and 16 μ s.	Y	Y
BEAM_CHANGE	FORMAT is HE_SU or HE_EXT_SU(#2675)	Boolean value: true indicates that the pre-HE-STF portion of the PPDU is spatially mapped differently from HE-LTF1. false indicates that the pre-HE-STF portion of the PPDU is spatially mapped the same way as HE-LTF1 on each tone.(#481)	Y (# 21 53)	Y (# 21 53)
	Otherwise	Not present(#2675)		
BSS_COLOR	FORMAT is HE_SU or HE_MU or HE_EXT_SU or HE_TRIG	Set to a value of the AP's choosing within the range 0 to 63(#835) (see 25.11 (TXVECTOR parameters STA_ID_LIST, UPLINK_FLAG, BEAM_CHANGE and BSS_COLOR for an HE PPDU(#2517))).	Y	Y
	Otherwise	Not present	N	N
UPLINK_FLAG	FORMAT is HE_SU or HE_MU or HE_EXT_SU	Set to 1 if the HE PPDU is addressed to an AP.(#1611) Set to 0 otherwise (see 25.11 (STA ID, Uplink Flag and BSS Color in HE PDUs)).	Y	Y
	Otherwise	Not present	N	N
STA_ID_LIST	FORMAT is HE_MU	Indicates the list of STA IDs for an HE MU PPDU (see 25.11 (TXVECTOR parameters STA_ID_LIST, UPLINK_FLAG, BEAM_CHANGE and BSS_COLOR for an HE PPDU(#2517))).	M U	Y
	Otherwise	Not present	N	N
SCRAMBLER_INITIAL_STATE	FORMAT is NON_HT	In TXVECTOR, if present, indicates the initial state of the scrambler of the transmitted PPDU. In RXVECTOR, indicates the Scrambler Initialization value in the Service field, prior to descrambling.(#127)	O	Y

	FORMAT is HE_MU or HE_TRIG	Not present.	N	N
	Otherwise	Indicates the Scrambler Initialization value in the Service field, prior to descrambling.	N	Y

NOTE—In the “TXVECTOR” and “RXVECTOR” columns, the following apply:
Y = Present;
N = Not present;
O = Optional;
MU indicates that the parameter is present once for an HE SU PPDU and HE extended range SU PPDU and present per user for an HE MU PPDU. For an HE trigger-based PPDU, MU in the TXVECTOR column indicates that the parameter is present once and MU in the RXVECTOR column indicates the parameter is present per user. (#2676) Parameters specified to be present per user are conceptually supplied as an array of values indexed by u , where u (#2356) takes values 0 to NUM_USERS–1.

26.3 HE PHY

26.3.1 Introduction

26.3.2 MU transmission(#507)

26.3.2.1 Introduction

The MU transmissions include DL MU transmissions and UL MU transmissions.

The DL MU transmission allows an AP to simultaneously transmit frames to more than one non-AP STAs. For the DL MU transmission, the AP uses the HE MU PPDU format, and employs either DL OFDMA, DL MU-MIMO, or a mixture of both. The UL MU transmission allows an AP to receive simultaneous frames from more than one non-AP STAs. Non-AP STAs transmit their frames using HE trigger-based PPDU format and employ either UL OFDMA, UL MU-MIMO, or a mixture of both.

The HE PHY supports OFDMA transmissions, both in the DL and the UL where different users can occupy different RUs in a PPDU (see Math). On an RU in a PPDU, it is allowed to have single stream transmissions to one user or spatial multiplexing to one user (SU-MIMO) or spatial multiplexing to multiple users (MU-MIMO). Note that the VHT PHY supports only full bandwidth DL MU-MIMO as described in 21.3.11 (SU-MIMO and DL-MU-MIMO Beamforming). The HE PHY defines DL MU-MIMO and UL MU-MIMO, for the full bandwidth case as well as for the case where they are being used on only certain RUs in the PPDU. The combination of SU transmissions and MU-MIMO transmissions on different RUs in one PPDU is also supported.

26.3.3 OFDMA and SU tone allocation

Orthogonal Frequency Division Multiple Access (OFDMA) is an OFDM-based multiple access scheme where different subsets of subcarriers are allocated to different users (#1946), allowing simultaneous data transmission to or from (#2524) several users. In OFDMA, in general, users are allocated different subsets of subcarriers which can change from one PPDU (#Ed) to the next (#2525). In HE, the time region covers the entire data portion of an HE PPDU, and the frequency region includes a number of contiguous subcarriers with the exception of the RUs which straddle DC where nulls are placed in the middle of the band. The difference between OFDM and OFDMA is illustrated in CH_BANDWIDTH and . Similar to OFDM, OFDMA employs multiple subcarriers, but the subcarriers are divided into several groups of subcarriers where each group is denoted as a resource unit (RU). The grouping of subcarriers into groups of resource units is referred to as subchannelization. In HE, the subcarriers that form an RU (#1948) are physically adjacent (contiguous except at the middle of the band where nulls are placed at DC).

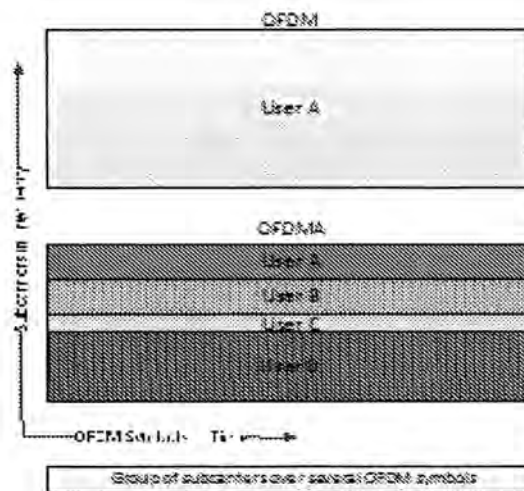


Figure 26-1—Illustration of OFDM and OFDMA concepts

Subchannelization defines subchannels that can be allocated to stations depending on their channel conditions and service requirements. An OFDMA system may allocate different transmit powers to different subchannels. (#1949)

(#2365)(#2526) In OFDMA, an OFDM symbol is constructed of subcarriers, the number of which is a function of the DFT (#2366) size. There are several subcarrier types: 1) Data subcarriers which are used for data transmission; defined in Resource unit, guard and DC subcarriers, 2) Pilot subcarriers which are utilized for phase information and parameter tracking; defined in Pilot tones, and 3) unused subcarriers which are not used for data/pilot transmission. The unused subcarriers are the DC subcarrier (defined in Resource unit, guard and DC subcarriers), the Guard band subcarriers at the band edges (defined in Resource unit, guard and DC subcarriers), and the Null subcarriers (defined in Null subcarriers).

26.3.3.1 Resource unit, guard and DC subcarriers(#1951)

The following resource units (RUs) are defined for DL and UL transmission: a 26-tone RU, 52-tone RU, 106-tone RU, 242-tone RU, 484-tone RU and 996-tone RU and 2×996-tone RU(#838)(#1337)(#353).

The 26-tone RU, 52-tone RU, 106-tone RU and 242-tone RU(PHY Motion #172) are used in the 20 MHz, 40 MHz, 80 MHz, 160 MHz and 80+80 MHz HE MU PPDU formats or HE trigger-based PPDU formats using OFDMA transmission. The 484-tone RU(#838) is used in the 40 MHz, 80 MHz, 160 MHz and 80+80 MHz HE MU PPDU formats or HE trigger-based PPDU formats using OFDMA transmission. The 996-tone RU(#838) is used in the 80 MHz, 160 MHz and 80+80 MHz HE MU PPDU formats or HE trigger-based PPDU formats using OFDMA transmission. The 2×996-tone RU is used in the 160 MHz and 80+80 MHz HE MU PPDU formats or HE trigger-based PPDU formats using OFDMA transmission.(#888)

The 242-tone and larger RUs are used in the HE SU PPDU formats. The 242-tone RU(#838) is used in the 20 MHz HE SU PPDU format. The 484-tone RU(#838) is used in the 40 MHz HE SU PPDU format. The 996-tone RU(#838) is used in the 80 MHz HE SU PPDU format. The 2×996-tone RU(#838)(#1337) is used in the 160 MHz and 80+80 MHz HE SU PPDU formats.(#888)

The maximum number(#Ed) of RUs in the 20 MHz, 40 MHz, 80 MHz, 160 MHz and 80+80 MHz HE PPDU formats are defined in Maximum number of RUs for each channel width.(#285).

Table 26-2—Maximum number of RUs for each channel width(#1850)

RU type	CBW20	CBW40	CBW80	CBW80+80 and CBW160
26-tone RU(#838)	9	18	37	74
52-tone RU	4	8	16	32
106-tone RU	2	4	8	16
242-tone RU	1-SU/MU-MIMO	2	4	8
484-tone RU	N/A	1-SU/MU-MIMO	2	4
996-tone RU	N/A	N/A	1-SU/MU-MIMO	2
2×996 tone RU(#1337)	N/A	N/A	N/A	1-SU/MU-MIMO

An HE MU PPDU using OFDMA transmission can carry a mixture of 26-, 52- and 106-tone RUs within any of the 242-tone RU(#838) boundaries(#888).

Table 26-3—Subcarrier indices for RUs in a 20 MHz HE PPDU

RU type					
26-tone RU(#838)	RU 1 [−121: −96](#1111)	RU 2 [−95: −70]	RU 3 [−68: −43]	RU 4 [−42: −17]	RU 5 [−16: −4, 4: 16](#1111)
	RU 6 [17: 42]	RU 7 [43: 68]	RU 8 [70: 95]	RU 9 [96: 121]	
52-tone RU	RU 1 [−121: −70]	RU 2 [−68: −17]	RU 3 [17: 68]	RU 4 [70: 121]	
106-tone RU	RU 1 [−122: −17]		RU 2 [17: 122]		
242-tone RU	RU 1 [−122: −2, 2: 122]				

Table 26-4—Subcarrier indices for RUs in a 40 MHz HE PPDU

RU type					
26-tone RU(#838)	RU 1 [−243: −218]	RU 2 [−217: −192]	RU 3 [−189: −164]	RU 4 [−163: −138]	RU 5 [−136: −111]
	RU 6 [−109: −84]	RU 7 [−83: −58]	RU 8 [−55: −30]	RU 9 [−29: −4]	
	RU 10 [4: 29]	RU 11 [30: 55]	RU 12 [58: 83]	RU 13 [84: 109]	RU 14 [111: 136]
	RU 15 [138: 163]	RU 16 [164: 189]	RU 17 [192: 217]	RU 18 [218: 243]	
52-tone RU	RU 1 [−243: −192]	RU 2 [−189: −138]	RU 3 [−109: −58]	RU 4 [−55: −4]	
	RU 5 [4: 55]	RU 6 [58: 109]	RU 7 [138: 189]	RU 8 [192: 243]	
106-tone RU	RU 1 [−243: −138]	RU 2 [−109: −4]	RU 3 [4: 109]	RU 4 [138: 243]	
242-tone RU	RU 1 [−244: −3]		RU 2 [3: 244]		

484-tone RU	RU 1 [−244: −3, 3: 244]	
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Table 26-5—Subcarrier indices for RUs in an 80 MHz HE PPDU

RU type					
26-tone RU	RU 1 [−499: −474]	RU 2 [−473: −448]	RU 3 [−445: −420]	RU 4 [−419: −394]	RU 5 [−392: −367]
	RU 6 [−365: −340]	RU 7 [−339: −314]	RU 8 [−311: −286]	RU 9 [−285: −260]	
	RU 10 [−257: −232]	RU 11 [−231: −206]	RU 12 [−203: −178]	RU 13 [−177: −152]	RU 14 [−150: −125]
	RU 15 [−123: −98]	RU 16 [−97: −72]	RU 17 [−69: −44]	RU 18 [−43: −18]	RU 19 [−16: −4, 4: 16]
	RU 20 [18: 43]	RU 21 [44: 69]	RU 22 [72: 97]	RU 23 [98: 123]	RU 24 [125: 150]
	RU 25 [152: 177]	RU 26 [178: 203]	RU 27 [206: 231]	RU 28 [232: 257]	
	RU 29 [260: 285]	RU 30 [286: 311]	RU 31 [314: 339]	RU 32 [340: 365]	RU 33 [367: 392]
	RU 34 [394: 419]	RU 35 [420: 445]	RU 36 [448: 473]	RU 37 [474: 499]	
52-tone RU	RU 1 [−499: −448]	RU 2 [−445: −394]	RU 3 [−365: −314]	RU 4 [−311: −260]	
	RU 5 [−257: −206]	RU 6 [−203: −152]	RU 7 [−123: −72]	RU 8 [−69: −18]	
	RU 9 [18: 69]	RU 10 [72: 123]	RU 11 [152: 203]	RU 12 [206: 257]	
	RU 13 [260: 311]	RU 14 [314: 365]	RU 15 [394: 445]	RU 16 [448: 499]	
106-tone RU	RU 1 [−499: −394]	RU 2 [−365: −260]	RU 3 [−257: −152]	RU 4 [−123: −18]	

	RU 5 [18: 123]	RU 6 [152: 257]	RU 7 [260: 365]	RU 8 [394: 499]	
242-tone RU	RU 1 [−500: −259]	RU 2 [−258: −17]	RU 3 [17: 258]	RU 4 [259: 500]	
484-tone RU	RU 1 [−500: −17]		RU 2 [17: 500](#2758)		
996-tone RU	RU 1 [−500: −3, 3: 500]				

A 26-tone RU(#838) consists of 24 data subcarriers and 2 pilot subcarriers. The positions of the pilots for the 26-tone RU(#838) are(#1957) defined in Pilot tones. The location of the 26-tone RUs(#838) are fixed as defined in Subcarrier indices for RUs in a 20 MHz HE PPDU, Subcarrier indices for RUs in a 40 MHz HE PPDU and Subcarrier indices for RUs in an 80 MHz HE PPDU(#1958) and shown in RU locations in a 20 MHz HE PPDU, RU locations in a 40 MHz HE PPDU and RU locations in an 80 MHz HE PPDU(#2759) for the 20 MHz, 40 MHz and 80 MHz HE MU PPDU formats or HE trigger-based PPDU formats using OFDMA transmission, respectively. The same structure as used for the 80 MHz HE MU PPDU formats or HE trigger-based PPDU formats using OFDMA transmission is used for each 80 MHz frequency segment of the 160 MHz and 80+80 MHz HE MU PPDU or HE trigger-based PPDU formats using OFDMA transmission. The center 26-tone RU(#838) in the 20 MHz and 80 MHz HE MU PPDU or HE trigger-based PPDU formats using OFDMA transmission (RU locations in a 20 MHz HE PPDU and RU locations in an 80 MHz HE PPDU) is located on subcarriers [−16: −4, 4: 16].(#888)

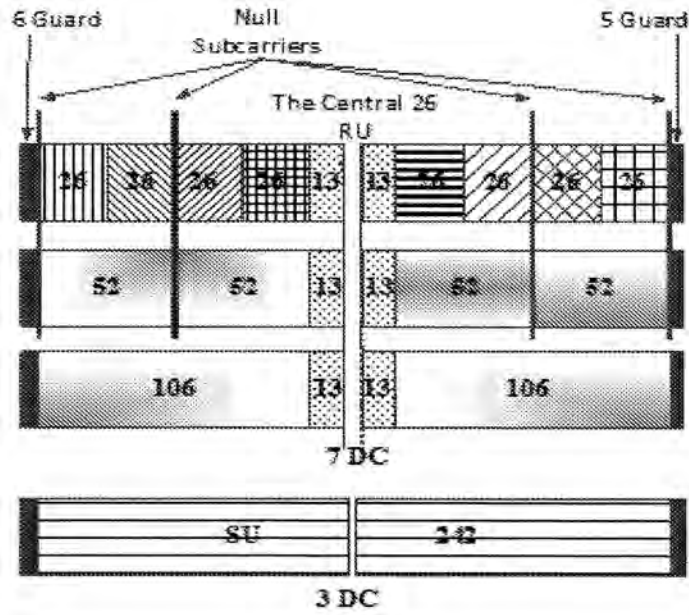


Figure 26-2—RU locations in a 20 MHz HE PPDU

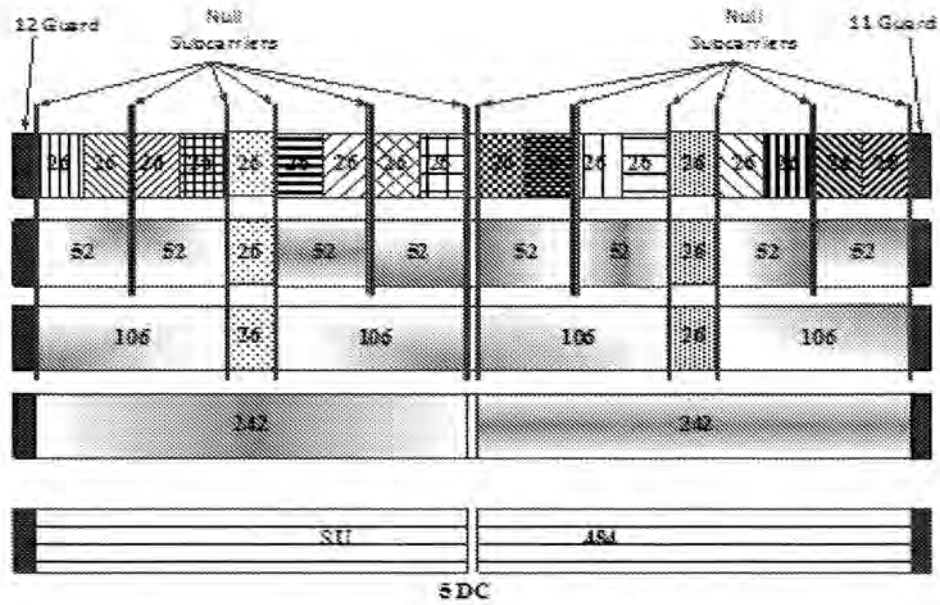


Figure 26-3—RU locations in a 40 MHz HE PPDU

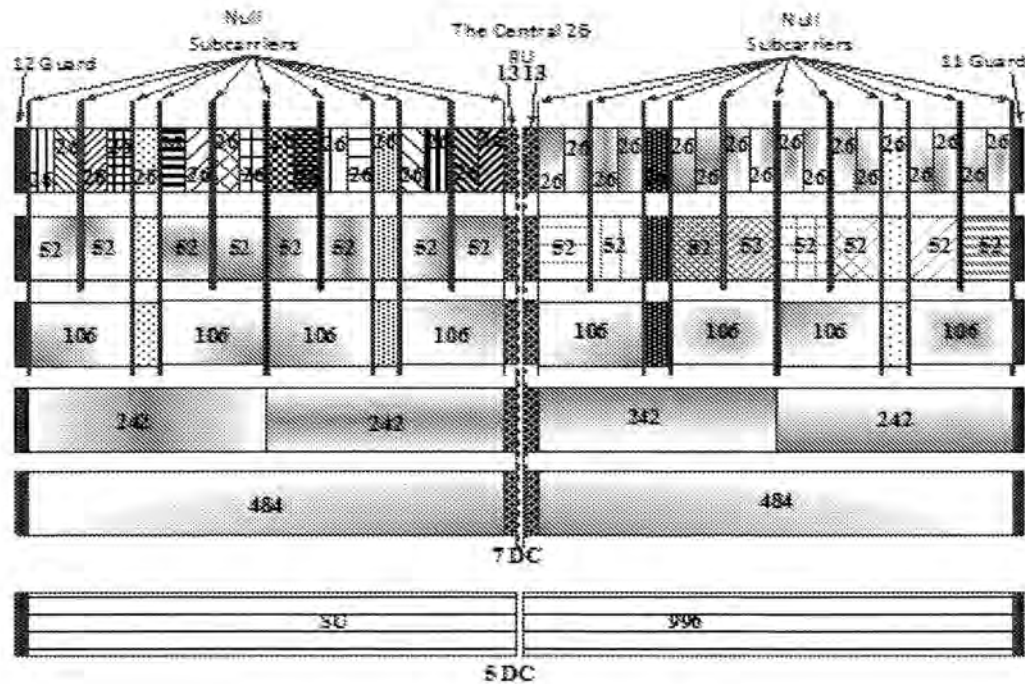


Figure 26-4—RU locations in an 80 MHz HE PPDU

A 52-tone RU(#838) consists of 48 data subcarriers and 4 pilot subcarriers. The positions of the pilots for the 52-tone RU(#838) are(#1960) defined in Pilot tones. The locations of the 52-tone RUs(#838) are fixed as defined in Subcarrier indices for RUs in a 20 MHz HE PPDU, Subcarrier indices for RUs in a 40 MHz HE PPDU and Subcarrier indices for RUs in an 80 MHz HE PPDU and illustrated in RU locations in a 20 MHz HE PPDU, RU locations in a 40 MHz HE PPDU and RU locations in an 80 MHz HE PPDU for the 20 MHz, 40 MHz and 80 MHz HE MU PPDU formats or HE trigger-based PPDU formats using OFDMA transmission, respectively. The same structure as used in the 80 MHz HE MU PPDU format or HE trigger-based PPDU formats using OFDMA transmission is used for each 80 MHz frequency segment of the 160 MHz and 80+80 MHz HE MU PPDU formats or HE trigger-based PPDU formats using OFDMA transmission.(#888)

A 106-tone RU(#838) consists of 102 data subcarriers and 4 pilot subcarriers. The positions of the pilots for the 106-tone RU(#838) are(#1961) defined in Pilot tones. The locations of the 106-tone RUs(#838) are fixed as defined in Subcarrier indices for RUs in a 20 MHz HE PPDU, Subcarrier indices for RUs in a 40 MHz HE PPDU and Subcarrier indices for RUs in an 80 MHz HE PPDU and illustrated in RU locations in a 20 MHz HE PPDU, RU locations in a 40 MHz HE PPDU and RU locations in an 80 MHz HE PPDU for the 20 MHz, 40 MHz and 80 MHz HE MU PPDU formats or HE trigger-based PPDU formats using OFDMA transmission, respectively. The same structure as used in the 80 MHz HE MU PPDU formats or HE trigger-based PPDU formats using OFDMA transmission is used for each 80 MHz frequency segment

of the 160 MHz and 80+80 MHz HE MU PPDU formats or HE trigger-based PPDU formats using OFDMA transmission.

A 242-tone RU(#838) consists of 234 data subcarriers and 8 pilot subcarriers. The positions of pilots for the 242-tone RU(#838) are (#1962) defined in Pilot tones. The locations of the 242-tone RUs(#838) are fixed as defined in Subcarrier indices for RUs in a 20 MHz HE PPDU, (#1669) Subcarrier indices for RUs in a 40 MHz HE PPDU and Subcarrier indices for RUs in an 80 MHz HE PPDU and illustrated in RU locations in a 20 MHz HE PPDU, RU locations in a 40 MHz HE PPDU and RU locations in an 80 MHz HE PPDU for the 20 MHz, 40 MHz and 80 MHz HE PPDU formats, respectively. The same structure as used in the 80 MHz HE PPDU formats is used for each 80 MHz frequency segment of the 160 MHz and 80+80 MHz HE PPDU formats.(#888)

A 484-tone RU(#838) consists of 468 data subcarriers and 16 pilot subcarriers. The position of the pilots for the 484-tone RU(#838) is defined in Pilot tones. The locations of the 484-tone RUs(#838) are fixed as defined in Subcarrier indices for RUs in a 40 MHz HE PPDU and Subcarrier indices for RUs in an 80 MHz HE PPDU and illustrated in RU locations in a 40 MHz HE PPDU and RU locations in an 80 MHz HE PPDU for the 40 MHz and 80 MHz HE PPDU formats. The same structure as used for the 80 MHz HE PPDU formats is used for each 80 MHz frequency segment of the 160 MHz and 80+80 MHz HE PPDU formats.(#888)

A 996-tone RU(#838) consists of 980 data subcarriers and 16 pilot subcarriers. The position of the pilots for the 996-tone RU(#838) is defined in Pilot tones. The locations of the 996-tone RUs(#838) are fixed and located on subcarrier [-1012: -515, -509: -12] and [12: 509, 515: 1012] for each half of the BW, respectively, for 160 MHz and 80+80 MHz(#Ed) HE PPDU formats.(#888)

The 20 MHz HE MU PPDU and HE trigger-based PPDU with more than one RU has 7 DC subcarriers located at [-3: 3]. The 20 MHz HE SU PPDU with a 242-tone RU(#838) has 3 DC subcarriers located at [-1: 1]. The 40 MHz HE PPDU with a 484-tone RU has 5 DC subcarriers located at [-2: 2]. An 80 MHz HE MU PPDU and HE trigger-based PPDU with more than one RU has 7 DC subcarriers located at [-3: 3]. The 80 MHz HE SU PPDU with a 996-tone RU has 5 DC subcarriers located at [-2: 2]. The same structure as used in the 80 MHz HE PPDU is used for each 80 MHz frequency segment of the 160 MHz and 80+80 MHz HE PPDU. The DC tones are located on subcarriers [-11: 11].(#1963)(#888)

The 20 MHz HE PPDU format has 11 guard subcarriers (6, 5) located at [-128: -123] and [123: 127] as shown in RU locations in a 20 MHz HE PPDU. The 40 MHz HE PPDU has 23 guard subcarriers (12, 11) located at [-256: -245] and [245: 255] as shown in RU locations in a 40 MHz HE PPDU. The 80 MHz HE PPDU has 23 guard subcarriers (12, 11) located at [-512: -501] and [501: 511] as shown in RU locations in an 80 MHz HE PPDU. For 160 MHz and 80+80 MHz HE PPDU, the same number of leftmost and rightmost guard subcarriers as 80 MHz are defined at each edge of the 160 MHz.

(PHY Motion #165) In an HE MU PPDU, at least $N \times 4 \times 26$ subcarriers (contiguous or non-contiguous), where N is the number of 20 MHz channels' legacy preambles present, shall be occupied throughout the signaled BW.

26.3.3.2 Null subcarriers

There are null subcarriers between the 26-, 52- and 106-tone RU(#838) locations as illustrated in RU locations in a 20 MHz HE PPDU, RU locations in a 40 MHz HE PPDU and RU locations in an 80 MHz HE PPDU. The null subcarriers have zero energy. The indices of the null subcarrier are enumerated in Null subcarrier indices .

Table 26-6— Null subcarrier indices

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Channel Width	RU Size	Null Subcarrier Indices
20 MHz	26, 52	$\pm 69, \pm 122$
	106	none
	242	none
40 MHz	26, 52	$\pm 3, \pm 56, \pm 57, \pm 110, \pm 137, \pm 190, \pm 191, \pm 244$
	106	$\pm 3, \pm 110, \pm 137, \pm 244$
	242, 484	none
80 MHz	26, 52	$\pm 17, \pm 70, \pm 71, \pm 124, \pm 151, \pm 204, \pm 205, \pm 258, \pm 259, \pm 312, \pm 313, \pm 366, \pm 393, \pm 446, \pm 447, \pm 500$
	106	$\pm 17, \pm 124, \pm 151, \pm 258, \pm 259, \pm 366, \pm 393, \pm 500$
	242, 484	none
	996	none

26.3.3.3 Pilot tones

If pilot tones are present in the HE-LTF field, the pilot tone locations in the HE-LTF field and Data field shall be the same. All pilot tones are at the even indices enumerated in Pilot tone indices .(#1789)

Table 26-7— Pilot tone indices

Channel Width	RU Size	Pilot Tone Indices
20 MHz	26, 52	$\pm 10, \pm 22, \pm 36, \pm 48, \pm 62, \pm 76, \pm 90, \pm 102, \pm 116$
	106, 242	$\pm 22, \pm 48, \pm 90, \pm 116$
40 MHz	26, 52	$\pm 10, \pm 24, \pm 36, \pm 50, \pm 64, \pm 78, \pm 90, \pm 104, \pm 116, \pm 130, \pm 144, \pm 158, \pm 170, \pm 184, \pm 198, \pm 212, \pm 224, \pm 238$
	106, 242, 484	$\pm 10, \pm 36, \pm 78, \pm 104, \pm 144, \pm 170, \pm 212, \pm 238$

80 MHz	26, 52	$\pm 10, \pm 24, \pm 38, \pm 50, \pm 64, \pm 78, \pm 92, \pm 104, \pm 118, \pm 130, \pm 144, \pm 158, \pm 172, \pm 184, \pm 198, \pm 212, \pm 226, \pm 238, \pm 252, \pm 266, \pm 280, \pm 292, \pm 306, \pm 320, \pm 334, \pm 346, \pm 360, \pm 372, \pm 386, \pm 400, \pm 414, \pm 426, \pm 440, \pm 454, \pm 468, \pm 480, \pm 494$
	106, 242, 484	$\pm 24, \pm 50, \pm 92, \pm 118, \pm 158, \pm 184, \pm 226, \pm 252, \pm 266, \pm 292, \pm 334, \pm 360, \pm 400, \pm 426, \pm 468, \pm 494$
	996	$\pm 24, \pm 92, \pm 158, \pm 226, \pm 266, \pm 334, \pm 400, \pm 468$
160 MHz	26, 52, 106, 242, 484	{ pilot tone indices in 80 MHz -512 , pilot tone indices in 80 MHz $+512$ }
	996	{ for the first 80 MHz, pilot tone indices in 80 MHz -512 , for the second 80 MHz, pilot tone indices in 80 MHz $+512$ } (#841)

The pilot tones locations for 160 MHz or 80+80 MHz shall use the same 80 MHz locations for both 80 MHz.

26.3.3.4 RU restriction rules when operating 20 MHz(#854)

A non-AP STA can operate with 20 MHz, because either it is a 20 MHz-only HE device (see **Erreur ! Source du renvoi introuvable.**), or it reduces operating channel width to 20 MHz by ROM (see 25.8 (Operating mode indication)). When a 20 MHz operating non-AP STA is either a recipient of 40, 80, 80+80 or 160 MHz DL-OFDMA, or one of transmitters of 40, 80, 80+80 or 160 MHz UL-OFDMA, RU tone mapping in 20 MHz is not aligned with 40, 80, 80+80 or 160 MHz RU tone mapping (see Resource unit, guard and DC subcarriers). Due to misalignment of these RU locations, some of these RUs may cause significant performance penalty or interference to neighbor RUs. To improve the throughput and interoperability, some RUs in 20 MHz operating STAs are restricted to be used in 40, 80, 80+80 or 160 MHz OFDMA operation.

An AP shall not assign the following RUs to 20 MHz operating STAs

- For 26-tone RUs, [Subcarrier indices for RUs in a 40 MHz HE PPDU and Subcarrier indices for RUs in an 80 MHz HE PPDU]
 - RU 5 and 14 in 40 MHz DL/UL OFDMA (2 26-tone RUs are restricted)
 - RU 5, 10, 14, 19, 24, 28, 33 in 80 MHz DL/UL OFDMA (7 26-tone RUs are restricted)
 - RU 5, 10, 14, 19, 24, 28, 33 in lower 80 MHz and upper 80 MHz, in 80+80 or 160 MHz DL/UL OFDMA (14 26-tone RUs are restricted)
- For 52-tone RUs, [Subcarrier indices for RUs in a 40 MHz HE PPDU and Subcarrier indices for RUs in an 80 MHz HE PPDU]
 - RU 5, 12 in 80 MHz DL/UL OFDMA (2 of 52-tone RUs are restricted)
 - RU 5, 12 in lower 80 MHz and upper 80 MHz, in 80+80 or 160 MHz DL/UL OFDMA (4 of 52-tone RUs are restricted)
- For 106-tone RUs, [Subcarrier indices for RUs in a 40 MHz HE PPDU and Subcarrier indices for RUs in an 80 MHz HE PPDU]
 - RU 3, 6 in 80MHz DL/UL OFDMA (2 of 106-tone RUs are restricted)

- * RU 3, 6 in lower 80 MHz and upper 80 MHz, in 80+80 or 160 MHz DL/UL OFDMA (4 of 106-tone RUs are restricted)

Center 26-tone RU in primary 20 channel shall not be assigned to any STAs where 20 MHz operating STAs are recipients of 40/80/160/80+80 OFDMA.

It is optional whether all 242-tone RUs of 20 MHz operating STAs to be supported in 40/80/160/80+80 MHz DL-OFDMA. If supported, there is no restriction on 242-tone RUs. A 242-tone RU shall not be allocated to 20 MHz operating STAs in 40/80/160/80+80 for UL-OFDMA.

26.3.3.5 20 MHz only HE STAs

(PHY Motion #163) A 20 MHz only HE STA operates with 20 MHz channel width only, in frequency bands between 1 GHz and 6 GHz. A 20 MHz only HE STA operates in the primary 20 MHz channel as a mandatory mode. It is indicated in the capability field, whether an HE STA is 20 MHz only, 80 MHz, 160 MHz or 80+80MHz capable. Only a non-AP HE STA can be a 20 MHz-only STA.

An HE AP in 5 GHz shall be 80 MHz capable and operate for both 80 MHz capable non-AP HE STAs and 20 MHz only non-AP HE STAs.

A 20 MHz only non-AP HE STA supports tone mapping of 26-tone RU, 52-tone RU, 106-tone RU and 242-tone RU, for 20 MHz and 40 MHz OFDMA in 2.4 GHz and 5 GHz frequency band, and for 80 MHz, 80+80 MHz and 160 MHz OFDMA in 5 GHz frequency band, where some of RUs are restricted to operate (see RU restriction rules when operating 20 MHz).

26.3.3.6 DL MU transmission

DL MU transmission allows an AP to simultaneously transmit to more than one non-AP STA. The AP uses the HE MU PPDU for DL MU transmission.

26.3.3.7 DL MU-MIMO

26.3.3.7.1 Minimum RU size in DL MU-MIMO

A STA capable of receiving DL MU-MIMO transmission on an RU that does not span the entire PPDU bandwidth in an HE MU PPDU shall support reception of DL MU-MIMO transmissions for all RU sizes greater than or equal to 106-tons.

26.3.3.7.2 Maximum number of spatial streams in an HE MU PPDU

An HE STA shall support reception of DL MU-MIMO transmissions on full bandwidth with maximum number of space-time streams (per user) equal to minimum of 4 and the maximum number of space-time streams supported for reception of HE SU PPDU. The maximum number of space-time streams supported for reception of HE SU PPDU is indicated for various bandwidths in 'HE-MCS and Nss Map' field in the HE Capabilities element.

An HE STA shall support reception of DL MU-MIMO transmissions on full bandwidth with the total number of space-time streams (across NUM_USERS) less than or equal to a maximum value indicated by the Beamformee STS Capability in the HE Capabilities element(#1785).

All of the aforementioned restrictions on the per-user and total number of space-time-streams are also applicable to an MU-MIMO transmission on an RU in an HE MU PPDU where the RU does not span the entire PPDU bandwidth.

26.3.3.7.3 Maximum number of total spatial streams in an HE MU PPDU(#1863)

A DL MU-MIMO capable STA shall support reception of DL MU PPDU's with the total number of space-time streams across the N_{user} users being less than or equal to its DL MU-MIMO STS Capability in the HE Capabilities.

26.3.3.7.4 Resource indication in an HE MU PPDU(#Ed)

An AP that transmits an HE MU PPDU shall set the UL/DL field in the HE-SIG-A field to 0.(#1862) A full bandwidth MU MIMO transmission using HE MU PPDU format has a value of 1 for the SIGB Compression field in HE-SIG-A and the SIGB Common field is not present.(#2126) If the value of SIGB Compression field in HE-SIG-A is 0, the RU allocation signaling in the HE-SIG-B common field indicates the combination of RUs in current PPDU bandwidth and the number of STAs on each RU for SU/MU-MIMO(#1507) transmission. The number of users in RU r for MU-MIMO transmission, $N_{user,r}$ is indicated together with the RU allocation as defined in RU allocation signaling; arrangement and number of MU-MIMO al. If the value of the SIGB Compression field in HE-SIG-A is 1, there is no RU allocation signaling in HE-SIG-B Common field and HE-SIG-B contains only User specific fields. The number of STAs in the MU-MIMO(#1507) group is indicated in the Number Of HE-SIG-B Symbols Or MU-MIMO Users field(#853) in HE-SIG-A. For bandwidths larger than 20 MHz, the User block fields are split equitably between two SIG-B channels, i.e., for a k user MU-MIMO PPDU, 1, ..., $\text{ceil}(k/2)$ User block fields are carried in HE-SIG-B content channel 1 and $\text{ceil}(k/2) + 1, \dots, k$ User block fields in HE-SIG-B content channel 2.(#1005) The number of spatial streams, $N_{SS,r,u}$, is indicated by the NSTS field in user specific block as defined in Fields of the HE-SIG-B user field for an and Fields of the HE-SIG-B user field for an.(#946) The allocated spatial streams for a designated MU-MIMO(#1507) user and the total number of spatial streams on the RU are indicated in spatial configuration field of user specific block containing the STA ID of designated MU-MIMO(#1507) STA as defined in Spatial Configuration subfield encoding .

When processing the HE-SIG-B, a STA will look at information of each RU to find out its membership status, i.e., if it belongs to a beamformee group in a certain RU. If $N_{user,r}$ STAs are scheduled in RU r , there are $N_{user,r}$ user specific blocks for RU r . Each user specific block has an 11-bit field indicating the STA ID. A STA identifies itself as a member in the beamformee group in the RU, if its STA ID matches one of the STA IDs. The user position is indicated by the block index. From a multiplexing information lookup table for $N_{user,r}$, the ordered number of spatial streams for all members in the beamformee group in RU r , $N_{SS,r,u}$, $u = 1, \dots, N_{user,r}$, is obtained. The spatial streams of different users are ordered in accordance to user position values, i.e., the spatial streams for the user in user position 0 come first, followed by the spatial streams for the user in position 1, followed by the spatial streams for the user in position 2, and followed by the spatial streams for the user in position 3, and so on.

A STA is also able to identify the space-time streams intended for other STAs that act as interference. HE-LTF symbols in the DL HE MU PPDU are used to measure the channel for the space-time streams intended for the STA and can also be used to measure the channel for the interfering space-time streams. To successfully demodulate the space-time streams intended for the STA, it is recommended that the STA uses the channel knowledge for all space-time streams to reduce the effect of interfering space-time streams.

If a STA finds that it is a member of the beamformee group in RU r , its corresponding $N_{STS,r,u}$ interpreted from the HE-SIG-B user specific blocks shall not be zero for the STA in the PPDU. If a STA finds that it is

not a member of the beamformee group in RU r , then the STA may elect not to process RU r in the remainder of the PPDU.

26.3.3.8 UL MU transmission

26.3.3.8.1 Introduction

UL MU transmissions allow an AP to receive simultaneous frames from more than one non-AP STA. UL MU transmissions are preceded by a Trigger frame from the AP. The non-AP STA uses the HE trigger-based PPDU for UL MU transmission.

26.3.3.9 UL MU-MIMO

26.3.3.9.1 Introduction

UL MU-MIMO is a technique to allow multiple STAs to transmit simultaneously over the same frequency resource to the receiver. The concept is very similar to SU-MIMO where multiple space-time streams are transmitted simultaneously over the same frequency resource utilizing spatial multiplexing through multiple antennas at the transmitter and receiver. The key difference from SU-MIMO is that in UL MU-MIMO, the transmitted streams originate from multiple STAs.

26.3.3.9.2 Minimum RU size in UL MU-MIMO

A STA capable of an UL MU-MIMO transmission on an RU that does not span the entire PPDU bandwidth in an HE trigger-based PPDU shall support UL MU-MIMO transmission for all RU sizes greater than or equal to 106 subcarriers. (#1862)

26.3.3.9.3 MU-MIMO LTF Mode

A STA capable of UL MU-MIMO transmission on full bandwidth shall support single stream pilot and masking LTF sequence of each spatial stream by a distinct orthogonal code.

A STA capable of UL OFDMA with MU-MIMO transmission on an RU in an HE trigger-based PPDU shall support single stream pilot for any UL OFDMA transmission, including UL OFDMA with MU-MIMO transmission on an RU in an HE trigger-based PPDU.

26.3.3.9.4 Maximum number of spatial streams in an HE trigger-based PPDU

A STA capable of UL MU-MIMO transmission shall support UL MU-MIMO transmissions on full bandwidth with maximum number of space-time streams (per user) equal to minimum of 4 and the maximum number of space-time streams supported for transmission of HE SU PPDU. The maximum number of space-time streams supported for transmission of HE SU PPDU is indicated for various bandwidths in 'HE-MCS and Nss Map' field in the HE Capabilities element (#1785).

A STA capable of UL MU-MIMO transmission on the full bandwidth shall support a total of up to 8 space-time streams in the UL MU-MIMO transmission.

All of the aforementioned restrictions on the per-user and total number of space-time-streams are also applicable to an MU-MIMO transmission on an RU in an HE MU PPDU where the RU does not span the entire PPDU bandwidth.

26.3.3.9.5 Resource allocation for an HE trigger-based PPDU

UL MU transmissions are preceded by a Trigger frame from the AP. The Trigger frame indicates the transmitting STAs in the Common Info field(#948) about when to transmit the UL MU-MIMO PPDU, the duration of the payload, and packet-extension. The GI duration(#1420) for UL OFDMA/MU-MIMO transmissions shall also be explicitly indicated by AP in the Trigger frame. The value of GI duration(#1420) for all users addressed by the Trigger frame shall be the same. The Trigger frame indicates whether the UL MU transmission following it uses single stream pilots or a mask on each spatial stream of the LTF sequence by a distinct orthogonal code. When single stream pilot is used, no masking is applied to the HE-LTF. Single stream pilot is used for any UL OFDMA transmission, including UL OFDMA with MU-MIMO transmissions. The appropriate MU-MIMO LTF mode indicated by the Trigger frame is used for full bandwidth UL MU-MIMO transmission.(#1862) The allocated RU and spatial streams are carried in the fields of RU allocation info and SS allocation of User Info(#1520) field, where Address field is set as the AID of designated MU-MIMO(#1507) STA.(PHY Motion #169)

If a STA finds that there is no User Info(#1520) field in Trigger frame carrying the STA's AID in the Address field, then the STA will not transmit in the following HE trigger-based PPDU.

26.3.4 HE PPDU formats

Four HE PPDU formats are defined: HE SU PPDU, HE MU PPDU, HE extended range SU PPDU and HE trigger-based PPDU.

The format of the HE SU PPDU is defined as in HE SU PPDU format. This PPDU format is used for SU transmission and, in this format, the HE-SIG-A field is not repeated.(#1838).



Figure 26-5—HE SU PPDU format

The format of the HE MU PPDU is defined as in HE MU PPDU format. This format is used for transmission to one or more users that is not a response of a Trigger frame.(#271) The HE-SIG-B field is present in this format.(#1839)

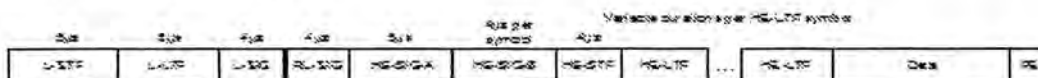


Figure 26-6—HE MU PPDU format

The format of the HE extended range SU PPDU is defined as in HE extended range SU PPDU format. This format is used for SU transmission and, in this format, (#1840) the HE-SIG-A field is repeated.

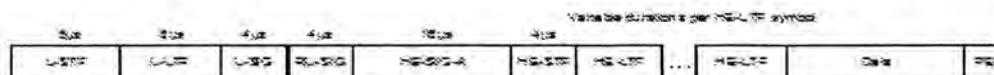


Figure 26-7—HE extended range SU PPDU format

The format of the HE trigger-based PPDU is defined as in HE trigger-based PPDU format. This format is used for a transmission that is a response to a Trigger frame.(#1032) The HE trigger-based PPDU format is identical to the HE SU PPDU format for the L-STF, L-LTF, L-SIG, RL-SIG, HE-SIG-A fields. The duration of the HE-STF field is 8 μ s.(#881)

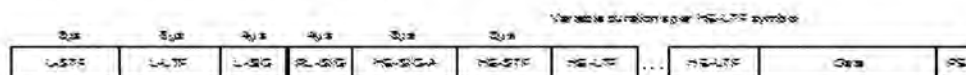


Figure 26-8—HE trigger-based PPDU format

The fields of the HE PPDU formats are summarized in HE PPDU fields.

Table 26-8—HE PPDU fields(#2343)

Field	Description
L-STF	Non-HT Short Training field
L-LTF	Non-HT Long Training field
L-SIG	Non-HT SIGNAL field
RL-SIG	Repeated Non-HT SIGNAL field
HE-SIG-A	HE Signal A field
HE-SIG-B	HE Signal B field

HE-STF	HE Short Training field
HE-LTF	HE Long Training field
Data	The Data field carrying the PSDU(s)
PE	Packet Extension field

The RL-SIG, HE-SIG-A, HE-SIG-B, HE-STF, HE-LTF, and PE fields exist only in HE PPDU. (#1612)The HE-SIG-B field is present only in the HE MU PPDU. The duration of the PE field is determined by the TXVECTOR parameter PE_DURATION.

(#2061)The HE NDP PPDU has the following properties:

- Uses the HE SU PPDU format but without the Data field
- Has a Packet Extension field that is 4 μ s in duration

NOTE—The number of HE-LTF OFDM symbols, N_{HE-LTF} , (#1612) is a function of the total number of space-time streams N_{STS} as shown in Frequently used parameters.

(#883)The L-STF, L-LTF, L-SIG, RL-SIG, HE-SIG-A, HE-SIG-A-R, and HE-SIG-B fields are referred to as the Pre-HE modulated fields, while the HE-STF, HE-LTF and Data fields are referred to as the HE modulated fields.(#472)

26.3.5 Transmitter block diagram

The generation of each field in an(#2829) HE PPDU uses many of the following blocks:

- a) pre-FEC PHY padding
- b) Scrambler
- c) FEC (BCC or LDPC) encoders
- d) post-FEC PHY padding
- e) Stream parser
- f) Segment parser (for contiguous 160 MHz and noncontiguous 80+80 MHz transmissions)
- g) BCC interleaver
- h) Constellation mapper
- i) DCM tone mapper
- j) Pilot insertion
- k) Replicate over multiple 20 MHz (if BW > 20 MHz)
- l) Multiply by 1st column of P_{HE-LTF} (#1090)
- m) LDPC tone mapper

- n) Segment deparser
- o) Space time block code (STBC) encoder
- p) Cyclic shift diversity (CSD) per STS insertion
- q) Spatial mapper
- r) Spatial and frequency mapping(PHY Motion #172)
- s) Inverse discrete Fourier transform (IDFT)
- t) Cyclic shift diversity (CSD) per chain insertion
- u) Guard interval (GI) insertion
- v) Windowing

Transmitter block diagram for the L-SIG, RL-SIG and HE-SIG-A fields for an HE to Transmitter block diagram for the Data field of an HE SU PPDU in 80+80 MHz with LD show example transmitter block diagrams. The actual structure of the transmitter is implementation dependent.

In particular, Transmitter block diagram for the L-SIG, RL-SIG and HE-SIG-A fields for an HE shows the transmit process for the L-SIG, RL-SIG, and HE-SIG-A fields of an(#2829) HE PPDU using one frequency segment, when the Beam Change subfield in HE-SIG-A field is set to 1. These transmit blocks are also used to generate the L-STF and L-LTF fields(#470) of the HE PPDU when the Beam Change subfield in HE-SIG-A field is set to 1, with the following exceptions(#Ed):

- The BCC encoder and interleaver are not used when generating the L-STF and L-LTF fields.
- The BCC interleaver is not applied in the repeated HE-SIG-A symbols (i.e. the 2nd and the 4th OFDM symbols of HE-SIG-A field) in the HE extended range SU PPDU.

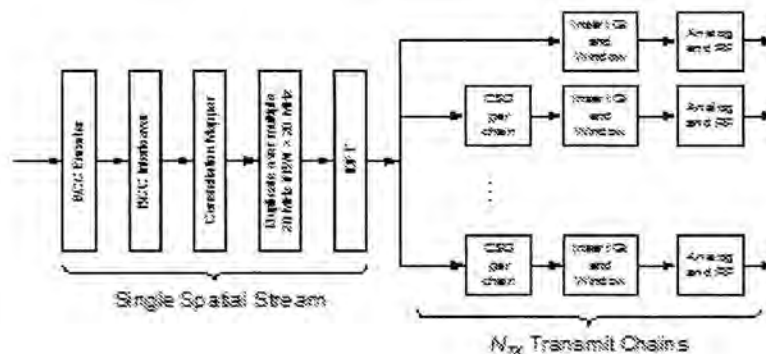


Figure 26-9—Transmitter block diagram for the L-SIG, RL-SIG and HE-SIG-A fields for an HE SU PPDU and HE extended range SU PPDU when the Beam Change field is 1 and the HE MU PPDU(#1659)

Transmitter block diagram for the L-SIG, RL-SIG and HE-SIG-A fields for an HE shows the transmit process for the L-SIG, RL-SIG, and HE-SIG-A fields of an(#2829) HE PPDU using one frequency segment, when the Beam Change subfield in HE-SIG-A field is set to 0. These transmit blocks are also

used to generate the L-STF and L-LTF fields (#471) of the HE PPDU when the Beam Change subfield in HE-SIG-A field is set to 0, with the following exceptions:

- The BCC encoder and interleaver are not used when generating the L-STF and L-LTF fields.
- The BCC interleaver is not applied in the repeated HE-SIG-A field OFDM symbols (i.e., the 2nd and the 4th OFDM symbols of HE-SIG-A field) in the HE extended range SU PPDU.

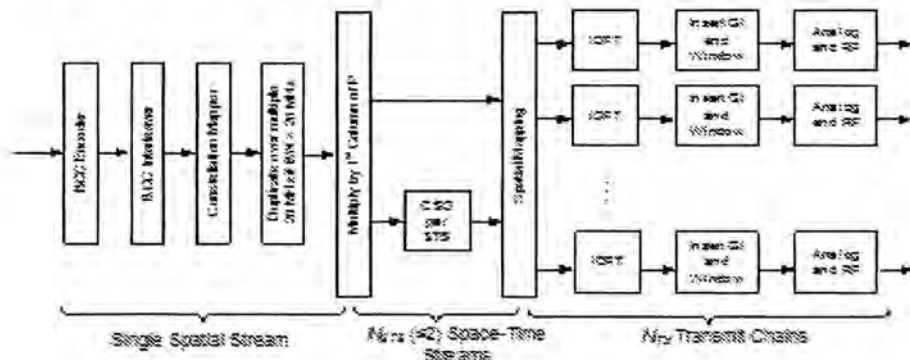


Figure 26-10—Transmitter block diagram for the L-SIG, RL-SIG and HE-SIG-A fields for an HE SU PPDU and HE extended range SU PPDU when the Beam Change field is 0(#2360)(#1659)

Transmitter block diagram for the L-SIG, RL-SIG and HE-SIG-A fields of an HE shows the transmit process for the L-SIG, RL-SIG and HE-SIG-A fields of an HE trigger-based PPDU using one frequency segment. In the HE trigger-based PPDU, the pre-HE-STF preamble, which includes legacy preamble, RL-SIG and HE-SIG-A fields, is sent only on the 20 MHz channels where the HE modulated fields are located. When the HE modulated fields are located in more than one 20 MHz channel, the pre-HE-STF preamble is duplicated over the multiple 20 MHz channels. The BCC encoder and interleaver are not used when generating the L-STF and L-LTF fields.

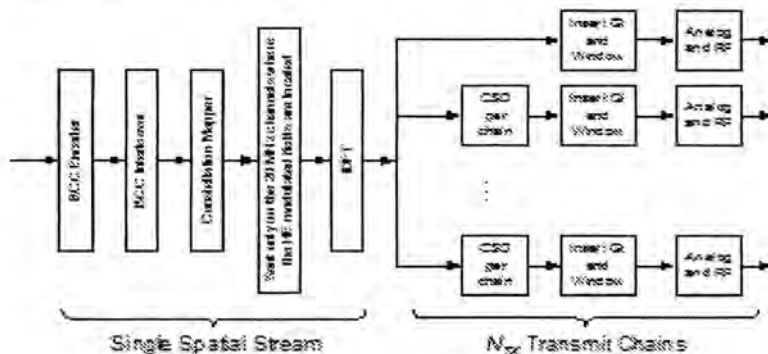


Figure 26-11—Transmitter block diagram for the L-SIG, RL-SIG and HE-SIG-A fields of an HE trigger-based PPDU(#1659)

(#1659)

Transmitter block diagram for the HE-SIG-B field shows the transmit process for the HE-SIG-B field of an HE MU PPDU using one frequency segment. This block diagram is for transmitting HE-SIG-B in one 20 MHz subchannel. Refer to Encoding and modulation for the methods of transmitting HE-SIG-B in 40 MHz, 80 MHz and 160 MHz. The DCM tone mapper is applied only if the DCM indication in HE-SIG-A field is set to 1.(#519)

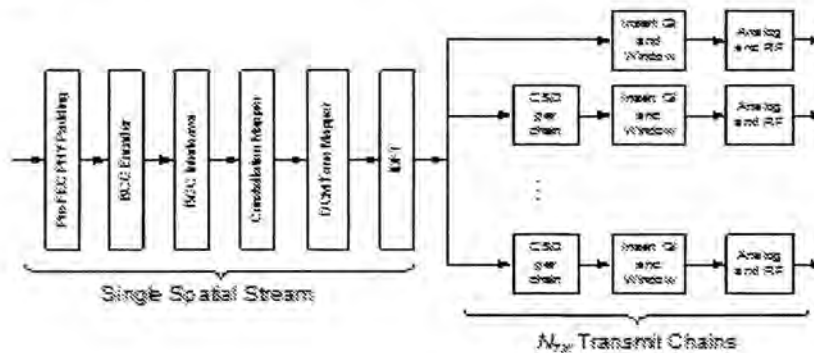


Figure 26-12—Transmitter block diagram for the HE-SIG-B field

Transmitter block diagram for the Data field of an HE SU transmission in a 26-, 52-, 106-, or 242-tone RU(#838) with BCC encoding for a single frequency segment when the number of spatial stream is less than or equal to 4. This also includes the SU transmission in an RU that is part of a downlink or uplink OFDMA PPDU, and a transmission from one STA that is part of an UL MU-MIMO transmission in current RU. The STBC block may be applied only for single spatial stream and only when DCM is not applied. The DCM tone mapper is applied only when the DCM indication for the RU is set to 1. 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 HE-LTF fields. This is illustrated in Generation of HE-LTF symbols per frequency segment in an HE SU PPDU, HE. 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 and frequency mapping block of Transmitter block diagram for the Data field of an HE SU transmission in a 26-, 52-, 106-, or 242-tone RU(#1117), are also used to generate the HE-STF field. (#520)This figure also applies to the data field with BCC encoding in an(#2829) HE trigger-based PPDU.

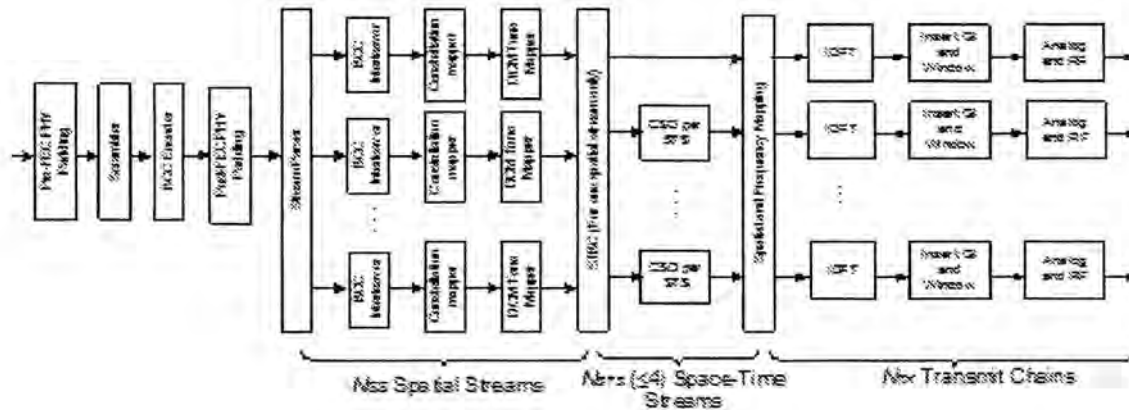


Figure 26-13—Transmitter block diagram for the Data field of an HE SU transmission in a 26-, 52-, 106- or 242-tone RU (#838) with BCC encoding

Transmitter block diagram for the Data field of an HE SU transmission in 26-, 52-, 106-, 242-, 484-, or 996-tone (#838) RU with LDPC encoding for a single frequency segment. This also includes the SU transmission in an RU that is part of a downlink or uplink OFDMA PPDU, and a transmission from one STA that is part of an UL MU-MIMO transmission in current RU. The STBC block may be applied only for single spatial stream and only when DCM is not applied. The DCM tone Mapper is applied only when the DCM indication for the RU is set to 1. (#519) This figure also applies to the data field with LDPC encoding in an (#2829) HE trigger-based PPDU.

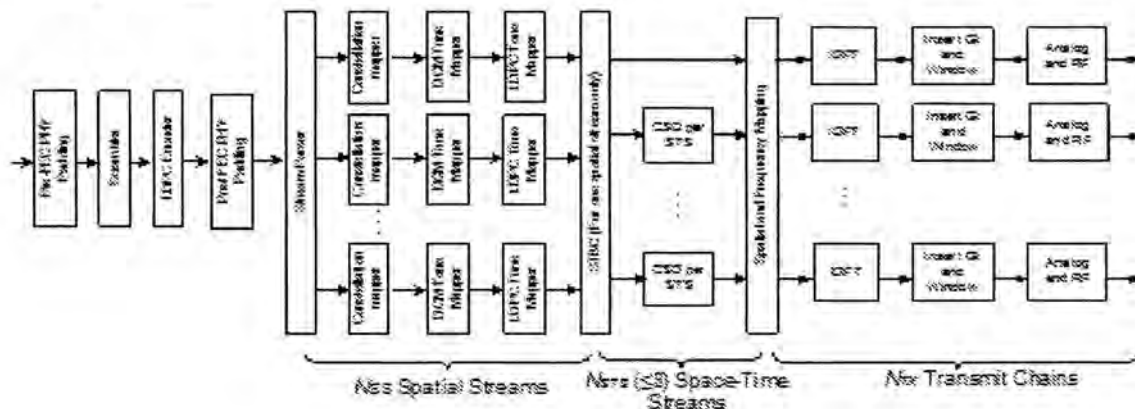


Figure 26-14—Transmitter block diagram for the Data field of an HE SU transmission in 26-, 52-, 106-, 242-, 484-, or 996-tone RU (#838) with LDPC encoding

52-, 106-, 242-, 484- or 996-tone(#838) RU with LDPC encoding

Transmitter block diagram for the Data field of an HE downlink MU-MIMO transmission shows the transmitter blocks used to generate the Data field of an HE downlink MU-MIMO transmission within a 106-, 242-, 484-, or 996-tone(#838) RU with LDPC encoding. This also includes the downlink MU-MIMO transmission in an RU that is part of a downlink (#276)OFDMA PPDU.

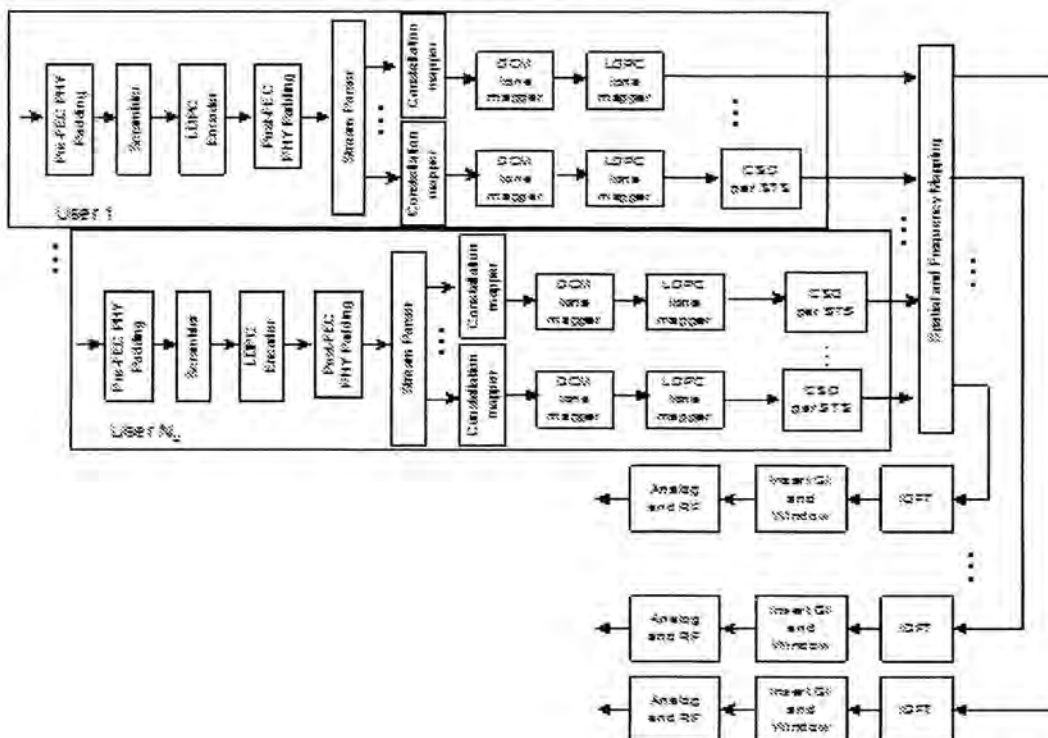


Figure 26-15—Transmitter block diagram for the Data field of an HE downlink MU-MIMO transmission in 106-, 242-, 484- or 996-tone(#838) RU with LDPC encoding(#277)

Transmitter block diagram for the Data field of an HE SU PPDU in 160 MHz with LD shows the transmitter blocks used to generate the Data field of a single-user HE transmission in 160 MHz with LDPC encoding.

Transmitter block diagram for the Data field of an HE SU PPDU in 80+80 MHz with LD shows the transmitter blocks used to generate the Data field of a single-user HE transmission in 80+80 MHz with LDPC encoding.

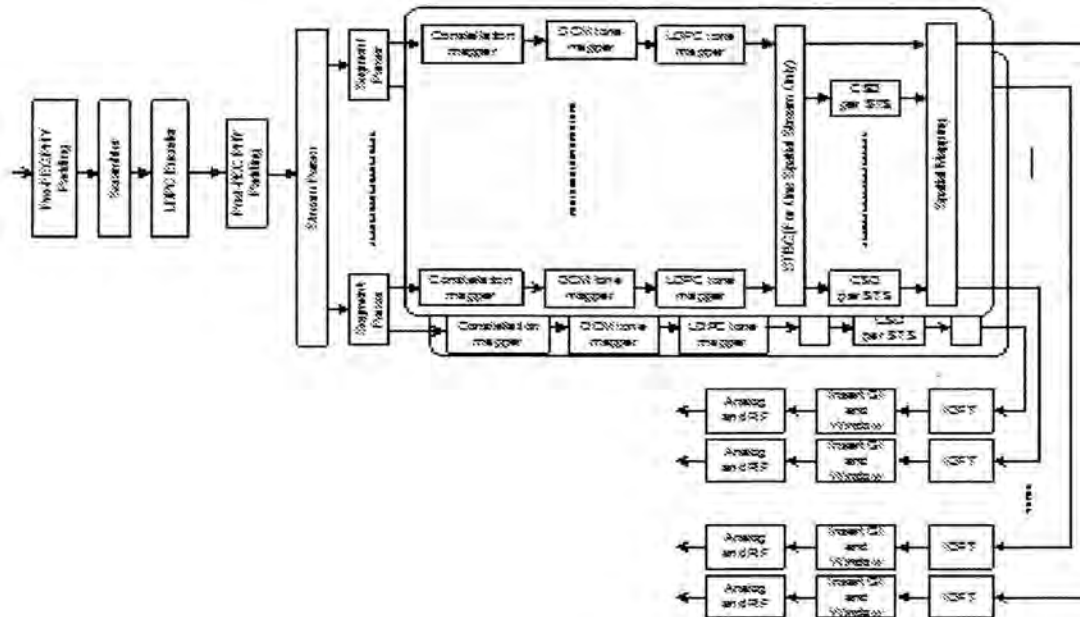


Figure 26-17—Transmitter block diagram for the Data field of an HE SU PPDU in 80+80 MHz with LDPC encoding

26.3.6 Overview of the PPDU encoding process

26.3.7 HE modulation and coding schemes (HE-MCSs)

The HE-MCS is a compact representation of the modulation and coding used in the Data field of the PPDU. For an HE SU PPDU and an HE extended range SU PPDU it is carried in the HE-SIG-A field. For an HE MU PPDU it is carried in the HE-SIG-B field. For an HE trigger-based PPDU, it is carried in the User Info fields(#Ed) of the Trigger frame.

The HE-SIG-B-MCS is a compact representation of the modulation and coding used in the HE-SIG-B field of the PPDU. For an HE MU PPDU, it is carried in the HE-SIG-A field. HE-SIG-B-MCS consists of indices 0 to 5 and each HE-SIG-B-MCS represents the same modulation and coding as the HE-MCS with the same index.(#2518)

Rate-dependent parameters for the full set of HE-MCSs are shown in HE-MCSs for mandatory 26-tone RU, to HE-MCSs for optional non-OFDMA 160 MHz and 80+80 MHz, (in Parameters for HE-MCSs). These tables give rate-dependent parameters for HE-MCSs with indices 0 to 11, with number of spatial streams from 1 to 8, RU options of 26-tone, 52-tone, 106-tone, 242-tone, 484-tone and 996-tone, and bandwidth options of 20 MHz, 40 MHz, 80 MHz, and either 160 MHz or 80+80 MHz. HE-MCSs with

indices 10 and 11 (1024-QAM) are optionally applied to the Data field of an HE PPDU with RUs equal to or larger than 242-tone. The HE extended range SU PPDU is 20 MHz and can only be transmitted with the <HE-MCS, NSS> tuples <MCS 0, 1>, <MCS 1, 1> and <MCS 2, 1> (#1616)(#278). The 106-tone RU can only be transmitted with the <HE-MCS, NSS> tuples <MCS 0, 1>. The 106-tone RU location within the 20MHz tone plan is fixed as the right one.(PHY Motion #166)

DCM is an optional modulation scheme used for the HE-SIG-B field and the Data field in an HE PPDU. It is indicated in the HE-SIG-A field for the HE-SIG-B field in an HE MU PPDU and for the Data field in HE SU PPDU, HE trigger-based PPDU and HE extended range SU PPDU and indicated in the HE-SIG-B field for the Data field in an HE MU PPDU. It is only applied for the HE-MCSs with indices 0, 1, 3 and 4.

26.3.8 Timing-related parameters

Refer to Table 19-6 (Timing-related constants) and Table 21-5 (Timing-related constants) for timing-related parameters for non-HE PPDU formats..

Timing-related constants defines the timing-related parameters for HE PPDU formats..

Table 26-9— Timing-related constants

Parameter	Values	Description
$\Delta F_{\text{Pre-HE}}$	312.5 kHz	Subcarrier frequency spacing for the pre-HE modulated fields(#279).
ΔF_{HE}	78.125 kHz	Subcarrier frequency spacing for the HE modulated fields(#279).
$T_{\text{DFT,Pre-HE}}$	3.2 μs	IDFT/DFT period for the pre-HE modulated fields(#279).
$T_{\text{DFT,HE}}$	12.8 μs	IDFT/DFT period for the HE Data field(#279)(#Ed).
$T_{\text{GI,LegacyPreamble}}$	0.8 μs	Guard interval duration for the legacy preamble, RL-SIG, HE-SIG-A and HE-SIG-B
$T_{\text{GI,HE-LTF}}$	1.6 μs	Guard interval duration for the L-LTF field.
$T_{\text{GI,HE-LTF}}$	$T_{\text{GI1,Data}}$, $T_{\text{GI2,Data}}$ or $T_{\text{GI4,Data}}$ depending on the GI used for data	Guard interval duration for the HE-LTF field, same as $T_{\text{GI,Data}}$
$T_{\text{GI,Data}}$	$T_{\text{GI1,Data}}$, $T_{\text{GI2,Data}}$ or $T_{\text{GI4,Data}}$ depending on the GI used for data	Guard interval duration for the HE-Data field
$T_{\text{GI1,Data}}$	0.8 μs	Base guard interval duration for the HE-Data field.
$T_{\text{GI2,Data}}$	1.6 μs	Double guard interval duration for the HE-Data field.

$T_{GI,Data}$	3.2 μ s	Quadruple guard interval duration for the HE-Data field.
T_{SYM1}	13.6 μ s = $T_{DFT,HE} + T_{GI,Data} = 1.0625 \times T_{DFT,HE}$	OFDM symbol duration with base GI(#1108)(#279)
T_{SYM2}	14.4 μ s = $T_{DFT,HE} + T_{GI2,Data} = 1.125 \times T_{DFT,HE}$	OFDM symbol duration with double GI(#1109)
T_{SYM4}	16 μ s = $T_{DFT,HE} + T_{GI4,Data} = 1.25 \times T_{DFT,HE}$	OFDM symbol duration with quadruple GI(#1110)
T_{SYM}	T_{SYM1} , T_{SYM2} , or T_{SYM4} depending on the GI used (see Tone scaling factor and guard interval duration values for HE PPDU fields (#2757))	Symbol interval
T_{L-STF}	8 μ s = $10 \times T_{DFT,Pre-HE} / 4$	Non-HT Short Training field duration
$T_{L-LTF}(\#1040)$	8 μ s = $2 \times T_{DFT,Pre-HE} + T_{GI2,Data}$	Non-HT Long Training field duration
T_{L-SIG}	4 μ s	Non-HT SIGNAL field duration
T_{RL-SIG}	4 μ s	Repeated non-HT SIGNAL field duration
$T_{HE-SIG-A}$	8 μ s = $2 \times 4 \mu$ s	HE-SIG-A field duration in an HE SU PPDU, HE MU PPDU and HE trigger-based PPDU
$T_{HE-SIG-A-R}$	16 μ s = $4 \times 4 \mu$ s(#279)	HE-SIG-A field duration in an HE extended range SU PPDU
$T_{HE-STF-T}$	8 μ s = $5 \times 1.6 \mu$ s	HE-STF field duration for an HE trigger-based PPDU
$T_{HE-STF-NT}$	4 μ s = $5 \times 0.8 \mu$ s	HE-STF field duration for an HE SU PPDU, HE extended range SU PPDU and HE MU PPDU
$T_{HE-LTF-1X}$	3.2 μ s	Duration of each 1x HE-LTF OFDM symbol without GI
$T_{HE-LTF-2X}$	6.4 μ s	Duration of each 2x HE-LTF OFDM symbol without GI
$T_{HE-LTF-4X}$	12.8 μ s	Duration of each 4x HE-LTF OFDM symbol without GI
T_{HE-LTF}	$T_{HE-LTF-1X}$, $T_{HE-LTF-2X}$ or $T_{HE-LTF-4X}$ depending upon the LTF duration used	Duration of each OFDM symbol without GI in the HE-LTF field (#279)

$T_{\text{HE-LTF-SYM}}$	sum of $T_{\text{HE-LTF}}$ and $T_{\text{GI-HE-LTF}}$	Duration of each OFDM symbol including GI in the HE-LTF field
$T_{\text{HE-SIG-B}}$	$4 \mu\text{s} = T_{\text{DFT-Pic-HE}} + T_{\text{GI-Legacy-Preamble}}$	Duration of each OFDM symbol in the HE-SIG-B field(#Ed)
N_{service}	16	Number of bits in the SERVICE field
N_{tail}	6 for BCC encoder, 0 for LDPC encoder	Number of tail bits per encoder(#2521)
T_{SYM}	$4 \mu\text{s}$	Symbol duration including GI prior to the HE-STF field
T_{PE}	0, 4 μs , 8 μs , 12 μs or 16 μs depending on the actual extension duration used	Duration of the Packet Extension field(#279)

Tone allocation related constants for Data field in a non-OFDMA HE PPDU defines tone allocation related parameters for a non-OFDMA HE PPDU.

Table 26-10—Tone allocation related constants for Data field in a non-OFDMA HE PPDU

Parameter	CBW20	CBW40	CBW80	CBW80+80	CBW160	Description
N_{SD}	234	468	980	980	1960	Number of complex data numbers per frequency segment
N_{SP}	8	16	16	16	32	Number of pilot values per frequency segment
N_{ST}	242	484	996	996	1992	Total number of subcarriers per frequency segment
N_{SR}	122	244	500	500	1012	Highest data subcarrier index per frequency segment
N_{Seg}	1	1	1	2	1	Number of frequency segments
N_{DC}	3	5	5	5	23	Number of null tones at DC per segment
$N_{Guard,Left}$	6	12	12	12	12	Number of guard tones at the lower side of the spectrum

$N_{\text{Guard, Right}}$	5	11	11	11	11	Number of guard tones at the higher end of the spectrum
NOTE: $N_{ST} = N_{SD} + N_{SP}$						

Tone allocation related constants for RUs in an OFDMA HE PPDU(#281) defines tone allocation related parameters for a OFDMA HE PPDU.

Table 26-11—Tone allocation related constants for RUs in an OFDMA HE PPDU(#2522)

Parameter	RU Size (tones)							Description
	26	52	106	242	484	996	2x996	
N_{SD}	24	48	102	234	468	980	1960	Number of complex data numbers per RU
N_{SP}	2	4	4	8	16	16	32	Number of pilot values per RU
N_{ST}	26	52	106	242	484	996	1992	Total number of subcarriers per RU
NOTE: $N_{ST} = N_{SD} + N_{SP}$								

Frequently used parameters defines parameters used frequently in High Efficiency (HE) PHY specification.

Table 26-12—Frequently used parameters(#282)

Symbol	Explanation
$N_{CBPS}, N_{CBPS,u}$	Number of coded bits per symbol at r -th RU for user u , $u = 0, \dots, N_{\text{user, total}} - 1$. (#2522) For an HE SU PPDU, $N_{CBPS} = N_{CBPS,0,0}$ (#1042) For an HE MU PPDU, N_{CBPS} is undefined
$N_{CBPSS}, N_{CBPSS,u}$	Number of coded bits per symbol per spatial stream. For the Data field, $N_{CBPSS,r,u}$ equals the number of coded bits per symbol per spatial stream at r -th RU for user u , $u = 0, \dots, N_{\text{user, total}} - 1$. (#2522) For the Data field of an HE SU PPDU, $N_{CBPSS} = N_{CBPSS,0,0}$ For the Data field of an HE MU PPDU, N_{CBPSS} is undefined

$N_{DBPS}, N_{DBPS,u}$	Number of data bits per symbol for user u , $u = 0, \dots, N_{user,total} - 1$, (#2522) For an HE SU PPDU, $N_{DBPS} = N_{DBPS,0}$ For an HE MU PPDU, N_{DBPS} is undefined
$N_{BPSCS}, N_{BPSCS,u}$	Number of coded bits per subcarrier per spatial stream at r -th RU for user u , $u = 0, \dots, N_{user,total} - 1$, (#2522) For an HE SU PPDU, $N_{BPSCS} = N_{BPSCS,0,0}$ For an HE MU PPDU, N_{BPSCS} is undefined
N_{RA}	Number of receive chains
N_{RU}	For pre-HE modulated fields, $N_{RU} = 1$. For HE modulated fields, N_{RU} represents the number of RUs in the transmission (equal to the TXVECTOR parameter NUM_RUS).
$N_{user,r}$ (#1043)	For pre-HE modulated fields, $N_{user,r} = 1$. For HE modulated fields, $N_{user,r}$ represents the number of users at r -th RU in the transmission (summing over all RUs equals to the TXVECTOR parameter NUM_USERS_TOTAL).
$N_{STS}, N_{STS,r,u}$	For pre-HE modulated fields, $N_{STS,r,u} = 1$ (see NOTE). For HE modulated fields, $N_{STS,r,u}$ represents (#1044) the number of space-time streams at r -th RU for user u , $u = 0, \dots, N_{user,r} - 1$. In case of STBC, $N_{STS,r,u} = 2$ For an HE SU PPDU, $N_{STS} = N_{STS,0,0}$ For an HE MU PPDU, $N_{STS} = \max_{r=0}^{N_{RU}-1} N_{STS,r,total}$
$N_{STS,r,total}$	For HE modulated fields, $N_{STS,r,total}$ (#522) is the total number of space-time streams at the r -th RU in a PPDU. $N_{STS,r,total} = \sum_{u=0}^{N_{user,r}-1} N_{STS,r,u}$ For pre-HE modulated fields, $N_{STS,r,total}$ is undefined when the TXVECTOR parameter BEAM_CHANGE is 1 and $N_{STS,r,total} = N_{STS}$ when BEAM_CHANGE is 0 (#2531). Note that $N_{STS,r,total} = N_{STS}$ for an HE SU PPDU.
$N_{SS}, N_{SS,r,u}, N_{SS,u}$	Number of spatial streams. For the Data field, $N_{SS,r,u}$ is the number of spatial streams at r -th RU for user u , $u = 0, \dots, N_{user,r} - 1$ and $N_{SS,u}$ is the number of spatial streams for user u , $u = 0, \dots, N_{user,total} - 1$, (#2522) For the Data field of an HE SU PPDU, $N_{SS} = N_{SS,0,0}$ For the Data field of an HE MU PPDU, $N_{SS} = \max_{r=0}^{N_{RU}-1} N_{SS,r,total}$

$N_{SS,r,total}$	For HE modulated fields, $N_{SS,r,total}$ is the total number of spatial streams at r-th RU in a PPDU. $N_{SS,r,total} = \sum_{u=0}^{N_{user,r}-1} N_{SS,r,u}$ For pre-HE modulated fields, $N_{SS,r,total}$ is undefined. Note that $N_{SS,r,total} = N_{SS}$ for an HE SU PPDU.
N_{TX}	Number of transmit chains
N_{HE-LTF}	The number of OFDM symbols in the HE-LTF field (see 26.3.9.10 (HE-LTF))
$N_{HE-SIG-B}$	The number of OFDM symbols in the HE-SIG-B field
K_r	Set of subcarrier indices in the r -th RU
R, R_u	R_u is the coding rate for user u, $u = 0, \dots, N_{user,total} - 1$. (#2522) For an HE SU PPDU, $R = R_0$ For an HE MU PPDU, R is undefined
$M_{r,u}$	For pre-HE modulated fields, $M_{r,u} = 0$. For HE modulated fields, $M_{r,0} = 0$ for $u = 0$ and $M_{r,u} = \sum_{u'=0}^{u-1} N_{STS,r,u'} \quad \text{for } u, u = 1, \dots, N_{user,r} - 1.$
(#472)NOTE—For pre-HE modulated fields, u and r are zeros only since $N_{user,r} = 1$ and $N_{RU} = 1$.	

26.3.9 Mathematical description of signals

For a description of the conventions used for the mathematical description of the signals, see 17.3.2.5 (Mathematical conventions in the signal descriptions). In addition, the following notational conventions are used in High Efficiency (HE) PHY specification:

$[Q]_{m,n}$ indicates the element in row m and column n of matrix, where $1 \leq m \leq N_{row}$ and $1 \leq n \leq N_{col}$ (#2369)

N_{row} and N_{col} are the number of rows and columns, respectively, of the matrix Q .

$[Q]_{m:n}$ indicates a matrix consisting of columns m to n (#1966) of matrix Q .

For a description on subcarrier indices over which the signal is transmitted for non-HT, HT and VHT PPDUs, see 22.3.7 (Mathematical description of signals).

For a 20 MHz non-OFDMA HE PPDU (#Ed) transmission, the 20 MHz is divided into 256 subcarriers. The signal is transmitted on subcarriers -122 to -2 and 2 to 122 , with 0 being the center (DC) subcarrier.

The time offset, t_{Field} , determines the starting time of the corresponding field relative to the start of L-STF ($t = 0$).

(26-2) The signal transmitted on frequency segment i_{Seg} of transmit chain i_{TX} shall be as shown in

(26-2)

$$r_{PPDU}^{(i_{Seg}, i_{TX})}(t) = r_{L-STF}^{(i_{Seg}, i_{TX})}(t) + r_{L-LTF}^{(i_{Seg}, i_{TX})}(t - t_{L-LTF}) \\ + r_{L-SIG}^{(i_{Seg}, i_{TX})}(t - t_{L-SIG}) + r_{RL-SIG}^{(i_{Seg}, i_{TX})}(t - t_{RL-SIG}) + r_{HE-SIG-A}^{(i_{Seg}, i_{TX})}(t - t_{HE-SIG-A}) + r_{HE-SIG-B}^{(i_{Seg}, i_{TX})}(t - t_{HE-SIG-B}) \\ + r_{HE-STF}^{(i_{Seg}, i_{TX})}(t - t_{HE-STF}) + r_{HE-LTF}^{(i_{Seg}, i_{TX})}(t - t_{HE-LTF}) + r_{HE-Data}^{(i_{Seg}, i_{TX})}(t - t_{HE-Data}) + r_{HE-PE}^{(i_{Seg}, i_{TX})}(t - t_{HE-PE}) \quad \text{wh}$$

ere

$r_{HE-SIG-B}^{(i_{Seg}, i_{TX})}(t - t_{HE-SIG-B})$ is only applicable to an HE MU PPDU (#1970)

$$0 \leq i_{Seg} \leq N_{Seg} - 1$$

$$1 \leq i_{TX} \leq N_{TX}$$

$$t_{L-LTF} = T_{L-STF}$$

$$t_{L-SIG} = t_{L-LTF} + T_{L-LTF}$$

$$t_{RL-SIG} = t_{L-SIG} + T_{L-SIG}$$

$$t_{HE-SIG-A} = t_{RL-SIG} + T_{RL-SIG}$$

$$t_{HE-SIG-B} = \begin{cases} t_{HE-SIG-A} + T_{HE-SIG-A} & \text{for an HE MU PPDU} \\ \text{undefined,} & \text{otherwise} \end{cases}$$

$$t_{HE-STF} = \begin{cases} t_{HE-SIG-A} + T_{HE-SIG-A} & \text{for an HE SU PPDU and HE trigger-based PPDU} \\ t_{HE-SIG-A} + T_{HE-SIG-A-R} & \text{for an HE extended range SU PPDU} \\ t_{HE-SIG-B} + N_{HE-SIG-B} T_{HE-SIG-B} & \text{for an HE MU PPDU} \end{cases}$$

where $N_{HE-SIG-B}$ is the number of OFDM symbols in the HE-SIG-B field

$$t_{HE-LTF} = \begin{cases} t_{HE-STF} + T_{HE-STF-T} & \text{for an HE trigger-based PPDU} \\ t_{HE-STF} + T_{HE-STF-NT} & \text{otherwise} \end{cases}$$

$$t_{HE-Data} = \begin{cases} t_{HE-LTF} + N_{HE-LTF} \cdot (T_{HE-LTF-1X} + T_{GI,HE-LTF}), & \text{for 1x HE-LTF} \\ t_{HE-LTF} + N_{HE-LTF} \cdot (T_{HE-LTF-2X} + T_{GI,HE-LTF}), & \text{for 2x HE-LTF} \\ t_{HE-LTF} + N_{HE-LTF} \cdot (T_{HE-LTF-4X} + T_{GI,HE-LTF}), & \text{for 4x HE-LTF} \end{cases}$$

$$t_{HE-PE} = t_{HE-Data} + N_{SYM} T_{SYM}$$

(26-3) In an HE SU PPDU, HE MU PPDU and HE extended range SU PPDU, for each field excluding the PE field, $r_{Field}^{(i_{Seg}, i_{TX})}(t)$ is defined in

(26-4) and

as the summation of one or more subfields. Each subfield is defined to be an inverse discrete Fourier transform (#2158), (#526), (#286), (#1976), (#1971), (PHY Motion #172)

(26-3)

$$r_{Field}^{(i_{Se}, i_{TX})}(t) = w_{T_{Field}}(t) \sum_{r=0}^{N_{RU}-1} \frac{\alpha_r \beta_r^{Field}}{\sqrt{N_{Norm,r}}} \sum_{k \in K_r} \eta_{Field,k} \sum_{u=0}^{N_{MTC,r}-1} \sum_{m=1}^{N_{STS,r,u}} \left[Q_k^{(i_{Se})} \right]_{i_{TX}, (M_{r,u}+m)} Y_{k,BW}^{(i_{Se}, i_{TX})} \exp(j2\pi k \Delta_{F,Field}(t - T_{GI,Field} - T_{CS,HE}(M_{r,u} + m)))$$

(26-4)

In an HE trigger-based PPDU, transmitted by user- u in the r -th RU, each field, $r_{Field}^{(i_{Se}, i_{TX})}(t)$, is defined in

. (#526)(#286)

(26-4)

$$r_{Field}^{(i_{Se}, i_{TX})}(t) = \frac{\alpha_r \beta_r^{Field}}{\sqrt{N_{Norm,r}}} w_{T_{Field}}(t) \sum_{k \in K_r} \eta_{Field,k} \sum_{m=1}^{N_{STK,r,u}-1} \left[Q_k^{(i_{Se})} \right]_{i_{TX}, (M_{r,u}+m)} Y_{k,BW}^{(i_{Se}, i_{TX})} \exp(j2\pi k \Delta_{F,Field}(t - T_{GI,Field} - T_{CS,HE}(M_{r,u} + m)))$$

In the remainder of this subclause, pre-HE modulated fields refer to the L-STF, L-LTF, L-SIG, RL-SIG, HE-SIG-A, and HE-SIG-B fields, while HE modulated fields refer to the HE-STF, HE-LTF, Data, and PE fields, as shown in Timing boundaries for HE PPDU fields. The total power of the time domain HE modulated field signals summed over all transmit chains should not exceed the total power of the time domain pre-HE modulated field signals summed over all transmit chains. For notational simplicity, the parameter BW is omitted from some bandwidth dependent terms.

(26-3)In

the following notations (#1975) are used:

$N_{Norm,r}$ If the TXVECTOR parameter BEAM_CHANGE is 1, then for pre-HE modulated fields, $N_{Norm,r} = N_{TX}$. If the TXVECTOR parameter BEAM_CHANGE is 0, then for pre-HE modulated fields $N_{Norm,r} = N_{STS,r,total}$, where $N_{STS,r,total}$ is given in Frequently used parameters. For HE modulated fields $N_{Norm,r} = N_{STS,r,total}$.

$w_{T_{Field}}(t)$ is a windowing function. An example function, $w_{T_{Field}}(t)$, is given in 18.3.2.5 (Mathematical conventions in the signal descriptions).

K_r For pre-HE modulated fields, K_r (#2760) is the set of subcarriers indices from $-N_{SR}$ to N_{SR} as defined in Highest data subcarrier index.

Table 26-13—Highest data subcarrier index N_{SR} for pre-HE modulated fields

Field	N_{SR} as a function of bandwidth			
	20 MHz	40 MHz	80 MHz	160 MHz

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1

L-STF	26	52	104	208
L-LTF	26	52	104	208
L-SIG	28	56	112	224
RL-SIG	28	56	112	224
HE-SIG-A	28	56	112	224
HE-SIG-B	28	56	112	224

(#289) For HE modulated fields in a non-OFDMA HE PPDU, K_r is the set of subcarriers indices from $-N_{SR}$ to N_{SR} as defined in Tone allocation related constants for Data field in a non-OFDMA HE PPDU(#289). For HE modulated fields in an OFDMA HE PPDU, K_r is the set of subcarrier indices for the tones in the r -th RU.

$\eta_{Field,k}$ is the power boost factor per OFDM symbol, which is $\sqrt{2}$ for the L-STF, L-LTF, HE-STF and HE-LTF fields in the HE extended range SU PPDU, and 1 otherwise.(#526)

$$\eta_{L-SIG,k} = \begin{cases} \sqrt{2}, & k = -28, -27, 27, 28 \text{ for an HE extended range SU PPDU} \\ 1, & \text{otherwise} \end{cases} \quad (26-5) \quad (\#526)$$

α_r is the power boost factor for the r -th RU. A STA shall support α_r in the range $[0.7, \sqrt{2}]$. A STA may support α_r in the range $[0.5, 2]$.(#1689)

β_r^{Field} is the power normalization factor and is defined in

$$\beta_r^{Field} = \begin{cases} \frac{\mathcal{E}_{Field}}{\sqrt{N_{Field}^{Tone}}}, & \text{Pre-HE modulated fields when BEAM_CHANGE = 1} \\ \mathcal{E}_{Field} \sqrt{\frac{|K_r|}{|K_r^{Field}|}} / \sqrt{\sum_{r=1}^{N_{RU}} \alpha_r^2 |K_r|}, & \text{otherwise} \end{cases} \quad (\#5(\#286))$$

$$\beta_r^{Field} = \begin{cases} \frac{\mathcal{E}_{Field}}{\sqrt{N_{Field}^{Tone}}}, & \text{Pre-HE modulated fields when BEAM_CHANGE = 1} \\ \mathcal{E}_{Field} \sqrt{\frac{|K_r|}{|K_r^{Field}|}} / \sqrt{\sum_{r=1}^{N_{RU}} \alpha_r^2 |K_r|}, & \text{otherwise} \end{cases} \quad (26-6) \quad (\#526)$$

$|K_r|$ is the cardinality of the set of subcarriers K_r .

$|K_r^{Field}|$ is the cardinality of the set of modulated subcarriers within K_r for each field.(#298)(#1978)

N_{Field}^{Tone} Tone scaling factor and guard interval duration values for HE PPDU fields summarizes the various values of N_{Field}^{Tone} as a function of bandwidth per frequency segment. In the case of an HE OFDMA PPDU, the N_{Field}^{Tone} value of HE-STF, HE-LTF and HE-Data fields is variable, and is determined by which RUs of the current full bandwidth are transmitted in the PPDU.

Table 26-14—Tone scaling factor and guard interval duration values for HE PPDU fields

Field	N_{Field}^{Tone} as a function of bandwidth, and RU size per frequency segment				Guard interval duration
	20 MHz	40 MHz	80 MHz	160 MHz	
L-STF	12	24	48	96	-
L-LTF	52	104	208	416	$T_{GI,2L\ LTF}$
L-SIG in an HE PPDU	56	112	224	448	$T_{GI,LegacyPreamble}$
L-SIG in a non-HT duplicate PPDU(#1988)	-	104	208	416	
RL-SIG	56	112	224	448	$T_{GI,LegacyPreamble}$
HE-SIG-A	56	112	224	448	$T_{GI,LegacyPreamble}$
HE-SIG-B	56	112	224	448	$T_{GI,LegacyPreamble}$
HE-STF not in an HE trigger-based PPDU	14	30	62	124(#287)	-
HE-STF in an HE trigger-based PPDU	30	60	124	248	-
HE-LTF 1x Duration	60	122	250	500	$T_{GI,HE\ LTF1}$
HE-LTF 2x Duration	122	242	498	996	$T_{GI,HE\ LTF2}$
HE-LTF 4x Duration	242	484	996	1992	$T_{GI,HE\ LTF4}$
HE-Data	242	484	996	1992	$T_{GI,Data}$
NON_HT_DUP_OFDM-Data(#1988)	-	104	208	416	$T_{GI,LegacyPreamble}$

NOTE—in the case of an HE OFDMA PPDU, the N_{Field}^{Tone} value of HE-STF, HE-LTF and HE-Data fields is variable, and is determined by which RUs of the current full bandwidth are transmitted in the PPDU.

(#1977)

$$\varepsilon_{Field} = \begin{cases} \sqrt{\frac{N_{L-LTF}^{Tone}}{N_{L-SIG}^{Tone}}}, & \text{For the L-STF and L-LTF fields} \\ 1, & \text{otherwise} \end{cases} \quad (\#526)$$

$Q_k^{(i_{seg})}$

is the spatial mapping matrix for the subcarrier k in frequency segment i_{seg} . For HE modulated fields, $Q_k^{(i_{seg})}$ is a matrix with N_{TX} rows and $N_{STS, total}$ columns. If the TXVECTOR parameter BEAM_CHANGE is 1, then for pre-HE modulated fields $Q_k^{(i_{seg})}$ is a column vector with N_{TX} elements with element i_{TX} being $\exp(-j2\pi k \Delta_{F, Pre-HE} T_{CS}^{i_{TX}})$, where $T_{CS}^{i_{TX}}$ represents the cyclic shift for the transmitter chain whose values are TBD; otherwise it is identical to the spatial mapping $Q_k^{(i_{seg})}$ for HE modulated fields (#1848).

$\Delta_{F, Field}$

is the subcarrier frequency spacing. For pre-HE modulated fields, $\Delta_{F, Field} = \Delta_{F, Pre-HE}$ given in Table 26.3. For HE modulated fields, $\Delta_{F, Field} = \Delta_{F, HE}$ given in Timing-related constants.

$X_{k, r, u}^{(i_{seg}, m)}$

is the frequency-domain symbol in subcarrier k of user u in the r -th RU for frequency segment i_{seg} of space-time stream m . Some of the $X_{k, r, u}^{(i_{seg}, m)}$ within $-N_{SR} \leq k \leq N_{SR}$ have a value of zero. Examples of such cases include the DC tones, guard tones on each side of the transmit spectrum, the null subcarriers (#902) in an HE OFDMA PPDU, as well as the unmodulated tones of L-STF, HE-STF, and HE-LTF fields. Note that the multiplication matrices A_{HE-LTF}^k are included in the calculation of $X_{k, r, u}^{(i_{seg}, m)}$ for the HE-STF and HE-LTF fields. When the TXVECTOR parameter BEAM_CHANGE is 0, the first column of the multiplication matrices A_{HE-LTF}^k are included in the calculation of $X_{k, r, u}^{(i_{seg}, m)}$ for the pre-HE modulated fields.

$T_{GI, Field}$

is the guard interval duration used for each OFDM symbol in the field. The value for each field is as defined in Timing-related constants (#1674).

$T_{CS, HE}(l)$

For pre-HE modulated fields, $T_{CS, HE}(l) = 0$. For HE modulated fields, $T_{CS, HE}(l)$ represents the cyclic shift per space-time stream, whose value is defined in Table 25-xx (Cyclic shift values for the HE modulated fields of a PPDU).

$\Upsilon_{k, BW}$

is used to represent tone rotation. BW in $\Upsilon_{k, BW}$ is determined by the TXVECTOR parameter CH_BANDWIDTH as defined in CH_BANDWIDTH and . In HE modulated fields, $\Upsilon_{k, BW} = 1$ in all the subcarriers. In pre-HE modulated fields, $\Upsilon_{k, BW}$ is defined as in 21.3.7.5 (Definition of tone rotation) when TXVECTOR parameter BEAM_CHANGE is set to 1 and $\Upsilon_{k, BW} = 1$ for all the tones when TXVECTOR parameter BEAM_CHANGE is set to 0. When the TXVECTOR parameter BEAM_CHANGE is not present (such as in an HE MU PPDU and HE trigger-based PPDU), BEAM_CHANGE is assumed to be set to 1. (#2761)(#293)

Table 26-15—CH_BANDWIDTH and $\Upsilon_{k, BW}$ for pre-HE modulated fields

CH_BANDWIDTH	$\Upsilon_{k,BW}$
CBW20	$\Upsilon_{k,20}$
CBW40	$\Upsilon_{k,40}$
CBW80	$\Upsilon_{k,80}$
CBW160	$\Upsilon_{k,160}$
CBW80+80	$\Upsilon_{k,80}$ per frequency segment

26.3.10 HE preamble

26.3.10.1 Introduction

The HE portion of HE format preamble consists of pre-HE modulated fields and HE modulated fields. The HE modulated fields consist of HE-STF, HE-LTF and Data fields(#2762). The pre-HE modulated fields for the various HE PPDU formats are the following(#291):

- RL-SIG and HE-SIG-A fields of an HE SU PPDU
- RL-SIG, HE-SIG-A and HE-SIG-B fields of an HE MU PPDU
- RL-SIG, HE-SIG-A and repeated HE-SIG-A fields of an HE extended range SU PPDU
- RL-SIG and HE-SIG-A fields of an HE trigger-based PPDU

26.3.10.2 Cyclic shift(#1052)

26.3.10.2.1 Cyclic shift for pre-HE modulated fields

When the TXVECTOR parameter BEAM_CHANGE is 1(#Ed), the cyclic shift value T_{CS}^{rx} for the L-STF, L-LTF, L-SIG, RL-SIG, HE-SIG-A and HE-SIG-B fields of the PPDU for transmit chain i_{TX} out of a total of N_{TX} are defined in Table 21-10 (Cyclic shift values for L-STF, L-LTF, L-SIG, and VHT-SIG-A fields of the PPDU)(PHY Motion #172). In UL MU transmission the cyclic shift value T_{CS}^{rx} is based on the transmit chain index of each STA.

When the TXVECTOR parameter BEAM_CHANGE is 0(#Ed), the cyclic shift value T_{CS}^{rx} for the L-STF, L-LTF, L-SIG, RL-SIG, and HE-SIG-A fields is not specified.

26.3.10.2.2 Cyclic shift for HE modulated fields

The cyclic shift values defined in this subclause apply to the HE-STF, HE-LTF and Data fields of the HE PPDU when the TXVECTOR parameter BEAM_CHANGE is 1(#Ed), and apply to the entire PPDU when the TXVECTOR parameter BEAM_CHANGE is 0(#Ed).

Throughout the HE modulated fields of the preamble, cyclic shifts are applied to prevent unintended beamforming when correlated signals are transmitted in multiple space-time streams. The same cyclic shift is also applied to these streams during the transmission of the Data field of the HE PPDU. The cyclic shift value $T_{CS, HE}(n)$ for the HE modulated fields for space-time stream n out of $N_{STS, total}$ total space-time streams is shown in Table 21-11 (Cyclic shift values for the VHT modulated fields of a PPDU)(PHY Motion #172).

26.3.10.3 L-STF

(26-7) If the TXVECTOR parameter BEAM_CHANGE is 1, the time domain representation of the L-STF field shall be as specified in

The equation applies to all contiguous signals up to 160 MHz and non contiguous 80+80 MHz.

(26-7)

$$r_{L-STF}^{(i_{STX}, i_{TX})}(t) = \frac{\varepsilon}{\sqrt{N_{TX} \cdot N_{L-STF}^{Tone}}} w_{T_{L-STF}}(t) \sum_{i_{BW} \in \Omega_{20MHz}} \sum_{k=-26}^{26} \eta_{L-STF, k} \left(X_{(k - K_{Shift}(i_{BW})), BW} S_{k, 20} \cdot \exp(j2\pi(k - K_{Shift}(i_{BW}))\Delta_{F, Pre-HE}(t - T_{CS}^{TX})) \right) \quad (\#525) \text{ where}$$

$$\varepsilon = \sqrt{\frac{N_{L-STF}^{L-LTF}}{N_{L-STF}^{L-SIG}}}$$

ε is a power scaling factor with the value

$\eta_{L-STF, k}$ is a PPDU format dependent scaling factor for the L-STF field on tone index k with the following value

$$\eta_{L-STF, k} = \begin{cases} \sqrt{2}, & \text{for an HE extended range SU PPDU} \\ 1, & \text{otherwise} \end{cases} \quad (\#1986)$$

N_{20MHz} is defined in 22.3.8.3.4 (L-SIG definition)

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

T_{CS}^{TX}

represents the cyclic shift for transmit chain i_{TX} with a value given in Cyclic shift for pre-HE modulated fields.

N_{L-STF}^{Tone}

has the value given in Tone scaling factor and guard interval duration values for HE PPDU fields (#1988).

$\Omega_{20\text{MHz}}$ is a set of 20 MHz channels that contains the channels where pre-HE modulated fields are located and the channel indices are within 0 to $N_{20\text{MHz}} - 1$ in an HE trigger-based PPDU or HE MU PPDU with preamble puncturing, or equal to $\{0, 1, \dots, N_{20\text{MHz}} - 1\}$ otherwise.

$S_{k,20}$ is defined as $S_{-26,26}$ in Equation (18-6). (#1985)(#1989)

If the TXVECTOR parameter BEAM_CHANGE is 0, the time domain representation of the L-STF field of contiguous 20 MHz, 40 MHz, 80 MHz and 160 MHz transmission shall be as specified in

$$r_{\text{L-STF}}^{(i_{\text{seg}}^{i_{\text{TX}}})}(t) = \frac{\mathcal{E}}{\sqrt{N_{\text{STS}, \text{total}} \cdot N_{\text{L-STF}}^{\text{Tone}}}} w_{\text{L-STF}}(t) \sum_{i_{\text{BW}}=0}^{N_{20\text{MHz}}-1} \sum_{k=-26}^{26} \sum_{m=1}^{N_{\text{STS}}} \eta_{\text{L-STF}, k} \left(\left[Q_{4(k-K_{\text{sub}}(i_{\text{BW}}))}^{(i_{\text{seg}})} \right]_{i_{\text{TX}}, m} \left[A_{\text{HE-LTF}}^{4(k-K_{\text{sub}}(i_{\text{BW}}))} \right]_{m, 1} S_{k, 20} \cdot \exp(j2\pi(k - K_{\text{Shift}}(i_{\text{BW}}))\Delta_{F, \text{Pre-HE}}(t - T_{\text{CS, HE}}(m))) \right) \quad (\#2. \quad \text{The}$$

equation applies to all contiguous signals up to 160 MHz and non contiguous 80+80 MHz.

$$r_{\text{L-STF}}^{(i_{\text{seg}}^{i_{\text{TX}}})}(t) = \frac{\mathcal{E}}{\sqrt{N_{\text{STS}, \text{total}} \cdot N_{\text{L-STF}}^{\text{Tone}}}} w_{\text{L-STF}}(t) \sum_{i_{\text{BW}}=0}^{N_{20\text{MHz}}-1} \sum_{k=-26}^{26} \sum_{m=1}^{N_{\text{STS}}} \eta_{\text{L-STF}, k} \left(\left[Q_{4(k-K_{\text{sub}}(i_{\text{BW}}))}^{(i_{\text{seg}})} \right]_{i_{\text{TX}}, m} \left[A_{\text{HE-LTF}}^{4(k-K_{\text{sub}}(i_{\text{BW}}))} \right]_{m, 1} S_{k, 20} \cdot \exp(j2\pi(k - K_{\text{Shift}}(i_{\text{BW}}))\Delta_{F, \text{Pre-HE}}(t - T_{\text{CS, HE}}(m))) \right) \quad (\#2531)$$

(#1050)(#525)where

$T_{\text{CS, HE}}(m)$ represents the cyclic shift for space time stream m as defined in Cyclic shift for HE modulated fields(#1052)

$Q_k^{(i_{\text{seg}})}$ is the spatial mapping/steering matrix for subcarrier k , in frequency segment i_{seg} on the data symbols over tone spacing $\Delta_{F, \text{HE}}$ as defined in Timing-related constants. Refer to the descriptions in 22.3.10.11.1 (Transmission in VHT format) for examples of $Q_k^{(i_{\text{seg}})}$. (#1991)

(26-56) $A_{\text{HE-LTF}}^k$ is defined in

26.3.10.4 L-LTF

(26-10) If the TXVECTOR parameter BEAM_CHANGE is 1, the time domain representation of the L-LTF field shall be as specified in

. The equation applies to all contiguous signals up to 160 MHz and non contiguous 80+80 MHz.(PHY Motion #172)

(26-10)

$$r_{L-LTF}^{(i_{seg}, i_{TX})}(t) = \frac{\varepsilon}{\sqrt{N_{TX} \cdot N_{L-LTF}^{Tone}}} w_{T_{L-LTF}}(t) \sum_{i_{BW} \in \Omega_{20MHz}, k=-26}^{26} \eta_{L-LTF, k} \left(Y_{(k-K_{Shift}(i_{BW})), BW, L_{k, 20}} \cdot \exp(j2\pi(k-K_{Shift}(i_{BW}))\Delta_{F, Pre-HE}(t-T_{GI, L-LTF}-T_{CS}^{i_{TX}})) \right)$$

$\eta_{L-LTF, k}$ is a PPDU format dependent scaling factor for the L-LTF field on tone index k with the same value as $\eta_{L-STF, k}$ (#525)

N_{20MHz} is defined in 21.3.7.3 (Channel frequencies)

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

$T_{CS}^{i_{TX}}$ represents the cyclic shift for transmit chain i_{TX} with a value given in Cyclic shift for pre-HE modulated fields.

N_{L-LTF}^{Tone} has the value given in Tone scaling factor and guard interval duration values for HE PPDU fields (#1988).

$L_{k, 20}$ is defined as $L_{-26, 26}$ in Equation (18-8). (#1992)

(26-11) If the TXVECTOR parameter BEAM_CHANGE is 0, the time domain representation of the L-LTF field of contiguous 20 MHz, 40 MHz, 80 MHz and 160 MHz transmission shall be as specified in

The equation applies to all contiguous signals up to 160 MHz and non contiguous 80+80 MHz.

(26-11)

$$r_{L-LTF}^{(i_{seg}, i_{TX})}(t) = \frac{\varepsilon}{\sqrt{N_{STS, total} \cdot N_{L-LTF}^{Tone}}} w_{T_{L-LTF}}(t) \sum_{i_{BW}=0}^{N_{20MHz}-1} \sum_{k=-26}^{26} \sum_{m=1}^{N_{STS}} \eta_{L-LTF, k} \left(\left[Q_{4(k-K_{Shift}(i_{BW}))}^{(i_{seg})} \right]_{i_{TX}, m} \left[A_{HE-LTF}^{4(k-K_{Shift}(i_{BW}))} \right]_{m, 1} L_{k, 20} \cdot \exp(j2\pi(k-K_{Shift}(i_{BW}))\Delta_{F, Pre-HE}(t-T_{GI, Legacy Preamble}-T_{CS, HE}(m))) \right)$$

(#2531)(#1050) where

$T_{CS, HE}(m)$ represents the cyclic shift for space time stream m as defined in Cyclic shift for HE modulated fields (#1052)

$Q_k^{(i_{seg})}$ is defined in **Erreur ! Source du renvoi introuvable.** (#1094)

(26-56) A_{HE-LTF}^k is defined in

26.3.10.5 L-SIG

The L-SIG field is used to communicate rate and length information. The structure of the L-SIG field is defined in Figure 17-5 (SIGNAL field bit assignment) (#1835).

In an(#2829) HE PPDU, the RATE field shall be set to the value representing 6 Mb/s in the 20 MHz channel spacing column of Table 17-6 (Contents of the SIGNAL field)(#1835). In a non-HT duplicate PPDU, the RATE field is defined in 17.3.4.2 (RATE field)(#1835) using the L_DATARATE parameter in the TXVECTOR.

The LENGTH field shall be set to the value given by

$$\text{Length} = \left\lceil \frac{\text{TXTIME} - 20}{4} \right\rceil \times 3 - 3 - m \quad (\#1)$$

$$(26-12) \quad \text{Length} = \left\lceil \frac{\text{TXTIME} - 20}{4} \right\rceil \times 3 - 3 - m \quad (\#1683)$$

where

TXTIME (in μs) is defined in 26.4.3 (TXTIME and PSDU_LENGTH calculation).

m is 1 for an HE MU PPDU and HE extended range SU PPDU, and 2 otherwise.

The LSB of the binary expression of the Length value shall be mapped to B5. In a non-HT duplicate PPDU, the LENGTH field is defined in 17.3.4.3 (LENGTH field)(#2859) using the L_LENGTH parameter in the TXVECTOR.

The Reserved (R) field shall be set to 0.

The Parity (P) field has the even parity of bits 0-16.

The SIGNAL TAIL field shall be set to 0.

The L-SIG field shall be encoded, interleaved, and mapped following the steps described in 17.3.5.6 (Convolutional encoder), 17.3.5.7 (Data interleaving), and 17.3.5.8 (Subcarrier modulation mapping). The stream of 48 complex numbers generated by these steps is denoted by $d_k, k = 0, \dots, 47$. Pilots shall be inserted as described in 17.3.5.9 (Pilot subcarriers). Extra 4 BPSK modulated tones are added(#1997). The 4 extra tones $[-28, -27, 27, 28]$ of L-SIG in 20 MHz HE PPDU is $[-1, -1, -1, 1]$ (#1835)

(26-13) If the TXVECTOR parameter BEAM_CHANGE is 1, the time domain waveform of the L-SIG field shall be as given by

(26-13)

$$r_{L-SIG}^{(i_{TX})}(t) = \frac{1}{\sqrt{N_{TX} \cdot N_{L-SIG}^{\text{Tone}}}} w_{T_{L-SIG}}(t) \sum_{i_{BW} = \Omega_{20MHz}}^{28} \sum_{k=-28}^{28} \left(Y(k - K_{Shift}(i_{BW})), \text{BW} \eta_{L-SIG, k}(D_{k, 20} + p_0 P_k) \cdot \exp(j2\pi(k - K_{Shift}(i_{BW}))\Delta_{F, \text{Pre-HE}}(t - T_{Gf, \text{Legacy Preamble}} - T_{CS}^{TX})) \right) \quad \text{where}$$

N_{20MHz} is defined in 21.3.7.3 (Channel frequencies)

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

$$D_{k,20} = \begin{cases} 0, & k = 0, \pm 7, \pm 21 \\ -1, & k = -28, -27, 27 \\ 1, & k = 28 \\ d_{M_{20}^r(k)}, & \text{otherwise} \end{cases} \quad (\#1684)$$

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

P_k is defined in 17.3.5.10 (OFDM modulation)(#1835)

P_0 is the first pilot value in the sequence defined in 17.3.5.10 (OFDM modulation)

N_{L-SIG}^{Tone} is defined in Tone scaling factor and guard interval duration values for HE PPDU fields (#476)

$T_{CS}^{i_{TX}}$ represents the cyclic shift for transmit chain i_{TX} with a value given in Cyclic shift for pre-HE modulated fields.

NOTE— $M_{20}^r(k)$ is a “reverse” function of the function $M(k)$ defined in 17.3.5.10 (OFDM modulation)(#1835).

(26-14) If the TXVECTOR parameter BEAM_CHANGE is 0, the time domain waveform of the L-SIG field shall be as given by

(26-14)

$$r_{L-SIG}^{(i_{SER}, i_{TX})}(t) = \frac{1}{\sqrt{N_{STS, total} \cdot N_{L-SIG}^{\text{Tone}}}} w_{T_{L-SIG}}(t) \sum_{i_{BW}=0}^{N_{20MHz}} \sum_{k=-28}^{28} \sum_{m=1}^{N_{STS}} \left(\left[Q_{4(k-K_{Shift}(i_{BW}))}^{(i_{SER})} \right]_{i_{TX}, m} \left[A_{HE-LTF}^{4(k-K_{Shift}(i_{BW}))} \right]_{m, 1} \eta_{L-SIG, k}(D_{k, 20}) + p_0 P_k \right) \cdot \exp(j2\pi(k - K_{Shift}(i_{BW}))\Delta_{F, Pre-HE}(t - T_{GI, Legacy Preamble} - T_{CS, HE}(m))) \quad (\#25)$$

31)(#1050)(#525) where

$\eta_{L-SIG, k}$ is a PPDU dependent scaling factor for the L-SIG field on the tone index k with the following value:

$$\eta_{L-SIG, k} = \begin{cases} \sqrt{2}, & k = \pm 28, \pm 27 \text{ for an HE extended range SUPPDU} \\ 1, & \text{otherwise} \end{cases} \quad (\#525)$$

$T_{CS, HE}(m)$ represents the cyclic shift for space time stream m as defined in Cyclic shift for HE modulated fields(#1052)

$Q_k^{(i_{\text{Sig}})}$ is defined in **Erreur ! Source du renvoi introuvable.**(#1094)

(26-56) $A_{\text{HE-LTF}}^k$ is defined in

26.3.10.6 RL-SIG

The RL-SIG field is used to identify an(#2829) HE PPDU.

(26-15) If the TXVECTOR parameter BEAM_CHANGE is 1, the time domain waveform of the RL-SIG field shall be as given by

(#294)

(26-15)

$$s_{\text{RL-SIG}}^{(i_{\text{TX}})}(t) = \frac{1}{\sqrt{N_{\text{TX}} \cdot N_{\text{RL-SIG}}^{\text{Tone}}}} w_{\text{RL-SIG}}(t) \sum_{i_{\text{BW}} \in \text{S20MHz}} \sum_{k=-28}^{28} \eta_{\text{L-SIG},k} \left(Y_{(k-K_{\text{Shift}}(i_{\text{BW}})), \text{BW}} \eta_{\text{L-SIG},k}(D_{k,20} + p_1 P_k) \cdot \exp(j2\pi(k - K_{\text{Shift}}(i_{\text{BW}}))\Delta_{F, \text{Pre-HE}}(t - T_{\text{GI, Legacy Preamble}} - T_{\text{CS}}^{(i_{\text{TX}})})) \right)$$

(26-16) If the TXVECTOR parameter BEAM_CHANGE is 1, the time domain waveform of the RL-SIG field shall be as given by

(#294)

(26-16)

$$s_{\text{RL-SIG}}^{(i_{\text{TX}})}(t) = \frac{1}{\sqrt{N_{\text{STS}} \cdot N_{\text{RL-SIG}}^{\text{Tone}}}} w_{\text{RL-SIG}}(t) \sum_{i_{\text{BW}}=0}^{N_{\text{20MHz}}-1} \sum_{k=-28}^{28} \eta_{\text{L-SIG},k} \sum_{m=1}^{N_{\text{STS}}} \left(\left[Q_{4(k-K_{\text{Shift}}(i_{\text{BW}}))}^{(i_{\text{Sig}})} \right]_{i_{\text{TX}},m} \left[A_{\text{HE-LTF}}^{4(k-K_{\text{Shift}}(i_{\text{BW}}))} \right]_{m,1} (D_{k,20} + p_0 P_k) \cdot \exp(j2\pi(k - K_{\text{Shift}}(i_{\text{BW}}))\Delta_{F, \text{Pre-HE}}(t - T_{\text{GI, Legacy Preamble}} - T_{\text{CS, HE}}(m))) \right)$$

26.3.10.7 HE-SIG-A

26.3.10.7.1 General

The HE-SIG-A field carries information required to interpret HE PPDU's.(#1846)

26.3.10.7.2 Content

The HE-SIG-A field for an HE SU PPDU or an HE extended range SU PPDU contains the fields listed in HE-SIG-A field of an HE SU PPDU and HE extended range SU PPDU.

Table 26-16—HE-SIG-A field of an HE SU PPDU and HE extended range SU PPDU(#Ed)

Two Parts of HE-SIG-A	Bit	Field	Number of bits	Description
HE-SIG-A1	B0	Format	1	Differentiate an HE SU PPDU from an HE trigger-based PPDU:(#1685) Set to 0 for HE trigger-based PPDU Set to 1 for HE SU PPDU This field is reserved and set to 1 for an HE extended range SU PPDU.(#1196)
	B1	Beam Change	1	Set to 1 indicates that the pre-HE-STF portion of the PPDU(#481) is spatially mapped differently from HE-LTF1. Set to 0 indicates that the pre-HE-STF portion of the PPDU(#481) is spatially mapped the same way as HE-LTF1 on each tone.
	B2	UL/DL	1	Indicates whether the PPDU is sent UL or DL: Set to 0 for DL Set to 1 for UL(#2002) This field indicates DL for TDLS, mesh and IBSS(#2864). NOTE—The TDLS peer can identify the TDLS frame by To DS and From DS fields in the MAC header of the MPDU.
	B3-B6	MCS	4	For an HE SU PPDU: Set to n for MCS n , where $n = 0, 1, 2, \dots, 11$ Values 12-15 are reserved For HE extended range SU PPDU with Bandwidth field set to 0 (242-tone RU): Set to n for MCS n , where $n = 0, 1, 2$ Values 3-15 are reserved For HE extended range SU PPDU with Bandwidth field set to 1 (right 106-tone RU in P20): Set to 0 for MCS 0 Values 1-15 are reserved

B7	DCM	1	Indicates whether or not DCM is applied to the Data field for the MCS indicated. Set to 1 to indicate that DCM is applied to the Data field Set to 0 to indicate that DCM is not applied to the Data field. DCM is only applied for MCS0, MCS1, MCS3 and MCS4. DCM is only applied for 1 and 2 spatial streams. DCM is not applied when STBC is used.(#2007)
B8-B13	BSS Color	6	The BSS Color field is an identifier of the BSS
B14	Reserved	1	Reserved and set to 1(PHY Motion #162)
B15-B18	Spatial Re-use	4	Set to SR Disallowed to disallow SRP-based spatial reuse (see 25.9 (Spatial reuse operation) and 25.11a (TXVECTOR parameters SPATIAL_REUSE for an HE PPDU)).(#226) NOTE—This part needs further development.(#2169)
B19-B20	Bandwidth	2	For an HE SU PPDU: Set to 0 for 20 MHz Set to 1 for 40 MHz Set to 2 for 80 MHz Set to 3 for 160 MHz and 80+80 MHz(#Ed) For an HE extended range SU PPDU: Set to 0 for 242-tone RU Set to 1 for right 106-tone RU within the primary 20 MHz
B21-B22	GI+LTF Size(#1420)	3	Indicates the GI duration(#1420) and HE-LTF size. Set to 0 to indicate a 1x HE-LTF and 0.8 μs GI Set to 1 to indicate a 2x HE-LTF and 0.8 μs GI Set to 2 to indicate a 2x HE-LTF and 1.6 μs GI Set to 3 to indicate a 4x HE-LTF and 3.2 μs GI(#2005)
B23-B25	Nsts	3	Indicates the number of space time streams.(#1457) For an HE SU PPDU: Set to the number of space time streams minus 1 For an HE extended range SU PPDU: Set to 0 for one space time stream when STBC field is set to 0 Set to 1 for two space time streams when STBC field is set to 1(#2001) Values 2-7 are reserved

HE-SIG-A2	B0-B6	TXOP Duration	7	Set to 127 to indicate no duration information. Set to value other than 127 to indicate duration information for NAV setting and protection of the TXOP. NOTE—The encoding of TXOP Duration field is the same as the TXOP_DURATION parameter(#Ed) in TXVECTOR and RXVECTOR parameters.(#783)
	B7	Coding	1	Indicates whether BCC or LDPC is used: Set to 0 to indicate BCC Set to 1 to indicate LDPC(#1197)
	B8	LDPC Extra Symbol	1	Indicates the presence of the extra OFDM symbol for LDPC.(#1197) Set to 1 if an extra OFDM symbol for LDPC is present Set to 0 if an extra OFDM symbol for LDPC is present Reserved and set to 1 when the Coding field is 0.
	B9	STBC	1	Set to 1 if space time block coding is used. Set to 0 otherwise
	B10	TxBF	1	Set to 1 if a Beamforming steering matrix is applied to the waveform in an SU transmission Set to 0 otherwise
	B11-B12	Pre-FEC Padding Factor(#2564)	2	Indicates the pre-FEC padding factor(#1626)(#2564) value as defined in Pre-FEC Padding Factor.(#2534)
	B13	PE Disambiguity	1	Indicate PE Disambiguity as defined in Packet extension.(#2534)
	B14	Reserved	1	Reserved and set to 1
	B15	Doppler	1	Set to 0 if Doppler mode is not used Set to 1 if Doppler mode is used(#2167)
	B16-B19	CRC	4	CRC for bits 0-41 of the HE-SIG-A field (see CRC computation). The first bit to be transmitted is bit c7 as explained in CRC computation).(#2535)

B20-B25	Tail	6	Used to terminate the trellis of the convolutional decoder. Set to 0.
NOTE—Integer fields are transmitted in unsigned binary format, LSB first, where the LSB is in the lowest numbered bit position.			

(#475)The HE-SIG-A field of an HE MU PPDU contains the fields listed in HE-SIG-A field of an HE MU PPDU.

Table 26-17—HE-SIG-A field of an HE MU PPDU(#Ed)

Two Parts of HE-SIG-A	Bit	Field	Number of bits	Description
HE-SIG-A1	B0	UL/DL	1	Indicates whether the PPDU is sent UL or DL: Set to 0 for DL. Set to 1 for UL(#2002) This field indicates DL for TDLS, mesh and IBSS(#2864). NOTE—The TDLS peer can identify the TDLS frame by To DS and From DS fields in the MAC header of the MPDU.
	B1-B3	SIGB MCS	3	Indicates the MCS of the HE-SIG-B field: Set to 0 for MCS 0 Set to 1 for MCS 1 Set to 2 for MCS 2 Set to 3 for MCS 3 Set to 4 for MCS 4 Set to 5 for MCS 5(#1616) The values 6 and 7 are reserved(#847)
	B4	SIGB DCM	1	Set to 1 indicates that the HE-SIG-B is modulated with dual sub-carrier modulation for the MCS. Set to 0 indicates that the HE-SIG-B is not modulated with dual sub-carrier modulation for the MCS. DCM is only applicable to MCS0, MCS1, MCS3, and MCS4.
	B5-B10	BSS Color	6	The BSS Color field is an identifier of the BSS

	B11-B14	Spatial Re-use	4	Set to SR Disallowed to disallow SRP-based spatial reuse (see 25.9 (Spatial reuse operation) and 25.11a (TXVECTOR parameters SPATIAL_REUSE for an HE PPDU)).(#226) NOTE—This part needs further development.(#2169)
	B15-B17	Bandwidth	3(#846)	Set to 0 for full 20 MHz Set to 1 for full 40 MHz Set to 2 for full 80 MHz Set to 3 for full 160 MHz and 80+80 MHz(#Ed) Set to 4 for preamble puncturing in 80 MHz, where in the preamble only the secondary 20 MHz is punctured Set to 5 for preamble puncturing in 80 MHz, where in the preamble only one of the two 20 MHz sub-channels in secondary 40 MHz is punctured Set to 6 for preamble puncturing in 160 MHz or 80+80 MHz, where in the primary 80 MHz of the preamble only the secondary 20 MHz is punctured Set to 7 for preamble puncturing in 160 MHz or 80+80 MHz, where in the primary 80 MHz of the preamble the primary 40 MHz is present.(PHY Motion #161)
	B18-B21	Number Of HE-SIG-R Symbols Or MU-MIMO Users	4	If the SIGB Compression field is 0, indicates the number of OFDM symbols in the HE-SIG-B field minus 1.(#821) If the SIGB Compression field is 1, indicates the number of MU-MIMO users minus 1.(#296)
	B22	SIGB Compression	1	Set to 1 for full BW MU-MIMO. Set to 0 otherwise.
	B23-B24	GI+LTF Size(#1420)	3	Indicates the GI duration(#1420) and HE-LTF size. Set to 1 to indicate a 2x HE-LTF and 0.8 μ s GI Set to 2 to indicate a 2x HE-LTF and 1.6 μ s GI Set to 3 to indicate a 4x HE-LTF and 3.2 μ s GI(#2005) The value 0 is reserved(#Ed)
	B25	Doppler	1	Set to 0 if Doppler mode is not used Set to 1 if Doppler mode is used(#2167)
HE-SIG-A2	B0-B6	TXOP Duration	7	Set to 127 to indicate no duration information. Set to value other than 127 to indicate duration information for NAV setting and protection of the TXOP. NOTE—The encoding of TXOP Duration field is the same as the TXOP_DURATION parameter(#Ed) in TXVECTOR and RXVECTOR parameters.(#783)

B7	Reserved	1	Reserved and set to 1
B8-B10	Number of HE-LTF Symbols	3	Indicates the number of HE-LTF symbols: Set to 0 for 1 HE-LTF symbol Set to 1 for 2 HE-LTF symbols Set to 2 for 4 HE-LTF symbols Set to 3 for 6 HE-LTF symbols Set to 4 for 8 HE-LTF symbols Other values are reserved.(#2127)
B11	LPDC Extra Symbol	1	Indication of the presence of the extra OFDM symbol for LDPC.
B12	STBC	1	In an HE MU PPDU where each RU includes no more than 1 user, set to 1 to indicate all RUs are STBC encoded in the payload, set to 0 to indicate all RUs are not STBC encoded in the payload. STBC is not applied in MU-MIMO RUs. STBC doesn't apply to HE-SIG-B.(#540)
B13-B14	Pre-FEC Padding Factor(#2564)	2	Indicates the pre-FEC padding factor(#1626)(#2564) value as defined in Pre-FEC Padding Factor.(#2534)
B15	PE Disambiguity	1	Indicate PE Disambiguity as defined in Packet extension.(#2534)
B16-B19	CRC	4	CRC for bits 0-41 of the HE-SIG-A field (see CRC computation). The first bit to be transmitted is bit <i>c</i> 7 as explained in CRC computation).(#2535)
B20-B25	Tail	6	Used to terminate the trellis of the convolutional decoder. Set to 0.
NOTE—Integer fields are transmitted in unsigned binary format, LSB first, where the LSB is in the lowest numbered bit position.			

When the Bandwidth field is set to 5 or 7, the HE-SIG-B field may indicate which 20 MHz sub-channel(s) in the preamble of secondary 40 MHz channel are punctured by its RU allocation signaling; when the Bandwidth field is set to 6 or 7, the HE-SIG-B field may indicate which 20 MHz sub-channel(s) in the preamble of secondary 80 MHz channel are punctured by its RU allocation signaling. See HE-SIG-B for the RU allocation signaling.

It is optional for an HE STA to receive a preamble-punctured HE MU PPDU with the Bandwidth field in HE-SIG-A setting to a values 4 to 7. Whether or not an HE STA is capable of receiving preamble-punctured HE MU PPDU with the Bandwidth field of HE-SIG-A field setting to 4, 5, 6, 7 are indicated by the Preamble Puncturing Receive Capable subfield in the HE Capabilities field (see 9.4.2.218 (HE Capabilities element)).

The HE-SIG-A field for an HE trigger-based PPDU contains the fields listed in HE-SIG-A field of an HE trigger-based PPDU.

Table 26-18—HE-SIG-A field of an HE trigger-based PPDU(#Ed)

Two Parts of HE-SIG-A	Bit	Field	Number of bits	Description
HE-SIG-A1	B0	Format	1	Set to 0 for an HE SU PPDU Set to 1 for an HE trigger-based PPDU
	B1-B6	BSS Color	6	The BSS Color field is an identifier of the BSS
	B7-B10	Spatial Reuse 1 (SR Motion #11)	4	If the Bandwidth field indicates 20 MHz, 40 MHz, or 80 MHz: Spatial Reuse field for the first 20 MHz subband (see NOTE 1) If the Bandwidth field indicates 160/80+80 MHz: Spatial Reuse field for first 40 MHz subband of the 160 MHz operating band. (see NOTE 1) Set to 0 (SR disallowed Entry) to disallow SRP-based spatial reuse (see 25.9 (Spatial reuse operation) and 25.11a (TXVECTOR parameters SPATIAL_REUSE for an HE PPDU)). Set to value 1 to 14 corresponding to SRP value (see Spatial Reuse subfield encoding) for SRP-based SR operation. The value 15 is reserved.(#226)

B11-B14	Spatial Reuse 2	4	If the Bandwidth field indicates 20 MHz, 40 MHz, or 80 MHz: Spatial Reuse field for the second 20 MHz subband (see NOTE 1) When operating 20 MHz, this field is set to same value as Spatial Reuse 1 field. When operating 40 MHz in 2.4 GHz band, this field is set to same value as Spatial Reuse 1 field If the Bandwidth field indicates 160/80+80 MHz: Spatial Reuse field for second 40 MHz subband of the 160 MHz operating band. (see NOTE 1) Set to 0 (SR disallowed Entry) to disallow SRP-based spatial reuse (see 25.9 (Spatial reuse operation) and 25.11a (TXVECTOR parameters SPATIAL_REUSE for an HE PPDU)). Set to value 1 to 14 corresponding to SRP value (see Spatial Reuse subfield encoding) for SRP-based SR operation. The value 15 is reserved.(#226)
B15-B18	Spatial Reuse 3	4	If the Bandwidth field indicates 20 MHz, 40 MHz or 80 MHz: Spatial Reuse field for the third 20 MHz subband (see NOTE 1) When operating in 20 MHz or 40 MHz, this field is set to same value as Spatial Reuse 1 field. If the Bandwidth field indicates 160/80+80 MHz: Spatial Reuse field for third 40 MHz subband of the 160 MHz operating band. (see NOTE 1) When operating in 80+80 MHz, this field is set to same value as Spatial Reuse 1 field. Set to 0 (SR disallowed Entry) to disallow SRP-based spatial reuse (see 25.9 (Spatial reuse operation) and 25.11a (TXVECTOR parameters SPATIAL_REUSE for an HE PPDU)). Set to value 1 to 14 corresponding to SRP value (see Spatial Reuse subfield encoding) for SRP-based SR operation. The value 15 is reserved.(#226)

	B19-B22	Spatial Reuse 4	4	If the Bandwidth field indicates 20 MHz, 40 MHz or 80 MHz: Spatial Reuse field for the fourth 20 MHz subband (see NOTE 1) When operating in 20 MHz, this field is set to same value as Spatial Reuse 1 field. When operating in 40 MHz, this field is set to same value as Spatial Reuse 2 field. If the Bandwidth field indicates 160/80+80 MHz: Spatial Reuse field for fourth 40 MHz subband of the 160 MHz operating band. (see NOTE 1) When operating in 80+80 MHz, this field is set to same value as Spatial Reuse 2 field Set to 0 (SR disallowed Entry) to disallow SRP-based spatial reuse (see 25.9 (Spatial reuse operation) and 25.11a (TXVECTOR parameters SPATIAL_REUSE for an HE PPDU)). Set to value 1 to 14 corresponding to SRP value (see Spatial Reuse subfield encoding) for SRP-based SR operation. The value 15 is reserved.(#226)
	B23	Reserved	1	Reserved and set to 1. NOTE—Unlike other Reserved fields in HE-SIG-A of the HE trigger-based PPDU, B23 does not have a corresponding bit in the Trigger frame.(PHY Motion #169)
	B24-B25	Bandwidth	2	For HE trigger-based PPDU: Set to 0 for 20 MHz Set to 1 for 40 MHz Set to 2 for 80 MHz Set to 3 for 160 MHz and 80+80 MHz(#2001)
	B0-B6	TXOP Duration	7	Set to 127 to indicate no duration information. Set to value other than 127 to indicate duration information for NAV setting and protection of the TXOP. NOTE—The encoding of TXOP Duration field is the same as the TXOP_DURATION parameter(#Ed) in TXVECTOR and RXVECTOR parameters.(#783)
	B7-B15	Reserved	9	Reserved and set to value indicated in the Trigger frame
	B16-B19	CRC	4	CRC of bits 0-41 of the HE-SIG-A field. See CRC computation. The first bit to be transmitted is bit C3 as explained in CRC computation).(#2535)
HE-SIG-A2				

B20-B25	Tail	6	Used to terminate the trellis of the convolutional decoder. Set to 0.
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NOTE 1—The four Spatial Reuse fields, 1, 2, 3, and 4, are arranged in increasing order of frequency and correspond to:

- For 20 MHz one Spatial Reuse field corresponding to the entire 20 MHz (other 3 fields indicate identical values)
- For 40 MHz two Spatial Reuse fields for each 20 MHz sub-band (other 2 fields indicate identical values)
- For 80 MHz four Spatial Reuse fields for each 20 MHz sub-band
 - For an OFDMA transmission of a given BW, each of the Spatial Reuse fields that corresponds to a 20 MHz sub-band is also applicable to the 242-tone RU which is most closely aligned in frequency (in the tone-plan of that BW) with the aforementioned 20 MHz sub-band. The correspondence from an Spatial Reuse field to a 242-tone RU also holds for any RU within the 242-tone RU. The above also implies that a 20 MHz OBSS STA uses the Spatial Reuse field corresponding to its 20 MHz channel, a 40 MHz OBSS STA located on the lower frequency half of the 80 MHz BSS uses Spatial Reuse 1 field, Spatial Reuse 2 field values and a 40 MHz OBSS STA located on the upper frequency half of the 80 MHz BSS uses Spatial Reuse 3 field, Spatial Reuse 4 field values
- For 160 MHz and 80+80 MHz four Spatial Reuse fields for each 40 MHz sub-band
 - For an OFDMA transmission of a given BW, each of the Spatial Reuse fields that corresponds to a 40 MHz sub-band is also applicable to the 484-tone RU which is most closely aligned in frequency (in the tone-plan of that BW) with the aforementioned 40 MHz sub-band. The correspondence from an Spatial Reuse field to a 484-tone RU also holds for any RU within the 484-tone RU.

NOTE 2—Integer fields are transmitted in unsigned binary format, LSB first, where the LSB is in the lowest numbered bit position.

(#226) Spatial Reuse subfield encoding defines the encoding for the Spatial Reuse 1, Spatial Reuse 2, Spatial Reuse 3 and Spatial Reuse 4 subfields.

Table 26-19—Spatial Reuse sub-field encoding

Value	Meaning
0	SR disallow
1	SRP = -80 dBm
2	SRP = -74 dBm
3	SRP = -68 dBm
4	SRP = -62 dBm
5	SRP = -56 dBm
6	SRP = -50 dBm

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7	SRP = -47 dBm
8	SRP = -44 dBm
9	SRP = -41 dBm
10	SRP = -38 dBm
11	SRP = -35 dBm
12	SRP = -32 dBm
13	SRP = -29 dBm
14	SRP = -26 dBm
15	Reserved

$SRP = TX\ PWR_{AP} + \text{Acceptable Receiver Interference level}_{AP}$

Adjustment range for parameters (referenced to the antenna connector and normalized to 20 MHz bandwidth):

- $TX\ PWR_{AP}$: -10 dBm to 26 dBm
- Acceptable Receiver Interference Level_{AP}: -82dBm to -36 dBm

If SRP is below -80 dBm, set Spatial Reuse to 1, if SRP is above -26 dBm, set Spatial Reuse to 14. Same table is used for AP and STA.

26.3.10.7.3 CRC computation

The CRC computation defined in this subclause applies to HE-SIG-A, the Common field of HE-SIG-B and the User Specific field of HE-SIG-B.

The CRC is calculated over (#2015) bits 0 to 41 of the HE-SIG-A field and over bits 0 to L of the HE-SIG-B field ($L = x$ for each HE-SIG-B common block field where $x = N \times 8$ when the Center 26-tone RU subfield is present, and $x = N \times 8 - 1$ otherwise, and $L = 20$ for the HE-SIG-B user specific fields). Refer to Common Block field for N and the conditions under which the Center 26-tone RU subfield is present. (#2016)(#Ed)

The value of the CRC field shall be the 1s complement of

$$crc(D) = (M(D) + I(D))D^8 \bmod G(D)$$

where

$$M(D) = \sum_{i=0}^L m_{L-i} D^i$$

where

$$I(D) = \sum_{i=L-7}^L D^i$$

$G(D)$ is defined in Equation (19-18)(#2018)

The CRC field is transmitted from $c4$ to $c7$ with $c7$ first.(#2286)

Figure 19-8 (HT-SIG CRC calculation) shows the operation of the CRC, where the serial input are from $m1$ to $m0$, and the output is stopped at $c4$.

26.3.10.7.4 Encoding and modulation

(26-17)For an HE SU PPDU, HE MU PPDU and HE trigger-based PPDU, the HE-SIG-A field is composed of two parts, HE-SIG-A1 and HE-SIG-A2, each containing 26 data bits. HE-SIG-A1 is transmitted before HE-SIG-A2. The HE-SIG-A symbols shall be BCC encoded at rate, $R = 1/2$, interleaved, mapped to a BPSK constellation, and have pilots inserted following the steps described in 17.3.5.6 (Convolutional encoder), BCC interleavers(#2183), 17.3.5.8 (Subcarrier modulation mapping), and 17.3.5.9 (Pilot subcarriers)(#2771), respectively. The constellation mappings of HE-SIG-A in HE SU PPDU, HE MU PPDU and HE trigger-based PPDU are shown in Data tone constellation of HE-SIG-A symbols(#2772). The first and second half of the stream of 104 complex numbers generated by these steps (before pilot insertion) is divided into two groups of 52 complex numbers, where respectively, the first 52 complex numbers form the first symbol of HE-SIG-A and the second 52 complex numbers form the second symbol of HE-SIG-A. If the TXVECTOR parameter BEAM_CHANGE is 1, the time domain waveform for the HE-SIG-A field of an HE SU PPDU, HE MU PPDU and HE trigger-based PPDU shall be as specified in

.(#2287)(#525)

(26-17)

$$r_{\text{HE-SIG-A}}^{(i_{\text{seg}}, i_{\text{TX}})}(t) = \frac{1}{\sqrt{N_{\text{TX}} \cdot N_{\text{HE-SIG-A}}^{\text{tone}}}} \sum_{n=0}^{1} w_{T_{\text{SYM}}}(t - nT_{\text{SYM}}) \sum_{k=-28}^{28} \sum_{l_{\text{BW}} = \Omega_{20\text{MHz}}}^{28} \left(Y_{(k - K_{\text{Shift}}(l_{\text{BW}}))} \text{BW}(D_{k,n,20} + p_{n+2}P_k) \cdot \exp(j2\pi(k - K_{\text{Shift}}(l_{\text{BW}}))\Delta F_{\text{Pre-HIS}}(t - nT_{\text{SYM}} - T_{\text{GI, Legacy Preamble}} - T_{\text{CS}}^{i_{\text{TV}}})) \right)$$

$K_{\text{Shift}}(i)$ is defined in 21.3.7.3 (Channel frequencies)

$$D_{k,n,20} = \begin{cases} 0, & k = 0, \pm 7, \pm 21 \\ d_{M'_{20}(k),n}, & \text{otherwise} \end{cases}$$

$$M_{20}^r(k) = \begin{cases} k + 28, -28 \leq k \leq -22 \\ k + 27, -20 \leq k \leq -8 \\ k + 26, -6 \leq k \leq -1 \\ k + 25, 1 \leq k \leq 6 \\ k + 24, 8 \leq k \leq 20 \\ k + 23, 22 \leq k \leq 28 \end{cases} \quad (\#525)$$

P_k and p_n are defined in 17.3.5.10 (OFDM modulation)

$N_{\text{HE-SIG-A}}^{\text{Tone}}$ is defined in Tone scaling factor and guard interval duration values for HE PPDU fields (#476)

$T_{CS}^{i_{TX}}$ represents the cyclic shift for transmit chain i_{TX} with a value given in Cyclic shift for pre-HE modulated fields.

(26-18) If the TXVECTOR parameter BEAM_CHANGE is 0, the time domain waveform of the HE-SIG-A field shall be as given by

(26-18)

$$\begin{aligned} (i_{\text{SEC}}^{i_{TX}})_{\text{HE-SIG-A}}(t) &= \frac{1}{\sqrt{N_{TX} \cdot N_{\text{HE-SIG-A}}^{\text{Tone}}}} \sum_{n=0}^{N_{\text{HE-SIG-A}}^{\text{Tone}}-1} w_{T_{SYML}}(t - nT_{SYML}) \\ &\quad \sum_{i_{BW}=0}^{N_{\text{SIGNAL}}-1} \sum_{k=-N_{SR}}^{N_{SR}} \left((D_{k,n,i_{BW}}^{i_{\text{SEC}}} + p_n + i_{BW} P_k) \right. \\ &\quad \left. \cdot \exp(j2\pi(k - K_{\text{Shift}}(i_{BW}))\Delta_{F, \text{Pre-HE}}(t - nT_{SYML} - T_{GI, \text{Legacy Preamble}} - T_{CS}^{i_{TX}})) \right) \end{aligned} \quad (\#2288)$$

#1050)(#525) where

$T_{CS, \text{HE}}(m)$ represents the cyclic shift for space time stream m as defined in Cyclic shift for HE modulated fields (#1052)

$Q_k^{(i_{\text{SEC}})}$ is defined in **Erreur ! Source du renvoi introuvable.** (#1094)

(26-56) $A_{\text{HE-LTF}}^k$ is defined in

For an HE extended range SU PPDU, the HE-SIG-A field is composed of four parts, i.e. HE-SIG-A1, HE-SIG-A2, HE-SIG-A3 and HE-SIG-A4, each part containing 26 data bits. These four parts are transmitted sequentially from HE-SIG-A1 to HE-SIG-A4. HE-SIG-A1 and HE-SIG-A2 have the same data bits. HE-SIG-A3 and HE-SIG-A4 have same data bits. The data bits of HE-SIG-A1 and HE-SIG-A3 shall be BCC encoded at rate, $R = 1/2$, interleaved, mapped to a BPSK constellation, and have pilots inserted. HE-SIG-A2 shall be BCC encoded at rate, $R = 1/2$, mapped to a QPSK constellation without interleaving (#912) and have pilots inserted. The constellation mappings of the HE-SIG-A field in an HE extended range SU PPDU is shown in Data tone constellation of HE-SIG-A symbols. The QPSK constellation on HE-SIG-A2 is used to differentiate between an HE extended range SU PPDU and an HE

Length = $\left\lceil \frac{\text{TXTIME} - 20}{4} \right\rceil \times 3 - 3 - m$ (#1, which indicates HE MU PPDU or HE extended range SU PPDU(#1687). HE-SIG-A4 shall be BCC encoded at rate, $R = 1/2$, mapped to a BPSK constellation without interleaving(#913) and have pilots inserted. BCC encoding, Data interleaving, constellation mapping and pilot insertion follow the steps described in 17.3.5.6 (Convolutional encoder), BCC interleavers(#2183), 17.3.5.8 (Subcarrier modulation mapping), and 17.3.5.9 (Pilot subcarriers)(#2774), respectively.

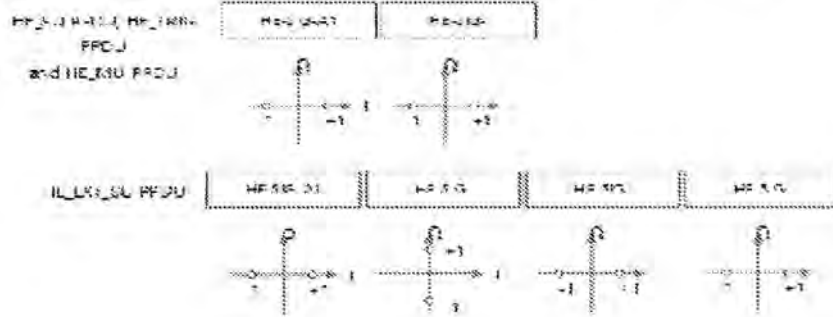


Figure 26-19—Data tone constellation of HE-SIG-A symbols

(26-19)If the TXVECTOR parameter BEAM_CHANGE is 1, the time domain waveform for the HE-SIG-A field in an HE extended range SU PPDU, shall be as specified in

(26-19)

$$r_{\text{HE-SIG-A}}^{(i_{\text{SC}}, t_{\text{TX}})}(t) = \frac{1}{\sqrt{N_{\text{TX}} \cdot N_{\text{HE-SIG-A}}^{\text{tone}}}} \sum_{n=0}^{N_{\text{HE-SIG-A}}^{\text{tone}}-1} w_{\text{SYM},n}(t - nT_{\text{SYM}}) \sum_{k=-28}^{28} \left(Y_{(k-K_{\text{Shift}}(i_{\text{BW}}))} \cdot \text{BW}(R_n D_{k,n,20} + P_n + 2P_k) \cdot \exp(j2\pi(k - K_{\text{Shift}}(i_{\text{BW}}))\Delta F_{\text{Pre-HE}}(t - nT_{\text{SYM}} - T_{\text{GL,Legacy Preamble}} - T_{\text{CS}}^{(i_{\text{TX}})})) \right) \quad (\#2289)$$

where

R_n is a phase rotation vector defined as [1, j , 1, 1](#2372)

(26-20)If the TXVECTOR parameter BEAM_CHANGE is 0, the time domain waveform for the HE-SIG-A field in an HE extended range SU PPDU, shall be as specified in

(#2290)(#2531)

(26-20)

$$\begin{aligned}
 s_{\text{HE-SIG-A}}^{(i_{\text{sig}}^{(rx)})}(t) &= \frac{1}{\sqrt{N_{\text{STS}} \cdot N_{\text{Tone}}^{\text{HE-SIG-A}}}} \sum_{n=0}^3 w_{T_{\text{SYM}}}(t - nT_{\text{SYM}}) \\
 &\sum_{i_{\text{BW}}=0}^{N_{\text{20MHz}}-1} \sum_{k=-28}^{28} \sum_{m=1}^{N_{\text{STS}}} \left(\left[Q_{4(k-K_{\text{Shift}}(i_{\text{BW}}))} \right]_{i_{\text{TS}},m} \left[A_{\text{HE-LTF}}^{4(k-K_{\text{Shift}}(i_{\text{BW}}))} \right]_{m,1} (R_n D_{k,n,20} + P_n + 2P_k) \right. \\
 &\quad \left. \cdot \exp(j2\pi(k - K_{\text{Shift}}(i_{\text{BW}}))\Delta_{F, \text{Prc-HE}}(t - nT_{\text{SYM}} - T_{\text{GL Legacy Preamble}} - T_{\text{CS, HE}}(m))) \right)
 \end{aligned}$$

26.3.10.8 HE-SIG-B

26.3.10.8.1 Encoding and modulation

The HE-SIG-B field is separately encoded on each 20 MHz band. The encoding structure in one such 20 MHz band is shown in HE-SIG-B field encoding structure in each 20 MHz. It consists of a Common Block field followed by a User Specific field which together are referred to as the HE-SIG-B content channel(#2020).

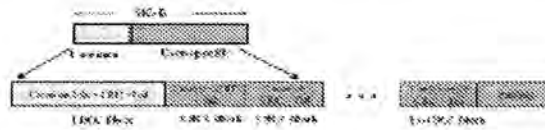


Figure 26-20—HE-SIG-B field encoding structure in each 20 MHz

The Common Block field of a HE-SIG-B content channel(#2020) contains information regarding the resource unit allocation such as the RU arrangement in frequency domain, the RUs allocated for MU-MIMO and the number of users in MU-MIMO allocations. The Common Block field is described in detail in HE-SIG-B common content.

The User Specific field of a HE-SIG-B content channel(#2020) consists of one or more(#2022) User Block fields. Each User Block field is made up of two user fields that contain(#2020) information for two STAs to decode their payloads. The last User Block field may contain information for one or two STAs depending on whether the number of users indicated by the RU allocation signaling is odd and depending on the signaling of the center 26-tone RU(#302). See HE-SIG-B per-user content for a description of the contents of the User Block field.

When the SIGB Compression field in the HE-SIG-A field of an HE MU PPDU is set to 1 (indicating full bandwidth MU-MIMO transmission), the Common Block field is not present and the content channel consists of only the User Specific field.(#2543)

26.3.10.8.2 Frequency domain mapping

The 20 MHz PPDU contains one content channel in which the Common Block field and User Specific field are carried as shown in HE-SIG-B content channel for a 20 MHz PPDU. The Common Block field contains the RU allocation signaling for RUs that occur within the 242-tone RU boundary.

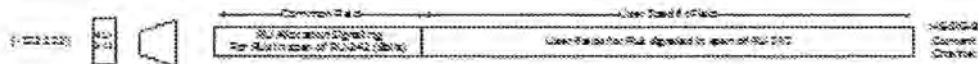


Figure 26-21—HE-SIG-B content channel for a 20 MHz PPDU

The 40 MHz PPDU contains two content channels, each occupying a 20 MHz segment. Each content channel contains a Common Block field followed by User Specific field as shown in HE-SIG-B content channel for a 40 MHz PPDU. The content channels are ordered in increasing order of the absolute frequency i.e., the first content channel carries Common Block field and User Specific field corresponding to RUs whose subcarrier indices fall between $[-244; -3]$ and the second content channel carries Common Block field and User Specific field corresponding to RUs whose subcarrier indices fall between $[3; 244]$. (#2544) If a 484-tone RU is signaled, both content channels will carry Common Block field and User Specific field corresponding to the 484-subcarrier RU.

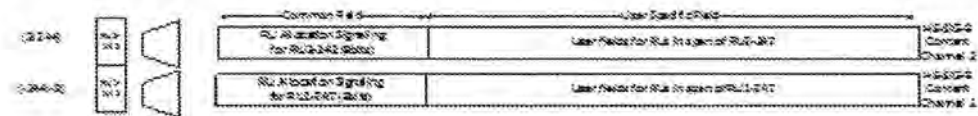


Figure 26-22—HE-SIG-B content channel for a 40 MHz PPDU

The 80 MHz PPDU contains two content channels each of which are duplicated once as shown in Default mapping of the two HE-SIG-B channels and their duplication in an 80. The arrangement of the content channels are in increasing order of the absolute frequency where HE-SIG-B content channel 1 occupies the tones in the 20 MHz segment with the lowest subcarrier indices followed by the HE-SIG-B content channel 2 in the adjacent 20 MHz segment. This structure of the first content channel occupying the lower subcarrier index followed by the second content channel is repeated with content duplication in the remaining two 20 MHz segments, respectively. The first content channel appearing in the 20 MHz segments carries a Common Block field and User Specific field corresponding to RUs whose subcarriers indices overlap those segments. (#2544) The Common Block field of content channel 1 contains the following: an RU allocation signaling field for RUs with subcarrier indices in the range $[-500; -259]$, followed by a second RU allocation signaling field for RUs with subcarrier indices between $[17; 258]$ and 1 bit to indicate the presence of the user field corresponding to the center 26-tone RU that spans subcarriers $[-16; -4, 4; 16]$. (#1692) The second content channel carries a Common Block field and User Specific field corresponding to RUs whose subcarrier indices fall in those segments. The Common Block field of content channel 2 contains the following: an RU allocation signaling field for RUs whose subcarrier indices fall in the range $[-258; -17]$, followed by a second RU allocation signaling field for RUs with subcarrier indices

between [259:500] and 1 bit to indicate presence of the user field corresponding to the center 26-tone RU that spans subcarriers [-16:-4, 4:16]. The same value for the bit signaling presence of the center 26-tone RU is carried in both content channels.(#1692) The user fields in the User Specific field that follow the common field are arranged in the same order as the RU allocation signaling. When assigned, the user field corresponding to the center 26-tone RU that spans subcarriers [-16:-4, 4:16] is carried as the last user field in the HE-SIG-B content channel 1.(#1692)(#2023) When RUs greater than 242 subcarriers are signaled in the RU allocation signaling in a portion of the bandwidth, the signaling is carried in both content channels placed in the order of the absolute subcarrier index.

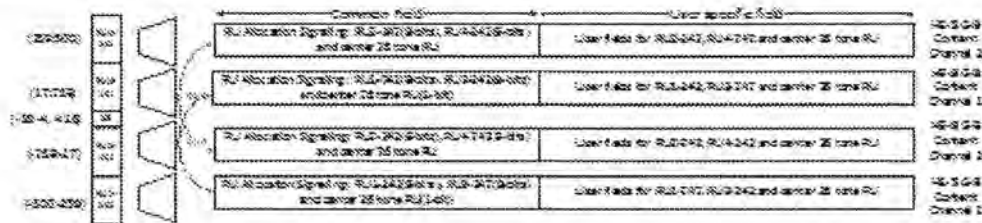


Figure 26-23—Default mapping of the two HE-SIG-B channels and their duplication in an 80 MHz PPDU

The 160 MHz PPDU contains two content channels each of which are duplicated four times as shown in Default mapping of the two HE-SIG-B channels and their duplication in a 16. The arrangement of the content channels are in increasing order of the absolute frequency.(#2023) The first content channel occupies the tones in the 20 MHz segment with the lowest subcarrier indices and the second content channel in the adjacent 20 MHz segment. This pattern of arranging HE-SIG-B content channel 1 and HE-SIG-B content channel 2 is duplicated over the other segments. The HE-SIG-B content channel 1 and HE-SIG-B content channel 2 carries RU allocation signaling at 242-tone RU granularity that overlap with the 20 MHz segments in which the content channels are carried (including duplication). The signaling for the presence of the user field corresponding to a center 26-tone RU in the 80 MHz segment with the lower sub-carrier index is carried in HE-SIG-B content channel 1 as a 1-bit sub-field placed at the end of the Common field. Similarly, signaling for the center 26-tone RU in the 80 MHz segment with the higher subcarrier index is carried in HE-SIG-B content channel 2 as 1-bit sub-field placed at the end of the common field. When assigned, the user field corresponding to the center 26-tone RU in the 80 MHz segments is carried as the last user field in their respective content channels.(#1692) When RUs greater than 242 subcarriers are signaled in the RU allocation signaling in a portion of the bandwidth, the signaling is carried in both content channels placed in the order of the absolute sub-carrier index.

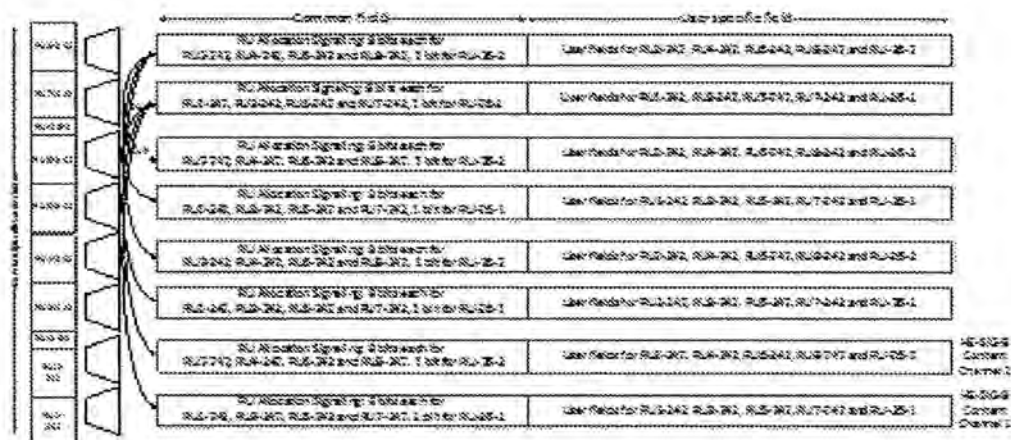


Figure 26-24—Default mapping of the two HE-SIG-B channels and their duplication in a 160 MHz PPDU

For an MU-MIMO allocation of RU size greater than 242 subcarriers(#2546), the User Block subfields are dynamically split between the two HE-SIG-B content channels (1/2) and the split is decided by the AP (on a per case basis). See HE-SIG-B common content and HE-SIG-B per-user content(#1006) for more details.

(PHY Motion #161)When preamble puncturing is present as indicated by values 4 to 7 in the Bandwidth field of HE-SIG-A field of an HE MU PPDU (see HE-SIG-A field of an HE MU PPDU), the frequency domain structure of HE-SIG-B is the same as defined for the full bandwidth, i.e. the HE-SIG-B field frequency domain structure is solely dependent on the total bandwidth.

26.3.10.8.3 Time domain encoding

In each 20 MHz band, the bits in the Common Block field shall have CRC and tail bits added and then be BCC encoded at rate $R = \frac{1}{2}$. The CRC bits are computed as described in CRC computation.(#2025) Padding bits are not added after the common block.

In the User Specific field, in any 20 MHz band, the bits corresponding to two STAs (i.e. two User fields) are encoded together. Specifically, the STAs scheduled in the HE MU PPDU(#Ed) are split into groups of two. Each group of two User fields shall have CRC and tail bits added and then BCC encoded at rate $R = \frac{1}{2}$ using the encoder described in 17.3.5.6 (Convolutional encoder)(#307). If the number of users in the content channel is odd, the User Block field corresponding to the last user, who is not grouped, is encoded after adding tail and CRC bits. After encoding, padding bits are added to each content channel to round up the number of symbols the content channel occupies to the nearest integer value. Further padding is added to each content channel until the number of OFDM symbols in the content channel equals the Number of HE-SIG-B symbols signaled by a 4-bit field in the HE-SIG-A field for an HE MU PPDU. Thus, padding ensures that the content channels in different 20 MHz bands end at the same OFDM symbol.(#306) (#2027)For both the Common Block and User Specific fields, when the code rate is not equal to $\frac{1}{2}$, the

convolutional encoder output bits for each field (including padding bits) are concatenated, then the concatenated bit streams are punctured as described in 17.3.5.6 (Convolutional encoder)(#307)(#2028).

The coded bits are interleaved as in BCC interleavers. The interleaved bits are mapped to constellation points from the MCS specified in HE-SIG-A and have pilots inserted following the steps described in 17.3.5.8 (Subcarrier modulation mapping) and 17.3.5.9 (Pilot subcarriers)(#307), respectively.(#2183)

The guard interval(#915) used for HE-SIG-B shall be 0.8 μ s.(#2030)

The number of OFDM symbols in the HE-SIG-B field, denoted by $N_{SYM,HE-SIG-B}$, shall be signaled by a 4-bit field in the HE-SIG-A field of a HE MU PPDU(#477) (see (#1304)Content(#2781)).

(26-21)(#2031)For the c -th content channel ($c = 1$ or 2), denote the sample on the k -th data(#525) subcarrier of the n -th symbol by $d_{k,n,c}$. The time domain waveform for the HE-SIG-B follows

(26-21)

$$r_{HE-SIG-B}^{(i_{ser}, i_{rx})}(t) = \frac{1}{\sqrt{N_{TX} \cdot N_{HE-SIG-B}^{Tone}}} \sum_{n=0}^{N_{SYM,HE-SIG-B}} w_{T_{HE-SIG-B}}(t - nT_{SYM,L}) \sum_{i_{BW} \approx \Omega_{20MHz}k = -N_{SB}}^{N_{SB}} \left(\sum_{k=-N_{SB}}^{N_{SB}} \left(Y(k - K_{sub}(i_{BW})), BW \Gamma_{M'_{20}(k)}(D_{k,n,i_{BW}}^{i_{ser}} + p_n + a P_k) \cdot \exp(j2\pi(k - K_{sub}(i_{BW}))\Delta_{F,Pre-HE}(t - nT_{SYM,L} - T_{GI,LegacyPreamble} - T_{CS}^{i_{rx}})) \right) \right) \quad ($$

#525)where

$\Gamma_{M'_{20}(k)}$

is the phase rotation value for HE-SIG-B field PAPR reduction. When the HE-SIG-B field is modulated with MCS=0 and DCM=1, $\Gamma_{M'_{20}(k)} = 1$. For all other modulation schemes of HE-SIG-B field,

$$\Gamma_{M'_{20}(k)} = \begin{cases} 1 & 0 \leq M'_{20}(k) < 26 \\ (-1)^{M'_{20}(k)} & 26 \leq M'_{20}(k) < 52 \end{cases} \quad (\#525)$$

N_{20MHz} and $K_{sub}(i)$ are defined in 21.3.8.2.4 (L-SIG definition)(#2782)

$$D_{k,n,i_{BW}}^{i_{ser}} = \begin{cases} 0, k = 0, \pm 7, \pm 21 \\ d_{M'_{20}(k), n, (i_{BW} \bmod 2) + 1}, \text{ otherwise} \end{cases}$$

$$M'_{20}(k) = \begin{cases} k + 28, -28 \leq k \leq -22 \\ k + 27, -20 \leq k \leq -8 \\ k + 26, -6 \leq k \leq -1 \\ k + 25, 1 \leq k \leq 6 \\ k + 24, 8 \leq k \leq 20 \\ k + 23, 22 \leq k \leq 28 \end{cases}$$

P_k and p_{ff} are defined in 17.3.5.10 (OFDM modulation)(#307)

$N_{SYM, HE-SIG-B}$ is the number of OFDM symbols in the HE-SIG-B field

26.3.10.8.4 HE-SIG-B common content

The Common Block field in the HE-SIG-B field carries the RU allocation subfields. Depending on the PPDU bandwidth, the Common Block field can contain multiple RU Allocation subfields. The format of the Common Block field is defined in Common Block field.

Table 26-20—Common Block field(#2024)

Subfield	Number of bits	Description
RU Allocation	$N \times 8$	Indicates the RU arrangement in the frequency domain. It also indicates the number of user fields in each RU. For RUs of size greater than or equal to 106-tones that support MU-MIMO, it indicates the number of users multiplexed using MU-MIMO. $N = 1$ for a 20 MHz and a 40 MHz HE MU PPDU $N = 2$ for an 80 MHz HE MU PPDU $N = 4$ for a 160 MHz or 80+80 MHz HE MU PPDU
Center 26-tone RU	1	This field is present only for full bandwidth 80 MHz, 160 MHz and 80+80 MHz. For full bandwidth 80 MHz: Set to 1 to indicate that the center 26-tone RU is allocated in the Common Block fields of both HE-SIG-B content channels with the same value. Set to 0, otherwise. For full bandwidth 160 MHz or 80+80 MHz: Set to 1 to indicate that the center 26-tone RU is allocated for one individual 80 MHz in the Common Block fields of both HE-SIG-B content channels. Set to 0, otherwise.
CRC	4	See CRC computation
Tail	6	Used to terminate the trellis of the convolutional decoder. Set to 0
NOTE—Integer fields are transmitted in unsigned binary format, LSB first, where the LSB is in the lowest numbered bit position.(#1010)		

An RU Allocation subfield in the Common Block field of HE-SIG-B consists of 8 bits that indicates the following for a 20 MHz PPDU BW:

- The RU arrangement in the frequency domain: indexes the size of the RUs and their placement in the frequency domain.

- Number of user fields in each RU in the HE-SIG-B content channel: the number of users multiplexed in the RUs indicated by the arrangement; for RUs of size greater than or equal to 106 tones that support MU-MIMO, it indicates the number of users multiplexed using MU-MIMO.

The mapping of the 8-bit RU Allocation subfield to the RU arrangement and the number of user fields per RU is defined in the RU allocation signaling: arrangement and number of MU-MIMO al. In the table, the number of entries column refers to the number of 8-bit indices that refer to the same RU arrangement in the frequency domain but differ in the number of users fields per RU. The RU arrangement and the number of user fields per RU together indicate the number of user-fields in the User specific field of HE-SIG-B. Signaling for the center 26-tone RU in BW ≥ 80 MHz follows the RU Allocation subfields. For full BW 80 MHz, 1 bit is added to indicate if center 26-tone RU is allocated in the Common Block fields of both HE-SIG-B content channels with same value. For full BW 160 MHz, 1 bit is added to indicate if center 26-tone RU is allocated for one individual 80 MHz in common block fields of both HE-SIG-B content channels(#1001).

Table 26-21—RU allocation signaling: arrangement and number of MU-MIMO allocations(#2032)

8 bits indices (B7 B6 B5 B4 B3 B2 B1 B0)	#1	#2	#3	#4	#5	#6	#7	#8	#9	Number of entries
00000000	26	26	26	26	26	26	26	26	26	1
00000001	26	26	26	26	26	26	26	52		1
00000010	26	26	26	26	26	52		26	26	1
00000011	26	26	26	26	26	52		52		1
00000100	26	26	52		26	26	26	26	26	1
00000101	26	26	52		26	26	26	52		1
00000110	26	26	52		26	52		26	26	1
00000111	26	26	52		26(# 1060)	52		52		1
00001000	52		26	26	26	26	26	26	26	1
00001001	52		26	26	26	26	26	52		1

00001010	52	26	26	26	52	26	26	1
00001011	52	26	26	26	52	52		1
00001100	52	52		26	26	26	26	1
00001101	52	52		26	26	26	52	1
00001110	52	52		26	52	26	26	1
00001111	52	52		26(# 1060)	52	52		1
00010y ₂ y ₁ y ₀	52	52		-	106			8
00011y ₂ y ₁ y ₀		106		-	52	52		8
00100y ₂ y ₁ y ₀	26	26	26	26	26	106		8
00101y ₂ y ₁ y ₀	26	26	52	26(# 1060)	106			8
00110y ₂ y ₁ y ₀	52	26	26	26	106			8
00111y ₂ y ₁ y ₀	52	52		26	106			8
01000y ₂ y ₁ y ₀		106		26	26	26	26	8
01001y ₂ y ₁ y ₀		106		26	26	26	52	8
01010y ₂ y ₁ y ₀		106		26	52	26	26	8
01011y ₂ y ₁ y ₀		106		26	52	52		8
0110y ₁ y ₀ z ₁ z ₀		106		-	106			16

01110000	52	52	-	52	52	1
01110001	242-tone RU empty					1
01110010	484-tone RU with zero HE-SIG-B User Specific field in the corresponding HE-SIG-B Content Channel					1
01110011	996-tone RU with zero HE-SIG-B User Specific field in the corresponding HE-SIG-B Content Channel					1
011101x ₁ x ₀	Reserved(#2035)					4
011111x ₁ x ₀	Reserved(#2035)					8
10y ₂ y ₁ y ₀ z ₂ z ₁ z ₀	106	26	106			64
11000y ₂ y ₁ y ₀	242					8
11001y ₂ y ₁ y ₀	484					8
11010y ₂ y ₁ y ₀	996					8
11011y ₂ y ₁ y ₀	2×996					8
111x ₄ x ₃ x ₂ x ₁ x ₀	Reserved(#2035)					32

$y_2y_1y_0 = 000-111$ indicates number of STAs multiplexed in the only 106-tone RU or the left 106-tone RU if there are two 106-tone RUs(#2035). The binary vector $y_2y_1y_0$ is indexed as $[y[3]y[2]y[1]]$ indicates $2^2 \times y[3] + 2^1 \times y[2] + y[1] + 1$ STAs multiplexed in the RU.

$z_2z_1z_0 = 000-111$ indicates number of STAs multiplexed in the right 106-tone RU if there are two 106-tone RUs(#2035). The binary vector $z_2z_1z_0$ is indexed as $[z[3]z[2]z[1]]$ indicates $2^2 \times z[3] + 2^1 \times z[2] + z[1] + 1$ STAs multiplexed in the RU.

Similarly, $y_1y_0 = 00-11$ indicates number of STAs multiplexed in the left 106-tone RU(#2035). The binary vector y_1y_0 is indexed as $[y[2]y[1]]$ indicates $2^1 \times y[2] + y[1] + 1$ STAs multiplexed in the RU.

Similarly, $z_1z_0 = 00-11$ indicates the number of STAs multiplexed in the right 106-tone RU(#2035). The binary vector z_1z_0 is indexed as $[z[2]z[1]]$ indicates $2^1 \times z[2] + z[1] + 1$ STAs multiplexed in the RU.

#1 to #9 (from left to the right) is ordered in increasing order of the absolute frequency.(#2035)

$x_1x_0 = 00-11$, $x_4x_3x_2x_1x_0 = 00000-11111$.(#2035)

'-' means no STA in that RU.

The number of RU Allocation subfields in the Common Block field depends on the PPDU bandwidth

- In the default mode, for a 20 MHz and a 40 MHz PPDU, each HE-SIG-B content channel contains one RU Allocation subfield followed by multiple user fields. The position of the user-field in the user-specific field together with the 8-bit RU Allocation subfield indicates the RU assignment to the user.
- In the default mode for an 80 MHz PPDU, each HE-SIG-B content channel contains two RU Allocation subfields for a total of 16 bits of RU allocation signaling, one each for the RUs in the two 20 MHz segments of the HE-SIG-B content channel. The user fields corresponding to the first RU allocation signaling field are followed by the user fields indicated by the second RU allocation signaling field in the user specific field.
- In the default mode for a 160 MHz PPDU, each HE-SIG-B content channel contains four RU Allocation subfields for a total of 32 bits of RU allocation signaling, one each for the RUs in the four 20 MHz segments of the HE-SIG-B content channel. The user fields for each of the 20 MHz segments in the content channel are arranged by the order in which their RU allocation signaling fields appear in the common field.(#2784)

26.3.10.8.5 HE-SIG-B per-user content

The user-specific field consists of multiple user fields. The user fields follow the common block field of HE-SIG-B. The RU allocation subfield in the Common block field and the position of the user field in the HE-SIG-B user specific field together identify the RU used to transmit a STA's data. Multiple RU allocations addressed to a single STA shall not be allowed in 802.11ax. Therefore, the signaling that enables STAs to decode its data is carried in only one user field.(#1010) An example for the mapping of the 8-bit RU allocation subfield and the position of the user field to an STA's data is illustrated in Illustration for the mapping of the 8-bit RU allocation subfield and the position. The RU arrangement signaling indicates

an arrangement of 106-tone RU followed by five 26-tone RUs and that the 106-tone RU contains three user-fields, i.e., the 106-tone RU supports multiplexing of three users using MU-MIMO. The eight user fields in the HE-SIG-B user-specific field thus map to the 6 RUs, with the first three user fields indicating MU-MIMO allocations in the first 106-tone RU followed by user fields corresponding to the each of the five 26-tone RUs.

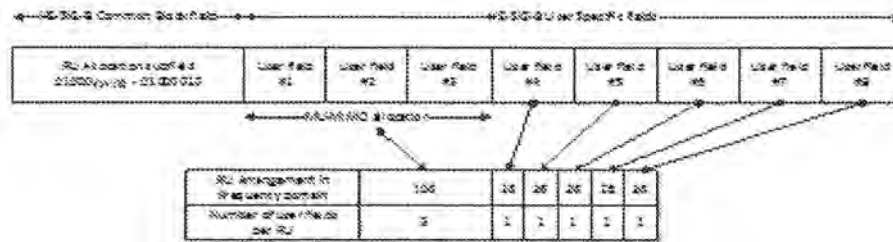


Figure 26-25—Illustration for the mapping of the 8-bit RU allocation subfield and the position of the user-field to the STA's assignment(PHY Motion #172)

The contents of the user field differ based on whether the field addresses a single-STA in an RU or a STA in an(#2817) MU-MIMO allocation in an RU. Irrespective of whether the allocation is for a STA in an(#196) SU or an MU-MIMO allocation, the size of the user field is the same.

The HE-SIG-B user field for an(#916) SU allocation contain the subfields shown in Fields of the HE-SIG-B user field for an.

Table 26-22—Fields of the HE-SIG-B user field for an(#916) non-MU-MIMO(#1101) allocation(#2037)

Bit	Field	Number of bits	Description
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B0-B10	STA-ID	11	The STA-ID refers to the AID described in 9.4.1.8 (AID field). The 11 LSBs of the AID field are used to address the STAs in this field.(#1002) For RUs that carry a broadcast allocation: — For single BSS AP, the STAID for broadcast will be 0 — For Multiple BSS AP, the STAID for broadcast to a specific BSS will follow the group addressed AID assignment in the TIM according to the existing Multi-BSSID TIM operation — For multiple BSS AP, the STAID for broadcast to all BSS of the AP is set to 2047(#2681) — STAID value 2046 is used to indicate that the RU carries no data — When a STA transmits on the uplink using the HE MU PPDU format, the STA-ID field is populated by the AID of the transmitter assigned by the AP
B11-B13	NSTS	3	Number of spatial streams. Set to the number of space time streams minus 1.(#Ed)
B14	Tx Beamforming	1	Use of transmit beamforming. Set to 1 if a beamforming steering matrix is applied to the waveform in an SU transmission. Set to 0 otherwise.
B15-B18	MCS	4	Modulation and coding scheme Set to n for MCSn, where $n = 0, 1, 2, \dots, 11$ Values 12 to 15 are reserved
B19	DCM	1	Indicates whether or not dual carrier modulation is used. Set to 1 to indicate that the payload of the HE MU PPDU is modulated with dual carrier modulation for the MCS. Set to 0 indicates that the payload of the PPDU is not modulated with dual carrier modulation for the MCS.
B20	Coding	1	Indicates whether BCC or LDPC is used. Set to 0 for BCC Set to 1 for LDPC

NOTE—Integer fields are transmitted in unsigned binary format, LSB first, where the LSB is in the lowest numbered bit position.(#1010)

The HE-SIG-B user field for an STA in MU-MIMO allocation contain the subfields shown in Fields of the HE-SIG-B user field for an.

Table 26-23—Fields of the HE-SIG-B user field for an(#2817) MU-MIMO allocation(#2037)

Bit	Field	Number of bits	Description
B0-B10	STA-ID	11	The STA-ID refers to the AID described in 9.4.1.8 (AID field). The 11 LSBs of the AID field are used to address STAs in this field.(#1003)
B11-B14	Spatial Configuration	4	Indication for the number of spatial streams for a STA in an(#2817) MU-MIMO allocation. See Spatial Configuration subfield encoding .
B15-B18	MCS	4	Modulation and coding scheme. Set to n for MCS $_n$, where $n = 0, 1, 2, \dots, 11$ Values 12 to 15 are reserved
B19	DCM	1	Indicates whether or not dual carrier modulation is used. Set to 1 to indicate that the payload of the HE MU PPDU is modulated with dual carrier modulation for the MCS. Set to 0 indicates that the payload of the PPDU is not modulated with dual carrier modulation for the MCS.
B20	Coding	1	Indicates whether BCC or LDPC is used. Set to 0 for BCC Set to 1 for LDPC
NOTE—Integer fields are transmitted in unsigned binary format, LSB first, where the LSB is in the lowest numbered bit position.(#1010)			

A user field for an MU-MIMO allocation includes a Spatial Configuration subfield consisting of 4 bits that indicates the number of spatial streams for each STA and the total number of spatial streams in the

MU-MIMO allocation. The subfield shown in Spatial Configuration subfield encoding is constructed by using the entries corresponding to the value of number of users (N_{user}) multiplexed using MU-MIMO in an RU. When MU-MIMO is used in an RU of size less than or equal to 242 subcarriers(#310), the number of users (N_{user}) in an MU-MIMO allocation is equal to the number of user fields per RU signaled for the RU in the RU allocation subfield of an HE-SIG-B Common block field. When MU-MIMO is used in RUs of size greater than 242 subcarriers(#310), the number of users (N_{user}) in an MU-MIMO allocation is computed as the sum of the number of user-fields per RU indicated for the RU by the 8-bit RU allocation subfield in each HE-SIG-B content channel. For a given value of N_{user} (#2786), the four bits of the spatial configuration subfield are used as follows: A STA with a STA-ID that matches the 11-bit ID signaled in the user field for an MU-MIMO allocation derives the number of spatial streams allocated to it using the row corresponding to the signaled 4-bit spatial configuration subfield and the column corresponding to the position of the user field in the user-specific field. The starting stream index for the STA is computed by summing the Nsts in the columns prior to the column indicated by the STA's user-field position. In the case of load balancing for RUs of size greater than 242 subcarriers(#310) where user fields corresponding to the same MU-MIMO allocations are split into two HE-SIG-B content channels, the user-field positions are logically continuous with the first user field corresponding to the same RU(#310) in the second HE-SIG-B content channel updating its position (and therefore, column index) from that of the last user field in the first HE-SIG-B content channel.

Table 26-24—Spatial Configuration subfield encoding

N_{user}	B3...B0(#2035)	Nsts [1]	Nsts [2]	Nsts [3]	Nsts [4]	Nsts [5]	Nsts [6]	Nsts [7]	Nsts [8]	Total Nsts	Number of entries
2	0000-0011	1-4	1							2-5	10
	0100-0110	2-4	2							4-6	
	0111-1000	3-4	3							6-7	
	1001	4	4							8	
3	0000-0011	1-4	1	1						3-6	13
	0100-0110	2-4	2	1						5-7	
	0111-1000	3-4	3	1						7-8	
	1001-1011	2-4	2	2						6-8	
	1100	3	3	2						8	
4	0000-0011	1-4	1	1	1					4-7	11

	0100-0110	2-4	2	1	1					6-8	
	0111	3	3	1	1					8	
	1000-1001	2-3	2	2	1					7-8	
	1010	2	2	2	2					8	
5	0000-0011	1-4	1	1	1	1				5-8	6
	0100-0101	2-3	2	1	1	1				7-8	
6	0000-0010	1-3	1	1	1	1	1			6-8	4
	0011	2	2	1	1	1	1			8	
7	0000-0001	1-2	1	1	1	1	1	1		7-8	2
8	0000	1	1	1	1	1	1	1	1	8	1

When the SIGB Compression field in the HE-SIG-A field of an HE MU PPDU is set to 1 (indicating full bandwidth MU-MIMO transmission), the number of STAs in the MU-MIMO group is indicated in the 'SIGB Number of Symbols/Number of MU-MIMO users field' in the HE-SIG-A field. For bandwidths larger than 20 MHz, the User block fields are split equitably between two HE-SIG-B content channels, i.e., for a k user MU-MIMO PPDU, $1, \dots, \lceil k/2 \rceil$ User block fields are carried in HE-SIG-B content channel 1 and $\lceil k/2 \rceil + 1, \dots, k$ User block fields in HE-SIG-B content channel 2.(#2543)

The total number of spatial streams (total N_{STS}) is computed by summing all columns for the row signaled by the spatial configuration subfield and is indicated in Spatial Configuration subfield encoding under the column Total Nsts(#311).

26.3.10.9 HE-STF

(26-22)The main purpose of the HE-STF field is to improve automatic gain control estimation in a MIMO transmission. The duration of the HE-STF field for HE PPDU's except HE trigger-based PPDU's is $T_{HE-STF-NT}$ (#312) (periodicity of 0.8 μ s with 5 periods) and the duration of the HE-STF field for an HE trigger-based PPDU is $T_{HE-STF-T}$ (#312) (periodicity of 1.6 μ s with 5 periods). The tone indices for HE-STF field for HE PPDU's except HE trigger-based PPDU's is defined in

(26-22)

$$i_{STF} \bmod 16 = 0, \lfloor N_{DC}/2 \rfloor < i_{STF} \leq N_{SR}$$

(26-23) i_{STF} : HE-STF tone index The tone indices for HE-STF fields for an HE trigger-based PPDU are defined in

(26-23)

$$i_{STF} \bmod 8 = 0, \lfloor N_{DC}/2 \rfloor < i_{STF} \leq N_{SR}$$

i_{STF} : HE-STF tone index

For the HE-STF field, the M sequence is defined by M .

$$(26-24) M = \{-1, -1, -1, 1, 1, 1, -1, 1, 1, -1, 1, 1, -1, 1\}$$

The HE-STF field is constructed from the M sequence(s) multiplied by $(1+j)/\sqrt{2}$ or $(-1-j)/\sqrt{2}$ and extra coefficients selected out of $(1+j)/\sqrt{2}$ or $(-1-j)/\sqrt{2}$ at tone indices which are null but shall have the HE-STF coefficients after mapping M sequences to each 20 MHz subchannel.(#313)

(26-25) For a 20 MHz transmission, the frequency domain sequence for HE PPDU except HE trigger-based PPDU is given by

(26-25)

$$HES_{-112:16:112} = \{M\} \cdot (1+j)/\sqrt{2}$$

$$HES_0 = 0$$

where $HES_{a:b:c}$ means coefficients of the HE-STF on every b tone indices from a to c tone indices and coefficients on other tone indices are set to zero.

(26-26) For a 40 MHz transmission, the frequency domain sequence for HE PPDU except HE trigger-based PPDU is given by

(26-26)

$$(26-27) HES_{-240:16:240} = \{M, 0, -M\} \cdot (1+j)/\sqrt{2}$$

For an 80 MHz transmission, the frequency domain sequence for HE PPDU except HE trigger-based PPDU is given by

(26-27)

(26-28) $HES_{-196:16:196} = \{M, 1, -M, 0, -M, 1, -M\} \cdot (1+j)/\sqrt{2}$ For a 160 MHz transmission, the frequency domain sequence for HE PPDUs except HE trigger-based PPDUs is given by

(#529)

(26-28)

(26-27) $HES_{-1008:16:1008} = \{M, 1, -M, 0, -M, 1, -M, 0, -M, -1, M, 0, -M, 1, -M\} \cdot (1+j)/\sqrt{2}$ For an 80+80 MHz transmission, the primary 80 MHz segment for HE PPDUs except HE trigger-based PPDUs shall use the HE-STF pattern for the 80 MHz defined in

(26-29) For an 80+80 MHz transmission, the frequency domain sequence of the secondary 80 MHz segment for HE PPDUs except HE trigger-based PPDUs is given by

(#529)

(26-29)

(26-30) $HES_{-496:16:496} = \{-M, -1, M, 0, -M, 1, -M\} \cdot (1+j)/\sqrt{2}$ For a 20 MHz transmission, the frequency domain sequence for HE trigger-based PPDUs is given by

(26-30)

(26-31) $HES_{-120:8:120} = \{M, 0, -M\} \cdot (1+j)/\sqrt{2}$ For a 40 MHz transmission, the frequency domain sequence for HE trigger-based PPDUs is given by

(26-31)

$$HES_{-248:8:248} = \{M, -1, -M, 0, M, -1, M\} \cdot (1+j)/\sqrt{2}$$

(26-32) $HES_{-248} = 0$ For an 80 MHz transmission, the frequency domain sequence for HE trigger-based PPDUs is given by

(26-32)

$$HES_{-504:8:504} = \{M, -1, M, -1, -M, -1, M, 0, -M, 1, M, 1, -M, 1, -M\} \cdot (1+j)/\sqrt{2}$$

(26-33) $HES_{-504} = 0$

For a 160

MHz transmission, the frequency domain sequence for HE trigger-based PPDU is given by

. (#530)

(26-33)

$$HES_{-1016:8:1016} = \{M, -1, M, -1, -M, -1, M, 0, -M, 1, M, 1, -M, 1, -M, 0, -M, 1, -M, 1, M, 1, -M, 0, -M, 1, M, 1, -M, 1, -M\} \cdot (1+j)/\sqrt{2}$$

(26-32) $HES_{-8} = 0, HES_{-1016} = 0$

For an

80+80 MHz transmission, the primary 80 MHz segment for HE trigger-based PPDU shall use the HE-STF pattern for the 80 MHz defined in

. (#530)

(26-34) For an 80+80 MHz transmission, the frequency domain sequence of the secondary 80 MHz segment for HE trigger-based PPDU is given by

. (#530)

(26-34)

$$HES_{-504:8:504} = \{-M, 1, -M, 1, M, 1, -M, 0, -M, 1, M, 1, -M, 1, -M\} \cdot (1+j)/\sqrt{2}$$

(26-25) $HES_{-504} = 0$

For an

OFDMA transmission, the coefficients in

(26-32) to

are set to zero if those values are corresponding to tone indices for which no RUs are defined (see Math)(#917).

(26-35) The time domain representation of the signal for HE PPDU except HE trigger-based PPDU on frequency segment i_{seg} of transmit chain i_{TX} shall be as specified in

(26-35)

$$r_{\text{HE-STF}}^{(i_{\text{seg}} i_{\text{TX}})}(t) = w_{T_{\text{HE-STF-NT}}}(t) \cdot \sum_{r=0}^{N_{\text{RU}}-1} \frac{\alpha_r \beta_r}{\sqrt{N_{\text{STS}, r, \text{total}}}} \sum_{k \in K} \sum_{u=0}^{N_{\text{STS}, r, u}-1} \sum_{m=1}^{N_{\text{STS}, r, u}} \left(\eta_{\text{HE-STF}, k} \left[Q_k^{(i_{\text{seg}})} \right]_{i_{\text{TX}}, M_{r,u}+m} HES_k \cdot \exp(j2\pi k \Delta_{F, \text{HE}}(t - T_{\text{CS}, \text{HE}}(M_{r,u} + m))) \right) \quad \text{where}$$

α_r is the power boost factor for the r -th RU. A STA shall support α_r in the range $[0.7, \sqrt{2}]$. A STA may support α_r in the range $[0.5, 2]$. (#1689)

$\eta_{\text{HE-STF}, k}$ is an HE PPDU format dependent scaling factor, defined by

$$\eta_{\text{HE-STF}, k} = \begin{cases} \sqrt{2}, & \text{for an HE extended range SU PPDU} \\ 1, & \text{otherwise} \end{cases} \quad (\#2045)(\#526)$$

β_r is the per-RU power normalization factor and defined by

$$\beta_r = \left(\sqrt{\frac{|K_r|}{|K_r^{\text{HE-STF}}|}} \right) / \left(\sqrt{\sum_{r=1}^{N_{\text{RU}}} \alpha_r^2 |K_r|} \right) \quad (\#315)$$

$|K_r|$ is the cardinality of the set of subcarriers K_r

$K_r^{\text{HE-STF}}$ is the set of subcarriers that have non-zero values within K_r in the HE-STF field (#2046)

$T_{\text{CS}, \text{HE}}(M_{r,u} + m)$ represents the cyclic shift for space time stream $M_{r,u} + m$ as defined in Cyclic shift for HE modulated fields (#1052)

$Q_k^{(i_{\text{seg}})}$ is defined in **Erreur ! Source du renvoi introuvable.** (#1094)

$w_{T_{\text{HE-STF-NT}}}$ is the windowing function for HE-STF field in the non-HE trigger-based PPDU

The time domain representation of the signal for HE trigger-based PPDU's on frequency segment i_{seg} of transmit chain i_{TX} shall be as specified in

$$r_{\text{HE-STF}}^{(i_{\text{seg}} i_{\text{TX}})}(t) = \frac{1}{\sqrt{|K_r^{\text{HE-STF}}|} N_{\text{STS}, r, \text{total}}} w_{T_{\text{HE-STF-T}}}(t) \sum_{k \in K} \sum_{m=1}^{N_{\text{STS}, r, u}} \left(\left[Q_k^{(i_{\text{seg}})} \right]_{i_{\text{TX}}, (M_{r,u} + m)} HES_k \cdot \exp(j2\pi k \Delta_{F, \text{HE}}(t - T_{\text{CS}, \text{HE}}(M_{r,u} + m))) \right) \quad (\#3.$$

$$r_{\text{HE-STF}}^{(i_{\text{seg}} i_{\text{TX}})}(t) = \frac{1}{\sqrt{|K_r^{\text{HE-STF}}|} N_{\text{STS}, r, \text{total}}} w_{T_{\text{HE-STF-T}}}(t) \sum_{k \in K} \sum_{m=1}^{N_{\text{STS}, r, u}} \left(\left[Q_k^{(i_{\text{seg}})} \right]_{i_{\text{TX}}, (M_{r,u} + m)} HES_k \cdot \exp(j2\pi k \Delta_{F, \text{HE}}(t - T_{\text{CS}, \text{HE}}(M_{r,u} + m))) \right) \quad (26-36) \quad (\#316)$$

where

$w_{T_{\text{HE-STF-T}}}$ is the windowing function for HE-STF field in the HE trigger-based PPDU

26.3.10.10 HE-LTF

The HE-LTF field(#918) provides a means for the receiver to estimate the MIMO channel between the set of constellation mapper outputs (or, if STBC is applied, the STBC encoder outputs) and the receive chains. In an HE SU PPDU, HE extended range SU PPDU and HE MU PPDU, the transmitter provides training for $N_{STS,r,total}$ space-time streams (spatial mapper inputs) used for the transmission of the PSDU(s) in the r -th RU. In an HE trigger-based PPDU, the transmitter of user u in the r -th RU provides training for $N_{STS,r,u}$ space-time streams used for the transmission of the PSDU. For each tone in the r -th RU, the MIMO channel that can be estimated is an $N_{RX} \times N_{STS,r,total}$ matrix. A HE transmission has a preamble that contains HE-LTF symbols, where the data tones of each HE-LTF symbol are multiplied by entries belonging to a matrix P_{HE-LTF} , to enable channel estimation at the receiver. The pilot tones of each HE-LTF symbol are multiplied by the entries of a matrix R_{HE-LTF} defined in the following text. The multiplication of the pilot tones in the HE-LTF symbol by the R_{HE-LTF} matrix instead of the P_{HE-LTF} matrix allows receivers to track phase and frequency offset during MIMO channel estimation using the HE-LTF. In an HE SU PPDU, HE extended range SU PPDU and HE MU PPDU with a single RU (the RU having an MU-MIMO allocation or an SU allocation)(PHY Motion #159), the number of HE-LTF symbols, N_{HE-LTF} , is a function of the total number of space-time streams N_{STS} as shown in Frequently used parameters(#2792). In an HE trigger-based PPDU, N_{HE-LTF} (#922) is indicated in the Trigger frame that triggers the transmission of the PPDU. In an HE MU PPDU, N_{HE-LTF} (#922) is indicated in the HE-SIG-A field. In an HE MU PPDU with more than one RU and an HE trigger-based PPDU, N_{HE-LTF} (#922) may take any value among one, two, four, six or eight, which is greater than or equal to the maximum value of the function in Frequently used parameters when it is calculated for each $N_{STS,r,total}$ separately.(PHY Motion #159)

An HE PPDU supports 3 HE-LTF modes, which are 1x HE-LTF, 2x HE-LTF and 4x HE-LTF. It is optional to support the 1x HE-LTF mode in an HE SU PPDU, HE extended range SU PPDU and HE MU PPDU. It is mandatory to support transmission of 1x HE-LTF in an UL MU-MIMO PPDU over the full bandwidth, for a STA declaring support for UL MU-MIMO. The 1x HE-LTF mode is disallowed in an HE MU PPDU and in an HE trigger-based PPDU with more than one RUs, and is also disallowed in an HE MU PPDU with one RU whenever the RU has an MU-MIMO allocation.(PHY Motion #159) In an HE SU PPDU, HE MU PPDU and HE extended range SU PPDU, the combination of HE-LTF modes and GI duration is indicated in HE-SIG-A field. In an HE trigger-based PPDU, the combination of HE-LTF modes and GI duration is indicated in the Trigger frame that triggers the transmission of the PPDU. The mandatory combinations of HE-LTF modes and GI duration are:

- 2x HE-LTF, $T_{GI1,Data}$ (#2498)
- 2x HE-LTF, $T_{GI2,Data}$ (#2496)
- 4x HE-LTF, $T_{GI4,Data}$ (#2497)

The optional combinations of HE-LTF mode and GI duration are:

- 1x HE-LTF, $T_{GI1,Data}$ (#2499) in an(#2829) HE SU PPDU or HE extended SU PPDU
- 1x HE-LTF, $T_{GI1,Data}$ (#2500) in a non-OFDMA, MU-MIMO HE MU PPDU
- 1x HE-LTF, $T_{GI2,Data}$ (#2501) in a non-OFDMA, MU-MIMO HE trigger-based PPDU

(26-37)The duration of each HE-LTF symbol is T_{HE-LTF} (#2875) is defined in

. In an HE SU PPDU, HE MU PPDU or HE extended range SU PPDU, the HE-LTF symbol duration is indicated in HE-SIG-A field. In an HE trigger-based PPDU, the HE-LTF symbol duration is indicated in the Trigger frame that triggers the transmission of the PPDU.

In a 20 MHz transmission, the 1x HE-LTF sequence transmitted and located on subcarriers $[-122:122](\#2553)$ is given by .

In a 20 MHz transmission, the 2x HE-LTF sequence transmitted and located on subcarriers $[-122:122](\#2553)$ is given by ,

In a 20 MHz transmission, the 4x HE-LTF sequence transmitted and located on subcarriers $[-122:122](\#2553)$ is given by ,

(26-40)

In a 40 MHz transmission, the 1x HE-LTF sequence transmitted and located on subcarriers $[-244:244](\#2553)$ is given by ,

(26-41)

In a 40 MHz transmission, the 2x HE-LTF sequence transmitted and located on subcarriers $[-244:244](\#2553)$ is given by :

HELTF_{244,244} =
 {+1, 0, -1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, -1,
 0, -1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1,
 0, -1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0,
 +1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0,
 +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0,
 +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1,
 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1,
 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1,
 +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, -1, 0, +1, 0, 0, 0, 0, 0, 0, -1,
 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1,
 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1,
 +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0,
 0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, -1,
 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0,
 -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0,
 +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, -1, 0, +1, 0, -1, 0, +1, 0, -1, 0, +1}

In a 40 MHz transmission, the 4x HE-LTF sequence transmitted and located on subcarriers $[-244:244](\#2553)$ is given by .

[illegible]

In an 80 MHz transmission, the 1x HE-LTF sequence transmitted and located on subcarriers $[-500:500](\#2553)$ is given by .

$$\begin{aligned}
 \text{HELTF}_{-500:500} = & \{-1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, \\
 & 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, \\
 & 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, \\
 & +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, \\
 & 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, \\
 & 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, + \\
 & 1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, \\
 & 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, \\
 & 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1 \\
 & 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, \\
 & +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, \\
 & 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, \\
 & 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, \\
 & -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, \\
 & 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, \\
 & 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, - \\
 & 1, 0, 0, 0, -1, 0, 0, 0, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, \\
 & +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, \\
 & 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, \\
 & 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, \\
 & +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, \\
 & 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0 \\
 & 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, + \\
 & 1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, \\
 & 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, \\
 & 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, \\
 & +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, \\
 & 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, \\
 & 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, \\
 & -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, \\
 & 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0 \\
 & 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1\}
 \end{aligned}
 \tag{26-44}$$

In an 80 MHz transmission, the 2x HE-LTF sequence transmitted and located on subcarriers $[-500:500](\#2553)$ is given by .

[illegible]

In an 80 MHz transmission, the 4x HE-LTF sequence transmitted and located on subcarriers $[-500:500](\#2553)$ is given by ,

$$HELTF_{-500,500} =$$
[illegible]

(26-46)

In a 160 MHz transmission, the 1x HE-LTF sequence is given by

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1

$$LTF_{80\text{MHz_primary_2x}} = \{LTF_{80\text{MHz_part1_2x}}, LTF_{80\text{MHz_part2_2x}}, LTF_{80\text{MHz_part3_2x}}, LTF_{80\text{MHz_part4_2x}}, LTF_{80\text{MHz_part5_2x}}\} \quad (26-49)$$

$$LTF_{80\text{MHz_secondary_}2x} = \{LTF_{80\text{MHz_part1_}2x}, LTF_{80\text{MHz_part2_}2x}, LTF_{80\text{MHz_part3_}2x}, LTF_{80\text{MHz_part4_}2x}, LTF_{80\text{MHz_part5_}2x}\} \quad (26-50)$$

[illegible]

[illegible]

$$LTF_{80MHz_part3_2x} = \{+1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, 0, 0, 0, 0, 0, +1, 0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1\}$$

[illegible]

[illegible]

1

1

1

1

1

1

1

1

1

1

1

1

Equation (22-46). $N_{nz\text{-}HE\text{-}LTF}$ is the number of nonzero elements in the common HE-LTF. $[P_{8 \times 8}]_{u, 1:M}$ is the first M elements of the u -th row of the $P_{8 \times 8}$. If $N_{nz\text{-}HE\text{-}LTF}$ is not a multiple of 8, the remaining M nonzero elements of the common HE-LTF sequence are masked by the first M elements of the orthogonal code.(#1059)

(26-56)The generation of the time domain HE-LTF symbols per frequency segment in an HE SU PPDU, HE MU PPDU, HE extended range SU PPDU, HE trigger-based PPDU (#1059)is shown in Generation of HE-LTF symbols per frequency segment in an HE SU PPDU, HE where $A_{HE\text{-}LTF}^k$ is given by

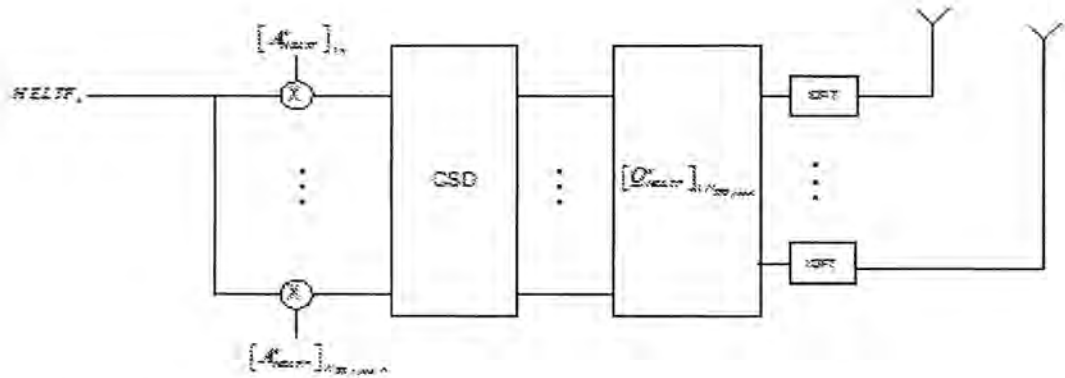


Figure 26-26—Generation of HE-LTF symbols per frequency segment in an HE SU PPDU, HE MU PPDU, HE extended range SU PPDU and HE trigger-based PPDU(#1059)

(26-56) $A_{HE\text{-}LTF}^k$ is given by

(26-56)

$$A_{HE\text{-}LTF}^k = \begin{cases} R_{HE\text{-}LTF} & \text{if } k \in K_{\text{Pilot}} \text{ and single stream pilots are used} \\ P_{HE\text{-}LTF} & \text{otherwise} \end{cases} \quad \text{where}$$

K_{Pilot} is the set of subcarrier indices for the pilot tones as defined in Pilot tones(#2794),

(26-57) $R_{HE\text{-}LTF}$ is a $N_{HE\text{-}LTF} \times N_{HE\text{-}LTF}$ matrix whose elements are defined in (#2877).

(26-57)

$$(26-58) \left[R_{\text{HE-LTF}} \right]_{m,n} = \left[P_{\text{HE-LTF}} \right]_{1,n}, 1 \leq m, n \leq N_{\text{HE-LTF}}, P_{\text{HE-LTF}} \text{ is defined in}$$

(26-58)

$$P_{\text{HE-LTF}} = \begin{cases} P_{4 \times 4}, N_{\text{HE-LTF}} \leq 4 \\ P_{6 \times 6}, N_{\text{HE-LTF}} = 6 \\ P_{8 \times 8}, N_{\text{HE-LTF}} = 8 \end{cases} \text{ where } P_{4 \times 4} \text{ is defined in Equation (19-27), } P_{6 \times 6} \text{ is defined in Equation (21-45), and } P_{8 \times 8} \text{ is defined in Equation (22-46) (#2878).}$$

When the 1x HE-LTF is used for non-OFDMA UL MU-MIMO, single stream pilot are not used. (#1059)

(26-59) In an HE SU PPDU, HE MU PPDU, HE extended range SU PPDU and HE trigger-based PPDU (#1059), the time domain representation of the waveform transmitted on frequency segment i_{scg} of transmit chain i_{TX} shall be as described by

(#2798),

(26-59)

$$\begin{aligned} (i_{\text{scg}} i_{\text{TX}})_{\text{HE-LTF}}(t) &= \frac{\eta_{\text{HE-LTF Mode}}}{\sqrt{\sum_{r=0}^{N_{RU}-1} \alpha_r^2 |K_r|}} \sum_{n=0}^{N_{\text{HE-LTF}}-1} w_{\text{HE-LTF}}(t-nT_{\text{HE-LTF}}) \sum_{r=0}^{N_{RU}-1} \frac{\alpha_r}{\sqrt{N_{\text{STS}, r, \text{total}}}} \eta_{\text{HE-LTF}, k} \\ &\quad \sum_{k \in K_r} \sum_{u=0}^{N_{\text{user}, r}-1} \sum_{m=1}^{N_{\text{STS}, r, u}} \left(\left[Q_k^{i_{\text{scg}}} \right]_{i_{\text{TX}}, (M_{r,u}+m)} \left[A_{\text{HE-LTF}}^k \right]_{(M_{r,u}+m), (n+1)} \text{HELTf}_k^n \right. \\ &\quad \left. \cdot \exp(j2\pi k \Delta_{F, \text{HE}}(t-nT_{\text{HE-LTF}}-T_{GI}-T_{CS, \text{HE}}(M_{r,u}+m))) \right) \end{aligned} \quad (\#1050) \text{ where}$$

$\text{HELTf}_k^n = \text{HELTf}_k$ if single stream pilots are used or when the 1x HE-LTF is used for non-OFDMA UL MU-MIMO, and $\text{HELTf}_k^n = \text{HELTf}_k'$ if single stream pilots are not used. (#1059)

26.3.11 Data field

26.3.11.1 General

The number of OFDM symbols in the Data field is determined by the Length field in L-SIG (see Length = $\left\lceil \frac{\text{TXTIME}-20}{4} \right\rceil \times 3 - 3 - m$ (#1625)), the preamble duration and the settings of the GI+LTF Size (#1420), Pre-FEC Padding Factor (#2564) and PE Disambiguity fields (#2560) in the HE-SIG-A field

(see HE-SIG-A). Data symbols in an HE PPDU shall use a DFT period of 12.8 μ s and subcarrier spacing of 78.125 kHz. Data symbols in an HE PPDU shall support guard interval durations of 0.8 μ s, 1.6 μ s and 3.2 μ s. HE PPDU shall have single stream pilots in the Data field. In UL MU-MIMO transmissions, all streams use the same pilot sequence.(#2561)

When BCC encoding is used, the Data field shall consist of the SERVICE field, the PSDU, the tail bits, the post-FEC padding bits and the packet extension (bits for SU and bits for each user u in MU). When LDPC encoding is used, the Data field shall consist of the SERVICE field, the PSDU, the post-FEC padding bits and the packet extension. No tail bits are present when LDPC encoding is used.

The Data field of the HE PPDU contains data for one or more users.

26.3.11.2 Pre-FEC encoding process

A two-step padding process is applied on all HE PPDU. A pre-FEC padding with both MAC and PHY padding is applied before conducting FEC coding, and a post-FEC PHY padding is applied on the FEC encoded bits.

The pre-FEC padding may pad toward 4 possible boundaries in the last one (in the case of non STBC), or two (in the case of STBC) OFDM symbols of an(#2829) HE PPDU, the 4 possible boundaries partition(#1837) the FEC output bit stream of the last OFDM symbol(s) into 4 symbol segments. The 4 possible boundaries are represented by a pre-FEC padding factor parameter(#326)(#2564).

HE PPDU padding process in the last OFDM symbol (non STBC) when illustrates these 4 possible symbol segments in the last OFDM symbol of a non STBC case, and the general padding process assuming the desired pre-FEC padding boundary, pre-FEC padding factor, is 1. In the case of STBC, the FEC output bits and post-FEC padding bits as shown in HE PPDU padding process in the last OFDM symbol (STBC) when , are modulated into the last two OFDM symbols by STBC encoding, each with the same number of effective symbol segments, the pre-FEC padding factor(#2564) being 1.



Figure 26-27—HE PPDU padding process in the last OFDM symbol (non STBC) when $a = 1$

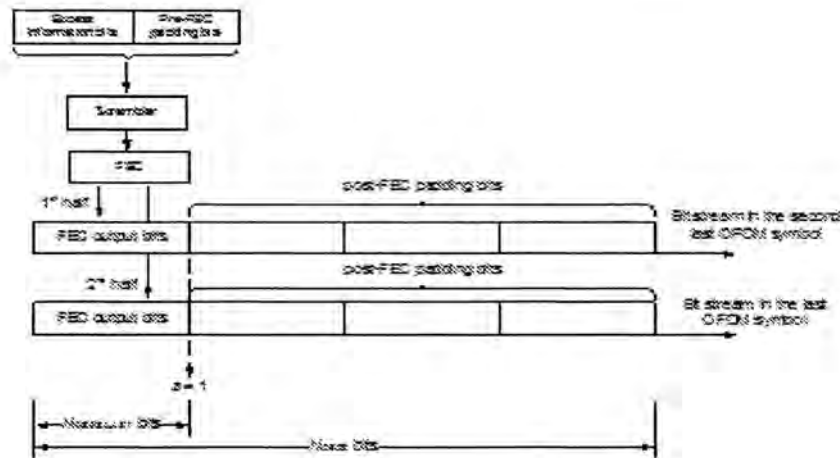


Figure 26-28—HE PPDU padding process in the last OFDM symbol (STBC) when $a = 1$

The pre-FEC padding process is described in this subclause, and the encoding and post-FEC padding process are described in Coding(#1113). While this subclause describes the pre-FEC padding processing of an SU transmission, its extension to MU transmission is described in 25.3.10.3.4 (Encoding Process for HE MU PPDUs).

(26-60) In an HE SU PPDU transmission, the transmitter first computes the number of excess bits in the last OFDM symbol(s). Specifically, for HE SU PPDU, the number of excess bits is calculated based on

(26-60)

$$N_{\text{Excess}} = \text{mod}(8 \cdot \text{APEP_LENGTH} \cdot N_{\text{Tail}} + N_{\text{service}}, m_{\text{STBC}} \cdot N_{\text{DBPS}}) \text{ where}$$

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

APEP_LENGTH is the TXVECTOR parameter APEP_LENGTH

(#2521) Based(#2060) on N_{Excess} , compute the initial number of symbol segments in the last OFDM symbol(s), pre-FEC padding factor(#1626)(#2564) value or a_{init} , as shown in

$$a_{\text{init}} = \begin{cases} 4, & \text{if } N_{\text{Excess}} = 0 \\ \min\left(\left\lceil \frac{N_{\text{Excess}}}{m_{\text{STBC}} \cdot N_{\text{DBPS, SHORT}}} \right\rceil, 4\right), & \text{otherwise} \end{cases} \quad (\text{PH.})$$

$$a_{init} = \begin{cases} 4, & \text{if } N_{Excess} = 0 \\ \min\left(\left\lceil \frac{N_{Excess}}{m_{STBC} \cdot N_{DBPS, SHORT}} \right\rceil, 4\right), & \text{otherwise} \end{cases} \quad (26-61) \quad (\text{PHY Motion \#174})$$

where

$$N_{DBPS, SHORT} = N_{CBPS, SHORT} \cdot R, \text{ in which } R \text{ is the coding rate, and}$$

$$N_{CBPS, SHORT} = N_{SD, SHORT} \cdot N_{SS} \cdot N_{BPS, CS};$$

The parameter $N_{SD, SHORT}$ values for different RU sizes are as shown in N .

Table 26-25— $N_{SD, SHORT}$ values(#1857)

RU Size	$N_{SD, SHORT}$	
	DCM = 0	DCM = 1
26-tone	6	2
52-tone	12	6
106-tone	24	12
242-tone	60	30
484-tone	120	60
996-tone	240	120
2×996-tone	492	246

(26-62) Given the a_{init} values, the initial number of data bits per symbol and the initial number of coded bits per symbol in the last OFDM symbol(s) are defined in

(26-62)

$$N_{DBPS, LAST_init} = \begin{cases} a_{init} N_{DBPS, SHORT}, & \text{if } a_{init} < 4 \\ N_{DBPS}, & \text{if } a_{init} = 4 \end{cases}$$

$$N_{CBPS, LAST_init} = \begin{cases} a_{init} N_{CBPS, SHORT}, & \text{if } a_{init} < 4 \\ N_{CBPS}, & \text{if } a_{init} = 4 \end{cases}$$

(26-63) For an (#2829) HE SU PPDU with BCC encoding, the number of pre-FEC pad bits is calculated using

(26-63)

$$(26-71) \quad N_{PAD, Pre-FEC} = (N_{SYM, init} - m_{STBC}) N_{DBPS} + m_{STBC} N_{DBPS, LAST_init} - 8 \cdot APEP_LENGTH - N_{Tail} - N_{service} \quad \text{where}$$

$$N_{SYM, init} = m_{STBC} \cdot \left\lceil \frac{8 \cdot APEP_LENGTH + N_{Tail} + N_{service}}{m_{STBC} N_{DBPS}} \right\rceil \quad (\#2 \text{ for BCC})$$

$N_{SYM, init}$ is defined as in encoding, and

(#2802) for LDPC encoding.

(26-64) For an (#2829) HE SU PPDU with LDPC encoding, the number of pre-FEC pad bits is calculated using

(26-64)

$$(26-65) \quad N_{PAD, Pre-FEC} = (N_{SYM, init} - m_{STBC}) N_{DBPS} + m_{STBC} N_{DBPS, LAST_init} - 8 \cdot APEP_LENGTH - N_{service} \quad \text{Among the}$$

pre-FEC padding bits, the MAC delivers a PSDU that fills the available octets in the Data field of the HE PPDU, toward the desired pre-FEC padding boundary, represented by a a_{init} value, in the last OFDM symbol(s). The PHY then determines the number of pad bits to add and appends them to the PSDU. The number of pre-FEC pad bits added by PHY will always be 0 to 7. The procedure is defined in

(26-65)

$$N_{PAD, Pre-FEC, MAC} = \left\lceil \frac{N_{PAD, Pre-FEC}}{8} \right\rceil \cdot 8$$

26.3.11.3 $N_{PAD, Pre-FEC, PHY} = N_{PAD, Pre-FEC} \bmod 8$ **SERVICE field**

The SERVICE field of HE PPDU is as shown in SERVICE field.

Table 26-26—SERVICE field

Bits	Field	Description
B0-B6	Scrambler Initialization	Set to 0
B7-B15	Reserved	Set to 0

26.3.11.4 Scrambler

The SERVICE field, PSDU, and PHY padding of the Data field shall be scrambled by the scrambler defined in 17.3.5.5 (PHY DATA scrambler and descrambler). The Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) TXVECTOR parameters CH_BANDWIDTH_IN_NON_HT and DYN_BANDWIDTH_IN_NON_HT are not present and therefore the initial state of the scrambler is set to a nonzero pseudorandom seed. A different nonzero pseudorandom seed may be used for each user in a HE MU PPDU (#2442).

26.3.11.5 Coding

The Data field shall be encoded using either the binary convolutional code (BCC) defined in Binary convolutional coding and puncturing or the low density parity check (LDPC) code defined in LDPC coding (#2803). The encoder is selected by the Coding field in HE-SIG-A in an HE SU PPDU or an HE extended range SU PPDU, or HE-SIG-B per-user subfield(s) in an (#2829) HE MU PPDU, as defined in HE-SIG-A and HE-SIG-B respectively.

When conducting BCC FEC encoding for an HE PPDU, the number of encoders is always 1.

LDPC is the only FEC coding scheme in the HE PPDU Data field for a 484-, 996-, and 2×996-tone RU (#838). LDPC is the only FEC coding scheme in the HE PPDU Data field for MCS10 and MCS11 in a 242- 484-, 996- and 2×996-tone RU.(PHY Motion #158) Support of BCC code is limited to less than or equal to four spatial streams and MCS0 to MCS9 (per user in case of MU-MIMO), and is mandatory (for both transmit and receive) for RU sizes less than or equal to a 242-tone RU (#838). Support of LDPC code (for both transmit and receive) is mandatory for HE STAs declaring support for at least one of HE 40/80/160/80+80 SU PPDU bandwidths, for HE STAs declaring support for more than 4 spatial streams, or for HE STAs declaring support for MCS10 and MCS11.(PHY Motion #158), according to HE capabilities field as defined in 9.4.2.218 (HE Capabilities element). Otherwise, support of LDPC code for either transmit or receive is optional.

26.3.11.5.1 Binary convolutional coding and puncturing

The information bits and pre-FEC padding bits of user u are encoded by a rate $R = \frac{1}{2}$ convolutional encoder defined in 17.3.5.6 (Convolutional encoder). After encoding, the encoded data is punctured by the method defined in 17.3.5.6 (Convolutional encoder) (#2804) (except for rate 5/6), to achieve the rate selected by the

modulation and coding scheme. In the case that rate 5/6 coding is selected, the puncturing scheme will be the same as described in 21.3.10.5.3 (Binary convolutional coding and puncturing)(#2805).

The initial number of OFDM symbols in the Data field with BCC encoding in an(#2829) HE SU PPDU is

calculated using

$$N_{SYM,init} = m_{STBC} \cdot \left\lceil \frac{8 \cdot APEP_LENGTH + N_{Tail} + N_{service}}{m_{STBC} N_{DBPS}} \right\rceil \quad (\#2829)$$

$$(26-66) \quad N_{SYM,init} = m_{STBC} \cdot \left\lceil \frac{8 \cdot APEP_LENGTH + N_{Tail} + N_{service}}{m_{STBC} N_{DBPS}} \right\rceil \quad (\#282)$$

For an(#2829) HE SU PPDU with BCC encoding,

$$(26-67) \quad N_{SYM} = N_{SYM,init}$$

and

$$(26-68) \quad \mu = \mu_{init}$$

The number of data bits per symbol in the last OFDM symbol(s) of an HE SU PPDU is $N_{DBPS, LAST} = N_{DBPS, LAST, init}$. (#328)

(26-69) The number of coded bits per symbol in the last OFDM symbol(s) of an(#2829) HE SU PPDU is given by

$$(26-69)$$

$$N_{CBPS, LAST} = \begin{cases} a \cdot N_{CBPS, SHORT} & \text{if } a < 4 \\ N_{CBPS} & \text{if } a = 4 \end{cases}$$

26.3.11.5.2

LDPC coding

(26-70) For an(#2829) HE SU PPDU using LDPC coding to encode the Data field, the LDPC code and encoding process described in 19.3.11.7 (LDPC codes)(#2806) shall be used with the following modifications. First, all bits in the Data field including the scrambled SERVICE, PSDU, and pre-FEC pad bits are encoded, i.e., $N_{pld} = N_{service} + 8 \times APEP_LENGTH + N_{PAD, Pre-FEC}$ (#2067). Thus, N_{pld} for HE PPDU's shall be computed using

instead of Equation (20-35).

$$(26-70)$$

$$N_{pld} = (N_{SYM,init} - m_{STBC}) N_{DBPS} + m_{STBC} N_{DBPS, LAST, init} \text{ where}$$

(26-71)

(26-72)
$$N_{SYM,init} = m_{STBC} \cdot \left\lceil \frac{8 \cdot APEP_LENGTH + N_{service}}{m_{STBC} \cdot N_{DBPS}} \right\rceil$$
 Following the calculation of N_{pbb} , N_{avbus} shall be computed using

instead of Equation (20-36).

(26-72)

$N_{avbus} = (N_{SYM,init} - m_{STBC}) \cdot N_{CBPS} + m_{STBC} \cdot N_{CBPS, LAST, init}$ In addition, in step d) of LDPC encoding process as described in 19.3.11.7.5 (LDPC PPDU encoding process)(#1405)(#2807), if the following condition is met:

$(N_{punc} > 0.1 \times N_{CW} \times L_{LDPC} \times (1 - R))$ AND $(N_{short} < 1.2 \times N_{punc} \times \frac{R}{1 - R})$ is true OR if $N_{punc} > 0.3 \times N_{CW} \times L_{LDPC} \times (1 - R)$ is true,

(26-73) then the LDPC Extra OFDM Symbol field of HE-SIG-A shall be set to 1, and increment N_{avbus} by the following

instead of Equations (19-39), followed by recomputing N_{punc} as in Equation (19-40)(#2808):

(26-73)

(26-74)
$$N_{avbus} = \begin{cases} N_{avbus} + m_{STBC} \cdot (N_{CBPS} - 3N_{CBPS, SHORT}), & \text{if } a_{init} = 3 \\ N_{avbus} + m_{STBC} \cdot N_{CBPS, SHORT}, & \text{otherwise} \end{cases}$$
 and then update a and N_{SYM} values by the following

-

(26-74)

$$\begin{cases} N_{SYM} = N_{SYM,init} + m_{STBC} \text{ and } a = 1, & \text{if } a_{init} = 4 \\ N_{SYM} = N_{SYM,init} \text{ and } a = a_{init} + 1, & \text{otherwise} \end{cases}$$
 If in step d) of LDPC encoding process as described in 19.3.11.7.5 (LDPC PPDU encoding process)(#1405)(#2809), the above mentioned condition is not met, then the LDPC Extra OFDM Symbol field of HE-SIG-A shall be set to 0, and

(26-75)
$$N_{SYM} = N_{SYM,init}$$

$$a = a_{init} \quad (\#2068)$$

With the final pre-FEC padding factor(#2564) value a , update the N_{CBPS} of the last symbol as:

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$$(26-76) \quad N_{CBPS, LAST} = \begin{cases} a \cdot N_{CBPS, SHORT} & \text{if } a < 4 \\ N_{CBPS} & \text{if } a = 4 \end{cases}$$

For completeness, the number of data bits of the last symbol $N_{DBPS, LAST} = N_{DBPS, LAST, init}$. (#329)

LDPC codes used in HE MU PPDU shall also follow the definitions in 19.3.11.7 (LDPC codes) (#2810). Refer to Encoding process for an HE MU PPDU (#2069) for a description of the LDPC encoding process for HE MU PPDU.

26.3.11.5.3 Post-FEC padding

The number of post-FEC padding bits in each of the last m_{STBC} symbol(s) is computed by:

$$(26-77) \quad N_{PAD, POST-FEC} = N_{CBPS} - N_{CBPS, LAST}$$

The last m_{STBC} symbols shall consist of $N_{CBPS, LAST}$ bits from the FEC output followed by $N_{PAD, POST-FEC}$ post-FEC padding bits. The values of the post-FEC padding bits are not specified and are left up to implementation. (#2070)

26.3.11.5.4 Encoding process for an HE MU PPDU

For an HE MU PPDU, all the users shall use a common pre-FEC padding factor (#2564) value and a common N_{SYM} value. The padding process is described as follows.

(26-71) First compute initial pre-FEC padding factor (#2564) value ($a_{init, u}$) for each user u using

$$a_{init} = \begin{cases} 4, & \text{if } N_{EXCESS} = 0 \\ \min\left(\left\lceil \frac{N_{EXCESS}}{m_{STBC} \cdot N_{DBPS, SHORT}} \right\rceil, 4\right), & \text{otherwise} \end{cases}$$

(PH, and the initial number of OFDM symbols

$$N_{SYM, init} = m_{STBC} \cdot \left\lceil \frac{8 \cdot APEP_LENGTH + N_{Tail} + N_{service}}{m_{STBC} N_{DBPS}} \right\rceil \quad (\#2 \text{ if } (N_{init, init}) (\#2071) \text{ for each user } u \text{ using user } u \text{ is BCC encoded, or}$$

(26-78) if user u is LDPC encoded. Among all the users, derive the user index with the longest encoded packet duration, as in

$$(26-78)$$

$u_{max} = \arg \max_{u=0}^{N_u-1} (N_{SYM, init, u} - m_{STBC} + 0.25 m_{STBC} a_{init, u})$ where m_{STBC} is the common STBC setting among all the users, as described in 26.3.10.8.

(26-79) Then the common a_{init} and N_{SYM} values among all the users are derived by

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;

(26-79)

$$N_{SYM,init} = N_{SYM,init,u_{max}}$$

$$a_{init} = a_{init,u_{max}}$$

Update each user's initial number of coded bits in its last symbol as below:

(26-80)

$$N_{DBPS,LAST,init,u} = \begin{cases} a_{init} N_{DBPS,SHORT,u} & \text{if } a_{init} < 4 \\ N_{DBPS,u} & \text{if } a_{init} = 4 \end{cases}$$

$$N_{CBPS,LAST,init,u} = \begin{cases} a_{init} N_{CBPS,SHORT,u} & \text{if } a_{init} < 4 \\ N_{CBPS,u} & \text{if } a_{init} = 4 \end{cases}$$

(26-81) For each user with LDPC encoding, the number of pre-FEC padding bits is computed as in

;

(26-81)

$$N_{PAD,pre-FEC,u} = (N_{SYM,init} - m_{STBC}) N_{DBPS,u} + m_{STBC} N_{DBPS,LAST,init,u} - 8 \cdot APEP_LENGTH_u - N_{service}$$

(26-82) For each user with LDPC encoding, the parameters $N_{pld,u}$ and $N_{avbus,u}$ are computed using

(26-83) and

respectively:

(26-82)

$$(26-83) N_{pld,u} = (N_{SYM,init} - m_{STBC}) N_{DBPS,u} + m_{STBC} N_{DBPS,LAST,init,u}$$

$N_{avbus,u} = (N_{SYM,init} - m_{STBC}) N_{CBPS,u} + m_{STBC} N_{CBPS,LAST,init,u}$ For each user(#2072) with LDPC encoding continue LDPC encoding process as in 19.3.11.7.5 (LDPC PPDU encoding process)(#1405)(#2811) starting with the parameters $N_{pld,u}$ and $N_{avbus,u}$. If there is at least one user with LDPC encoding, where step d) of its LDPC encoding process of 19.3.11.7.5 (LDPC PPDU encoding process)(#1405)(#2812), meets the following condition:

$$(N_{punc,u} > 0.1 \times N_{CW,u} \times L_{LDPC,u} \times (1 - R_u)) \text{ AND } (N_{shrt,u} < 1.2 \times N_{punc,u} \times \frac{R_u}{1 - R_u}) \text{ is true OR if } N_{punc,u} > 0.3 \times N_{CW,u} \times L_{LDPC,u} \times (1 - R_u) \text{ is true,}$$

where $N_{punc,u}$, $N_{CW,u}$, $L_{LDPC,u}$ and $N_{shrt,u}$ are the LDPC encoding parameters for user u , as defined in 19.3.11.7.5 (LDPC PPDU encoding process)(#2813), and R_u is the coding rate of user u , then the LDPC Extra symbol bit in HE-SIG-A shall be set to 1, and all the users with LDPC encoding shall increment N_{avbits} and recompute N_{punc} by the following two equations once:

$$(26-84) \quad N_{avbits,u} = \begin{cases} N_{avbits,u} + m_{STBC} \cdot (N_{CBPS} - 3N_{CBPS,SHORT,u}), & \text{if } a_{init} = 3 \\ N_{avbits,u} + m_{STBC} \cdot N_{CBPS,SHORT,u}, & \text{otherwise} \end{cases}$$

$$(26-85) \quad N_{punc,u} = \max(0, (N_{CW,u} \times L_{LDPC,u}) - N_{avbits,u} - N_{shrt,u})$$

Update the common pre-FEC padding factor(#2564) and N_{SYM} values for all users by the following equation:

$$(26-86)$$

$$\begin{cases} N_{SYM} = N_{SYM,init} + m_{STBC} \text{ and } a = 1, & \text{if } a_{init} = 4 \\ N_{SYM} = N_{SYM,init} \text{ and } a = a_{init} + 1, & \text{otherwise} \end{cases}$$

If among all the users with LDPC encoding, in step d) of 19.3.11.7.5 (LDPC PPDU encoding process)(#1405)(#2814), the above mentioned condition is not met, or if all the users in the HE MU PPDU are BCC encoded, then the LDPC Extra symbol bit in HE-SIG-A shall be set to 0, and:

$$(26-87)$$

$$(26-86) \quad a = a_{init}, N_{SYM} = N_{SYM,init} \quad \text{Note that users with BCC encoding shall also use the common } N_{SYM} \text{ and a parameters as in}$$

(#2073).

(#331)For the users with LDPC encoding, $N_{DBPS,LAST,u} = N_{DBPS,LAST,init,u}$.

For the users with BCC encoding, update the N_{DBPS} of the last symbol as

$$N_{DBPS,LAST,u} = \begin{cases} a \cdot N_{DBPS,SHORT,u} & \text{if } a < 4 \\ N_{DBPS,u} & \text{if } a = 4 \end{cases}$$

For each user with either LDPC or BCC encoding, update the N_{CBPS} of the last symbol as

$$N_{CBPS,LAST,u} = \begin{cases} a \cdot N_{CBPS,SHORT,u} & \text{if } a < 4 \\ N_{CBPS,u} & \text{if } a_{init} = 4 \end{cases}$$

(26-88)For the users with BCC encoding, the number of pre-FEC padding bits is shown in

$$(26-88)$$

$$N_{PAD, Pre-FEC, u} = (N_{SYM} - m_{STBC})N_{DBPS, u} + m_{STBC}N_{DBPS, LAST, u} - 8 \cdot APEP_LENGTH_u - N_{Tail} - N_{service}$$
 For each user with either LDPC or BCC encoding, the number of post-FEC padding bits in each of the last m_{STBC} symbol(s) is computed as in $N_{PAD, Post-FEC, u} = N_{CBPS, u} - N_{CBPS, LAST, u}$ (#2):

$$(26-89) N_{PAD, Post-FEC, u} = N_{CBPS, u} - N_{CBPS, LAST, u} \text{ (#2070)}$$

(26-90) Among the pre-FEC padding bits, the MAC delivers a PSDU that fills the available octets in the Data field of the HE PPDU, toward the desired pre-FEC padding boundary, represented by a_{init} in the last OFDM symbol(s). The PHY then determines the number of pad bits to add and appends them to the PSDU. The number of pre-FEC pad bits added by PHY will always be 0 to 7. The procedure is defined in

(26-91) and

(#2076)

(26-90)

$$(26-91) N_{PAD, Pre-FEC, MAC} = 8 \cdot \left\lceil \frac{N_{PAD, Pre-FEC}}{8} \right\rceil$$

26.3.11.5.5 $N_{PAD, Pre-FEC, PHY} = N_{PAD, Pre-FEC} \bmod 8$ Encoding process for an HE trigger-based PPDU

The AP indicates the common N_{SYM} , pre-FEC padding factor(#2564), STBC indication and LDPC Extra Symbol in the Trigger frame.

For an HE trigger-based PPDU with BCC encoding, follow the HE SU PPDU padding and encoding process as introduced in 25.3.10.1.1 (pre-FEC padding process), Binary convolutional coding and puncturing, and Post-FEC padding, with initial parameters setting to $N_{SYM, init} = N_{SYM}$, and $a_{init} = a$, where N_{SYM} and a are the common number of symbols and pre-FEC padding factor(#2564) indicated in the Trigger frame, respectively.

For an HE trigger-based PPDU with LDPC encoding, follow the HE SU PPDU padding and encoding process as introduced in Pre-FEC encoding process, LDPC coding, and Post-FEC padding, with the following exceptions:

(26-92) When the Trigger frame indicates LDPC Extra Symbol = 1, set the initial parameters following

:

(26-92)

$$(26-73) \begin{cases} a_{init} = 4 \text{ and } N_{SYM,init} = N_{SYM} - m_{STBC}, & \text{if } a = 1 \\ a_{init} = a - 1 \text{ and } N_{SYM,init} = N_{SYM}, & \text{otherwise} \end{cases}$$

where N_{SYM} and a are the common number of symbols and pre-FEC padding factor(#2564) indicated in the Trigger frame respectively, and m_{STBC} is 2 if the Trigger frame indicates STBC and 1 otherwise. Then continue with the LDPC encoding process as in 20.3.11.7.5 (LDPC PPDU encoding process)(#1405), during which in step d) of 20.3.11.7.5 (LDPC PPDU encoding process)(#1405), always increment N_{avbus} as in

, and always recompute N_{punc} as in Equation (20-40), followed by updating $a = a_{init} + 1$ if $a_{init} < 4$, or $a = 1$ if $a_{init} = 4$.

When the Trigger frame indicates LDPC Extra Symbol = 0, set initial parameters to $N_{SYM,init} = N_{SYM}$, and $a_{init} = a$, where N_{SYM} and a are the common number of symbols and pre-FEC padding factor(#1626)(#2564) indicated in the Trigger frame respectively. Then continue with the LDPC encoding process as in 20.3.11.7.5 (LDPC PPDU encoding process)(#1405), during which in step d) of 20.3.11.7.5 (LDPC PPDU encoding process)(#1405), N_{avbus} and N_{punc} are not changed, and $a = a_{init}$.

26.3.11.6 Stream parser

After coding, scrambling, (#2078) puncturing and post-FEC padding, the data bit streams at the output of the FEC encoder are processed in groups of N_{CBPS} bits. Each of these groups is re-arranged into N_{SS} blocks of $N_{CBPS,a}$ blocks of $N_{CBPS,a}$ bits in the case of an (#2829) HE MU transmission). This operation is referred to as “stream parsing” and is described in this subclause(#1304).

The description is given in terms of an SU transmission. For MU transmissions, the rearrangements are carried out in the same way per user.

(26-93)The number of bits assigned to a single axis (real or imaginary) in a constellation point in a spatial stream is denoted by

(26-93)

$$s = \max\left(1, \frac{N_{BPSCS}}{2}\right) \quad \text{The sum of these over all streams is } S = N_{SS} \cdot s$$

Consecutive blocks of s bits are assigned to different spatial streams in a round robin fashion.

For the N_{CBPS} bits of each OFDM symbol, S bits from the output of the encoder are divided among all spatial streams, s bits per stream.

Note that for all RU sizes the coded bits of each OFDM symbol are always evenly allocated to N_{SS} spatial streams.(#2079)(#Ed)

The following equations are an equivalent description to the above procedure. Bit i at the output of the encoder is assigned to input bit k of spatial stream i_{SS} where

$$i = (i_{SS} - 1)s + S \cdot \left\lfloor \frac{k}{s} \right\rfloor + (k \bmod s) \quad (\#2080)$$

$$\begin{aligned}
 i_{SS} &= 1, 2, \dots, N_{SS} \\
 \bar{i} &= 0, 1, \dots, N_{CBPS} - 1 \\
 k &= 0, 1, \dots, N_{CBPS} - 1 \quad (\#2081)
 \end{aligned}$$

26.3.11.7 Segment parser

The description in this subclause is for an SU transmission. For an MU transmissions, the rearrangements are carried out in the same way but per user. (#Ed)

(26-94) For a 20 MHz, 40 MHz, 80 MHz, 160 MHz and 80+80 MHz transmission with a 26-, 52-, 106-, 242-, 484- or 996-tone RU, the segment parser is bypassed and the output bits of each stream parser are as specified in

(26-94)

$y_{k,l} = x_k$ where

x_k is bit k of a block of N_{CBPS} bits, $k = 0$ to $N_{CBPS} - 1$
 l is the frequency subblock index and $l = 0$ for a 26-, 52-, 106-, 242-, 484- and 996-tone RU.
 $y_{k,l}$ is bit k of the frequency subblock l

(26-95) For a 160 MHz and 80+80 MHz transmission with a 2x996-tone RU, the output bits of each stream parser are first divided into blocks of N_{CBPS} bits ($N_{CBPS,u}$ bits in the case of an MU transmission). Then, each block is further divided into two frequency subblocks of $N_{CBPS}/2$ bits as shown in

(26-95)

$$(26-96) \quad y_{k,l} = x_m, \quad m = 2s \cdot \left\lfloor \frac{k}{s} \right\rfloor + l \cdot s + (k \bmod s), \quad k = 0, 1, \dots, \frac{N_{CBPS}}{2} - 1$$

and

x_m is bit m of a block of N_{CBPS} bits and $m = 0, \dots, N_{CBPS} - 1$
 l is the frequency subblock index and $l = 0, 1$
 $y_{k,l}$ is bit k of the frequency subblock l

(26-93) s is defined in

(#2566)

26.3.11.8 BCC interleavers

(#1866) For ease of explanation, the operation of the interleaver is described only for the SU case. For user u of an MU transmission, the interleaver operates in the same way on the output bits for the user from the stream parser by replacing N_{SS} , N_{CBPS} , N_{CBPS} , and N_{BPCS} with $N_{SS,u}$, $N_{CBPS,u}$, $N_{CBPS,u}$ and $N_{BPCS,u}$ respectively (#2522). That is, the operation of the interleaver is the same as if the transmission were an SU one, consisting of bits from only that user.

The BCC interleaver operation is specified in 21.3.10.8 (BCC interleaver). When DCM is used with BPSK modulation in a 106-tone RU or a 242-tone RU with $N_{SS} = 1$, after the $2 \times N_{BPCS}$ coded bits in each OFDM symbol, 1 padding bit is added before the bits are interleaved. (#482) (#2183) The interleaver parameters, N_{COL} , N_{ROW} , and N_{ROT} , for the Data field depend on the RU size and whether or not DCM is used and are defined in the RU size column of BCC interleaver parameters.

Table 26-27—BCC interleaver parameters

DCM	Parameter	RU size (tones)				HE-SIG-A/ HE-SIG-B (tones)
		26	52	106	242	
Not used	N_{COL}	8	16	17	26	13
	N_{ROW}	$3 \times N_{BPCS}$	$3 \times N_{BPCS}$	$6 \times N_{BPCS}$	$9 \times N_{BPCS}$	$4 \times N_{BPCS}$
	$N_{ROT} (2 \leq N_{SS} \leq 4)$	2	11	29	58	—
Used	N_{COL}	48	8	17	13	13
	N_{ROW}	$3 \times N_{BPCS}$	$3 \times N_{BPCS}$	$3 \times N_{BPCS}$	$9 \times N_{BPCS}$	$2 \times N_{BPCS}$
	$N_{ROT} (N_{SS} = 2)$	2	2	11	29	—

The interleaver parameters, N_{COL} and N_{ROW} , for the HE-SIG-A and HE-SIG-B fields are defined in the HE-SIG-A/HE-SIG-B column of BCC interleaver parameters.

NOTE—DCM is not used on the HE-SIG-A field.

26.3.11.9 Constellation mapping

The mapping between the input bits of the constellation mapper and complex constellation points for BPSK, QPSK, 16-QAM, 64-QAM and 256-QAM is as defined in 21.3.10.9 (Constellation mapping).

1024-QAM is optional for SU and MU for RUs equal to or larger than 242 subcarriers (#1782) (#Ed). For 1024-QAM, the mapping of the bits at the output of the interleaver to the complex constellation points is

defined in Constellation bit encoding for 1024-QAM (1st quadrant), Constellation bit encoding for 1024-QAM (2nd quadrant), Constellation bit encoding for 1024-QAM (3rd quadrant) and Constellation bit encoding for 1024-QAM (4th quadrant).

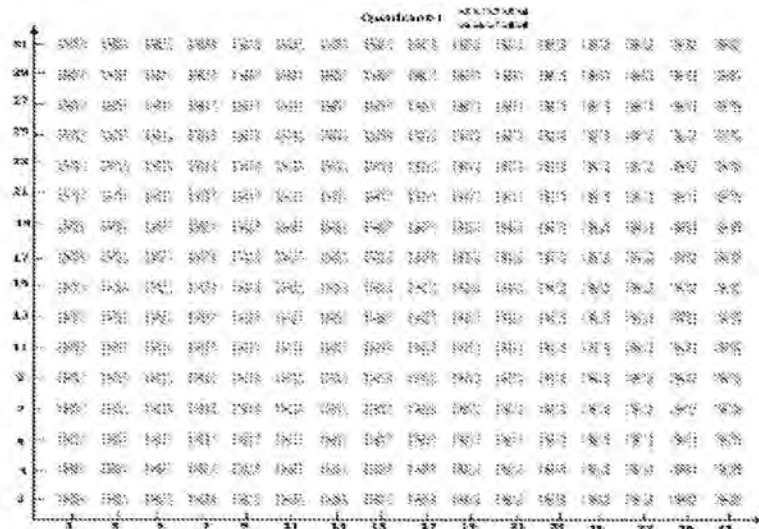


Figure 26-29—Constellation bit encoding for 1024-QAM (1st quadrant)

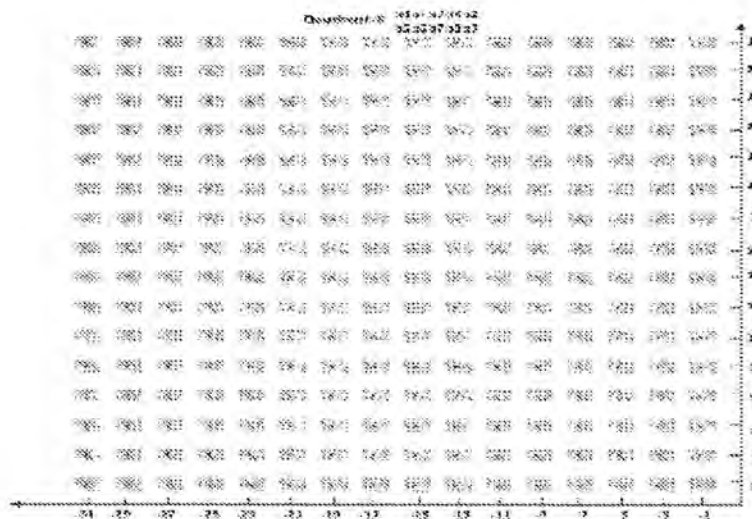


Figure 26-30—Constellation bit encoding for 1024-QAM (2nd quadrant)

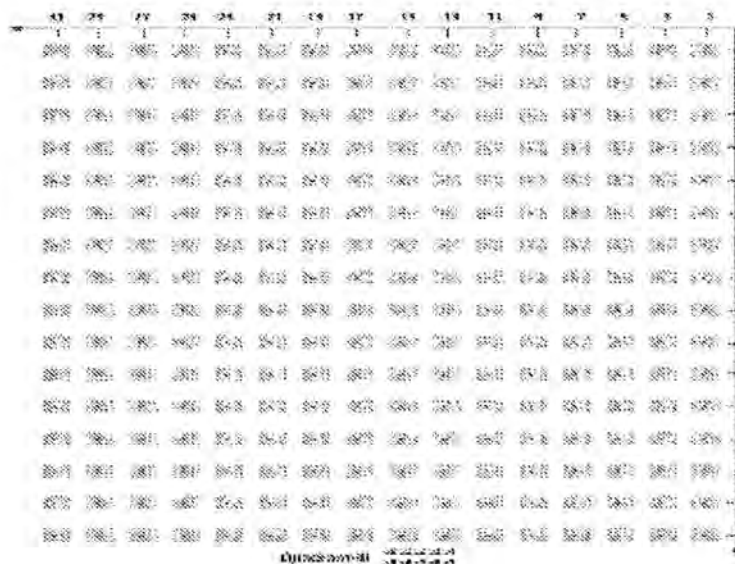


Figure 26-31—Constellation bit encoding for 1024-QAM (3rd quadrant)

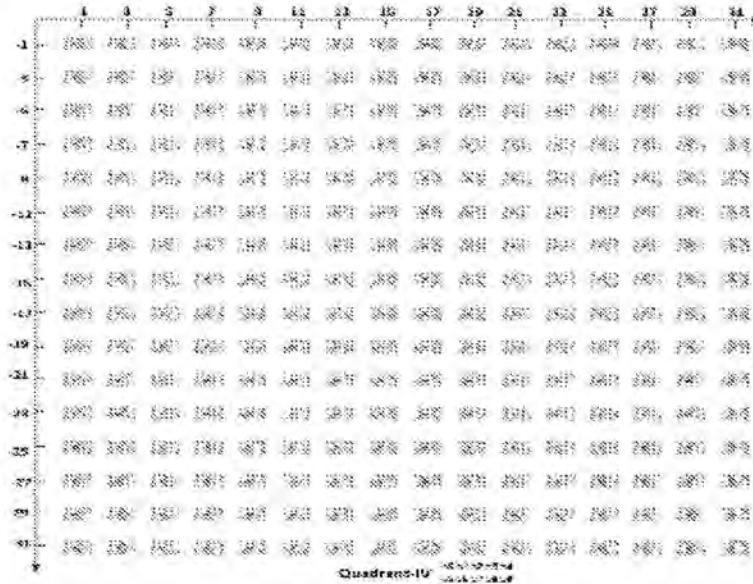


Figure 26-32—Constellation bit encoding for 1024-QAM (4th quadrant)

The normalization factor K_{mod} for 1024 QAM is $1/\sqrt{682}$. (#1782)

Dual subcarrier modulation (DCM) is an optional modulation scheme for the HE-SIG-B and Data fields. DCM can be applied to an HE SU PPDU and an HE extended range SU PPDU. In an HE MU PPDU, DCM can be applied only to RUs containing data for 1 user. (#482)

DCM is only applied to MCS0, MCS 1, MCS 3 and MCS 4. DCM is applied only with $N_{SS} = 1$ or $N_{SS} = 2$ (in the case of single user RU in an HE MU PPDU, $N_{SS,ru} = 1$ or $N_{SS,ru} = 2$). DCM is not applied with MU-MIMO or with STBC.

When DCM is employed, bit sequences are mapped to a pair symbols $(d_k, d_{q(k)})$ where k is in the range of $0 \leq k \leq N_{SD} - 1$ and $q(k)$ is in the range of $N_{SD} \leq k \leq N_{SD} - 1$ in order to exploit frequency diversity. To maximize the frequency diversity, the indices of a pair of DCM subcarriers $(k, q(k))$ is $q(k) = k + N_{SD}$. The N_{SD} here refers to the N_{SD} with DCM = 1, which is half the value of N_{SD} with DCM = 0. (#482)

For BPSK modulation with DCM, the input stream is broken into groups of N_{CBPS} or $N_{CBPS,u}$ bits $(B_0, B_1, \dots, B_{N_{CBPS,u}-1})$ (#2522). Each bit B_k is BPSK modulated to a sample d_k . This generates the samples for the lower half of the data subcarriers. For the upper half of the subcarriers, the samples are generated as $d_{k+N_{SD}} = d_k \times e^{j(k+N_{SD})\pi}$, $k = 0, 1, \dots, N_{SD} - 1$. The N_{SD} here refers to the N_{SD} with DCM = 1, which is half the value of N_{SD} with DCM = 0. (#482)

For QPSK modulation with DCM, the input stream is broken into groups of N_{CBPS} or $N_{CBPS,u}$ (#333) bits $(B_0, B_1, \dots, B_{N_{CBPS,u}-1})$ (#2522). Each pair of bits (B_{2k}, B_{2k+1}) is QPSK modulated to a symbol d_k . This generates the constellation points for the lower half the data subcarriers in the RU. For the upper half of the data sub-carriers in the RU, $d_{k+N_{SD}} = \text{conj}(d_k)$ (#482).

For 16-QAM modulation with DCM, the input stream is broken into groups of N_{CBPS} or $N_{CBPS,u}$ bits $(B_0, B_1, \dots, B_{N_{CBPS,u}-1})$ (#2522). A group of 4 bits $(B_{4k}, B_{4k+1}, B_{4k+2}, B_{4k+3})$ is 16-QAM modulated to a sample d_k as described in 18.3.5.8. This is the sample on subcarrier k in the lower half. In the upper half, the sample $d_{k+N_{SD}}$ on subcarrier $k + N_{SD}$ is obtained by 16-QAM modulating a permutation of the bits $(B_{4k}, B_{4k+1}, B_{4k+2}, B_{4k+3})$. Specifically, $d_{k+N_{SD}}$ is obtained by applying the 16-QAM modulation procedure in 18.3.5.8 to the bit group $(B_{4k+1}, B_{4k}, B_{4k+3}, B_{4k+2})$. The N_{SD} here refers to the N_{SD} with DCM = 1, which is half the value of N_{SD} with DCM = 0. (#482)

26.3.11.10 Space-time block coding

This subclause defines a set of optional robust transmission techniques that are applicable only when using STBC coding. For an HE PPDU, STBC is allowed only with single spatial stream and two space-time streams, and its application is as indicated by the STBC bit in HE-SIG-A (TBD: undecided whether in HE-SIG-A for HE_MU). In an HE MU PPDU, STBC coding is used in all RUs or not used in any of the RUs. If in an RU, DL MU-MIMO is applied, STBC shall not be used in any RU in the HE MU PPDU.

The STBC encoding process is as described in 22.3.10.9.4 (Space-time block coding) (#1405), with $N_{SS,0} = 1$ and $N_{STS,0} = 2$.

26.3.11.11 LDPC tone mapper

(#1859) The LDPC tone mapping shall be performed on all LDPC encoded streams mapped in an (#Ed) RU as described in this subclause. LDPC tone mapping shall not be performed on streams that are encoded using BCC. When DCM is applied to LDPC encoded streams, D_{TM_DCM} (#1860) shall be applied on both the lower half data subcarriers in an (#Ed) RU and the upper half data subcarriers of the RU. The LDPC tone-mapping distance parameters D_{TM} and D_{TM_DCM} are constant for each RU size and the values for different RU sizes are given in LDPC tone mapping distance for each RU size.

Table 26-28—LDPC tone mapping distance for each RU size

Parameter	RU Size (tones)						
	26	52	106	242	484	996	2x996(#1337)
D_{TM}	1	3	6	9	12	20	20
D_{TM_DCM}	1	1	3	9	9	14	14(#1861)

NOTE—The LDPC tone mapping parameters D_{TM} and D_{TM_DCM} are applied for each frequency subblock, $l = 0$ and $l = 1$. (#1866)

For an HE PPDU without DCM, the LDPC tone mapping for the LDPC encoded stream for user u in the r -th RU is done by permuting the stream of complex numbers generated by the constellation mappers (see Constellation mapping) to

$$d'_{n(k), l, n, i, r, u} = d_{k, l, n, i, r, u} \quad \begin{aligned} &k = 0, 1, \dots, N_{SD} - 1 \text{ for a 26-, 52-, 106-, 242-, 484- and 996-tone RU} \\ &k = 0, 1, \dots, \frac{N_{SD}}{2} - 1 \text{ for a 2x996-tone RU} \\ &i = 1, \dots, N_{SS, r, u} \\ &n = 0, 1, \dots, N_{SYM} - 1 \\ &l = 0 \text{ for a 26-, 52-, 106-, 242-, 484- and 996-tone RU} \\ &l = 0, 1 \text{ for a 2x996-tone RU} \\ &u = 0, \dots, N_{user, r} - 1 \\ &r = 0, \dots, N_{RU} - 1 \end{aligned} \quad (26-97)$$

where N_{SD} is the number of data tones in the r -th RU.

$$n(k) = \begin{cases} D_{TM} \left(k \bmod \frac{N_{SD}}{D_{TM}} \right) + \left\lfloor \frac{k \cdot D_{TM}}{N_{SD}} \right\rfloor, & \text{for a 26-, 52-, 106-, 242-, 484- and 996-tone RU} \\ D_{TM} \left(k \bmod \frac{N_{SD}/2}{D_{TM}} \right) + \left\lfloor \frac{k \cdot D_{TM}}{N_{SD}/2} \right\rfloor, & \text{for a 2x996-tone RU} \end{cases} \quad (26-98)$$

For an (#2829) HE PPDU with DCM, the LDPC tone mapping for the LDPC encoded stream corresponding to user u in the r -th RU is done by permuting the stream of complex numbers generated by the constellation mappers (see 25.3.10.7) to

$$d'_{n(k), l, n, i, r, u} = \begin{cases} d_{k', l, n, i, r, u} \\ d_{k', l, n, i, r, u}^* \end{cases} \quad (26-99)$$

where

$$\begin{aligned} &k = 0, 1, \dots, \frac{N_{SD}}{2} - 1 \\ &k' = k - \frac{N_{SD}}{2}, \text{ for } k = \frac{N_{SD}}{2}, \frac{N_{SD}}{2} + 1, \dots, N_{SD} - 1 \\ &i = 1, \dots, N_{SS, r, u} \\ &n = 0, 1, \dots, N_{SYM} - 1 \\ &l = \begin{cases} 0 & \text{for a 26-, 52-, 106-, 242-, 494- and 996-tone RU} \\ 0, 1 & \text{for a 2x996-tone RU} \end{cases} \\ &u = 0, \dots, N_{user, r} - 1 \\ &r = 0, \dots, N_{RU} - 1 \end{aligned}$$

N_{SD} is the number of data tones in the r -th RU and

$$t(k) = \begin{cases} D_{TM_DCM}\left(k \bmod \frac{N_{SD}/2}{D_{TM_DCM}}\right) + \left\lfloor \frac{k \cdot D_{TM_DCM}}{N_{SD}/2} \right\rfloor, & \text{for a 26-, 52-, 106-, 242-, 484- and 996-tone RU} \\ D_{TM_DCM}\left(k' \bmod \frac{N_{SD}/2}{D_{TM_DCM}}\right) + \left\lfloor \frac{k' \cdot D_{TM_DCM}}{N_{SD}/2} \right\rfloor + \frac{N_{SD}}{2}, & \text{for a 26-, 52-, 106-, 242-, 484- and 996-tone RU} \\ D_{TM_DCM}\left(k \bmod \frac{N_{SD}/2}{D_{TM_DCM}}\right) + \left\lfloor \frac{k \cdot D_{TM_DCM}}{N_{SD}/2} \right\rfloor, & \text{for a 2x996-tone RU} \end{cases} \quad (26-100)$$

D_{TM_DCM} is the LDPC tone mapping distance for the r -th RU when DCM is applied.

NOTE—LDPC tone mapper for a 26-, 52-, 106-, 242-, 484- and 996-tone RU is defined as one segment(#2088). LDPC tone mapping is performed separately for the upper and lower 80 MHz frequency segments of a 2x996-tone RU(#1337) as indicated by the frequency subblock index l in Error! Reference source not found. and Error! Reference source not found.

Since LDPC tone mapping is not performed on BCC-coded streams, for BCC-coded streams, the following applies:

$$d_{k,i,n,l,r,u}^{(i)} = d_{k,i,n,l,r,u}^{(i)} \quad \begin{aligned} k &= 0, 1, \dots, N_{SD} - 1 \text{ for a 26-, 52-, 106-, 242-, 484- and 996-tone RU} \\ k &= 0, 1, \dots, \frac{N_{SD}}{2} - 1 \text{ for a 2x996-tone RU} \\ i &= 1, \dots, N_{SC,r,u} \\ n &= 0, 1, \dots, N_{SYM} - 1 \\ l &= 0 \text{ for a 26-, 52-, 106-, 242-, 484- and 996-tone RU} \\ l &= 0, 1 \text{ for a 2x996-tone RU} \\ u &= 0, \dots, N_{user,r} - 1 \\ r &= 0, \dots, N_{RU} - 1 \end{aligned} \quad (26-101)$$

26.3.11.12 Segment deparser

(26-102) For a 26-, 52-, 106-, 242-, 484- and 996-tone RU(#Ed), the segment deparsing is not performed and $d_{k,i,n,l,r,u}^{(i_{Seg})}$ is specified in

(26-102)

(26-103) $d_{k,i,n,l,r,u}^{(i_{Seg})} = d_{k,i,n,0,r,u}^{(i)}$ if $0 \leq k \leq N_{SD} - 1$, $i_{Seg} = 0$ For a 2x996-tone RU in a 160 MHz HE PPDU(#Ed), the two frequency subblocks at the output of the LDPC tone mapper are combined into one frequency segment as specified in

(26-103)

$$d_{k,i,n,l,r,u}^{(i_{seg})} = \begin{cases} d'_{k,i,n,0,r,u} & \text{if } 0 \leq k \leq \frac{N_{SD}}{2} - 1 \\ d'_{k-\frac{N_{SD}}{2},i,n,l,r,u} & \text{if } \frac{N_{SD}}{2} \leq k \leq N_{SD} - 1 \end{cases}, i_{seg} = 0$$

(26-104) For a 2×996-tone RU in an 80+80 MHz HE PPDU, the segment deparsing is not performed and $d_{k,i,n,l,r,u}^{(i_{seg})}$ is specified in

(26-104)

$d_{k,i,n,l,r,u}^{(i_{seg})} = d'_{k,i,n,l_{seg},r,u}$ if $0 \leq k \leq N_{SD} - 1$, $i_{seg} = 0, 1$ NOTE—As per Table 21-7 (center frequency for frequency segment iSeg = 0), $f_c^{(0)}$ is always less than $f_c^{(1)}$ in case of 80+80 MHz HE PPDU. Hence, $d'_{k,i,n,0,r,u}$ (frequency subblock 0) is always transmitted in the frequency segment lower in frequency, while $d'_{k,i,n,1,r,u}$ (frequency subblock 1) is always transmitted in the frequency segment higher in frequency (#2092)

26.3.11.13 Pilot subcarriers

For a user transmitting on the i -th 26-tone RU in a given PPDU BW, two pilot tones shall be inserted in subcarriers $k \in K_{R26,i}$, where $K_{R26,i}$ is given by the (#926) i -th pilot index set in the row of given PPDU BW of Pilot indices for a 26-tone RU.

Table 26-29—Pilot indices for a 26-tone RU

PPDU BW	$K_{R26,i}$
20 MHz, $i = 1:9$	−116/−102, −90/−76, −62/−48, −36/−22, −10/10, 22/36, 48/62, 76/90, 102/116
40 MHz, $i = 1:18$	−238/−224, −212/−198, −184/−170, −158/−144, −130/−116, −104/−90, −78/−64, −50/−36, −24/−10, 10/24, 36/50, 64/78, 90/104, 116/130, 144/158, 170/184, 198/212, 224/238
80 MHz, $i = 1:37$	−494/−480, −468/−454, −440/−426, −414/−400, −386/−372, −360/−346, −334/−320, −306/−292, −280/−266, −252/−238, −226/−212, −198/−184, −172/−158, −144/−130, −118/−104, −92/−78, −64/−50, −38/−24, −10/10, 24/38, 50/64, 78/92, 104/118, 130/144, 158/172, 184/198, 212/226, 238/252, 266/280, 292/306, 320/334, 346/360, 372/386, 400/414, 426/440, 454/468, 480/494
160 MHz, $i = 1:74$	{pilot tone indices in 80 MHz −512, pilot tone indices in 80 MHz +512}

The pilot mapping P_n^k (#346) for the (#927) subcarrier k for symbol n shall be as specified in

$$P_n^{K_{R26i}} = \{\Psi_{n \bmod 2}, \Psi_{(n+1) \bmod 2}\}$$

$$P_n^{k \notin K_{R26i}} = 0 \quad (\#347)$$

$$(26-105) \quad P_n^{K_{R26i}} = \{\Psi_{n \bmod 2}, \Psi_{(n+1) \bmod 2}\}$$

$$(26-105) \quad P_n^{k \notin K_{R26i}} = 0 \quad (\#347)$$

where

Ψ_m is defined in The 2 pilot values for a 26-tone RU

Table 26-30—The 2 pilot values for a 26-tone RU(#347)

Ψ_0	Ψ_1
1	-1

For a user transmitting on the i -th 52-tone RU in a given PPDU BW, four pilot tones shall be inserted in subcarriers $k \in K_{R52i}$, where K_{R52i} is given by the (#Ed) i -th pilot index set in the row of given PPDU BW of Pilot indices for 52-tone RU transmission.

Table 26-31—Pilot indices for 52-tone RU transmission

PPD BW	K_{R52i}
20 MHz, $i = 1:4$	-116/-102/-90/-76, -62/-48/-36/-22, 22/36/48/62, 76/90/102/116
40 MHz, $i = 1:8$	-238/-224/-212/-198, -184/-170/-158/-144, -104/-90/-78/-64, -50/-36/-24/-10, 10/24/36/50, 64/78/90/104, 144/158/170/184, 198/212/224/238
80 MHz, $i = 1:16$	-494/-480/-468/-454, -440/-426/-414/-400, -360/-346/-334/-320, -306/-292/-280/-266, -252/-238/-226/-212, -198/-184/-172/-158, -118/-104/-92/-78, -64/-50/-38/-24, 24/38/50/64, 78/92/104/118, 158/172/184/198, 212/226/238/252, 266/280/292/306, 320/334/346/360, 400/414/426/440, 454/468/480/494
160 MHz, $i = 1:32$	{pilot tone indices in 80 MHz -512, pilot tone indices in 80 MHz +512}

The pilot mapping P_n^k (#346) for the (#933) subcarrier k for symbol n shall be as specified in

$$P_n^{K_{RS2_i}} = \{\Psi_{n \bmod 4} \Psi_{(n+1) \bmod 4} \Psi_{(n+2) \bmod 4} \Psi_{(n+3) \bmod 4}\}$$

$$P_n^{k \notin K_{RS2_i}} = 0 \quad (\#347)$$

$$P_n^{K_{RS2_i}} = \{\Psi_{n \bmod 4} \Psi_{(n+1) \bmod 4} \Psi_{(n+2) \bmod 4} \Psi_{(n+3) \bmod 4}\}$$

$$(26-106) \quad P_n^{k \notin K_{RS2_i}} = 0 \quad (\#347)$$

where

Ψ_m is defined in The 4 pilot values in a 52- and 106-tone RU

Table 26-32—The 4 pilot values in a 52- and 106-tone RU(#347)

Ψ_0	Ψ_1	Ψ_2	Ψ_3
1	1	1	-1

For a user transmitting on the i -th 106-tone RU in a given PPDU BW, four pilot tones shall be inserted in subcarriers $k \in K_{R106_i}$, where K_{R106_i} is given by the (#932) i -th pilot index set in the row of given PPDU BW of Pilot indices for 106-tone RU transmission.

Table 26-33—Pilot indices for 106-tone RU transmission

PPD BW	K_{R106_i}
20 MHz, $i = 1:2$	-116/-90/-48/-22, 22/48/90/116
40 MHz, $i = 1:4$	-238/-212/-170/-144, -104/-78/-36/-10, 10/36/78/104, 144/170/212/238
80 MHz, $i = 1:8$	-494/-468/-426/-400, -360/-334/-292/-266, -252/-226/-184/-158, -118/-92/-50/-24, 24/50/92/118, 158/184/226/252, 266/292/334/360, 400/426/468/494
160 MHz, $i = 1:16$	{pilot tone indices in 80 MHz -512, pilot tone indices in 80 MHz +512}

(26-107) The pilot mapping P_n^k (#346) for the (#930) subcarrier k for symbol n shall be as specified in

(26-107)

$$P_n^{K_{R106}} = \{\Psi_{n \bmod 4}, \Psi_{(n+1) \bmod 4}, \Psi_{(n+2) \bmod 4}, \Psi_{(n+3) \bmod 4}\}$$

$$P_n^{k \notin K_{R106}} = 0$$

where

Ψ_m is defined in The 4 pilot values in a 52- and 106-tone RU

For a user transmitting on the i -th 242-tone RU in a given PPDU BW, eight pilot tones shall be inserted in subcarriers $k \in K_{R242_i}$, where K_{R242_i} is given by the (#929) i -th pilot index set in the row of given PPDU BW of Pilot indices for 242-tone RU transmission.

Table 26-34—Pilot indices for 242-tone RU transmission

PPD BW	K_{R242_i}
20 MHz, $i = 1$	−116/−90/−48/−22/22/48/90/116
40 MHz, $i = 1:2$	−238/−212/−170/−144/−104/−78/−36/−10, 10/36/78/104/144/170/212/238
80 MHz, $i = 1:4$	−494/−468/−426/−400/−360/−334/−292/−266/−252/−226/−184/−158/−118/−92/−50/−24/24/50/92/118/158/184/226/252, 266/292/334/360/400/426/468/494
160 MHz, $i = 1:8$	{pilot tone indices in 80 MHz −512, pilot tone indices in 80 MHz +512}

(26-108) The pilot mapping P_n^k (#346) for the (#936) subcarrier k for symbol n shall be as specified in

(26-108)

$$P_n^{K_{R242_i}} = \{\Psi_{n \bmod 8}, \Psi_{n+1 \bmod 8}, \Psi_{n+2 \bmod 8}, \Psi_{n+3 \bmod 8}, \Psi_{(n+4) \bmod 8}, \Psi_{(n+5) \bmod 8}, \Psi_{(n+6) \bmod 8}, \Psi_{(n+7) \bmod 8}\}$$

$$P_n^{k \notin K_{R242_i}} = 0$$

where

Ψ_m is defined in The 8 pilot values in a 242-tone RU

Table 26-35—The 8 pilot values in a 242-tone RU(#347)

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 484-tone RU transmission, the pilot mapping for 8 pilots in 242-tone RU is replicated in the two 242-RUs of the 484-tone RU transmission. Specifically, for (#347) a user transmitting on the i -th 484-tone RU in a given PPDU BW, sixteen pilot tones shall be inserted in subcarriers $k \in K_{R484_i}$, where K_{R484_i} is given by the (#938) i -th pilot index set in the row of given PPDU BW of Pilot indices for 484-tone RU transmission.

Table 26-36—Pilot indices for 484-tone RU transmission

PPD BW	K_{R484_i}
40 MHz, $i = 1$	−238/−212/−170/−144/−104/−78/−36/−10/10/36/78/104/144/170/212/238
80 MHz, $i = 1:2$	−494/−468/−426/−400/−360/−334/−292/−266/−252/−226/−184/−158/−118/−92/−50/−24/24/50/92/118/158/184/226/252/266/292/334/360/400/426/468/494
160 MHz, $i = 1:4$	{pilot tone indices in 80 MHz −512, pilot tone indices in 80 MHz +512}

The pilot mapping P_n^k (#346) for the (#942) subcarrier k for symbol n shall be as specified in

$$P_n^{K_{R484_i}} = \{\Psi_{n \bmod 8} \otimes \Psi_{n+1 \bmod 8} \otimes \Psi_{n+2 \bmod 8} \otimes \Psi_{n+3 \bmod 8} \otimes \Psi_{(n+4) \bmod 8} \otimes \Psi_{(n+5) \bmod 8} \otimes \Psi_{(n+6) \bmod 8} \otimes \Psi_{(n+7) \bmod 8} \otimes \Psi_{(n+8) \bmod 8} \otimes \Psi_{(n+9) \bmod 8} \otimes \Psi_{(n+10) \bmod 8} \otimes \Psi_{(n+11) \bmod 8} \otimes \Psi_{(n+12) \bmod 8} \otimes \Psi_{(n+13) \bmod 8} \otimes \Psi_{(n+14) \bmod 8} \otimes \Psi_{(n+15) \bmod 8}\}$$

$$P_n^{k \notin K_{R484_i}} = 0 \quad (\#3).$$

$$P_n^{K_{R484_i}} = \{\Psi_{n \bmod 8} \otimes \Psi_{n+1 \bmod 8} \otimes \Psi_{n+2 \bmod 8} \otimes \Psi_{n+3 \bmod 8} \otimes \Psi_{(n+4) \bmod 8} \otimes \Psi_{(n+5) \bmod 8} \otimes \Psi_{(n+6) \bmod 8} \otimes \Psi_{(n+7) \bmod 8} \otimes \Psi_{(n+8) \bmod 8} \otimes \Psi_{(n+9) \bmod 8} \otimes \Psi_{(n+10) \bmod 8} \otimes \Psi_{(n+11) \bmod 8} \otimes \Psi_{(n+12) \bmod 8} \otimes \Psi_{(n+13) \bmod 8} \otimes \Psi_{(n+14) \bmod 8} \otimes \Psi_{(n+15) \bmod 8}\}$$

$$(26-109) P_n^{k \notin K_{R484_i}} = 0 \quad (\#347)$$

where

Ψ_m is defined in The 8 pilot values in a 242-tone RU

For a 996-tone RU transmission, the pilot mapping for its 16 pilots is the same as the mapping for 484-tone RU transmission. Specifically, for (#347) a user transmitting on the i -th 996-tone RU in a given PPDU BW, sixteen pilot tones shall be inserted in subcarriers $k \in K_{R996_i}$, where K_{R996_i} is given by the (#941) i -th pilot index set in the row of given PPDU BW of Pilot indices for 996-tone RU transmission.

Table 26-37—Pilot indices for 996-tone RU transmission

PPD BW	K_{R996_i}
80 MHz, $i = 1$	-468/-400/-334/-266/-226/-158/-92/-24/24/92/158/226/266/334/400/468
160 MHz, $i = 1:2$	{for $i = 1$ pilot tone indices in 80 MHz -512, for $i = 2$ pilot tone indices in 80 MHz +512} (#2095)

The pilot mapping P_n^k (#346) for the (#939) subcarrier k for symbol n shall be as specified in

$$P_n^{K_{R996_i}} = \{ \Psi_{n \bmod 8} \Psi_{(n+1) \bmod 8} \Psi_{(n+2) \bmod 8} \Psi_{(n+3) \bmod 8} \Psi_{(n+4) \bmod 8} \Psi_{(n+5) \bmod 8} \Psi_{(n+6) \bmod 8} \Psi_{(n+7) \bmod 8} \Psi_{(n+8) \bmod 8} \Psi_{(n+9) \bmod 8} \Psi_{(n+10) \bmod 8} \Psi_{(n+11) \bmod 8} \Psi_{(n+12) \bmod 8} \Psi_{(n+13) \bmod 8} \Psi_{(n+14) \bmod 8} \Psi_{(n+15) \bmod 8} \}$$

$$P_n^{k \notin K_{R996_i}} = 0 \quad (\#3.)$$

$$P_n^{K_{R996_i}} = \{ \Psi_{n \bmod 8} \Psi_{(n+1) \bmod 8} \Psi_{(n+2) \bmod 8} \Psi_{(n+3) \bmod 8} \Psi_{(n+4) \bmod 8} \Psi_{(n+5) \bmod 8} \Psi_{(n+6) \bmod 8} \Psi_{(n+7) \bmod 8} \Psi_{(n+8) \bmod 8} \Psi_{(n+9) \bmod 8} \Psi_{(n+10) \bmod 8} \Psi_{(n+11) \bmod 8} \Psi_{(n+12) \bmod 8} \Psi_{(n+13) \bmod 8} \Psi_{(n+14) \bmod 8} \Psi_{(n+15) \bmod 8} \}$$

$$(26-110) P_n^{k \notin K_{R996_i}} = 0 \quad (\#347)$$

where

Ψ_m is defined in The 8 pilot values in a 242-tone RU

For a 160 MHz transmission (equivalently two 996-tone RU transmissions), the 80 MHz (equivalently 996-tone RU)(#347) pilot mapping is replicated in the two 80 MHz subchannels of the 160 MHz transmission. Specifically, thirty-two pilot tones shall be inserted in subcarriers $k \in K_{R2 \times 996_i}$, where $K_{R2 \times 996_i}$ is given by {-980, -912, -846, -778, -738, -670, -604, -536, -488, -420, -354, -286, -246, -178, -112, -44, 44, 112, 178, 246, 286, 354, 420, 488, 536, 604, 670, 738, 778, 846, 912, 980}. The pilot

mapping P_n^k (#346) for the (#944) subcarrier k for symbol n shall be as specified in

$$P_n^{K_{820996}} = \{ \Psi_{(n \bmod 8)} \Psi_{(n+1) \bmod 8} \Psi_{(n+2) \bmod 8} \Psi_{(n+3) \bmod 8} \Psi_{(n+4) \bmod 8} \Psi_{(n+5) \bmod 8} \Psi_{(n+6) \bmod 8} \Psi_{(n+7) \bmod 8} \Psi_{(n+8) \bmod 8} \Psi_{(n+9) \bmod 8} \Psi_{(n+10) \bmod 8} \Psi_{(n+11) \bmod 8} \Psi_{(n+12) \bmod 8} \Psi_{(n+13) \bmod 8} \Psi_{(n+14) \bmod 8} \Psi_{(n+15) \bmod 8} \Psi_n \Psi_{(n+1) \bmod 8} \Psi_{(n+2) \bmod 8} \Psi_{(n+3) \bmod 8} \Psi_{(n+4) \bmod 8} \Psi_{(n+5) \bmod 8} \Psi_{(n+6) \bmod 8} \Psi_{(n+7) \bmod 8} \Psi_{(n+8) \bmod 8} \Psi_{(n+9) \bmod 8} \Psi_{(n+10) \bmod 8} \Psi_{(n+11) \bmod 8} \Psi_{(n+12) \bmod 8} \Psi_{(n+13) \bmod 8} \Psi_{(n+14) \bmod 8} \Psi_{(n+15) \bmod 8} \}$$

$$P_n^{k \notin K_{820996}} = 0 \quad (\#3).$$

$$P_n^{K_{820996}} = \{ \Psi_n \Psi_{(n+1) \bmod 8} \Psi_{(n+2) \bmod 8} \Psi_{(n+3) \bmod 8} \Psi_{(n+4) \bmod 8} \Psi_{(n+5) \bmod 8} \Psi_{(n+6) \bmod 8} \Psi_{(n+7) \bmod 8} \Psi_{(n+8) \bmod 8} \Psi_{(n+9) \bmod 8} \Psi_{(n+10) \bmod 8} \Psi_{(n+11) \bmod 8} \Psi_{(n+12) \bmod 8} \Psi_{(n+13) \bmod 8} \Psi_{(n+14) \bmod 8} \Psi_{(n+15) \bmod 8} \Psi_n \Psi_{(n+1) \bmod 8} \Psi_{(n+2) \bmod 8} \Psi_{(n+3) \bmod 8} \Psi_{(n+4) \bmod 8} \Psi_{(n+5) \bmod 8} \Psi_{(n+6) \bmod 8} \Psi_{(n+7) \bmod 8} \Psi_{(n+8) \bmod 8} \Psi_{(n+9) \bmod 8} \Psi_{(n+10) \bmod 8} \Psi_{(n+11) \bmod 8} \Psi_{(n+12) \bmod 8} \Psi_{(n+13) \bmod 8} \Psi_{(n+14) \bmod 8} \Psi_{(n+15) \bmod 8} \}$$

$$(26-111) P_n^{k \notin K_{820996}} = 0 \quad (\#347)$$

where

Ψ_m is defined in The 8 pilot values in a 242-tone RU

For a noncontiguous 80+80 MHz transmission, each frequency segment shall follow the 80 MHz pilot tone allocation and values defined for 996-tone RU in 80 MHz transmission as specified in

$$P_n^{K_{996}} = \{ \Psi_n \Psi_{(n+1) \bmod 8} \Psi_{(n+2) \bmod 8} \Psi_{(n+3) \bmod 8} \Psi_{(n+4) \bmod 8} \Psi_{(n+5) \bmod 8} \Psi_{(n+6) \bmod 8} \Psi_{(n+7) \bmod 8} \Psi_{(n+8) \bmod 8} \Psi_{(n+9) \bmod 8} \Psi_{(n+10) \bmod 8} \Psi_{(n+11) \bmod 8} \Psi_{(n+12) \bmod 8} \Psi_{(n+13) \bmod 8} \Psi_{(n+14) \bmod 8} \Psi_{(n+15) \bmod 8} \}$$

$$P_n^{k \notin K_{996}} = 0 \quad (\#3 \text{ and TBD pilot values for 996-tone RU in 80 MHz PPDU BW}).$$

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

26.3.11.14 OFDM modulation

(26-112) The time domain waveform of the Data field of an HE PPDU that is not an HE trigger-based PPDU, from transmit chain i_{TX} , $1 \leq i_{TX} \leq N_{TX}$ and frequency segment i_{seg} (#2097), shall be as defined in

(26-112)

$$r_{HE-Data}^{(i_{seg}, i_{TX})}(t) = \frac{1}{\sqrt{\sum_{r=1}^{N_{RU}} \alpha_r^2 [K_r]}} \sum_{n=0}^{N_{SYM}-1} w_{T_{GP, Data}}(t - nT_{SYM}) \sum_{r=0}^{N_{RU}-1} \frac{\alpha_r}{\sqrt{N_{STS, r, total}}} \left(\sum_{k \in K_r} \sum_{u=0}^{N_{RU, r}-1} \sum_{m=1}^{N_{STS, r, u}} \left(\left[Q_k^{(i_{seg})} \right]_{i_{TX}, (M_{r,u} + m)} \tilde{D}_{k, m, u, r}^{(i_{seg}, u)} (p_n + 2 + N_{HE-SIG-A} + N_{HE-SIG-B}) P_n^k \right) \cdot \exp(j2\pi k \Delta_{F, HE}(t - nT_{SYM} - T_{GI, Data} - T_{CS, HE}(M_{r,u} + m))) \right) \quad \text{where}$$

p_n is defined in 18.3.5.10 (OFDM modulation)

P_n^k is defined in Pilot subcarriers(#1056)(#334)

$N_{HE-Data}^{Tone}$ is defined in Tone scaling factor and guard interval duration values for HE PPDU fields (#476)

$T_{CS, HE}(M_{r,u} + m)$ represents the cyclic shift for space time stream $M_{r,u} + m$ as defined in Cyclic shift for HE modulated fields(#1052)

$T_{GI, Data}$ is the guard interval duration as defined in Timing-related constants

(26-113) $\tilde{D}_{k, m, u, r}^{(i_{seg}, u)}$ is the transmitted constellation for user u in the r -th RU at subcarrier k , space-time stream m , and Data field OFDM symbol n and is defined by

(26-113)

$$\tilde{D}_{k, m, u, r}^{(i_{seg}, u)} = \begin{cases} 0, & k \in K_{Pilot} \\ \tilde{d}_{M_r(k), m, n, r, u}^{(i_{seg})}, & \text{otherwise} \end{cases} \quad \text{where}$$

K_{Pilot} is the set of subcarrier indices of pilot tones, as defined in Pilot tones

(26-114) $M_r(k)$ is defined in

(26-114)

$$M_r(k) = k - K_{r, min} - \left\lfloor \{k' : K_{r, min} \leq k' < k\} \cap K_{Pilot} \right\rfloor \quad \text{where}$$

$K_{r,min}$ is the minimum value of the set K_r
 $|\Phi|$ is the cardinality of a set Φ

NOTE – $M_r(k)$ translates a subcarrier index k ($-N_{SR} \leq k \leq N_{SR}$) into the index of data symbols in a transmission over an RU(#1948) ($0 \leq M_r(k) \leq N_{SD,r}$). The subcarrier index k for the data tone is first offset by the minimum value of subcarrier index $K_{r,min}$ (for the lower edge tone) in this RU, and then subtracted by the number of pilot tones falling in between the data tone and the edge tone.

In a noncontiguous 80+80 MHz transmission, each frequency segment shall follow the 80 MHz HE subcarrier mapping as specified in Math.

The time domain waveform of the Data field of an HE trigger-based PPDU for user u in the r -th RU from transmit chain i_{TX} , $1 \leq i_{TX} \leq N_{TX}$ shall be as defined in

$$r_{HE,Data}^{(i_{seg}, i_{TX})}(t) = \frac{\alpha_r}{\sqrt{|K_r|}} \sum_{n=0}^{N_{SYM}-1} w_{T_{HE,Data}}(t - nT_{SYM}) \frac{1}{\sqrt{N_{STS,r,total}}} \sum_{k \in K_r} \sum_{m=1}^{N_{STS,r,u}} \left(\left[Q_k^{(i_{seg})} \right]_{i_{TX}, (M_{r,u} + m)} \left(\tilde{D}_{k,m,n,r}^{(i_{seg},u)} + p_{n+4} P_n^k \right) \cdot \exp(j2\pi k \Delta_{F,HE}(t - nT_{SYM} - T_{GI,Data} - T_{CS,HE}(M_{r,u} + m))) \right) \quad (\#2)$$

$$r_{HE,Data}^{(i_{seg}, i_{TX})}(t) = \frac{\alpha_r}{\sqrt{|K_r|}} \sum_{n=0}^{N_{SYM}-1} w_{T_{HE,Data}}(t - nT_{SYM}) \frac{1}{\sqrt{N_{STS,r,total}}} \sum_{k \in K_r} \sum_{m=1}^{N_{STS,r,u}} \left(\left[Q_k^{(i_{seg})} \right]_{i_{TX}, (M_{r,u} + m)} \left(\tilde{D}_{k,m,n,r}^{(i_{seg},u)} + p_{n+4} P_n^k \right) \cdot \exp(j2\pi k \Delta_{F,HE}(t - nT_{SYM} - T_{GI,Data} - T_{CS,HE}(M_{r,u} + m))) \right) \quad (26-115) \quad (\#2099)$$

where

$Q_k^{(i_{seg})}$ is a spatial mapping/steering matrix with N_{TX} rows and $N_{STS,r,total}$ columns for subcarrier k in frequency segment i_{seg} . $Q_k^{(i_{seg})}$ may be frequency dependent, and the dimension may be variant in each RU. Refer to the descriptions in 22.3.10.11.1 (Transmission in VHT format) for examples of $Q_k^{(i_{seg})}$.

26.3.11.15 Dual carrier modulation

Dual carrier modulation (DCM)(#2567) modulates the same information on a pair of sub-carriers. DCM is an optional modulation scheme for the HE-SIG-B and Data fields. DCM is only applied to BPSK, QPSK and 16-QAM modulations.

The constellation mapper for DCM is defined in Constellation mapping. The LDPC tone mapper for DCM is defined in LDPC tone mapper. The BCC interleaver for DCM is defined in BCC interleavers(#2183),(#335)

26.3.12 Packet extension(#1781)

A HE PPDU may have a Packet Extension (PE) field appended at the end of the PPDU, with possible durations being 0 μ s, 4 μ s, 8 μ s, 12 μ s, or 16 μ s. The PE field, when present, shall be transmitted with the same average power as the Data field, and its content is arbitrary(#2100).

The PE field is applied for the recipient of the PPDU to obtain longer processing time at the end of an(#2829) HE PPDU, and its duration is determined by both the pre-FEC padding factor(#2564) value in the last OFDM symbol(s) of the Data field, and the maximum PE duration requested by the recipient for the signal bandwidth (or RU size), the number of spatial streams, and the constellation size of the current PPDU, which is based on the PPE Thresholds(#1459) field in HE Capabilities element (see 9.4.2.218 (HE Capabilities element))(#1460)(#Ed).

For an(#2829) HE PPDU, the maximum PE durations as defined by the PPE Thresholds field in the HE Capabilities element (see 9.4.2.218 (HE Capabilities element))(#1459)(#Ed) are 0 μ s, 8 μ s and 16 μ s.

- A 0 μ s maximum PE duration means no PE is present.
- A 8 μ s maximum PE duration means that a PE field of 0 μ s, 0 μ s, 4 μ s, and 8 μ s are appended at the end of the PPDU, corresponding to a pre-FEC padding factor of(#2564) 1, 2, 3 and 4, respectively, as shown in PE field when maximum PE duration is 8 μ s (non STBC).
- A 16 μ s maximum PE duration means that a PE field of 4 μ s, 8 μ s, 12 μ s, and 16 μ s are appended at the end of the PPDU, corresponding to a pre-FEC padding factor of(#2564) 1, 2, 3 and 4, respectively, as shown in PE field when maximum PE duration is 16 μ s (non STBC).

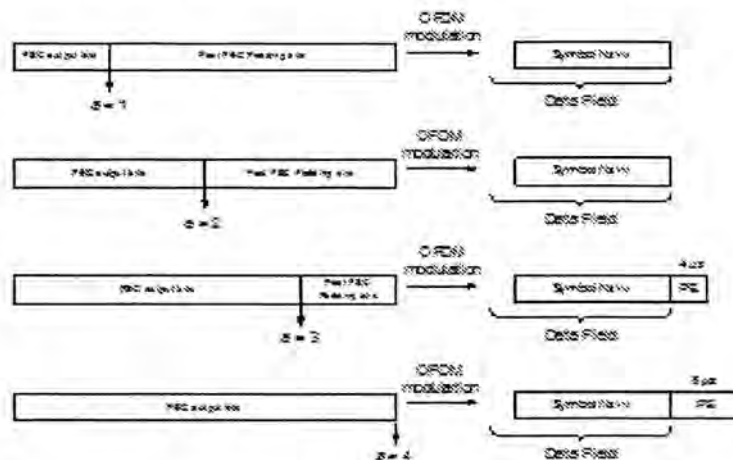


Figure 26-33—PE field when maximum PE duration is 8 μ s (non STBC)

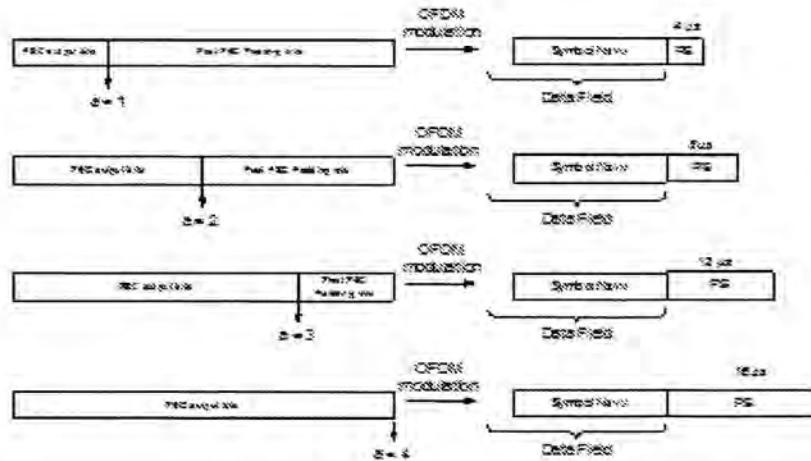


Figure 26-34—PE field when maximum PE duration is 16 μs (non STBC)

For an HE MU PPDU, the AP computes the PE duration, $T_{PE,u}$, for each user u , according to the common pre-FEC padding factor(#1626)(#2564) value among all users as described in Encoding process for an HE MU PPDU, the Maximum PE Duration capabilities, the RU size, the number of spatial streams and constellation size for user u . The AP shall choose the largest PE duration among all the users as the common PE duration of the current HE MU PPDU as:

(26-116)

$T_{PE} = \max_u(T_{PE,u})$ and then append the PE field at the end of the current HE MU PPDU, with duration T_{PE} .

(26-117) For an HE trigger-based PPDU, the AP indicates the packet extension duration information for all users in the Packet Extension subfield in the Common Info field of the Trigger frame(#Ed). The first two bits in the Packet Extension subfield indicate the pre-FEC padding factor(#2564) and the third bit indicates the PE-Disambiguity. Each user, when responding to(#2103) the Trigger frame with an HE trigger-based PPDU, shall append PE field at the end of the current HE trigger-based PPDU, with a duration T_{PE} . The value of T_{PE} can be calculated using

.(#2135)

(26-117)

$$T_{PE} = \left\lceil \frac{\left(\frac{\text{LENGTH} + m + 3}{3} \times 4 - T_{RL-SIG} - T_{HE-SIG-A} - T_{HE-PREAMBLE} \right) - N_{SYM} T_{SYM}}{4} \right\rceil \times 4$$

where

$$N_{SYM} = \left\lceil \left(\frac{\text{LENGTH} + m + 3}{3} \times 4 - T_{RL-SIG} - T_{HE-SIG-A} - T_{HE-PREAMBLE} \right) / T_{SYM} \right\rceil - b_{PE-Disambiguity}$$

LENGTH is the value indicated by Length subfield of the Common Info field in the Trigger frame

$b_{PE-Disambiguity}$ is B2 of the Packet Extension subfield of the Common Info field in the Trigger frame

$T_{HE-PREAMBLE} = T_{HE-STF-T} + N_{HE-LTF} T_{HE-LTF-SYM}$

$T_{HE-STF-T}$, $T_{HE-LTF-SYM}$, T_{RL-SIG} and $T_{HE-SIG-A}$ are defined in Timing-related constants

Editor's Note. The HE-SIG-A bits definition below should be moved into HE-SIG-A

The 3-bit Packet Extension field in HE-SIG-A are defined as in Packet Extension field in HE-SIG-A.

Table 26-38—Packet Extension field in HE-SIG-A

Name	bits	Definition
Pre-FEC Padding Factor(#2564)	B0-B1	Indicates the pre-FEC padding factor(#1626)(#2564) value of the current PPDU
PE Disambiguity	B2	Indicates PE disambiguity

The Pre-FEC Padding Factor(#2564) subfield of the Packet Extension field is encoded as shown in Pre-FEC Padding Factor.

Table 26-39—Pre-FEC Padding Factor(#2564) subfield encoding

Pre-FEC padding factor value	Pre-FEC Padding Factor subfield encoding
1	b01
2	b10
3	b11
4	b00

(26-118)The PE Disambiguity(#1049) subfield of the Packet Extension field shall be set to 1 if the condition in

is met, otherwise it shall be set to 0.

(26-118)

$$T_{PE} + 4 \times \left(\left\lceil \frac{\text{TXTIME} - 20}{4} \right\rceil - \left(\frac{\text{TXTIME} - 20}{4} \right) \right) \geq T_{SYM}$$

where
 T_{PE} is the PE field duration

26.3.8 T_{SYM} is the symbol duration of the Data field as defined in Timing-related parameters

TXTIME (in μs) is defined in TXTIME and PSDU_LENGTH calculation.

(26-119)(#2105)The receiver computes N_{SYM} and T_{PE} using

(26-120) and

respectively.

(26-119)

$$N_{SYM} = \left\lceil \left(\frac{\text{L_LENGTH} + m + 3}{3} \times 4 - T_{\text{HE-PREAMBLE}} \right) / T_{SYM} \right\rceil - b_{\text{PE-Disambiguity}}$$

(26-120)

$$T_{PE} = \left\lceil \frac{\left(\frac{\text{L_LENGTH} + m + 3}{3} \times 4 - T_{\text{HE-PREAMBLE}} \right) - N_{SYM} T_{SYM}}{4} \right\rceil \times 4$$

where

$$T_{\text{HE-PREAMBLE}} = \begin{cases} T_{\text{RL-SIG}} + T_{\text{HE-SIG-A}} + T_{\text{HE-STF-T}} + N_{\text{HE-LTF}} T_{\text{HE-STF,SYM}}, & \text{for an HE trigger-based PPDU} \\ T_{\text{RL-SIG}} + T_{\text{HE-SIG-A}} + T_{\text{HE-STF-NT}} + N_{\text{HE-LTF}} T_{\text{HE-STF,SYM}}, & \text{for an HE SU PPDU} \\ T_{\text{RL-SIG}} + T_{\text{HE-SIG-A}} + N_{\text{HE-SIG-B}} T_{\text{HE-SIG-B}} + T_{\text{HE-STF-NT}} + N_{\text{HE-LTF}} T_{\text{HE-STF,SYM}}, & \text{for an HE MU PPDU} \\ T_{\text{RL-SIG}} + T_{\text{HE-SIG-A}} + T_{\text{HE-SIG-A-R}} + T_{\text{HE-STF-NT}} + N_{\text{HE-LTF}} T_{\text{HE-STF,SYM}}, & \text{for an HE extended range SU PPDU} \end{cases}$$

$T_{\text{RL-SIG}}, T_{\text{HE-STF-T}}, T_{\text{HE-STF-NT}}, T_{\text{HE-LTF}}, T_{\text{HE-SIG-A}}, T_{\text{HE-SIG-A-R}}, T_{\text{HE-SIG-B}}$ are defined in Timing-related constants

$N_{\text{HE-SIG-B}}, N_{\text{HE-LTF}}$ are defined in Frequently used parameters

$b_{\text{PE-Disambiguity}}$ is PE Disambiguity subfield in the Packet Extension subfield of the HE-SIG-A field

26.3.13 Non-HT duplicate transmission

When the TXVECTOR parameter FORMAT is NON-HT and the TXVECTOR parameter NON_HT_MODULATION is NON_HT_DUP_OFDM, the transmitted PPDU is a non-HT duplicate. Non-HT duplicate transmission is used to transmit to non-HT OFDM STAs, HT STAs, VHT STAs, HE STAs that may be present in a part of a 40 MHz, 80 MHz, or 160 MHz channel (see Error! Reference source not found.). The RL-SIG, HE-SIG-A, HE-SIG-B, HE-STF, and HE-LTF fields are not transmitted. The L-STF, L-LTF, and L-SIG fields shall be transmitted in the same way as in the HE transmission when

the TXVECTOR parameter BEAM_CHANGE is 0, with the exceptions for the Rate and Length fields which shall follow 17.3.4 (SIGNAL field).

(26-60) In a 40 MHz non-HT duplicate transmission, the Data field shall be as defined by

For 80 MHz and 160 MHz non-HT duplicate transmissions, the Data field shall be as defined by Error! Reference source not found..

In a noncontiguous 80+80 MHz non-HT duplicate transmission, data transmission in each frequency segment shall be as defined for an 80 MHz non-HT duplicate transmission in Error! Reference source not found..

26.3.14 Transmit requirements for an HE trigger-based PPDU(#340)

26.3.14.1 Introduction

HE trigger-based PPDU transmissions are preceded by a Trigger frame from the AP. Since multiple transmitters take part in an HE trigger-based PPDU transmission, it requires transmission time, frequency, sampling symbol clock, and power pre-correction by the participating STAs to mitigate the synchronization related issues at the AP. Frequency and sampling clock pre-corrections are needed to prevent inter-carrier interference. Power pre-correction is required to control interference among participating STAs HE trigger-based PPDU transmission. An AP can schedule in the same HE trigger-based PPDU transmission both Class A and Class B devices. A STA participating in HE trigger-based PPDU transmissions shall support power pre-correction described in **Erreur ! Source du renvoi introuvable.** and shall meet pre-correction accuracy requirements described in Pre-correction accuracy requirements.

26.3.14.2 Power pre-correction

An AP indicates in the AP Tx Power subfield of the Common Info field in Trigger frame the combined transmit power of all the transmit antennas used to transmit the Trigger frame normalized to 20 MHz bandwidth. An AP indicates in the Target RSSI subfield of the User Info field in Trigger frame the target receive signal power averaged over the AP's antennas for the HE trigger-based PPDU.

Each STA that is scheduled in the Trigger frame calculates UL transmit power, T_{pwr}^{STA} , of the HE trigger-based PPDU for the assigned MCS using **Erreur ! Source du renvoi introuvable.**

$$(26-121) T_{pwr}^{STA} = PL_{DL} + Target_{RSSI}$$

where PL_{DL} represents DL pathloss and $Target_{RSSI}$ represents target receive signal power averaged over the AP's antennas for the HE trigger-based PPDU. $Target_{RSSI}$ is dBm value of Target RSSI subfield of User Info field in Trigger frame, the encoding of which is specified in Table 9-25g (Target RSSI subfield encoding). Note that an encoded value of 127 in Target RSSI subfield indicates to the STA to transmit an HE trigger-based PPDU at its maximum transmit power for the assigned MCS.

Each STA computes PL_{DL} using **Erreur ! Source du renvoi introuvable.**

$$(26-122) \quad PL_{DL} = Tx_{pwr}^{AP} - DL_{RSSI}$$

where Tx_{pwr}^{AP} represents AP's combined transmit power of all the transmit antennas used to transmit the Trigger frame normalized to 20 MHz bandwidth and DL_{RSSI} represents measured received power from the legacy preamble portion of the Trigger frame at the STA, also normalized to 20 MHz bandwidth. Tx_{pwr}^{AP} is dBm value of AP Tx Power subfield of the Common Info field in Trigger frame, the encoding of which is specified in Table 9-25e (AP Tx Power subfield encoding). DL_{RSSI} is an average of the received power over the antennas on which the average PL_{DL} is being computed.

A STA that applies beamforming (BF) in the UL should take the BF gain into account when calculating the transmit power needed to meet the target RSSI.(PHY Motion #170)

The UL transmit power of HE trigger-based PPDU is further subject to a STA's minimum and maximum transmit power limit due to hardware capability, regulatory requirements as well as non-802.11 in-device coexistence requirements.

(26-123)Each STA that is scheduled in the Trigger frame transmits UL Power headroom HR_{STA} in the HE trigger-based PPDU to assist in the AP's MCS selection. The UL power headroom for the assigned MCS is defined in

(26-123)

$HR_{STA} = Tx_{pwr}^{Max} - Tx_{pwr}^{STA}$ where Tx_{pwr}^{Max} and Tx_{pwr}^{STA} represent maximum UL transmit power of HE trigger-based PPDU for the assigned MCS and current UL transmit power of HE trigger-based PPDU for the assigned MCS, respectively. HR_{STA} is dB value of UL Headroom in HE trigger-based PPDU, the encoding of which is specified in 9.2.4.6.5.1 (UL power headroom). Note that the MSB bit of the UL Headroom subfield being set to 1 indicates that the STA is transmitting the HE trigger-based PPDU at its minimum Tx_{pwr}^{STA} for the assigned MCS.

26.3.14.3 Pre-correction accuracy requirements

A STA that transmits an HE trigger-based PPDU shall support per chain $\max(P-32, -10 \text{ dBm})$ (#1422) as the minimum transmit power, with P the maximum power the STA can transmit at the antenna connector of that chain using MCS 0(#1616) while meeting the TX EVM and spectral mask requirements. A STA transmitting at and above the minimum power shall support the EVM requirements for MCS 7(#1616)(PHY Motion #173).

A STA that transmits an HE trigger-based PPDU shall support the absolute transmit power requirements and the RSSI measurement accuracy requirements defined in Transmit power and RSSI measurement accuracy .

Table 26-40—Transmit power and RSSI measurement accuracy

Parameter	Minimum Requirement	Comments
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	Class A	Class B	
Absolute transmit power accuracy	± 3 dB	± 9 dB	Accuracy of achieving a specified transmit power
RSSI measurement accuracy	± 3 dB(#340)	± 5 dB	The difference between the RSSI and the received power(#1786) Requirements are valid from minimum Rx to maximum Rx input power
Relative transmit power accuracy	-	± 3 dB	Accuracy of achieving a change in transmit power for consecutive HE trigger-based PPDU The relative transmit power accuracy is applicable only to Class B devices.(#340)

The absolute transmit power accuracy is applicable for the entire range of transmit power that the STA is capable of. The RSSI accuracy requirements shall be applied to receive signal level range from -82 dBm to -20 dBm in 2.4 GHz and -82 dBm to -30 dBm in 5 GHz. The requirements are for nominal (room) temperature conditions. The RSSI shall be measured during the reception of the PHY legacy preamble.(#340)

A STA that transmits an HE trigger-based PPDU shall pre-compensate for carrier frequency offset (CFO) error and symbol clock error. After compensation, the absolute value of residual CFO error with respect to the PPDU carrying the associated Trigger frame shall not exceed 350 Hz for data subcarriers when measured as the 10% point of CCDF of CFO errors in AWGN at a received power of -60 dBm in the primary 20 MHz. The residual CFO error measurement shall be made on the HE trigger-based PPDU following the HE-SIG-A field. The symbol clock error shall be pre-compensated by the same ppm amount as CFO error.(#340)

A STA that transmits an HE trigger-based PPDU shall have timing accuracy of ± 0.4 μ s relative to the PPDU carrying the Trigger frame. This requirement does not include round trip delay.

26.3.15 SU-MIMO and DL MU-MIMO beamforming

26.3.15.1 General

(26-124)(#507) For SU-MIMO DL MU-MIMO beamforming in RU r , the receive signal vector in subcarrier k (where subcarrier k is one of the subcarriers in RU r , $k \in K_r$) at beamformee u ,

$\mathbf{y}_{k,u} = [y_{k,0}, y_{k,1}, \dots, y_{k,N_{\text{ant},r}} - 1]^T$, is shown in

, where $\mathbf{x}_k = [x_{k,0}, x_{k,1}, \dots, x_{k,N_{\text{ant},r}} - 1]^T$ denotes the transmit signal vector in subcarrier k for all N_{ant} beamformers, with $\mathbf{x}_{k,u} = [x_{k,0}, x_{k,1}, \dots, x_{k,N_{\text{STX},r,u}} - 1]^T$ being the transmit signal for beamformer u .

(26-124)

$$y_{k,u} = H_{k,u} \times [Q_{k,0}, Q_{k,1}, \dots, Q_{k,N_{user,r}-1}] \times x_k + n$$

where

- $H_{k,u}$ is the channel matrix from the beamformer to beamformee u in subcarrier k with dimensions $N_{RX,u} \times N_{TX}$
- $N_{RX,u}$ is the number of receive antennas at beamformee u
- $Q_{k,u}$ is a steering matrix for beamformee u in subcarrier k with dimensions $N_{TX} \times N_{STS,r,u}$
- $N_{user,r}$ is the number of HE MU PPDU recipients (see Frequently used parameters) in RU r
- n is a vector of additive noise and may include interference

The DL MU-MIMO steering matrix $Q_k = [Q_{k,0}, Q_{k,1}, \dots, Q_{k,N_{user,r}-1}]$ can be determined by the beamformer using the beamforming feedback for subcarrier k from beamformee u , where $u = 0, 1, \dots, N_{user,r}-1$. The feedback report format is described in 9.4.1.63 (HE Compressed Beamforming Report field) and 9.4.1.64 (HE MU Exclusive Beamforming Report field). The steering matrix that is computed (or updated) using new beamforming feedback from some or all of participating beamformees might replace the existing steering matrix Q_k for the next DL MU-MIMO data transmission.

For SU-MIMO beamforming, the steering matrix Q_k can be determined from the beamforming feedback matrix V_k that is sent back to the beamformer by the beamformee using the compressed beamforming feedback matrix format as defined in 19.3.12.3.6 (Compressed beamforming feedback matrix). The feedback report format is described in 9.4.1.63 (HE Compressed Beamforming Report field).

26.3.15.2 Beamforming feedback matrix V

Upon receipt of a HE NDP PPDU, the beamformee computes a set of matrices for feedback to the beamformer as described in 21.3.11.2 (Beamforming Feedback Matrix V). The eligible beamformees shall remove the space-time stream CSD in Table 21-11 (Cyclic shift values for the VHT modulated fields of a PPDU) from the measured channel before computing a set of matrices for feedback to the beamformer.

The beamforming feedback matrix, $V_{k,u}$, found by the beamformee u for subcarrier k in RU r shall be compressed in the form of angles using the method described in 20.3.12.3.6. The angles, $\phi(k,v)$ and $\psi(k,u)$, are quantized according to Table 8-53e. The number of bits for quantization is set by the beamformer, i.e., HE AP. The number of bits for quantization, tone grouping factor, and the number of columns in the HE Compressed beamforming feedback are set by the beamformee, i.e., non-AP STA, only if the NDP Announcement frame is addressed to a single non-AP STA and SU type feedback is solicited. The compressed beamforming feedback matrix as defined in (#Ed) 19.3.12.3.6 (Compressed beamforming feedback matrix) is the only Clause 26 beamforming feedback matrix defined.

The beamformee shall generate the beamforming feedback matrices with the number of rows (N_r) equal to the N_{STS} of the NDP.

After receiving the angle information, $\phi(k,v)$ and $\psi(k,u)$, the beamformer reconstructs $V_{k,u}$ using Equation (20-79). For SU-MIMO beamforming, the beamformer uses $V_{k,0}$ matrix to determine the steering matrix Q_k . For MU-MIMO beamforming, the beamformer may calculate a steering matrix $Q_k = [Q_{k,0}, Q_{k,1}, \dots, Q_{k,N_{user,r}-1}]$ using $V_{k,u}$ and $SNR_{k,u}$ ($0 \leq u \leq N_{user,r}-1$) in order to suppress crosstalk

between participating beamformers. The method used by the beamformer to calculate the steering matrix Q_k is implementation specific.

26.3.15.3 CQI-only feedback

Whenever the HE NDP Announcement frame is requesting a CQI-only feedback, upon receipt of the HE NDP, the beamformee computes HE CQI-only feedback as described in 9.4.1.64. The CQI-only feedback $CQI_{s,ru}$ in RU r for space time stream s shall be estimated using the method described in 9.4.1.64. The CQI values to be fed back are derived from quantized SNRs according to Table XX-4. The beamformee shall transmit the HE CQI-only feedback for space-time stream 1, ..., N_c for each of the RU indices for which the CQI-only report is being requested by the beamformer. After receiving the CQI information, the beamformer may use it to identify the best range of RUs for compressed beamforming feedback or for RU assignment during subsequent MU transmissions. The actual use is implementation specific.

26.3.16 Transmit specification

26.3.16.1 Transmit spectral mask

(#2351)The bandwidth of the spectral mask applied to an HE PPDU(#Ed) shall be determined by the bandwidth indicated in the Bandwidth subfield of the HE-SIG-A field. All HE PPDU formats shall be compliant with the transmit spectral mask described in this section.

NOTE 1—In the presence of additional regulatory restrictions, the device has to meet both the regulatory requirements and the mask defined in this subclause.

NOTE 2—Transmit spectral mask figures in this subclause are not drawn to scale.

NOTE 3—For rules regarding TX center frequency leakage levels, see Transmit center frequency leakage. The spectral mask requirements in this subclause do not apply to the RF LO.

For a 20 MHz mask PPDU of HE format, the interim transmit spectral mask shall have a 0 dBr (dB relative to the maximum spectral density of the signal) bandwidth of 19.5 MHz, -20 dBr at 10.25 MHz frequency offset, -28 dBr at 20 MHz frequency offset, and -40 dBr at 30 MHz frequency offset and above. The interim transmit spectral mask for frequency offsets in between 9.75 and 10.25 MHz, 10.25 and 20 MHz, and 20 and 30 MHz shall be linearly interpolated in dB domain from the requirements for 9.75 MHz, 10.25 MHz, 20 MHz, and 30 MHz frequency offsets. The transmit spectrum shall not exceed the maximum of the interim transmit spectral mask and -53 dBm/MHz at any frequency offset. Example transmit spectral mask for a 20 MHz mask PPDU shows an example of the resulting overall spectral mask when the -40 dBr spectrum level is above -53 dBm/MHz.

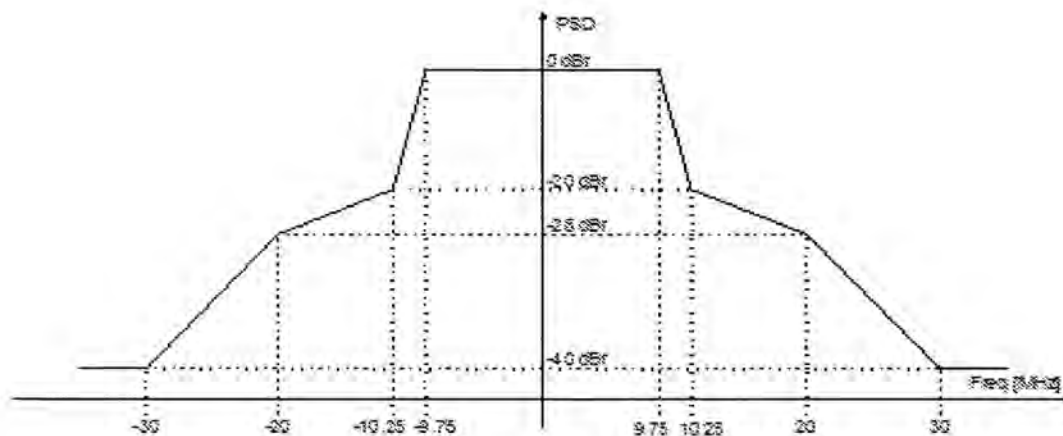


Figure 26-35—Example transmit spectral mask for a 20 MHz mask PDU

For a 40 MHz mask PDU of HE format, the interim transmit spectral mask shall have a 0 dBr (dB relative to the maximum spectral density of the signal) bandwidth of 39 MHz, -20 dBr at 20.5 MHz frequency offset, -28 dBr at 40 MHz frequency offset, and -40 dBr at 60 MHz frequency offset and above. The interim transmit spectral mask for frequency offsets in between 19.5 and 20.5 MHz, 20.5 and 40 MHz, and 40 and 60 MHz shall be linearly interpolated in dB domain from the requirements for 19.5 MHz, 20.5 MHz, 40 MHz, and 60 MHz frequency offsets. The transmit spectrum shall not exceed the maximum of the interim transmit spectral mask and -56 dBm/MHz at any frequency offset greater than 19.5 MHz. Example transmit spectral mask for a 40 MHz mask PDU shows an example of the resulting overall spectral mask when the -40 dBr spectrum level is above -56 dBm/MHz.

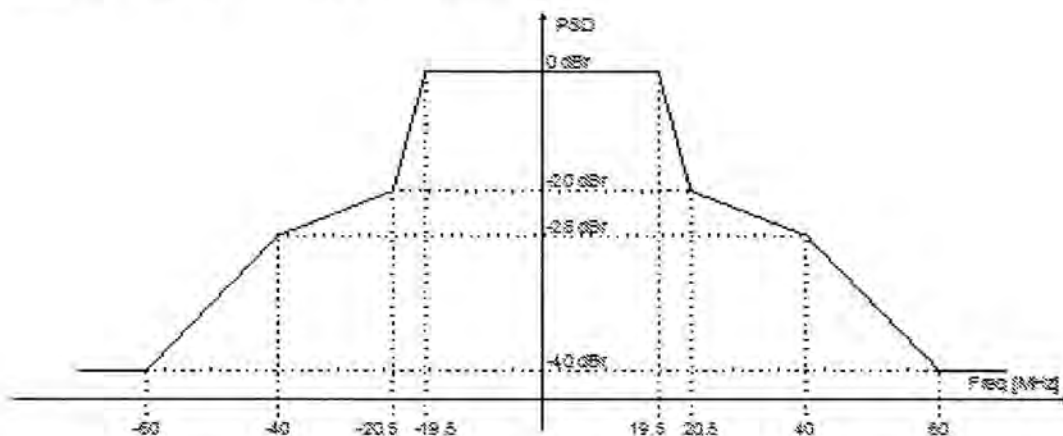
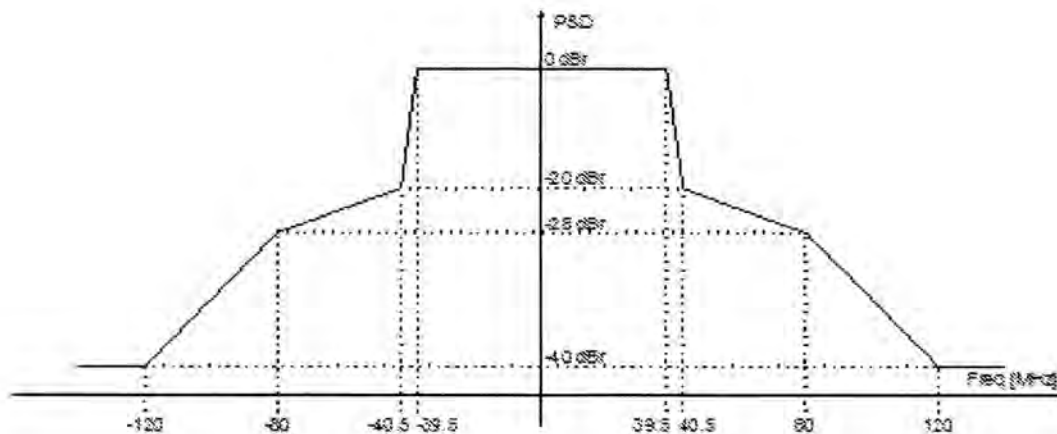


Figure 26-36—Example transmit spectral mask for a 40 MHz mask PPDU

For an 80 MHz mask PPDU of HE format, the interim transmit spectral mask shall have a 0 dBr (dB relative to the maximum spectral density of the signal) bandwidth of 79 MHz, -20 dBr at 40.5 MHz frequency offset, -28 dBr at 80 MHz frequency offset, and -40 dBr at 120 MHz frequency offset and above. The interim transmit spectral mask for frequency offsets in between 39.5 and 40.5 MHz, 40.5 and 80 MHz, and 80 and 120 MHz shall be linearly interpolated in dB domain from the requirements for 39.5 MHz, 40.5 MHz, 80 MHz, and 120 MHz frequency offsets. The transmit spectrum shall not exceed the maximum of the interim transmit spectrum mask and -59 dBm/MHz at any frequency offset. Example transmit spectral mask for a 80 MHz mask PPDU shows an example of the resulting overall spectral mask when the -40 dBr spectrum level is above -59 dBm/MHz.

**Figure 26-37—Example transmit spectral mask for a 80 MHz mask PPDU**

For a 160 MHz mask PPDU of HE format, the interim transmit spectral mask shall have a 0 dBr (dB relative to the maximum spectral density of the signal) bandwidth of 159 MHz, -20 dBr at 80.5 MHz frequency offset, -28 dBr at 160 MHz frequency offset, and -40 dBr at 240 MHz frequency offset and above. The interim transmit spectral mask for frequency offsets in between 79.5 and 80.5 MHz, 80.5 and 160 MHz, and 160 and 240 MHz shall be linearly interpolated in dB domain from the requirements for 79.5 MHz, 80.5 MHz, 160 MHz, and 240 MHz frequency offsets. The transmit spectrum shall not exceed the maximum of the interim transmit spectrum mask and -59 dBm/MHz at any frequency offset. Example transmit spectral mask for a 160 MHz mask PPDU shows an example of the resulting overall spectral mask when the -40 dBr spectrum level is above -59 dBm/MHz.

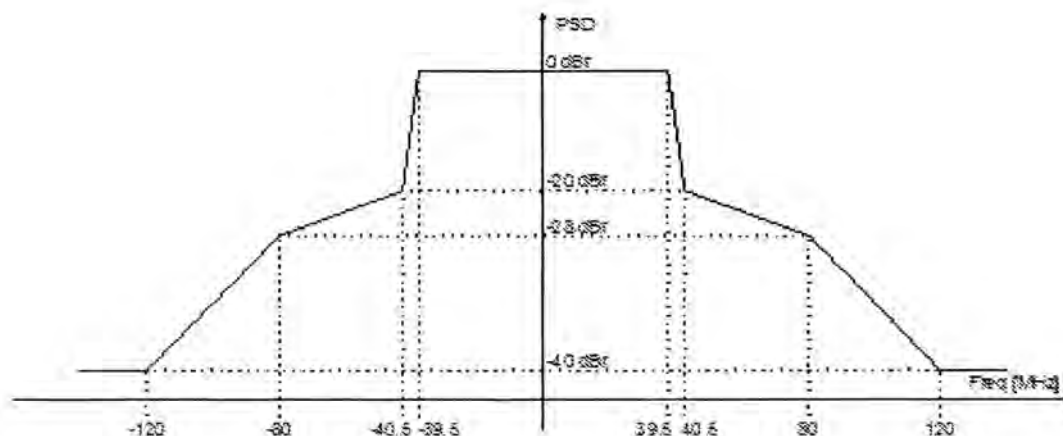


Figure 26-38—Example transmit spectral mask for a 160 MHz mask PPDU

For an 80+80 MHz mask PPDU of HE format, the overall transmit spectral mask is constructed in the following manner. First, the 80 MHz interim spectral mask is placed on each of the two 80 MHz segments. Then, for each frequency at which both of the 80 MHz interim spectral masks have values greater than -40 dBm/MHz and less than -20 dBm/MHz, the sum of the two interim mask values (summed in linear domain) shall be taken as the overall spectral mask value. Next, for each frequency at which neither of the two 80 MHz interim masks have values greater than or equal to -20 dBm/MHz and less than or equal to 0 dBm/MHz, the higher value of the two interim masks shall be taken as the overall interim 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 interim spectral mask value defined shall be used to define the interim spectral mask value. The transmit spectrum shall not exceed the maximum of the interim transmit spectrum mask and -59 dBm/MHz at any frequency offset. Example transmit spectral mask for a 80+80 MHz mask PPDU shows an example of a transmit spectral mask for a noncontiguous transmission using two 80 MHz channels where the center frequency of the two 80 MHz channels are separated by 160 MHz and the -40 dBm/MHz spectrum level is above -59 dBm/MHz.

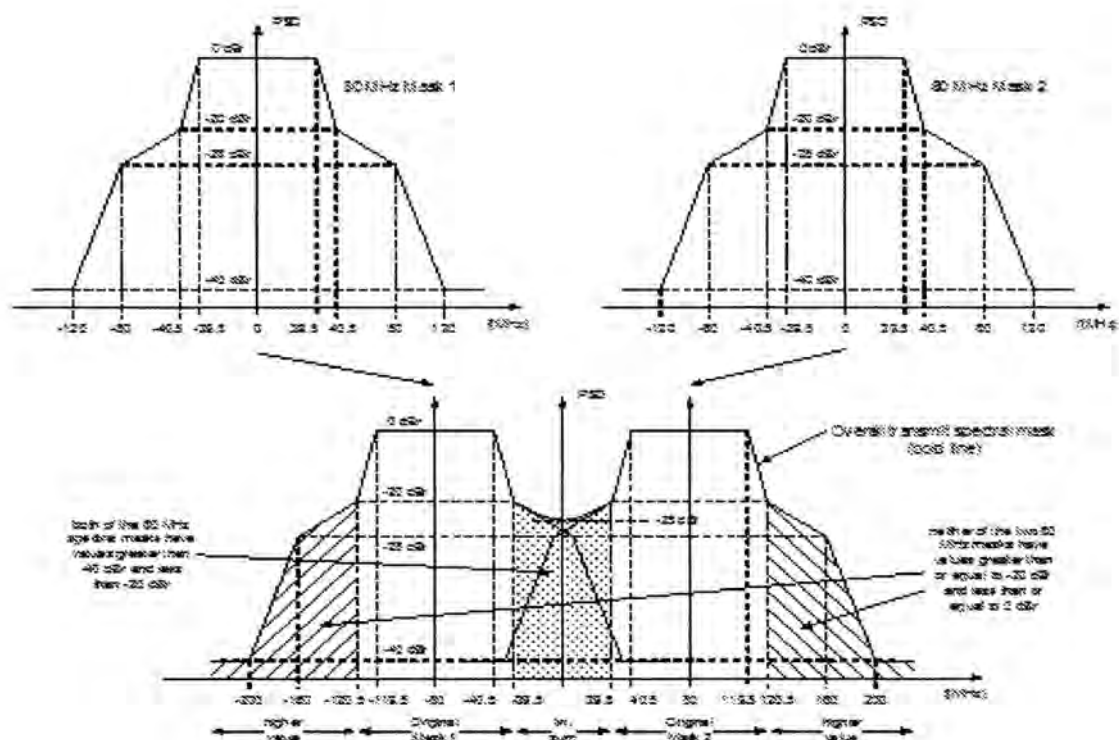


Figure 26-39—Example transmit spectral mask for a 80+80 MHz mask PPDU

Different center frequency separation between the two 80 MHz frequency segments of the spectral mask as well as different peak levels of each 80 MHz frequency segment of the spectral mask are possible, in which case a similar procedure in determining the spectral mask as in Example transmit spectral mask for a 80+80 MHz mask PPDU is followed.

The transmit spectral mask for noncontiguous transmissions using two nonadjacent 80 MHz channels is applicable only in regulatory domains that allow for such transmissions.

Measurements shall be made using a 25 kHz resolution bandwidth and a 7.5 kHz video bandwidth.

(PHY Motion #161) When channel puncturing happens in an HE MU PPDU, the HE MU PPDU is still treated as an 80 MHz or 160 MHz (80+80 MHz) PPDU, therefore the spectral mask is the same as those defined for the total channel width.

26.3.16.2 Spectral flatness

(#2351) Spectral flatness measurements shall be conducted using BPSK modulated HE PPDU. Demodulate the HE PPDU according to the following (or equivalent) procedure:

- Start of PPDU shall be detected.
- Transition from L-STF to L-LTF shall be detected and fine timing shall be established.
- Coarse and fine frequency offsets shall be estimated.
- Symbols in a PPDU shall be manipulated to account for both frequency error and timing drift error.
- For each HE-LTF symbol, transform the symbol into subcarrier received values, estimate the phase from the pilot subcarriers, and compensate the subcarrier values according to the estimated phase.
- For each of the data OFDM symbols: transform the symbol into subcarrier received values.

The spectral flatness test shall be performed over at least 20 HE PPDU. The PPDU under test shall be at least 16 data OFDM symbols long.

Evaluate spectral flatness using the subcarrier received values or the magnitude of the channel estimation of the occupied subcarriers of the transmission HE PPDU. Non-occupied subcarriers of the transmitted HE PPDU shall be ignored during averaging and testing. Resource unit power boosting and beamforming should not be used when measuring spectral flatness.

Let $E_{i,avg}$ denote the magnitude of the channel estimation on subcarrier i or the average constellation energy of a BPSK modulated subcarrier i in a HE data symbol. In a contiguous HE transmission having a bandwidth listed in Maximum transmit spectral flatness deviations, $E_{i,avg}$ of each of the subcarriers with indices listed as tested subcarrier indices shall not deviate by more than the specified maximum deviation in Maximum transmit spectral flatness deviations from the average of $E_{i,avg}$ over subcarrier indices listed as averaging subcarrier indices. Averaging of $E_{i,avg}$ is done in the linear domain.

Table 26-41—Maximum transmit spectral flatness deviations

Bandwidth of transmission (MHz)	Averaging subcarrier indices (inclusive)	Tested subcarrier indices (inclusive)	Maximum deviation (dB)
20	-84 to -2 and +2 to +84	-84 to -2 and +2 to +84	±4
		-122 to -85 and +85 to +122	+4/-6
40	-168 to -3 and +3 to +168	-168 to -3 and +3 to +168	±4
		-244 to -169 and +169 to +244	+4/-6
80	-344 to -3 and +3 to +344	-344 to -3 and +3 to +344	±4
		-500 to -345 and +345 to +500	+4/-6

160	-696 to -515, -509 to -166, +166 to +509, and +515 to +696	-696 to -515, -509 to -166, +166 to +509, and +515 to +696	± 4
		-1012 to -697, -165 to -12, +12 to +165, and +697 to +1012	$\pm 4/-6$

In an 80+80 MHz transmission, each segment shall meet the spectral flatness requirement for an 80 MHz transmission.

For the spectral flatness test, the transmitting STA shall be configured to use a spatial mapping matrix Q_i (see OFDM modulation) with flat frequency response. Each output port under test of the transmitting STA shall be connected through a cable to one input port of the testing instrumentation. The requirements apply to 20 MHz, 40 MHz, 80 MHz, and 160 MHz contiguous transmissions as well as 80+80 MHz transmissions.

26.3.16.3 Transmit center frequency and symbol clock frequency tolerance

Transmit center frequency and the symbol clock frequency for all transmit antennas and frequency segments shall be derived from the same reference oscillator. The symbol clock frequency and transmit center frequency maximum tolerance shall be ± 20 ppm. HE trigger-based PPDU format is subject to additional requirements as defined in Tra.(#2351)

26.3.16.4 Modulation accuracy

26.3.16.4.1 Introduction to modulation accuracy tests

Transmit modulation accuracy specifications are described in Transmit center frequency leakage and Transmitter constellation error. The test method is described in Transmitter modulation accuracy (EVM) test.(#2351)

26.3.16.4.2 Transmit center frequency leakage

The TX LO leakage requirement for all transmission modes shall be the following. The power measured at the location of the RF LO using resolution BW 78.125 kHz shall not exceed the maximum of -32 dB relative to the total transmit power and -20 dBm, or equivalently $\max(P-32, -20)$, where P is the transmit power per antenna in dBm. The transmit center frequency leakage is specified per antenna.

For an 80+80 MHz transmission where the RF LO falls outside both frequency segments, the RF LO shall additionally met the spectral mask requirements as defined in Transmit spectral mask.(#2351)

26.3.16.4.3 Transmitter constellation error

(26-125)(#2351)The relative constellation RMS error, calculated by first averaging over subcarriers, frequency segments, HE PPDU, and spatial streams (see

) shall not exceed a data-rate dependent value according to Allowed relative constellation error versus constellation size and coding rate. 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, $N_{SS} = N_{STS}$ (no STBC) 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 requirements apply to 20 MHz, 40 MHz, 80 MHz, and 160 MHz contiguous transmissions as well as 80+80 MHz noncontiguous transmissions.

Table 26-42—Allowed relative constellation error versus constellation size and coding rate

Modulation		Coding rate	Relative constellation error in an HE SU PPDU, HE extended rate SU PPDU and HE MU PPDU without preamble puncturing (dB)	Relative constellation error in HE MU PPDU with preamble puncturing and HE trigger-based PPDU (dB)
Without DCM	With DCM			
N/A	BPSK	1/2	−5	TBD
BPSK	QPSK	1/2	−5	TBD
QPSK	16-QAM	1/2	−10	TBD
QPSK	16-QAM	3/4	−13	TBD
16-QAM	N/A	1/2	−16	TBD
16-QAM	N/A	3/4	−19	TBD
64-QAM	N/A	2/3	−22	TBD
64-QAM	N/A	3/4	−25	TBD
64-QAM	N/A	5/6	−27	TBD
256-QAM	N/A	3/4	−30	TBD
256-QAM	N/A	5/6	−32	TBD
1024-QAM	N/A	3/4	−35	TBD
1024-QAM	N/A	5/6	−35	TBD

26.3.16.4.4 Transmitter modulation accuracy (EVM) test

(#2351) The transmit modulation accuracy test shall be performed by instrumentation capable of converting the transmitted signals into a stream of complex samples at sampling rate greater than or equal to the bandwidth of the signal being transmitted except that for a noncontiguous transmissions each frequency segment may be tested independently.

In this case, transmit modulation accuracy of each segment shall meet the required value in Allowed relative constellation error versus constellation size and coding rate using only the occupied data subcarriers within the corresponding segment.

LO leakage that can potentially show up in center frequency of the HE PPDU tone plan and its ± 3 tone neighbors shall be excluded from the computation of the transmitter modulation accuracy test. The potential LO leakage tones for 20 MHz operating devices are the center of primary 20 MHz of the HE PPDU tone plan and ± 3 tones. The potential LO leakage tones for 40 MHz operating devices are the center of the primary 40 MHz of the PPDU tone plan and ± 3 tones. For 80 MHz capable devices that transmits 20 MHz or 40 MHz PPDU, the potential LO leakage tone exist outside the PPDU bandwidth and should not affect the transmitter modulation accuracy test.

The instrument shall have sufficient accuracy in terms of I/Q branch 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 PPDU shall be detected.
- b) Transition from L-STF to L-LTF shall be detected and fine timing shall be established.
- c) Coarse and fine frequency offsets shall be estimated.
- d) Symbols in a PPDU shall be derotated according to estimated frequency offset. Sampling offset drift shall be also compensated. Note that amplitude drift shall not be compensated by the testing instrument.
- e) For each HE-LTF symbol, transform the symbol into subcarrier received values, estimate the phase from the pilot subcarriers, and derotate the subcarrier values according to the estimated phase.
- f) Estimate the complex channel response coefficient for each of the subcarriers and each of the transmit streams.
- g) For each of the data OFDM symbols: transform the symbol into subcarrier received values, estimate the phase from the pilot subcarriers, and compensate the subcarrier values according to the estimated phase, group the results from all of the receiver chains in each subcarrier to a vector, and multiply the vector by a zero-forcing equalization matrix generated from the estimated channel.
- h) For each data-carrying subcarrier in each spatial stream of RU under test, find the closest constellation point and compute the Euclidean distance from it.

(26-125) Compute the average across PPDU's of the RMS of all errors per PPDU as given by

i) .

(26-125)

$Error_{RMS} =$

$$\frac{1}{N_f} \sum_{i_f=1}^{N_f} \sqrt{\frac{\sum_{i_s=1}^{N_{SS}} \sum_{i_{sc}=1}^{N_{ST}} (I_e(i_f, i_s, i_{ss}, i_{sc}) - I_0(i_f, i_s, i_{ss}, i_{sc}))^2 + (Q_e(i_f, i_s, i_{ss}, i_{sc}) - Q_0(i_f, i_s, i_{ss}, i_{sc}))^2}{N_{SYM} N_{SS} N_{ST} P_0}}$$

where

$I_0(i_f, i_s, i_{ss}, i_{sc})$ $Q_0(i_f, i_s, i_{ss}, i_{sc})$ denotes the ideal symbol point in the complex plane in i_{sc} -th data tone of the RU under test, spatial stream i_{ss} , and the OFDM symbol of frame i_f .

$I_e(i_f, i_s, i_{ss}, i_{sc})$ $Q_e(i_f, i_s, i_{ss}, i_{sc})$ denotes the equalized observed symbol point in the complex plane of the i_{sc} -th data tone of the RU under test, spatial stream i_{ss} , and the OFDM symbol of frame i_f .

P_0 is the average power of constellation

N_f is the number of tested frames

N_{ST} is the number of data tones of the occupied RU

N_{SS} is the number of spatial streams of the data

N_{SYM} is the number of data OFDM symbols

NOTE 1—In the case the transmit modulation accuracy test is performed simultaneously for the two frequency segments of the 80+80 MHz transmissions with 2x996-subcarrier RU.

(26-125)The test shall be performed over at least 20 PPDU's (N_f as defined in

). The PPDU's under test shall be at least 16 data OFDM symbols long. Random data shall be used for the symbols.

For an HE trigger-based PPDU and a preamble-punctured HE MU PPDU, additional transmit modulation accuracy test for the unoccupied subcarriers of the PPDU shall be performed. The transmit modulation accuracy of unoccupied subcarriers of the PPDU test shall be performed by instrumentation capable of converting the transmitted signals into a stream of complex samples at sampling rate greater than or equal to the bandwidth of the signal being transmitted except that for noncontiguous transmissions, only the frequency segment with occupied subcarriers is tested. The transmit modulation accuracy of maximum average unoccupied subcarriers error of the PPDU shall meet relative constellation error minus TBD margin in dB scale for each modulation and code rates using the unoccupied subcarriers within the corresponding segment.

The instrument shall have sufficient accuracy in terms of I/Q branch 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:

- Start of PPDU shall be detected.
- Transition from L-STF to L-LTF shall be detected and fine timing shall be established.
- Coarse and fine frequency offsets shall be estimated.
- Symbols in a PPDU shall be derotated according to estimated frequency offset. Sampling offset drift shall be also compensated. Note that amplitude drift shall not be compensated by the testing instrument.

- e) For each of the data OFDM symbols: transform the symbol into subcarrier received values, estimate the power of each subcarriers.

(26-126) Compute the average un-occupied subcarrier error vector magnitude for each PPDU over 26 subcarriers and average across PPDU's of the RMS of all errors per PPDU as given by

f) .

(26-126)

(26-127) $UnusedToneError_{RMS}(k) = TBD$ Compute the maximum average unoccupied subcarrier error vector magnitude as given by

g) .

(26-127)

(26-125) $UnusedToneError_{MAX-RMS} = \max_{\forall k}(UnusedToneError_{RMS}(k))$ The test shall be performed over at least 20 PPDU's (N_f as defined in

). The PPDU's under test shall be at least 16 data OFDM symbols long. The unequalized observed symbol of potential LO leakage subcarrier locations shall be treated as zero during un-occupied subcarriers transmit modulation accuracy test. Random data shall be used for the symbols.

26.3.16.5 Time of Departure accuracy

(#2351) The Time of Departure accuracy test evaluates `TIME_OF_DEPARTURE` against `aTxPHYTxStartRMS` and `aTxPHYTxStartRMS` against `TIME_OF_DEPARTURE_ACCURACY_TEST_THRESH` as defined in Annex P with the following test parameters:

— `MULTICHANNEL_SAMPLING_RATE` is:

$20 \times 10^6 \left(1 + \left\lceil \frac{f_H - f_L}{20 \text{ MHz}} \right\rceil \right)$ sample/s, for a `CH_BANDWIDTH` parameter equal to CBW20

$40 \times 10^6 \left(1 + \left\lceil \frac{f_H - f_L}{40 \text{ MHz}} \right\rceil \right)$ sample/s, for a `CH_BANDWIDTH` parameter equal to CBW40

$80 \times 10^6 \left(1 + \left\lceil \frac{f_H - f_L}{80 \text{ MHz}} \right\rceil \right)$ sample/s, for a `CH_BANDWIDTH` parameter equal to CBW80

$160 \times 10^6 \left(1 + \left\lceil \frac{f_H - f_L}{160 \text{ MHz}} \right\rceil \right)$ sample/s, for a `CH_BANDWIDTH` parameter equal to CBW160 or CBW80+80

where

f_H is the nominal center frequency in Hz of the highest channel in the channel set

26.3.17 HE transmit procedure

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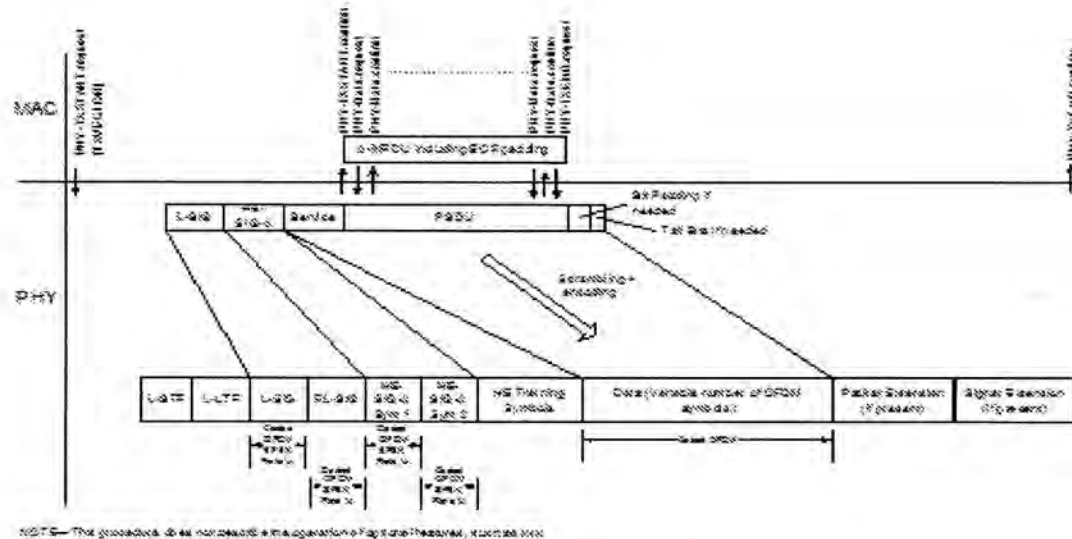


Figure 26-43—PHY transmit procedure for an HE trigger-based PPDU

The fifth option is to follow the transmit procedure in Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) if the FORMAT parameter of the PHYTXSTART.request(TXVECTOR) primitive is NON_HT and the NON_HT_MODULATION parameter is set to NON_HT_DUP_OFDM except that the signal referred to in Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) is instead generated simultaneously on each of the 20 MHz channels that are indicated by the CH_BANDWIDTH parameter as defined in HE preamble and Non-HT duplicate transmission.

NOTE 1—For an HE MU PPDU the A-MPDU is per user in the MAC sublayer and the HE Training Symbols, and Data are per user in the PHY in PHY transmit procedure for an HE MU PPDU, with the number HE Training Symbols depending on the maximum total number of space-time streams across all RUs.

NOTE 2—The transmit procedure for NON_HT, HT_MF, HT_GF, and VHT format are specified in 26.2.x (Support for NON-HT, HT, and VHT formats).

In all options, in order to transmit data, the MAC generates a PHY-TXSTART.request primitive, which causes the PHY entity to enter the transmit state. Further, the PHY is set to operate at the appropriate frequency through station management via the PLME, as specified in 26.4 (HE PLME). Other transmit parameters, such as HE-MCS Coding types and transmit power, are set via the PHY-SAP using the PHYTXSTART.request(TXVECTOR) primitive, as described in TXVECTOR and RXVECTOR parameters. The remainder of the clause applies to the first four options.

The PHY indicates the state of the primary channel and other channels (if any) via the PHY-CCA.indication primitive (see 22.3.18.5 (CCA sensitivity) and 7.3.5.12 (PHY-CCA.indication)).

Transmission of the PPDU shall be initiated by the PHY after receiving the PHY-TXSTART.request(TXVECTOR) primitive. The TXVECTOR elements for the PHY-TXSTART.request primitive are specified in TXVECTOR and RXVECTOR parameters.

Transmission of the PHY preamble may start if TIME_OF_DEPARTURE_REQUESTED is false, and shall start immediately if TIME_OF_DEPARTURE_REQUESTED is true, based on the parameters passed in the PHY-TXSTART.request primitive.

If all of the following conditions are met:

- if dot11TODImplemented and dot11TODActivated are true or if dot11TimingMsmtActivated is true,
- the TXVECTOR parameter TIME_OF_DEPARTURE_REQUESTED is true,

then the PHY shall issue a PHY-TXSTART.confirm(TXSTATUS) primitive to the MAC, forwarding the TIME_OF_DEPARTURE corresponding to the time when the first frame energy is sent by the transmitting port and TIME_OF_DEPARTURE_ClockRate parameter within the TXSTATUS vector. If dot11TimingMsmtActivated is true, then the PHY shall forward the value of TX_START_OF_FRAME_OFFSET in TXSTATUS vector.

After the PHY preamble transmission is started, the PHY entity immediately initiates data scrambling and data encoding. The encoding method for the Data field is based on the FEC_CODING, CH_BANDWIDTH, NUM_STS, STBC, MCS, and NUM_USERS parameter of the TXVECTOR, as described in HE PPDU formats.

The SERVICE field and PSDU are encoded as described in Transmitter block diagram. The data shall 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. PHY padding bits are appended to the PSDU to make the number of bits in the coded PSDU an integral multiple of the number of coded bits per OFDM symbol.

Transmission can be prematurely terminated by the MAC through the PHY-TXEND.request primitive. PSDU transmission is terminated by receiving a PHY-TXEND.request primitive. Each PHY-TXEND.request primitive is acknowledged with a PHY-TXEND.confirm primitive from the PHY.

A packet extension and/or a signal extension may be present in the PPDU. When no packet extension and signal extension are present, the PHY-TXEND.confirm primitive is generated at the end of last symbol of the PPDU. When a packet extension and/or a signal extension present, the PHY-TXEND.confirm primitive is generated at the end of the packet extension or signal extension.

In the PHY, the GI with GI duration indicated in GI_TYPE parameter of the TXVECTOR is inserted in every data OFDM symbol as a countermeasure against delay spread.

When the PPDU transmission is completed the PHY entity enters the receive state.

A typical state machine implementation of the transmit PHY for an HE PPDU transmission is provided in PHY transmit state machine for an HE PPDU. Request (.request) and confirmation(.confirm) primitives are issued once per state as shown. This state machine does not describe the operation of optional features, such as DCM.



for an HE SU PPDU, PHY
for an HE MU PPDU, and
a typical state machine
receive procedure and state
detected format indicates a
7 (Orthogonal frequency

division multiplexing (OFDM) PHY specification). If the detected format indicates an HT PPDU format, refer to the receive procedure and state machine in Clause 19 (High Throughput (HT) PHY specification). If the detected format indicates a VHT PPDU format, refer to the receive procedure and state machine in Clause 21 (Very High Throughput (VHT) PHY specification). Through station management (via the PLME) the PHY is set to the appropriate frequency, as specified in HE PLME. The PHY has also been configured with cell identification information and STA identification information (i.e., BSS Color value and STA ID in the cell) so that it can receive data intended for the STA in the specific cell. Other receive parameters, such as RSSI and indicated DATARATE, may be accessed via the PHY-SAP.

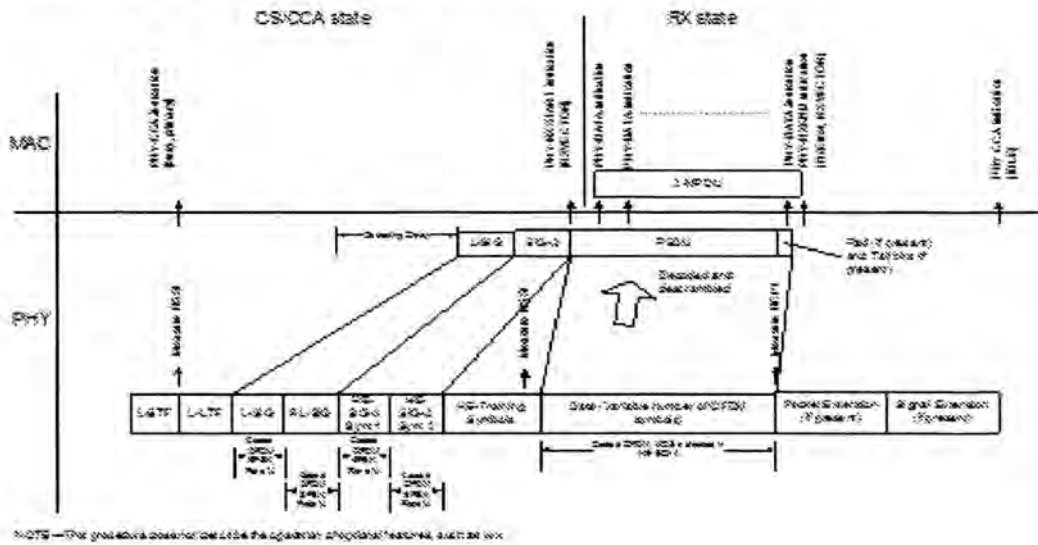


Figure 26-45—PHY receive procedure for an HE SU PPDU

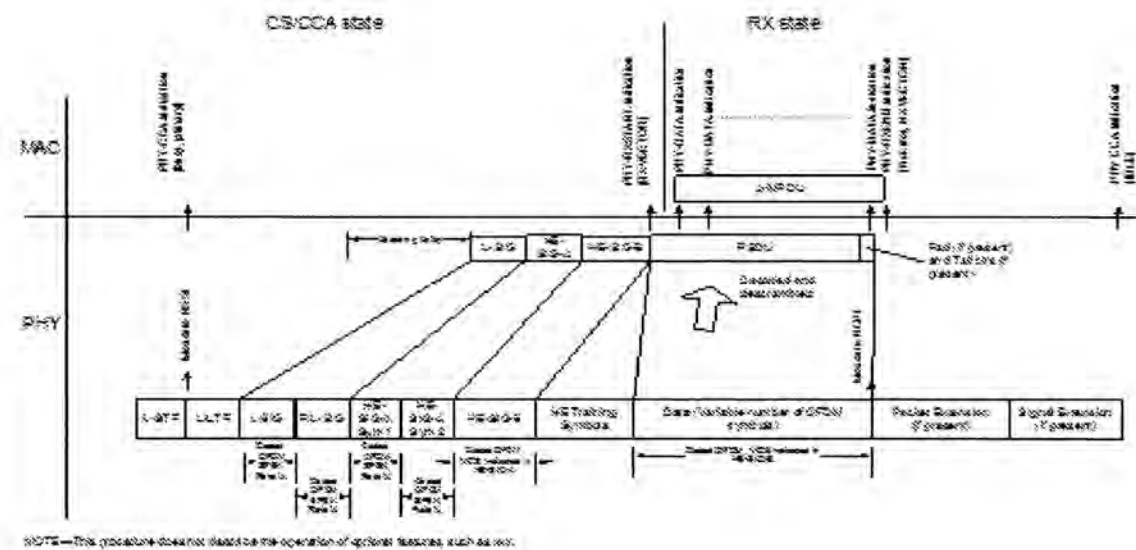
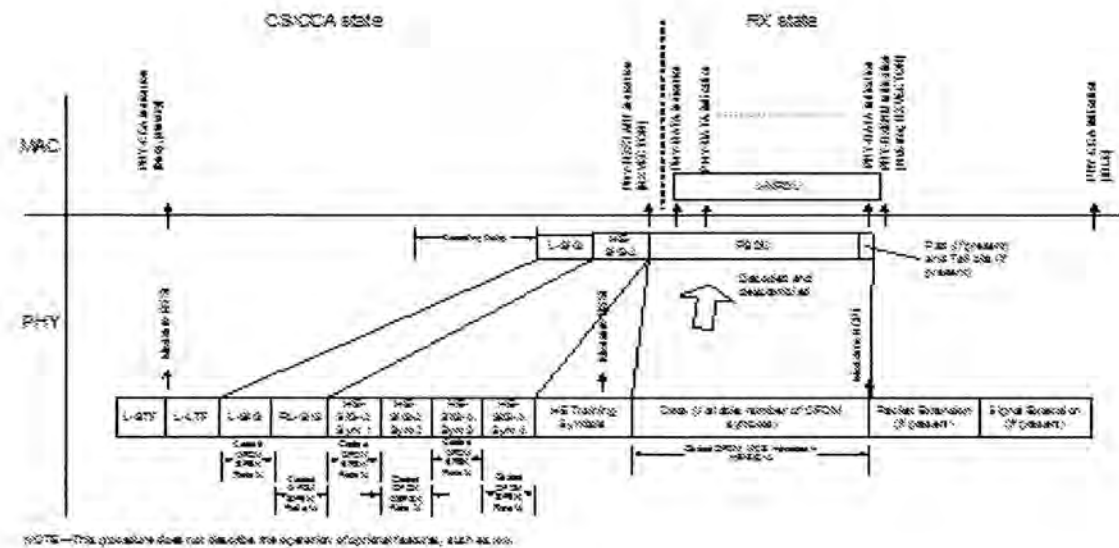


Figure 26-47—PHY receive procedure for an HE MU PPDU

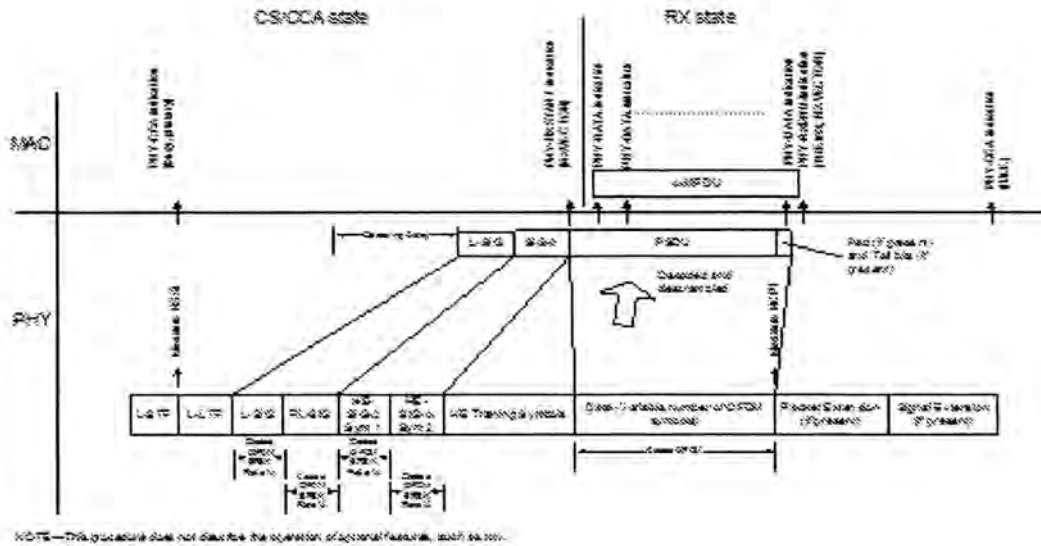


Figure 26-48—PHY receive procedure for an HE trigger-based PPDU

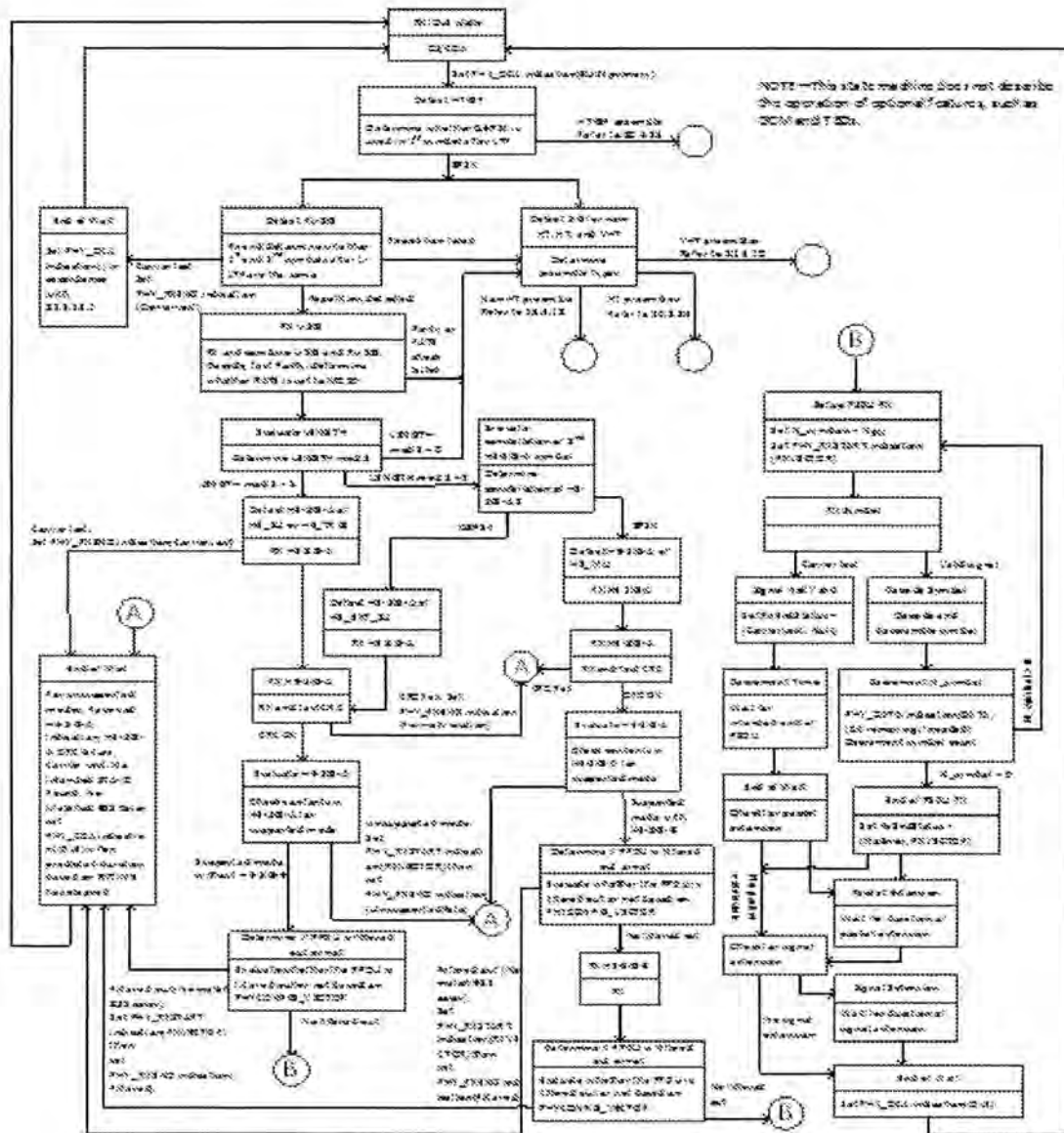


Figure 26-49—PHY receive state machine

Upon receiving the transmitted PHY preamble overlapping the primary 20 MHz channel in a greater than or equal to 20 MHz BSS, the PHY measures a receive signal strength. This activity is indicated by the PHY to the MAC via a PHY-CCA.indication primitive. A PHY-CCA.indication(BUSY, channel-list) primitive is also issued as an initial indication of reception of a signal as specified in 22.3.18.5 (CCA sensitivity). The channel-list parameter of the PHYCCA.indication primitive is absent when the operating channel width is 20 MHz. The channel-list parameter is present and includes the element primary when the operating channel width is 40 MHz, 80 MHz, 160 MHz, or 80+80 MHz.

The PHY shall not issue a PHY-RXSTART.indication primitive in response to a PPDU that does not overlap the primary channel, except when the PHY at an AP receives the HE-trigger based PPDU. In such case, the PHY shall issue a PHY-RXSTART.indication primitive in response to a PPDU transmission either at the primary or at the secondary channel.

The PHY includes the most recently measured RSSI value in the PHY-RXSTART.indication(RXVECTOR) primitive issued to the MAC.(PHY Motion #173)

After the PHY-CCA.indication(BUSY, channel-list) primitive is issued, the PHY entity shall begin receiving the training symbols and searching for the preambles for NON-HT, HT, VHT, and HE PPDU, respectively. If the constellation used in the first symbol after the first long training field is QPSK, the PHY entity shall continue to detect the received signal using the receive procedure for HT-GF depicted in Clause 19. Otherwise, for detecting the HE preamble, the PHY entity shall search for L-SIG and RL-SIG in order to set the maximum duration of the data stream. If RL-SIG is detected, the PHY entity should check the parity bit and RATE fields in L-SIG and RL-SIG. If either the check of the parity bit is invalid or the RATE field is not set to MCS0 in NON-HT, a PHY-RXSTART.indication primitive is not issued. If the check of the parity bit is valid and the RATE field is set to MCS0 but the LENGTH field value in L-SIG is a multiple of 3, a PHY-RXSTART.indication primitive is not issued. In both cases, the PHY should continue to detect the received signal using non-HT, HT, and VHT receive procedure in Clauses 17, 19, and 21, respectively.

If a valid parity bit and the RATE with MCS0 are indicated in L-SIG and RL-SIG and the LENGTH field value in L-SIG and RL-SIG meet the condition that the remainder is 1 after LENGTH divided by 3, the PHY entity should begin receiving the sequence of HE-SIG-A, HE-STF, and HE-LTF for HE SU PPDU and HE trigger-based PPDU as shown in PHY receive procedure for an HE SU PPDU and PHY receive procedure for an HE trigger-based PPDU, respectively. After RL-SIG, the PHY entity shall receive two symbols of HE-SIG-A immediately followed by HE-STF. The PHY entity shall check CRC of HE-SIG-A. If the CRC check is valid, the PHY entity shall report TXOP, BSS Color and check Format field, and continue to receive HE-STF. The PHY entity shall report to the MAC entity the predicted duration of the TXOP in HE-SIG-A. The PHY entity shall check the BSS color in HE-SIG-A. If the BSS color doesn't contain an intended value, the PHY entity shall set PHY_RXSTART.indication(RXVECTOR) then set PHY_RXEND.indication(Filtered). The PHY entity shall check Format field in HE-SIG-A. If the Format field indicates an HE SU PPDU, the PHY entity shall receive HE-STF for 4 μ s after HE-SIG-A. If the Format field indicates an HE trigger-based PPDU, the PHY entity shall receive HE-STF for 8 μ s after HE-SIG-A. The PHY entity shall maintain PHY-CCA.indication(BUSY, channel-list) primitive for the predicted duration of the transmitted PPDU, as defined by RXTIME in Equation (21-106), for all supported modes, unsupported modes, Reserved HE-SIG-A Indication, and invalid HE-SIG-A CRC. Reserved HE-SIG-A Indication is defined as an HE-SIG-A with Reserved bits equal to 0(PHY Motion #169). If the HE-SIG-A indicates an unsupported mode, the PHY shall issue a PHY-RXEND.indication(UnsupportedRate)primitive. If the HE-SIG-A indicates an invalid CRC or Reserved HE-SIG-A Indication, the PHY shall issue the error condition PHY-RXEND.indication(FormatViolation)primitive.

If a valid parity bit of L-SIG and RL-SIG is indicated and the LENGTH field value in L-SIG and RL-SIG meet the condition that the remainder is 2 after LENGTH divided by 3, the PHY entity should detect the signal constellations in the second symbol after RL-SIG. If the constellation is QPSK, the PHY entity

shall continue receiving the sequence of HE-SIG-A, HE-STF, and HE-LTF for HE_EXT_SU PPDU shown in Figure 26-42. After RL-SIG, the PHY entity shall receive four symbols of HE-SIG-A immediately followed by HE-STF. The PHY entity shall check CRC of HE-SIG-A. If the CRC check is valid, the PHY entity shall report TXOP, BSS Color, and continue to receive HE-STF. The PHY entity shall report to the MAC entity the predicted duration of the TXOP in HE-SIG-A. The PHY entity shall check the BSS color in HE-SIG-A. If the BSS color doesn't contain an intended value, the PHY entity shall set PHY_RXSTART.indication(RXVECTOR) then set PHY_RXEND.indication(Filtered). The PHY entity shall receive HE-STF for 4 μ s after HE-SIG-A. The PHY entity shall maintain PHY-CCA.indication(BUSY, channellist) primitive for the predicted duration of the transmitted PPDU, as defined by RXTIME in Equation (21-106), for all supported modes, unsupported modes, Reserved HE-SIG-A Indication, and invalid HE-SIG-A CRC. Reserved HE-SIG-A Indication is defined as an HE-SIG-A with Reserved bits equal to 0(PHY Motion #169). If the HE-SIG-A indicates an unsupported mode, the PHY shall issue a PHY-RXEND.indication(UnsupportedRate)primitive. If the HE-SIG-A indicates an invalid CRC or Reserved HE-SIG-A Indication, the PHY shall issue the error condition PHY-RXEND.indication(FormatViolation)primitive.

(26-128) If a valid parity bit of L-SIG and RL-SIG is indicated and the LENGTH field value in L-SIG and RL-SIG meet the condition that the remainder is 2 after LENGTH divided by 3, the PHY entity should detect the signal constellations in the second symbol after RL-SIG. If the constellation is BPSK, the PHY entity shall continue receiving the sequence of HE-SIG-A, HE-SIG-B, HE-STF, and HE-LTF for HE_MU PPDU shown in Figure 26-43. After RL-SIG, the PHY entity shall receive two symbols of HE-SIG-A immediately followed by HE-SIG-B. The PHY entity shall check CRC of HE-SIG-A. If the CRC check is valid, the PHY entity shall report TXOP, BSS Color, and continue to receive HE-SIG-B. The PHY entity shall report to the MAC entity the predicted duration of the TXOP in HE-SIG-A. The PHY entity shall check the BSS color in HE-SIG-A. If the BSS color doesn't contain an intended value, the PHY entity shall set PHY_RXSTART.indication(RXVECTOR) then set PHY_RXEND.indication(Filtered). After HE-SIG-A, the PHY entity shall receive HE-SIG-B for the number of symbols predicted from HE-SIG-A. If the common field presents in HE-SIG-B, the PHY entity shall check the CRC of the common field. If the CRC in the common field is valid or the common field is not present, the PHY entity shall search for intended STA-ID in each user-specific subfield with a valid CRC. If no CRC is valid or no intended STA-ID is detected, the PHY entity shall set PHY_RXSTART.indication(RXVECTOR) then set PHY_RXEND.indication(Filtered). If a complete allocation of an intended STA-ID is detected in block with valid CRC, the PHY entity shall continue receiving HE-STF for 4 μ s after HE-SIG-B for the detected and intended STA. The PHY entity shall maintain PHY-CCA.indication(BUSY, channellist) primitive for the predicted duration of the transmitted PPDU, as defined by RXTIME in

, for all supported modes, unsupported modes, Reserved HE-SIG-A Indication, and invalid HE-SIG-A CRC. Reserved HE-SIG-A Indication is defined as an HE-SIG-A with Reserved bits equal to 0(PHY Motion #169). If the HE-SIG-A indicates an unsupported mode, the PHY shall issue a PHY-RXEND.indication(UnsupportedRate)primitive. If the HE-SIG-A indicates an invalid CRC or Reserved HE-SIG-A Indication, the PHY shall issue the error condition PHY-RXEND.indication(FormatViolation)primitive.

(26-128) If signal loss occurs during reception prior to completion of the PSDU reception, the error condition PHYRXEND.indication(CarrierLost) shall be reported to the MAC. After waiting for the end of the PPDU as determined by

the PHY shall set the PHY-CCA.indication (IDLE) primitive and return to the RX IDLE state.

(26-128)

$$\text{RXTIME}_{\mu\text{s}} = \left\lceil \frac{\text{L_LENGTH} + 3}{3} \right\rceil 4 + 20 + \text{Signal Extension}$$
 Signal Extension is 0 μs when TXVECTOR parameter NO_SIG_EXTN is true and is aSignalExtension as defined in Table xxx of HE PHY when TXVECTOR parameter NO_SIG_EXTN is false.

(26-119) Except in an HE NDP PPDU, a Data field follows the HE-STF and HE-LTF fields. The number of symbols in the Data field and the packet extension duration are computed from

(26-120) and

, respectively. (#2105)

The received PSDU bits are assembled into octets, decoded, and present 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 discarded. After the reception of the final bit of the last PSDU octet, and possible padding and tail bits, the PHY entity shall check whether packet extension and/or signal extension is applied. If packet extension and/or signal extension is applied, the PHY entity shall wait until the packet extension and/or signal extension expires before returning to the RX IDLE state, as shown in PHY receive state machine.

The receiving procedures are subject to further changes depending on the decisions of spatial reuse and 20 MHz only devices.

26.4 HE PLME

26.4.1 PLME_SAP sublayer management primitives

Table 25-1 (HE PHY MIB attributes (11ax)) lists the MIB attributes that may be accessed by the PHY entities and the intralayer of higher level LMEs. These attributes are accessed via the PLME-GET, PLME-SET, PLME-RESET, and PLME-CHARACTERISTICS primitives defined in 6.5 (PLME SAP interface). (PHY Motion #173)

26.4.2 TXTIME and PSDU_LENGTH calculation

(26-129) The value of the TXTIME parameter returned by the PLME-TXTIME.confirm primitive shall be calculated for an (#2829) HE PPDU using

(26-130) for an HE SU PPDU and HE trigger-based PPDU,

(26-131) for an HE MU PPDU and

for an HE extended range SU PPDU.

(26-129)

$$(26-130) \text{TXTIME} = T_{\text{LEG_PREAMBLE}} + T_{\text{L-SIG}} + T_{\text{RL-SIG}} + T_{\text{HE-SIG-A}} + T_{\text{HE_PREAMBLE}} + N_{\text{SYM}} T_{\text{SYM}} + T_{\text{PE}}$$

$$(26-131) \text{TXTIME} = T_{\text{LEG_PREAMBLE}} + T_{\text{L-SIG}} + T_{\text{RL-SIG}} + T_{\text{HE-SIG-A}} + N_{\text{HE-SIG-B}} T_{\text{HE-SIG-B}} + T_{\text{HE_PREAMBLE}} + N_{\text{SYM}} T_{\text{SYM}} + T_{\text{PE}}$$

$$\text{TXTIME} = T_{\text{LEG_PREAMBLE}} + T_{\text{L-SIG}} + T_{\text{RL-SIG}} + T_{\text{HE-SIG-A}} + T_{\text{HE_PREAMBLE}} + N_{\text{SYM}} T_{\text{SYM}} + T_{\text{PE}} \text{ where}$$

$$T_{\text{LEG_PREAMBLE}} = T_{\text{L-STF}} + T_{\text{L-LTF}}$$

$$T_{\text{HE_PREAMBLE}} = \begin{cases} T_{\text{HE-STF-T}} + N_{\text{HE-LTF}} T_{\text{HE-LTF-SYM}} & \text{for an HE trigger-based PPDU} \\ T_{\text{HE-STF-NT}} + N_{\text{HE-LTF}} T_{\text{HE-LTF-SYM}} & \text{otherwise} \end{cases}$$

$T_{\text{L-STF}}$, $T_{\text{L-LTF}}$, $T_{\text{HE-STF-T}}$, $T_{\text{HE-STF-NT}}$, $T_{\text{HE-LTF-SYM}}$, $T_{\text{L-SIG}}$, $T_{\text{RL-SIG}}$, $T_{\text{HE-SIG-A}}$, $T_{\text{HE-SIG-A-R}}$, $T_{\text{HE-SIG-B}}$, and T_{SYM} are defined in Timing-related constants.

$N_{\text{HE-SIG-B}}$ and $N_{\text{HE-LTF}}$ are defined in Frequently used parameters

For an HE NDP PPDU, there is no Data field and $N_{\text{SYM}} = 0$.

For an HE SU PPDU and HE extended range SU PPDU using BCC encoding, the total number of OFDM symbols in the Data field is given by $N(\#2108)$.

For an HE SU PPDU and HE extended range SU PPDU using LDPC encoding, the total number of OFDM symbols in the Data field, N_{SYM} , is given in LDPC coding.

For an HE MU PPDU (including both MU-MIMO and OFDMA), the total number of OFDM symbols in the Data field, N_{SYM} , is given in Encoding process for an HE MU PPDU.

For an HE trigger-based PPDU, the total number of OFDM symbols in the Data field, N_{SYM} , is given in Encoding process for an HE trigger-based PPDU.

(26-116) T_{PE} is given by

(26-132) The value of the PSDU_LENGTH parameter returned in the PLME-TXTIME.confirm primitive for an HE SU PPDU and HE extended range SU PPDU is calculated using

(#2521)

(26-132)

$$\text{PSDU_LENGTH} = \left\lfloor \frac{(N_{\text{SYM,init}} - m_{\text{STBC}}) N_{\text{DBPS}} + m_{\text{STBC}} N_{\text{DBPS,Last,init}} - N_{\text{service}} - N_{\text{tail}}}{8} \right\rfloor \text{ where}$$

$$(26-71) N_{\text{SYM,init}} \text{ is given by} \quad N_{\text{SYM,init}} = m_{\text{STBC}} \cdot \left\lceil \frac{8 \cdot \text{APEP_LENGTH} + N_{\text{Tail}} + N_{\text{service}}}{m_{\text{STBC}} N_{\text{DBPS}}} \right\rceil \quad (\#2 \text{ for BCC encoding and by}$$

for LDPC encoding:

m_{STBC} is 2 when STBC is used, and 1 otherwise;
 N_{DBPS} is given in 26.5 (Parameters for HE-MCSs);

(26-62) $N_{DBPS,Last,mu}$ is given by

(26-133) The value of the PSDU_LENGTH parameter for user u returned in the PLME-TXTIME.confirm primitive and in the RXVECTOR for an (#2829) HE MU PPDU is calculated using

(#2521)

(26-133)

$$(26-79) \quad \text{PSDU_LENGTH}_u = \left\lfloor \frac{(N_{SYM,mu} - m_{STBC})N_{DBPS} + m_{STBC}N_{DBPS,Last,mu} - N_{service} - N_{tail}}{8} \right\rfloor N_{ST}$$

(26-79) is given by

(26-80) $N_{DBPS,Last,mu}$ is given by

The value of the PSDU_LENGTH parameter returned in the PLME-TXTIME.confirm primitive for an HE NDP PPDU is 0.

26.4.3 HE PHY

The static HE PHY characteristics, provided through the PLME-CHARACTERISTICS service primitive, shall be as shown in Table 20-25 (HT PHY characteristics) unless otherwise listed in HE PHY characteristics. The definitions for these characteristics are given in 6.5 (PLME SAP interface).

Table 26-43—HE PHY characteristics

Characteristic	Value
aTxPHYDelay	Implementation dependent
aRxPHYDelay	Implementation dependent
aCCAMidTime	25 μ s
aPPDUMaxTime	5.484 ms
aPSDUMaxLength	TBD

26.5 Parameters for HE-MCSs(#552)

The rate-dependent parameters for 26-tone RU, 52-tone RU, 106-tone RU, 242-tone RU and non-OFDMA 20 MHz, 484-tone RU and non-OFDMA 40 MHz, 996-tone RU and non-OFDMA 80 MHz, non-OFDMA 160 MHz and 80+80 MHz $N_{SS} = 1, \dots, 8$ are given in HE-MCSs for optional non-OFDMA 160 MHz and 80+80 MHz, through HE-MCSs for optional non-OFDMA 160 MHz and 80+80 MHz. Support for HE-MCS 8, 9, 10, and 11 (when valid) is optional in all cases. HE-MCS 10 and 11 (1024-QAM) are applicable only to RU sizes equal to or larger than 242 tones.

Dual sub-carrier modulation (DCM) is an optional modulation scheme for any OFDMA and non OFDMA transmissions. DCM is only applied to MCS 0, MCS 1, MCS 3 and MCS 4. DCM is applied only with $N_{SS} = 1$ or $N_{SS} = 2$ (in the case of single user RU in an HE MU PPDU, $N_{SS,ru} = 1$ or $N_{SS,ru} = 2$). (PHY Motion #171) A HE STA shall support single spatial stream HE-MCSs within the range HE-MCS 0 to HE-MCS 7 for all channel widths for which it has indicated support regardless of the Tx or Rx Highest Supported Long GI Data Rate subfield values in the Supported HE-MCS and NSS Set field. When more than one spatial stream is supported, the Tx or Rx Highest Supported Long GI Data Rate subfield values in the Supported HE-MCS and NSS Set field may result in a reduced HE-MCS range (cut-off) for $N_{SS} = 2, \dots, 8$. Support for OFDMA 26-tone RU, 52-tone RU, 106-tone RU, 242-tone RU and 996-tone RU with $N_{SS} = 1$ is mandatory (PHY Motion #173). Support for non-OFDMA 20 MHz, 40 MHz, and 80 MHz with $N_{SS} = 1$ is mandatory. Support for more than one spatial stream is optional in all cases. Support for OFDMA and non-OFDMA 160 MHz and 80+80 MHz with $N_{SS} = 1, \dots, 8$ is optional. (#282)

HE-MCSs for mandatory 26-tone RU, to HE-MCSs for optional non-OFDMA 160 MHz and 80+80 MHz, define HE-MCSs not only for SU transmission but also for user u at r -th RU of an MU transmission. In the case of HE-MCSs for MU transmissions, the parameters, N_{SS} , R , N_{BPSCS} , N_{CBPS} , and N_{DBPS} are replaced with $N_{SS,u}$, R_u , $N_{BPSCS,u}$, $N_{CBPS,u}$, and $N_{DBPS,u}$ respectively (#2522).

In the tables below, the number of streams and RU sizes that DCM is applicable to are TBD.

Table 26-44—HE-MCSs for mandatory 26-tone RU, $N_{SS} = 1$

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
									0.8 μ s GI	1.6 μ s GI	3.2 μ s GI
0	1	BPSK	1/4	1	24	2	24	6	0.4	0.4	0.4
0	0		1/2	1			24	12	0.9	0.8	0.8
1	1	QPSK	1/4	2			48	12	0.9	0.8	0.8
1	0		1/2	2			48	24	1.8	1.7	1.5
2	N/A		3/4	2			48	36	2.6	2.5	2.3
3	1	16-QAM	1/4	4			96	24	1.8	1.7	1.5

3	0		1/2	4			96	48	3.5	3.3	3.0
4	1		3/8	4			96	36	2.6	2.5	2.3
4	0		3/4	4			96	72	5.3	5.0	4.5
5	N/A	64-QAM	2/3	6			144	96	7.1	6.7	6.0
6			3/4	6			144	108	7.9	7.5	6.8
7			5/6	6			144	120	8.8	8.3	7.5
8		256-QAM	3/4	8			192	144	10.6	1.0	9.0
9			5/6	8			192	160	11.8	11.1	10.0

Table 26-45—HE-MCSs for mandatory 26-tone RU, $N_{SS} = 2$

HE-MCS Index	DCM	Modulation	R	N_{BPS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
									0.8 μ s GI	1.6 μ s GI	3.2 μ s GI
0	1	BPSK	1/4	1	24	2	48	12	0.9	0.8	0.8
0	0		1/2	1			48	24	1.8	1.7	1.5
1	1	QPSK	1/4	2			96	24	1.8	1.7	1.5
1	0		1/2	2			96	48	3.5	3.3	3.0
2	N/A		3/4	2			96	72	5.3	5.0	4.5
3	1	16-QAM	1/4	4			192	48	3.5	3.3	3.0
3	0		1/2	4			192	96	7.1	6.7	6.0
4	1		3/8	4			192	72	5.3	5.0	4.5
4	0		3/4	4			192	144	10.6	10.0	9.0

5	N/A	64-QAM	2/3	6			288	192	14.1	13.3	12.0
6			3/4	6			288	216	15.9	15.0	13.5
7			5/6	6			288	240	17.6	16.7	15.0
8		256-QAM	3/4	8			384	288	21.2	20.0	18.0
9			5/6	8			384	320	23.5	22.2	20.0

Table 26-46—HE-MCSs for mandatory 26-tone RU, $N_{ss} = 3$

HE-MCS Index	DCM	Modulation	R	N_{BPS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
									0.8 μ s GI	1.6 μ s GI	3.2 μ s GI
0	1	BPSK	1/4	1	24	2	72	18	1.3	1.3	1.1
0	0		1/2	1			72	36	2.6	2.5	2.3
1	1	QPSK	1/4	2			144	36	2.6	2.5	2.3
1	0		1/2	2			144	72	5.3	5.0	4.5
2	N/A		3/4	2			144	108	7.9	7.5	6.8
3	1	16-QAM	1/4	4			288	72	5.3	5.0	4.5
3	0		1/2	4			288	144	10.6	10.0	9.0
4	1		3/8	4			288	108	7.9	7.5	6.8
4	0		3/4	4			288	216	15.9	15.0	13.5
5	N/A	64-QAM	2/3	6			432	288	21.2	20.0	20.3
6			3/4	6			432	324	23.8	22.5	20.3
7			5/6	6			432	360	26.5	25.0	22.5

8		256-QAM	3/4	8			576	432	31.8	30.0	27.0
9			5/6	8			576	480	35.3	33.3	30.0

Table 26-47—HE-MCSs for mandatory 26-tone RU, $N_{ss} = 4$

HE-MCS Index	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
									0.8 μ s GI	1.6 μ s GI	3.2 μ s GI
0	1	BPSK	1/4	1	24	2	96	24	1.8	1.7	1.5
0	0		1/2	1			96	48	3.5	3.3	3.0
1	1	QPSK	1/4	2			192	48	3.5	3.3	3.0
1	0		1/2	2			192	96	7.1	6.7	6.0
2	N/A		3/4	2			192	144	10.6	10.0	9.0
3	1	16-QAM	1/4	4			384	96	7.1	6.7	6.0
3	0		1/2	4			384	192	14.1	13.3	12.0
4	1		3/8	4			384	144	10.6	10.0	9.0
4	0		3/4	4			384	288	21.2	20.0	18.0
5	N/A	64-QAM	2/3	6			576	384	28.2	26.7	24.0
6			3/4	6			576	432	31.8	30.0	27.0
7			5/6	6			576	480	35.3	33.3	30.0
8		256-QAM	3/4	8			768	576	42.4	40.0	36.0
9			5/6	8			768	640	47.1	44.4	40.0

Table 26-48—HE-MCSs for mandatory 26-tone RU, $N_{ss} = 5$

HE-M CS Index	DCM	Modulat ion	R	N_{BPCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
									0.8 μ s GI	1.6 μ s GI	3.2 μ s GI
0	1	BPSK	1/4	1	24	2	120	30	2.2	2.1	1.9
0	0		1/2	1			120	60	4.4	4.2	3.8
1	1	QPSK	1/4	2			240	60	4.4	4.2	3.8
1	0		1/2	2			240	120	8.8	8.3	7.5
2	N/A		3/4	2			240	180	13.2	12.5	11.3
3	1	16-QAM	1/4	4			480	120	8.8	8.3	7.5
3	0		1/2	4			480	240	17.6	16.7	15.0
4	1		3/8	4			480	180	13.2	12.5	11.3
4	0		3/4	4			480	360	26.5	25.0	22.5
5	N/A	64-QAM	2/3	6			720	480	35.3	33.3	30.0
6			3/4	6			720	540	39.7	37.5	33.8
7			5/6	6			720	600	44.1	41.7	37.5
8		256-QAM	3/4	8			960	720	52.9	50.0	45.0
9			5/6	8			960	800	58.8	55.6	50.0

Table 26-49—HE-MCSs for mandatory 26-tone RU, $N_{SS} = 6$

HE-M CS Index	DCM	Modulat ion	R	N_{BPCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
									0.8 μ s GI	1.6 μ s GI	3.2 μ s GI
0	1	BPSK	1/4	1	24	2	144	36	2.6	2.5	2.3

0	0		1/2	1			144	72	5.3	5.0	4.5
1	1	QPSK	1/4	2			288	72	5.3	5.0	4.5
1	0		1/2	2			288	144	10.6	10.0	9.0
2	N/A		3/4	2			288	216	15.9	15.0	13.5
3	1	16-QAM	1/4	4			576	144	10.6	10.0	9.0
3	0		1/2	4			576	288	21.2	20.0	18.0
4	1		3/8	4			576	216	15.9	15.0	13.5
4	0		3/4	4			576	432	31.8	30.0	27.0
5	N/A	64-QAM	2/3	6			864	576	42.4	40.0	36.0
6			3/4	6			864	648	47.6	45.0	40.5
7			5/6	6			864	720	52.9	50.0	45.0
8		256-QAM	3/4	8			1 152	864	63.5	60.0	54.0
9			5/6	8			1 152	960	70.6	66.7	60.0

Table 26-50—HE-MCSs for mandatory 26-tone RU, $N_{ss} = 7$

HE-MCS Index	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
									0.8 μ s GI	1.6 μ s GI	3.2 μ s GI
0	1	BPSK	1/4	1	24	2	168	42	3.1	2.9	2.6
0	0		1/2	1			168	84	6.2	5.8	5.3
1	1	QPSK	1/4	2			336	84	6.2	5.8	5.3
1	0		1/2	2			336	168	12.4	11.7	10.5

2	N/A		3/4	2			336	252	18.5	17.5	15.8
3	1	16-QAM	1/4	4			672	168	12.4	11.7	10.5
3	0		1/2	4			672	336	24.7	23.3	21.0
4	1		3/8	4			672	252	18.5	17.5	15.8
4	0		3/4	4			672	504	37.1	35.0	31.5
5	N/A	64-QAM	2/3	6			1 008	672	49.4	46.7	42.0
6			3/4	6			1 008	756	55.6	52.5	47.3
7			5/6	6			1 008	840	61.8	58.3	52.5
8		256-QAM	3/4	8			1 344	1 008	74.1	70.0	63.0
9			5/6	8			1 344	1 120	82.4	77.8	70.0

Table 26-51—HE-MCSs for mandatory 26-tone RU, $N_{ss} = 8$

HE-MCS Index	DCM	Modulation	R	N_{BPS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
									0.8 μ s GI	1.6 μ s GI	3.2 μ s GI
0	1	BPSK	1/4	1	24	2	192	48	3.5	3.3	3.0
0	0		1/2	1			192	96	7.1	6.7	6.0
1	1	QPSK	1/4	2			384	96	7.1	6.7	6.0
1	0		1/2	2			384	192	14.1	13.3	12.0
2	N/A		3/4	2			384	288	21.2	20.0	18.0
3	1	16-QAM	1/4	4			768	192	14.1	13.3	12.0
3	0		1/2	4			768	384	28.2	26.7	24.0

4	1		3/8	4			768	288	21.2	20.0	18.0
4	0		3/4	4			768	576	42.4	40.0	36.0
5	N/A	64-QAM	2/3	6			1 152	768	56.5	53.3	48.0
6			3/4	6			1 152	864	63.5	60.0	54.0
7			5/6	6			1 152	960	70.6	66.7	60.0
8		256-QAM	3/4	8			1 536	1 152	84.7	80.0	72.0
9			5/6	8			1 536	1 280	94.1	88.9	80.0

Table 26-52—HE-MCSs for mandatory 52-tone RU, $N_{ss} = 1$

HE-MCS Index	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
									0.8 μ s GI	1.6 μ s GI	3.2 μ s GI
0	1	BPSK	1/4	1	48	4	48	12	0.9	0.8	0.8
0	0		1/2	1			48	24	1.8	1.7	1.5
1	1	QPSK	1/4	2			96	24	1.8	1.7	1.5
1	0		1/2	2			96	48	3.5	3.3	3.0
2	N/A		3/4	2			96	72	5.3	5.0	4.5
3	1	16-QAM	1/4	4			192	48	3.5	3.3	3.0
3	0		1/2	4			192	96	7.1	6.7	6.0
4	1		3/8	4			192	72	5.3	5.0	4.5
4	0		3/4	4			192	144	10.6	10.0	9.0
5	N/A	64-QAM	2/3	6			288	192	14.1	13.3	12.0

6			3/4	6			288	216	15.9	15.0	13.5
7			5/6	6			288	240	17.6	16.7	15.0
8		256-QAM	3/4	8			384	288	21.2	20.0	18.0
9			5/6	8			384	320	23.5	22.2	20.0

Table 26-53—HE-MCSs for mandatory 52-tone RU, $N_{ss} = 2$

HE-MCS Index	DCM	Modulation	R	N_{BPS}	N_{SD}	N_{SP}	N_{CBPS}	N_{OBPS}	Data rate (Mbps)		
									0.8 μ s GI	1.6 μ s GI	3.2 μ s GI
0	1	BPSK	1/4	1	48	4	96	24	1.8	1.7	1.5
0	0		1/2	1			96	48	3.5	3.3	3.0
1	1	QPSK	1/4	2			192	48	3.5	3.3	3.0
1	0		1/2	2			192	96	7.1	6.7	6.0
2	N/A		3/4	2			192	144	10.6	10.0	9.0
3	1	16-QAM	1/4	4			384	96	7.1	6.7	6.0
3	0		1/2	4			384	192	14.1	13.3	12.0
4	1		3/8	4			384	144	10.6	10.0	9.0
4	0		3/4	4			384	288	21.2	20.0	18.0
5	N/A	64-QAM	2/3	6			576	384	28.2	26.7	24.0
6			3/4	6			576	432	31.8	30.0	27.0
7			5/6	6			576	480	35.3	33.3	30.0
8		256-QAM	3/4	8			768	576	42.4	40.0	36.0

9			5/6	8			768	640	47.1	44.4	40.0
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Table 26-54—HE-MCSs for mandatory 52-tone RU, $N_{SS} = 3$

HE-MCS Index	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
									0.8 μ s GI	1.6 μ s GI	3.2 μ s GI
0	1	BPSK	1/4	1	48	4	144	36	2.6	2.5	2.3
0	0		1/2	1			144	72	5.3	5.0	4.5
1	1	QPSK	1/4	2			288	72	5.3	5.0	4.5
1	0		1/2	2			288	144	10.6	10.0	9.0
2	N/A		3/4	2			288	216	15.9	15.0	13.5
3	1	16-QAM	1/4	4			576	144	10.6	10.0	9.0
3	0		1/2	4			576	288	21.2	20.0	18.0
4	1		3/8	4			576	216	15.9	15.0	13.5
4	0		3/4	4			576	432	31.8	30.0	27.0
5	N/A	64-QAM	2/3	6			864	576	42.4	40.0	36.0
6			3/4	6			864	648	47.6	45.0	40.5
7			5/6	6			864	720	52.9	50.0	45.0
8		256-QAM	3/4	8			1 152	864	63.5	60.0	54.0
9			5/6	8			1 152	960	70.6	66.7	60.0

Table 26-55—HE-MCSs for mandatory 52-tone RU, $N_{SS} = 4$

HE-MCS	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)
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Index									0.8 μs GI	1.6 μs GI	3.2 μs GI
0	1	BPSK	1/4	1	48	4	192	48	3.5	3.3	3.0
0	0		1/2	1			192	96	7.1	6.7	6.0
1	1	QPSK	1/4	2			384	96	7.1	6.7	6.0
1	0		1/2	2			384	192	14.1	13.3	12.0
2	N/A		3/4	2			384	288	21.2	20.0	18.0
3	1	16-QAM	1/4	4			768	192	14.1	13.3	12.0
3	0		1/2	4			768	384	28.2	26.7	24.0
4	1		3/8	4			768	288	21.2	20.0	18.0
4	0		3/4	4			768	576	42.4	40.0	36.0
5	N/A	64-QAM	2/3	6			1 152	768	56.5	53.3	48.0
6			3/4	6			1 152	864	63.5	60.0	54.0
7			5/6	6			1 152	960	70.6	66.7	60.0
8		256-QA M	3/4	8			1 536	1 152	84.7	80.0	72.0
9			5/6	8			1 536	1 280	94.1	88.9	80.0

Table 26-56—HE-MCSs for mandatory 52-tone RU, $N_{SS} = 5$

HE-M CS Index	DCM	Modulat ion	R	N_{RPCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
									0.8 μ s GI	1.6 μ s GI	3.2 μ s GI
0	1	BPSK	1/4	1	48	4	240	60	4.4	4.2	3.8
0	0		1/2	1			240	120	8.8	8.3	7.5

1	1	QPSK	1/4	2			480	120	8.8	8.3	7.5
1	0		1/2	2			480	240	17.6	16.7	15.0
2	N/A		3/4	2			480	360	26.5	25.0	22.5
3	1	16-QAM	1/4	4			960	240	17.6	16.7	15.0
3	0		1/2	4			960	480	35.3	33.3	30.0
4	1		3/8	4			960	360	26.5	25.0	45.0
4	0		3/4	4			960	720	52.9	50.0	45.0
5	N/A	64-QAM	2/3	6			1 440	960	70.6	66.7	60.0
6			3/4	6			1 440	1080	79.4	75.0	67.5
7			5/6	6			1 440	1 200	88.2	83.3	75.0
8		256-QAM	3/4	8			1 920	1 440	105.9	100.0	90.0
9			5/6	8			1 920	1 600	117.6	111.1	100.0

Table 26-57—HE-MCSs for mandatory 52-tone RU, $N_{ss} = 6$

HE-MCS Index	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
									0.8 μ s GI	1.6 μ s GI	3.2 μ s GI
0	1	BPSK	1/4	1	48	4	288	72	5.3	5.0	4.5
0	0		1/2	1			288	144	10.6	10.0	9.0
1	1	QPSK	1/4	2			576	144	10.6	10.0	9.0
1	0		1/2	2			576	288	21.2	20.0	18.0
2	N/A		3/4	2			576	432	31.8	30.0	27.0

3	1	16-QAM	1/4	4			1 152	288	21.2	20.0	18.0
3	0		1/2	4			1 152	576	42.4	40.0	36.0
4	1		3/8	4			1 152	432	31.8	30.0	27.0
4	0		3/4	4			1 152	864	63.5	60.0	54.0
5	N/A	64-QAM	2/3	6			1 728	1 152	84.7	80.0	72.0
6			3/4	6			1 728	1 296	95.3	90.0	81.0
7			5/6	6			1 728	1 440	105.9	100.0	90.0
8		256-QAM	3/4	8			2 304	1 728	127.1	120.0	108.0
9			5/6	8			2 304	1 920	141.2	133.3	120.0

Table 26-58—HE-MCSs for mandatory 52-tone RU, $N_{SS} = 7$

HE-MCS Index	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
									0.8 μ s GI	1.6 μ s GI	3.2 μ s GI
0	1	BPSK	1/4	1	48	4	336	84	6.2	5.8	5.3
0	0		1/2	1			336	168	12.4	11.7	10.5
1	1	QPSK	1/4	2			672	168	12.4	11.7	10.5
1	0		1/2	2			672	336	24.7	23.3	21.0
2	N/A		3/4	2			672	504	37.1	35.0	31.5
3	1	16-QAM	1/4	4			1 344	336	24.7	23.3	21.0
3	0		1/2	4			1 344	672	49.4	46.7	42.0
4	1		3/8	4			1 344	504	37.1	35.0	31.5

4	0		3/4	4			1 344	1 008	74.1	70.0	63.0
5			2/3	6			2 016	1 344	98.8	93.3	84.0
6		64-QAM	3/4	6			2 016	1 512	111.2	105.0	94.5
7	N/A		5/6	6			2 016	1 680	123.5	116.7	105.0
8		256-QAM	3/4	8			2 688	2 016	148.2	140.0	126.0
9			5/6	8			2 688	2 240	164.7	155.6	140.0

Table 26-59—HE-MCSs for mandatory 52-tone RU, $N_{SS} = 8$

HE-MCS Index	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
									0.8 μ s GI	1.6 μ s GI	3.2 μ s GI
0	1	BPSK	1/4	1	48	4	384	96	7.1	6.7	6.0
0	0		1/2	1			384	192	14.1	13.3	12.0
1	1	QPSK	1/4	2			768	192	14.1	13.3	12.0
1	0		1/2	2			768	384	28.2	26.7	24.0
2	N/A		3/4	2			768	576	42.4	40.0	36.0
3	1	16-QAM	1/4	4			1 536	384	28.2	26.7	24.0
3	0		1/2	4			1 536	768	56.5	53.3	48.0
4	1		3/8	4			1 536	576	42.4	40.0	36.0
4	0		3/4	4			1 536	1 152	84.7	80.0	72.0
5		64-QAM	2/3	6			2 304	1 536	112.9	106.7	96.0
6	N/A		3/4	6			2 304	1 728	127.1	120.0	108.0

7			5/6	6			2 304	1 920	141.2	133.3	120.0
8		256-QAM	3/4	8			3 072	2 304	169.4	160.0	144.0
9			5/6	8			3 072	2 560	188.2	177.8	160.0

Table 26-60—HE-MCSs for mandatory 106-tone RU, $N_{SS} = 1$

HE-MCS Index	DCM	Modulation	R	$N_{streams}$	N_{SD}	N_{SP}	N_{QAMs}	N_{QAMs}	N_{SS}	Data rate (Mb/s)		
										0.8 μ sec GI	1.6 μ sec GI	3.2 μ sec GI
0	1	BPSK	1/4	1	102	4	102	25	1	1.8	1.7	1.6
0	0		1/2	1			102	51	1	3.8	3.5	3.2
1	1	QPSK	1/4	2			204	51	1	3.8	3.5	3.2
1	0		1/2	2			204	102	1	7.5	7.1	6.4
2	N/A		3/4	2			204	153	1	11.3	10.6	9.6
3	1	16-QAM	1/4	4			408	102	1	7.5	7.1	6.4
3	0		1/2	4			408	204	1	15.0	14.2	12.8
4	1		3/8	4			408	153	1	11.3	10.6	9.6
4	0		3/4	4			408	306	1	22.5	21.3	19.1
5	N/A	64-QAM	2/5	6			612	408	1	30.0	28.3	25.5
6			3/4	6			612	459	1	33.8	31.9	28.7
7			5/6	6			612	510	1	37.5	35.4	31.9
8		256-QAM	3/4	8			816	612	1	45.0	42.5	38.3
9			5/6	8			816	680	1	50.0	47.2	42.5

Table 26-61—HE-MCSs for mandatory 106-tone RU, $N_{SS} = 2$

HE-MCS Index	DCM	Modulation	R	N_{avgSCS}	N_{SD}	N_{SP}	N_{dataSCS}	N_{dataSCS}	N_{SS}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	102	4	204	51	1	3.8	3.5	3.2
0	0		1/2	1			204	102	1	7.5	7.1	6.4
1	1	QPSK	1/4	2			408	102	1	7.5	7.1	6.4
1	0		1/2	2			408	204	1	15.0	14.2	12.8
2	N/A		3/4	2			408	306	1	22.5	21.3	19.1
3	1	16-QAM	1/4	4			816	204	1	15.0	14.2	12.8
3	0		1/2	4			816	408	1	30.0	28.3	25.5
4	1		3/8	4			816	306	1	22.5	21.3	19.1
4	0		3/4	4			816	612	1	45.0	42.5	38.3
5	N/A	64-QAM	2/3	6			1224	816	1	60.0	56.7	51.0
6			3/4	6			1224	918	1	67.5	63.8	57.4
7			5/6	6			1224	1,020	1	75.0	70.8	63.8
8		256-QAM	3/4	8			1632	1,224	1	90.0	85.0	76.5
9			5/6	8			1632	1,360	1	100.0	94.4	85.0

Table 26-62—HE-MCSs for mandatory 106-tone RU, $N_{SS} = 3$

HE-MCS Index	DCM	Modulation	R	N_{avgSCS}	N_{SD}	N_{SP}	N_{dataSCS}	N_{dataSCS}	N_{SS}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	102	4	306	76	1	5.5	5.3	4.8
0	0		1/2	1			306	153	1	11.3	10.6	9.6
1	1	QPSK	1/4	2			612	153	1	11.3	10.6	9.6
1	0		1/2	2			612	306	1	22.5	21.3	19.1
2	N/A		3/4	2			612	459	1	33.8	31.9	28.7
3	1	16-QAM	1/4	4			1224	306	1	22.5	21.3	19.1
3	0		1/2	4			1224	612	1	45.0	42.5	38.3
4	1		3/8	4			1224	459	1	33.8	31.9	28.7
4	0		3/4	4			1224	918	1	67.5	63.8	57.4
5	N/A	64-QAM	2/3	6			1836	1,224	1	90.0	85.0	76.5
6			3/4	6			1836	1,377	1	101.3	95.6	86.1
7			5/6	6			1836	1,530	1	112.5	106.3	95.6
8		256-QAM	3/4	8			2448	1,836	1	135.0	127.5	114.8
9			5/6	8			2448	2,040	1	150.0	141.7	127.5

Table 26-63—HE-MCSs for mandatory 106-tone RU, $N_{SS} = 4$

HE-MCS Index	DCM	Modulation	R	$N_{\text{SS}}/N_{\text{SCS}}$	N_{SD}	N_{SP}	N_{CBRS}	N_{CBSS}	N_{SS}	Data rate (Mb/s)		
										0.8 μsec GI	1.6 μsec GI	3.2 μsec GI
0	1	BPSK	1/4	1	102	4	408	102	1	7.5	7.1	6.4
0	0		1/2	1			408	204	1	15.0	14.2	12.8
1	1	QPSK	1/4	2			816	204	1	15.0	14.2	12.8
1	0		1/2	2			816	408	1	30.0	28.3	25.5
2	N/A		3/4	2			816	512	1	45.0	42.5	38.3
3	1		1/4	4			1632	408	1	30.0	28.3	25.5
3	0	16-QAM	1/2	4			1632	816	1	60.0	56.7	51.0
4	1		3/8	4			1632	612	1	45.0	42.5	38.3
4	0		3/4	4			1632	1,224	1	90.0	85.0	75.5
5	N/A	64-QAM	2/3	6			2448	1,532	1	120.0	113.3	102.0
6			3/4	6			2448	1,836	1	135.0	127.5	114.8
7			5/6	6			2448	2,040	1	150.0	141.7	127.5
8			3/4	8			3264	2,448	1	180.0	170.0	153.0
9		256-QAM	5/6	8			3264	2,720	1	200.0	188.9	170.0

Table 26-64—HE-MCSs for mandatory 106-tone RU, $N_{\text{SS}} = 5$

HE-MCS Index	DCM	Modulation	R	$N_{\text{SS}}/N_{\text{SCS}}$	N_{SD}	N_{SP}	N_{CBRS}	N_{CBSS}	N_{SS}	Data rate (Mb/s)		
										0.8 μsec GI	1.6 μsec GI	3.2 μsec GI
0	1	BPSK	1/4	1	102	4	510	127	1	9.3	8.8	7.9
0	0		1/2	1			510	255	1	18.8	17.7	15.9
1	1	QPSK	1/4	2			1020	255	1	18.8	17.7	15.9
1	0		1/2	2			1020	510	1	37.5	35.4	31.9
2	N/A		3/4	2			1020	765	1	56.3	53.1	47.8
3	1		1/4	4			2040	510	1	37.5	35.4	31.9
3	0	16-QAM	1/2	4			2040	1,020	1	75.0	70.8	63.8
4	1		3/8	4			2040	765	1	56.3	53.1	47.8
4	0		3/4	4			2040	1,530	1	112.5	106.3	95.6
5	N/A	64-QAM	2/3	6			3060	2,040	1	150.0	141.7	127.5
6			3/4	6			3060	2,295	1	168.8	159.4	143.4
7			5/6	6			3060	2,550	1	187.5	177.1	159.4
8			3/4	8			4080	3,060	1	225.0	212.5	191.3
9		256-QAM	5/6	8			4080	3,400	1	250.0	236.1	212.5

Table 26-65—HE-MCSs for mandatory 106-tone RU, $N_{\text{SS}} = 6$

HE-MCS Index	DCM	Modulation	R	N _{BPSK}	N _{QPSK}	N _{16QAM}	N _{64QAM}	N _{256QAM}	N _{SS}	Data rate (Mb/s)		
										0.8 usec	1.6 usec	3.2 usec
										GI	GI	GI
0	1	BPSK	1/4	1	102	4	512	153	1	11.3	10.6	9.6
0	0		1/2	1			512	306	1	22.5	21.3	19.1
1	1	QPSK	1/4	2			1224	306	1	22.5	21.3	19.1
1	0		1/2	2			1224	612	1	45.0	42.5	38.3
2	N/A		3/4	2			1224	918	1	67.5	63.8	57.4
3	1		1/4	4			2448	612	1	45.0	42.5	38.3
3	0	16-QAM	1/2	4			2448	1,224	1	90.0	85.0	76.5
4	1		3/8	4			2448	918	1	67.5	63.8	57.4
4	0		3/4	4			2448	1,836	1	135.0	127.5	114.8
5	N/A		2/3	6			3672	2,448	1	180.0	170.0	153.0
6		64-QAM	3/4	6			3672	2,754	1	202.5	191.3	172.1
7			5/8	6			3672	3,060	1	225.0	212.5	191.3
8			256-QAM	3/4			8	4896	3,672	1	270.0	255.0
9		5/8		8			4896	4,080	1	300.0	283.5	255.0

Table 26-66—HE-MCSs for mandatory 106-tone RU, $N_{\text{SS}} = 7$

HE-MCS Index	DCM	Modulation	R	N _{BPSK}	N _{QPSK}	N _{16QAM}	N _{64QAM}	N _{256QAM}	N _{SS}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	102	4	714	178	1	13.1	12.4	11.1
0	0		1/2	1			714	357	1	26.3	24.8	22.3
1	1	QPSK	1/4	2			1428	357	1	26.3	24.8	22.3
1	0		1/2	2			1428	714	1	52.5	49.6	44.6
2	N/A		3/4	2			1428	1,071	1	78.8	74.4	66.9
3	1		1/4	4			2856	714	1	52.5	49.6	44.6
3	0	16-QAM	1/2	4			2856	1,428	1	105.0	99.2	89.3
4	1		3/8	4			2856	1,071	1	78.8	74.4	66.9
4	0		3/4	4			2856	2,142	1	157.5	148.8	133.9
5	N/A		64-QAM	2/3			6	4284	2,856	1	210.0	198.3
6		3/4		6			4284	3,213	1	236.3	223.1	200.8
7		5/8		6			4284	3,570	1	262.5	247.9	223.1
8		256-QAM	3/4	8			5712	4,284	1	315.0	297.5	267.8
9			5/8	8			5712	4,760	1	350.0	330.6	297.5

Table 26-67—HE-MCSs for mandatory 106-tone RU, $N_{\text{SS}} = 8$

HE-MCS Index	DCM	Modulation	R	N_{BPSK}	N_{QPSK}	N_{16QAM}	N_{64QAM}	N_{256QAM}	N_{SS}	Data rate (Mb/s)		
										0.8 μsec GI	1.6 μsec GI	3.2 μsec GI
0	1	BPSK	1/4	1	102	4	816	204	1	15.0	14.2	12.8
0	0		1/2	1			816	408	1	30.0	28.3	25.5
1	1	QPSK	1/4	2			1632	408	1	30.0	28.3	25.5
1	0		1/2	2			1632	816	1	60.0	56.7	51.0
2	N/A		3/4	2			1632	1,224	1	90.0	85.0	76.5
3	1		1/4	4			3264	816	1	60.0	56.7	51.0
3	0	16-QAM	1/2	4			3264	1,632	1	120.0	113.3	102.0
4	1		3/8	4			3264	1,224	1	90.0	85.0	76.5
4	0		3/4	4			3264	2,448	1	180.0	170.0	153.0
5	N/A		64-QAM	2/3			6	4896	3,264	1	240.0	226.7
6		3/4		6			4896	3,672	1	270.0	255.0	229.5
7		5/6		6			4896	4,080	1	300.0	283.3	255.0
8		256-QAM	3/4	8			6528	4,896	1	360.0	340.0	306.0
9			5/6	8			6528	5,440	1	400.0	377.8	340.0

Table 26-68—HE-MCSs for mandatory 242-tone RU and mandatory non-OFDMA 20 MHz, $N_{\text{SS}} = 1$

HE-MCS Index	DCM	Modulation	R	N_{BPSK}	N_{QPSK}	N_{16QAM}	N_{64QAM}	N_{256QAM}	N_{SS}	Data rate (Mb/s)		
										0.8 μsec GI	1.6 μsec GI	3.2 μsec GI
0	1	BPSK	1/4	1	234	8	234	58	1	4.3	4.0	3.6
0	0		1/2	1			234	117	1	8.6	8.1	7.3
1	1	QPSK	1/4	2			468	117	1	8.6	8.1	7.3
1	0		1/2	2			468	234	1	17.2	16.3	14.6
2	N/A		3/4	2			468	351	1	25.8	24.4	21.9
3	1		1/4	4			936	234	1	17.2	16.3	14.6
3	0	16-QAM	1/2	4			936	468	1	34.4	32.5	29.3
4	1		3/8	4			936	351	1	25.8	24.4	21.9
4	0		3/4	4			936	702	1	51.6	48.8	43.9
5	N/A		64-QAM	2/3			6	1404	936	1	68.8	65.0
6		3/4		6			1404	1,053	1	77.4	73.1	65.8
7		5/6		6			1404	1,170	1	86.0	81.3	73.1
8		256-QAM	3/4	8			1872	1,404	1	103.2	97.5	87.8
9			5/6	8			1872	1,560	1	114.7	108.3	97.5
10		1024-QAM	3/4	10			2340	1,755	1	129.0	121.9	109.7
11			5/6	10			2340	1,950	1	143.4	135.4	121.9

Table 26-69—HE-MCSs for mandatory 242-tone RU and mandatory non-OFDMA 20 MHz, $N_{\text{SS}} =$

2

HE-MCS Index	DCM	Modulation	R	N_{avgSCS}	N_{ss}	N_{sp}	N_{dataSCS}	N_{dataSCS}	N_{ss}	Data rate (Mb/s)		
										0.8 μsec	1.6 μsec	3.2 μsec
										GI	GI	GI
0	1	BPSK	1/4	1	234	8	468	117	1	8.6	8.1	7.3
0	0		1/2	1			468	234	1	17.2	16.3	14.6
1	1	QPSK	1/4	2			936	234	1	17.2	16.3	14.6
1	0		1/2	2			936	468	1	34.4	32.5	29.3
2	N/A		3/4	2			936	702	1	51.6	48.8	43.9
3	1	16-QAM	1/4	4			1872	468	1	34.4	32.5	29.3
3	0		1/2	4			1872	936	1	68.8	65.0	58.5
4	1		3/8	4			1872	702	1	51.6	48.8	43.9
4	0		3/4	4			1872	1404	1	103.2	97.5	87.8
5	N/A	64-QAM	2/3	6			2808	1872	1	137.6	130.0	117.0
6			3/4	6			2808	2106	1	154.9	146.3	131.6
7			5/6	6			2808	2340	1	172.1	162.5	146.3
8		256-QAM	3/4	8			3744	2808	1	206.5	195.0	175.5
9			5/6	8			3744	3120	1	229.4	216.7	195.0
10		1024-QAM	3/4	10			4680	3510	1	258.1	243.8	219.4
11			5/6	10			4680	3900	1	286.8	270.8	243.8

Table 26-70—HE-MCSs for mandatory 242-tone RU and mandatory non-OFDMA 20 MHz, $N_{\text{ss}} =$

3

HE-MCS Index	DCM	Modulation	R	N_{avgSCS}	N_{ss}	N_{sp}	N_{dataSCS}	N_{dataSCS}	N_{ss}	Data rate (Mb/s)		
										0.8 μsec	1.6 μsec	3.2 μsec
										GI	GI	GI
0	1	BPSK	1/4	1	234	8	702	175	1	12.9	12.2	10.9
0	0		1/2	1			702	351	1	25.8	24.4	21.9
1	1	QPSK	1/4	2			1404	351	1	25.8	24.4	21.9
1	0		1/2	2			1404	702	1	51.6	48.8	43.9
2	N/A		3/4	2			1404	1053	1	77.4	73.1	65.8
3	1	16-QAM	1/4	4			2808	702	1	51.6	48.8	43.9
3	0		1/2	4			2808	1404	1	103.2	97.5	87.8
4	1		3/8	4			2808	1053	1	77.4	73.1	65.8
4	0		3/4	4			2808	2106	1	154.9	146.3	131.6
5	N/A	64-QAM	2/3	6			4212	2808	1	206.5	195.0	175.5
6			3/4	6			4212	3159	1	232.3	219.4	197.4
7			5/6	6			4212	3510	1	258.1	243.8	219.4
8		256-QAM	3/4	8			5616	4212	1	309.7	292.5	263.3
9			5/6	8			5616	4680	1	344.1	325.0	292.5
10		1024-QAM	3/4	10			7020	5265	1	367.1	365.6	329.1
11			5/6	10			7020	5850	1	430.1	406.5	365.6

Table 26-71—HE-MCSs for mandatory 242-tone RU and mandatory non-OFDMA 20 MHz, $N_{SS} = 4$

HE-MCS Index	DCM	Modulation	R	$N_{\text{avg}}/N_{\text{SCS}}$	N_{SD}	N_{SR}	N_{CRSS}	N_{CRPS}	N_{SS}	Data rate {Mb/s}		
										0.8 μsec GI	1.6 μsec GI	3.2 μsec GI
0	1	BPSK	1/4	1	234	8	936	234	1	17.2	15.3	14.6
0	0		1/2	1			936	468	1	34.4	32.5	29.3
1	1	QPSK	1/4	2			1872	468	1	34.4	32.5	29.3
1	0		1/2	2			1872	936	1	68.8	65.0	58.5
2	N/A		3/4	2			1872	1,404	1	103.2	97.5	87.8
3	1	16-QAM	1/4	4			3744	936	1	68.8	65.0	58.5
3	0		1/2	4			3744	1,872	1	137.6	130.0	117.0
4	1		3/8	4			3744	1,404	1	103.2	97.5	87.8
4	0		3/4	4			3744	2,808	1	206.5	195.0	175.5
5	N/A	64-QAM	2/3	6			5616	3,744	1	275.3	260.0	234.0
6			3/4	6			5616	4,212	1	309.7	292.5	263.3
7			5/6	6			5616	4,680	1	344.1	325.0	292.5
8		256-QAM	3/4	8			7488	5,616	1	412.9	390.0	351.0
9			5/6	8			7488	6,240	1	458.8	433.3	390.0
10		1024-QAM	3/4	10			9360	7,020	1	516.2	487.5	438.8
11			5/6	10			9360	7,800	1	573.5	541.7	487.5

Table 26-72—HE-MCSs for mandatory 242-tone RU and mandatory non-OFDMA 20 MHz, $N_{SS} = 5$

HE-MCS Index	DCM	Modulation	R	$N_{\text{SS}}^{\text{MCS}}$	$N_{\text{SC}}^{\text{MCS}}$	$N_{\text{ST}}^{\text{MCS}}$	$N_{\text{Data}}^{\text{MCS}}$	$N_{\text{Pilot}}^{\text{MCS}}$	$N_{\text{Total}}^{\text{MCS}}$	Data rate (Mb/s)		
										0.8 μs GI	1.6 μs GI	3.2 μs GI
0	1	BPSK	1/4	1	234	8	1170	292	1	21.5	20.3	18.3
0	0		1/2	1			1170	585	1	43.0	40.6	36.6
1	1	QPSK	1/4	2			2340	585	1	43.0	40.6	36.6
1	0		1/2	2			2340	1,170	1	86.0	81.3	73.1
2	N/A		3/4	2			2340	1,755	1	129.0	121.9	109.7
3	1	16-QAM	1/4	4			4680	1,170	1	86.0	81.3	73.1
3	0		1/2	4			4680	2,340	1	172.1	162.5	146.3
4	1		3/8	4			4680	1,755	1	129.0	121.9	109.7
4	0		3/4	4			4680	3,510	1	258.1	243.8	219.4
5	N/A	64-QAM	2/3	6			7020	4,680	1	344.1	325.0	292.5
6			3/4	6			7020	5,265	1	387.1	365.6	329.1
7			5/6	6			7020	5,850	1	450.1	406.3	365.6
8		256-QAM	3/4	8			9360	7,020	1	516.2	487.5	438.8
9			5/6	8			9360	7,800	1	573.5	541.7	487.5
10		1024-QAM	3/4	10			11700	8,775	1	645.2	609.4	548.4
11			5/6	10			11700	9,750	1	716.9	677.1	609.4

Table 26-73—HE-MCSs for mandatory 242-tone RU and mandatory non-OFDMA 20 MHz, $N_{\text{SS}} = 6$

HE-MCS Index	DCM	Modulation	R	$N_{\text{SS}}^{\text{MCS}}$	$N_{\text{SC}}^{\text{MCS}}$	$N_{\text{ST}}^{\text{MCS}}$	$N_{\text{Data}}^{\text{MCS}}$	$N_{\text{Pilot}}^{\text{MCS}}$	$N_{\text{Total}}^{\text{MCS}}$	Data rate (Mb/s)		
										0.8 μs GI	1.6 μs GI	3.2 μs GI
0	1	BPSK	1/4	1	234	8	1404	351	1	25.8	24.4	21.9
0	0		1/2	1			1404	702	1	51.6	48.8	43.9
1	1	QPSK	1/4	2			2808	702	1	51.6	48.8	43.9
1	0		1/2	2			2808	1,404	1	103.2	97.5	87.8
2	N/A		3/4	2			2808	2,106	1	154.9	146.3	131.6
3	1	16-QAM	1/4	4			5616	1,404	1	103.2	97.5	87.8
3	0		1/2	4			5616	2,808	1	206.5	195.0	175.5
4	1		3/8	4			5616	2,106	1	154.9	146.3	131.6
4	0		3/4	4			5616	4,212	1	309.7	292.5	263.3
5	N/A	64-QAM	2/3	6			8424	5,616	1	412.9	390.0	351.0
6			3/4	6			8424	6,318	1	464.6	438.8	394.9
7			5/6	6			8424	7,020	1	516.2	487.5	438.8
8		256-QAM	3/4	8			11232	8,424	1	619.4	585.0	526.5
9			5/6	8			11232	9,360	1	688.2	650.0	585.0
10		1024-QAM	3/4	10			14040	10,530	1	774.3	731.3	658.1
11			5/6	10			14040	11,700	1	860.3	812.5	731.3

Table 26-74—HE-MCSs for mandatory 242-tone RU and mandatory non-OFDMA 20 MHz, $N_{\text{SS}} = 1$

HE-MCS Index	DCM	Modulation	R	N_{avgSCS}	N_{ss}	N_{pr}	N_{data}	N_{pilot}	N_{total}	Data rate (Mb/s)		
										0.8 μsec GI	1.6 μsec GI	3.2 μsec GI
0	1	BPSK	1/4	1	234	8	1638	408	1	30.1	26.4	25.5
0	0		1/2	1			1638	819	1	60.2	56.9	51.2
1	1	QPSK	1/4	2			3276	819	1	60.2	56.9	51.2
1	0		1/2	2			3276	1,638	1	120.4	113.8	102.4
2	N/A		3/4	2			3276	2,457	1	180.7	170.6	153.6
3	1	16-QAM	1/4	4			6552	1,638	1	120.4	113.8	102.4
3	0		1/2	4			6552	3,276	1	240.9	227.5	204.8
4	1		3/8	4			6552	2,457	1	180.7	170.6	153.6
4	0		3/4	4			6552	4,914	1	361.3	341.3	307.1
5	N/A	64-QAM	2/3	6			9828	6,552	1	481.8	455.0	409.5
6			3/4	6			9828	7,371	1	542.0	511.9	460.7
7			5/6	6			9828	8,190	1	602.2	568.8	511.9
8		256-QAM	3/4	8			13104	9,828	1	722.6	682.5	614.3
9			5/6	8			13104	10,920	1	802.9	758.3	682.5
10		1024-QAM	3/4	10			16380	12,285	1	903.3	853.1	767.8
11			5/6	10			16380	13,650	1	1,003.7	947.9	853.1

Table 26-75—HE-MCSs for mandatory 242-tone RU and mandatory non-OFDMA 20 MHz, $N_{\text{ss}} = 8$

HE-MCS Index	DCM	Modulation	R	N_{avgSCS}	N_{ss}	N_{pr}	N_{data}	N_{pilot}	N_{total}	Data rate (Mb/s)		
										0.8 μsec GI	1.6 μsec GI	3.2 μsec GI
0	1	BPSK	1/4	1	234	8	1872	468	1	34.4	31.5	29.3
0	0		1/2	1			1872	936	1	68.8	65.0	58.5
1	1	QPSK	1/4	2			3744	936	1	68.8	65.0	58.5
1	0		1/2	2			3744	1,872	1	137.6	130.0	117.0
2	N/A		3/4	2			3744	2,808	1	206.5	195.0	175.5
3	1	16-QAM	1/4	4			7488	1,872	1	137.6	130.0	117.0
3	0		1/2	4			7488	3,744	1	275.3	260.0	234.0
4	1		3/8	4			7488	2,808	1	206.5	195.0	175.5
4	0		3/4	4			7488	5,616	1	412.9	390.0	351.0
5	N/A	64-QAM	2/3	6			11232	7,488	1	550.6	520.0	468.0
6			3/4	6			11232	8,424	1	619.4	585.0	526.5
7			5/6	6			11232	9,360	1	688.2	650.0	585.0
8		256-QAM	3/4	8			14976	11,232	1	825.9	780.0	702.0
9			5/6	8			14976	12,480	1	917.6	866.7	780.0
10		1024-QAM	3/4	10			18720	14,040	1	1,032.4	975.0	877.5
11			5/6	10			18720	15,600	1	1,147.1	1,083.3	975.0

Table 26-76—HE-MCSs for mandatory 484-tone RU and mandatory non-OFDMA 40 MHz, $N_{SS} = 1$

HE-MCS Index	DCM	Modulation	R	$N_{SS}Q$	N_{SC}	N_{ST}	N_{QPSK}	N_{QAM}	N_{SS}	Data rate (Mb/s)		
										0.8 μ sec GI	1.6 μ sec GI	3.2 μ sec GI
0	1	BPSK	1/4	1	488	16	468	117	1	8.6	8.1	7.3
0	0		1/2	1			468	234	1	17.2	16.3	14.6
1	1	QPSK	1/4	2			936	234	1	17.2	16.3	14.6
1	0		1/2	2			936	468	1	34.4	32.5	29.3
2	N/A	16-QAM	3/4	2			936	702	1	51.6	48.8	43.9
3	1		1/4	4			1872	468	1	34.4	32.5	29.3
3	0		1/2	4			1872	936	1	68.8	65.0	58.5
4	1		3/8	4			1872	702	1	51.6	48.8	43.9
4	0		3/4	4			1872	1,404	1	103.2	97.5	87.8
5	N/A	64-QAM	2/3	6			2808	1,872	1	137.6	130.0	117.0
6			3/4	6			2808	2,106	1	154.9	146.3	131.6
7			5/6	6			2808	2,340	1	172.1	162.5	145.3
8		256-QAM	3/4	8			3744	2,808	1	208.5	195.0	175.5
9			5/6	8			3744	3,120	1	229.4	216.7	195.0
10		1024-QAM	3/4	10			4680	3,510	1	258.1	243.8	219.4
11			5/6	10			4680	3,900	1	286.8	270.8	243.8

Table 26-77—HE-MCSs for mandatory 484-tone RU and mandatory non-OFDMA 40 MHz, $N_{SS} = 2$

HE-MCS Index	DCM	Modulation	R	$N_{\text{SS}} \leq 4$	$N_{\text{SS}} = 8$	$N_{\text{SS}} = 16$	$N_{\text{Data}} \leq 1023$	$N_{\text{Data}} = 2048$	$N_{\text{Data}} = 4096$	Data rate (Mb/s)		
										0.8 μscc GI	1.6 μscc GI	3.2 μscc GI
0	1	BPSK	1/4	1	468	16	936	234	1	17.2	16.3	14.6
0	0		1/2	1			936	468	1	34.4	32.5	29.3
1	1	QPSK	1/4	2			1872	468	1	34.4	32.5	29.3
1	0		1/2	2			1872	936	1	68.8	65.0	58.5
2	N/A		3/4	2			1872	1,404	1	103.2	97.5	87.8
3	1		1/4	4			3744	936	1	68.8	65.0	58.5
3	0	16-QAM	1/2	4			3744	1,872	1	137.5	130.0	117.0
4	1		3/8	4			3744	1,404	1	103.2	97.5	87.8
4	0		3/4	4			3744	2,808	1	206.5	195.0	175.5
5	N/A	64-QAM	2/3	6			5616	3,744	1	275.3	260.0	234.0
6			3/4	6			5616	4,212	1	309.7	292.5	263.3
7			5/6	6			5616	4,680	1	344.1	325.0	292.5
8			3/4	8			7488	5,616	1	412.9	390.0	351.0
9		256-QAM	5/6	8			7488	6,240	1	458.8	433.3	390.0
10			3/4	10			9360	7,020	1	515.2	487.5	438.8
11		1024-QAM	5/6	10			9360	7,800	1	573.5	541.7	487.5

Table 26-78—HE-MCSs for mandatory 484-tone RU and mandatory non-OFDMA 40 MHz, $N_{\text{SS}} = 3$

HE-MCS Index	DCM	Modulation	R	$N_{\text{SS}} \leq 4$	$N_{\text{SS}} = 8$	$N_{\text{SS}} = 16$	$N_{\text{Data}} \leq 1023$	$N_{\text{Data}} = 2048$	$N_{\text{Data}} = 4096$	Data rate (Mb/s)		
										0.8 μscc GI	1.6 μscc GI	3.2 μscc GI
0	1	BPSK	1/4	1	468	16	1404	351	1	25.8	24.4	21.9
0	0		1/2	1			1404	702	1	51.5	48.8	43.9
1	1	QPSK	1/4	2			2808	702	1	51.5	48.8	43.9
1	0		1/2	2			2808	1404	1	103.2	97.5	87.8
2	N/A		3/4	2			2808	2106	1	154.9	146.3	131.6
3	1		1/4	4			5616	1404	1	103.2	97.5	87.8
3	0	16-QAM	1/2	4			5616	2808	1	206.5	195.0	175.5
4	1		3/8	4			5616	2106	1	154.9	146.3	131.6
4	0		3/4	4			5616	4212	1	309.7	292.5	263.3
5	N/A		64-QAM	2/3			6	8424	5616	1	412.9	390.0
5		3/4		6			8424	6318	1	464.5	438.8	394.9
7		5/6		6			8424	7020	1	515.2	487.5	438.8
8		256-QAM	3/4	8			11232	8424	1	619.4	585.0	526.5
9			5/6	8			11232	9360	1	688.2	650.0	585.0
10		1024-QAM	3/4	10			14040	10530	1	774.3	731.3	658.1
11			5/6	10			14040	11700	1	860.3	812.5	731.3

Table 26-79—HE-MCSs for mandatory 484-tone RU and mandatory non-OFDMA 40 MHz, $N_{\text{SS}} = 194$

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HE-MCS Index	DCM	Modulation	R	$N_{\text{SS}}=5$	$N_{\text{SC}}=468$	$N_{\text{ST}}=16$	$N_{\text{data}}=1872$	$N_{\text{data}}=468$	$N_{\text{data}}=1$	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	468	16	1872	468	1	34.4	32.5	29.3
0	0		1/2	1			1872	936	1	68.8	65.0	58.5
1	1	QPSK	1/4	2			3744	936	1	68.8	65.0	58.5
1	0		1/2	2			3744	1,872	1	137.6	130.0	117.0
2	N/A		3/4	2			3744	2,808	1	206.5	195.0	175.5
3	1	16-QAM	1/4	4			7488	1,872	1	137.6	130.0	117.0
3	0		1/2	4			7488	3,744	1	275.3	260.0	234.0
4	1		3/8	4			7488	2,808	1	206.5	195.0	175.5
4	0		3/4	4			7488	5,616	1	412.9	390.0	351.0
5	N/A	64-QAM	2/3	6			11232	7,488	1	550.6	520.0	468.0
6			3/4	6			11232	8,424	1	619.4	585.0	526.5
7			5/6	6			11232	9,360	1	688.2	650.0	585.0
8		256-QAM	3/4	8			14976	11,232	1	825.9	780.0	702.0
9			5/6	8			14976	12,480	1	917.6	866.7	780.0
10		1024-QAM	3/4	10			18720	14,040	1	1,032.4	975.0	877.5
11			5/6	10			18720	15,600	1	1,147.1	1,083.3	975.0

Table 26-80—HE-MCSs for mandatory 484-tone RU and mandatory non-OFDMA 40 MHz, $N_{\text{SS}} = 5$

HE-MCS Index	DCM	Modulation	R	$N_{\text{SS}}=5$	$N_{\text{SC}}=468$	$N_{\text{ST}}=16$	$N_{\text{data}}=2340$	$N_{\text{data}}=585$	$N_{\text{data}}=1$	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	468	16	2340	585	1	43.0	40.6	36.6
0	0		1/2	1			2340	1,170	1	86.0	81.3	73.1
1	1	QPSK	1/4	2			4680	1,170	1	86.0	81.3	73.1
1	0		1/2	2			4680	2,340	1	172.1	162.5	146.3
2	N/A		3/4	2			4680	3,510	1	258.1	243.8	219.4
3	1	16-QAM	1/4	4			9360	2,340	1	172.1	162.5	146.3
3	0		1/2	4			9360	4,680	1	344.1	325.0	292.5
4	1		3/8	4			9360	3,510	1	258.1	243.8	219.4
4	0		3/4	4			9360	7,020	1	516.2	487.5	438.8
5	N/A	64-QAM	2/3	6			14040	9,360	1	688.2	650.0	585.0
6			3/4	6			14040	10,530	1	774.3	731.3	658.1
7			5/6	6			14040	11,700	1	860.3	812.5	731.3
8		256-QAM	3/4	8			18720	14,040	1	1,032.4	975.0	877.5
9			5/6	8			18720	15,600	1	1,147.1	1,083.3	975.0
10		1024-QAM	3/4	10			23400	17,550	1	1,290.4	1,218.8	1,096.9
11			5/6	10			23400	19,500	1	1,433.8	1,354.2	1,218.8

Table 26-81—HE-MCSs for mandatory 484-tone RU and mandatory non-OFDMA 40 MHz, $N_{SS} = 6$

HE-MCS index	DCM	Modulation	R	$N_{\text{data}}/N_{\text{SCS}}$	N_{RU}	$N_{\text{RU}}/N_{\text{SCS}}$	$N_{\text{data}}/N_{\text{SCS}}$	$N_{\text{data}}/N_{\text{SCS}}$	N_{SS}	Data rate (Mb/s)		
										0.8 μsec GI	1.6 μsec GI	3.2 μsec GI
0	1	BPSK	1/4	1	468	16	2808	702	1	51.5	48.8	43.9
0	0		1/2	1			2808	1,404	1	103.2	97.5	87.8
1	1	QPSK	1/4	2			5616	1,404	1	103.2	97.5	87.8
1	0		1/2	2			5616	2,808	1	206.5	195.0	175.5
2	N/A		3/4	2			5616	4,212	1	309.7	292.5	263.3
3	1	16-QAM	1/4	4			11232	2,808	1	206.5	195.0	175.5
3	0		1/2	4			11232	5,616	1	412.9	390.0	351.0
4	1		3/8	4			11232	4,212	1	309.7	292.5	263.3
4	0		3/4	4			11232	8,424	1	619.4	585.0	525.5
5	N/A	54-QAM	2/3	6			16848	11,232	1	825.9	780.0	702.0
6			3/4	6			16848	12,636	1	929.1	877.5	789.8
7			5/6	6			16848	14,040	1	1,032.4	975.0	877.5
8		256-QAM	3/4	8			22464	16,848	1	1,238.8	1,170.0	1,053.0
9			5/6	8			22464	18,720	1	1,376.5	1,300.0	1,170.0
10		1024-QAM	3/4	10			28080	21,060	1	1,548.5	1,462.5	1,316.3
11			5/6	10			28080	23,400	1	1,720.6	1,625.0	1,462.5

Table 26-82—HE-MCSs for mandatory 484-tone RU and mandatory non-OFDMA 40 MHz, $N_{SS} = 7$

HE-MCS Index	DCM	Modulation	R	$N_{\text{SS}}=1$	$N_{\text{SC}}=484$	$N_{\text{SP}}=1$	$N_{\text{DMRS}}=1$	$N_{\text{DMRS}}=2$	$N_{\text{DMRS}}=4$	$N_{\text{DMRS}}=8$	Data rate (Mb/s)		
											0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	468	16	3276	819	1		60.2	56.9	51.2
0	0		1/2	1			3276	1,638	1		120.4	113.8	102.4
1	1	QPSK	1/4	2			6552	1,638	1		120.4	113.8	102.4
1	0		1/2	2			6552	3,276	1		240.9	227.5	204.8
2	N/A		3/4	2			6552	4,914	1		361.3	341.3	307.1
3	1	16-QAM	1/4	4			13104	3,276	1		240.9	227.5	204.8
3	0		1/2	4			13104	6,552	1		481.8	455.0	409.5
4	1		3/8	4			13104	4,914	1		361.3	341.3	307.1
4	0		3/4	4			13104	9,828	1		722.6	682.5	614.3
5	N/A	64-QAM	2/3	6			19656	13,104	1		963.5	910.0	819.0
6			3/4	6			19656	14,742	1		1,084.0	1,023.8	921.4
7			5/6	6			19656	16,380	1		1,204.4	1,137.5	1,023.8
8		256-QAM	3/4	8			26208	19,656	1		1,445.3	1,365.0	1,228.5
9			5/6	8			26208	21,840	1		1,605.9	1,516.7	1,365.0
10		1024-QAM	3/4	10			32760	24,570	1		1,806.6	1,706.3	1,535.6
11			5/6	10			32760	27,300	1		2,007.4	1,895.8	1,706.3

Table 26-83—HE-MCSs for mandatory 484-tone RU and mandatory non-OFDMA 40 MHz, $N_{\text{SS}} = 8$

HE-MCS Index	DCM	Modulation	R	$N_{\text{SS}}=8$	$N_{\text{SC}}=484$	$N_{\text{SP}}=1$	$N_{\text{DMRS}}=1$	$N_{\text{DMRS}}=2$	$N_{\text{DMRS}}=4$	$N_{\text{DMRS}}=8$	Data rate (Mb/s)		
											0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	468	16	3744	936	1		68.8	65.0	58.5
0	0		1/2	1			3744	1,872	1		137.6	130.0	117.0
1	1	QPSK	1/4	2			7488	1,872	1		137.6	130.0	117.0
1	0		1/2	2			7488	3,744	1		275.3	260.0	234.0
2	N/A		3/4	2			7488	5,616	1		412.9	390.0	351.0
3	1	16-QAM	1/4	4			14976	3,744	1		275.3	260.0	234.0
3	0		1/2	4			14976	7,488	1		550.6	520.0	468.0
4	1		3/8	4			14976	5,616	1		412.9	390.0	351.0
4	0		3/4	4			14976	11,232	1		825.9	780.0	702.0
5	N/A	64-QAM	2/3	6			22464	14,976	1		1,101.2	1,040.0	936.0
6			3/4	6			22464	16,848	1		1,238.8	1,170.0	1,053.0
7			5/6	6			22464	18,720	1		1,376.5	1,300.0	1,170.0
8		256-QAM	3/4	8			29952	22,464	1		1,651.8	1,560.0	1,404.0
9			5/6	8			29952	24,960	1		1,835.3	1,733.3	1,560.0
10		1024-QAM	3/4	10			37440	28,080	1		2,064.7	1,950.0	1,755.0
11			5/6	10			37440	31,200	1		2,294.1	2,166.7	1,950.0

Table 26-84—HE-MCSs for mandatory 996-tone RU and mandatory non-OFDMA 80 MHz, $N_{SS} = 1$

HE-MCS Index	DCM	Modulation	R	N_{subCS}	N_{RU}	N_{SC}	N_{subRB}	N_{subCH}	N_{SS}	Data rate (Mb/s)		
										0.8 μsec GI	1.6 μsec GI	3.2 μsec GI
0	1	BPSK	1/4	1	980	16	980	245	1	18.0	17.0	15.3
0	0		1/2	1						36.0	34.0	30.6
1	1	QPSK	1/4	2						36.0	34.0	30.6
1	0		1/2	2						72.1	68.1	61.3
2	N/A		3/4	2						108.1	102.1	91.9
3	1	16-QAM	1/4	4						72.1	68.1	61.3
3	0		1/2	4						144.1	136.1	122.5
4	1		3/8	4						108.1	102.1	91.9
4	0		3/4	4						216.2	204.2	183.8
5	N/A	64-QAM	2/3	6						258.2	272.2	245.0
6			3/4	6						324.3	306.3	275.6
7			5/6	6						360.3	340.3	306.3
8		256-QAM	3/4	8						432.4	408.3	367.5
9			5/6	8						480.4	453.7	408.3
10		1024-QAM	3/4	10						540.4	510.4	459.4
11			5/6	10						600.4	567.1	510.4

Table 26-85—HE-MCSs for mandatory 996-tone RU and mandatory non-OFDMA 80 MHz, $N_{SS} = 2$

HE-MCS Index	DCM	Modulation	R	N_{BPS}/CS	N_{SC}/S	N_{SR}/S	N_{CARS}	N_{DARS}	N_{SS}	Data rate {Mb/s}		
										0.8 μsec GI	1.6 μsec GI	3.2 μsec GI
0	1	BPSK	1/4	1	980	15	1960	490	1	36.0	34.0	30.6
0	0		1/2	1			1960	980	1	72.1	68.1	61.3
1	1	QPSK	1/4	2			3920	980	1	72.1	68.1	61.3
1	0		1/2	2			3920	1,960	1	144.1	136.1	122.5
2	N/A		3/4	2			3920	2,940	1	216.2	204.2	183.8
3	1	16-QAM	1/4	4			7840	1,960	1	144.1	136.1	122.5
3	0		1/2	4			7840	3,920	1	288.2	272.2	245.0
4	1		3/8	4			7840	2,940	1	216.2	204.2	183.8
4	0		3/4	4			7840	5,880	1	432.4	408.3	367.5
5	N/A	64-QAM	2/3	6			11760	7,840	1	576.5	544.4	490.0
6			3/4	6			11760	8,820	1	648.5	612.5	551.3
7			5/6	6			11760	9,800	1	720.6	680.6	612.5
8		256-QAM	3/4	8			15680	11,760	1	864.7	816.7	735.0
9			5/6	8			15680	13,066	1	960.7	907.4	816.6
10		1024-QAM	3/4	10			19600	14,700	1	1,080.9	1,020.8	918.8
11			5/6	10			19600	16,333	1	1,201.0	1,134.2	1,020.8

Table 26-86—HE-MCSs for mandatory 996-tone RU and mandatory non-OFDMA 80 MHz, $N_{\text{SS}} = 3$

HE-MCS Index	DCM	Modulation	R	N_{BPS}/CS	N_{SC}/S	N_{SR}/S	N_{CARS}	N_{DARS}	N_{SS}	Data rate {Mb/s}		
										0.8 μsec GI	1.6 μsec GI	3.2 μsec GI
0	1	BPSK	1/4	1	980	15	2940	735	1	54.0	51.0	45.9
0	0		1/2	1			2940	1,470	1	108.1	102.1	91.9
1	1	QPSK	1/4	2			5880	1,470	1	108.1	102.1	91.9
1	0		1/2	2			5880	2,940	1	216.2	204.2	183.8
2	N/A		3/4	2			5880	4,410	1	324.3	306.3	275.6
3	1	16-QAM	1/4	4			11760	2,940	1	216.2	204.2	183.8
3	0		1/2	4			11760	5,880	1	432.4	408.3	367.5
4	1		3/8	4			11760	4,410	1	324.3	306.3	275.6
4	0		3/4	4			11760	8,820	1	648.5	612.5	551.3
5	N/A	64-QAM	2/3	6			17640	11,760	1	864.7	816.7	735.0
6			3/4	6			17640	13,230	1	972.8	918.8	826.9
7			5/6	6			17640	14,700	1	1,080.9	1,020.8	918.8
8		256-QAM	3/4	8			23520	17,640	1	1,297.1	1,225.0	1,102.5
9			5/6	8			23520	19,600	1	1,441.2	1,361.1	1,225.0
10		1024-QAM	3/4	10			29400	22,050	1	1,621.3	1,531.3	1,378.1
11			5/6	10			29400	24,500	1	1,801.5	1,701.4	1,531.3

Table 26-87—HE-MCSs for mandatory 996-tone RU and mandatory non-OFDMA 80 MHz, $N_{\text{SS}} = 1$

HE-MCS Index	DCM	Modulation	R	$N_{\text{SS}} \times \text{CS}$	N_{SC}	N_{SP}	N_{CWS}	N_{DWS}	N_{ES}	Data rate (Mb/s)		
										0.8 μsec GI	1.6 μsec GI	3.2 μsec GI
0	1	BPSK	1/4	1	960	16	3920	960	1	72.1	68.1	61.3
0	0		1/2	1			3920	1,960	1	144.1	136.1	122.5
1	1	QPSK	1/4	2			7840	1,960	1	144.1	136.1	122.5
1	0		1/2	2			7840	3,920	1	288.2	272.2	245.0
2	N/A	16-QAM	3/4	2			7840	5,880	1	432.4	408.3	367.5
3	1		1/4	4			15680	3,920	1	288.2	272.2	245.0
3	0		1/2	4			15680	7,840	1	576.5	544.4	490.0
4	1		3/8	4			15680	5,880	1	432.4	408.3	367.5
4	0		3/4	4			15680	11,760	1	864.7	816.7	735.0
5	N/A	64-QAM	2/3	6			23520	15,680	1	1,152.9	1,088.9	980.0
6			3/4	6			23520	17,640	1	1,297.1	1,225.0	1,102.5
7			5/6	6			23520	19,600	1	1,441.2	1,361.1	1,225.0
8		256-QAM	3/4	8			31360	23,520	1	1,729.4	1,633.3	1,470.0
9			5/6	8			31360	26,133	1	1,921.5	1,814.6	1,633.3
10		1024-QAM	3/4	10			39200	29,400	1	2,161.8	2,041.7	1,837.5
11			5/6	10			39200	32,666	1	2,401.9	2,268.5	2,041.6

Table 26-88—HE-MCSs for mandatory 996-tone RU and mandatory non-OFDMA 80 MHz, $N_{\text{SS}} =$

5

HE-MCS Index	DCM	Modulation	R	$N_{\text{SS}} \times \text{CS}$	N_{SC}	N_{SP}	N_{CWS}	N_{DWS}	N_{ES}	Data rate (Mb/s)		
										0.8 μsec GI	1.6 μsec GI	3.2 μsec GI
0	1	BPSK	1/4	1	960	16	4900	1,225	1	90.1	85.1	76.6
0	0		1/2	1			4900	2,450	1	180.1	170.1	153.1
1	1	QPSK	1/4	2			9800	2,450	1	180.1	170.1	153.1
1	0		1/2	2			9800	4,900	1	360.3	340.3	306.3
2	N/A	16-QAM	3/4	2			9800	7,350	1	540.4	510.4	459.4
3	1		1/4	4			19600	4,900	1	360.3	340.3	306.3
3	0		1/2	4			19600	9,800	1	720.6	680.6	612.5
4	1		3/8	4			19600	7,350	1	540.4	510.4	459.4
4	0		3/4	4			19600	14,700	1	1,080.9	1,020.8	918.8
5	N/A	64-QAM	2/3	6			29400	19,600	1	1,441.2	1,361.1	1,225.0
6			3/4	6			29400	22,050	1	1,621.3	1,531.3	1,378.1
7			5/6	6			29400	24,500	1	1,801.5	1,701.4	1,531.3
8		256-QAM	3/4	8			39200	29,400	1	2,161.8	2,041.7	1,837.5
9			5/6	8			39200	32,666	1	2,401.9	2,268.5	2,041.6
10		1024-QAM	3/4	10			49000	36,750	1	2,701.2	2,552.1	2,296.9
11			5/6	10			49000	40,833	1	3,002.4	2,835.6	2,552.1

Table 26-89—HE-MCSs for mandatory 996-tone RU and mandatory non-OFDMA 80 MHz, $N_{ss} = 6$

HE-MCS Index	DCM	Modulation	R	N_{BPSK}	N_{QPSK}	N_{16QAM}	N_{64QAM}	N_{256QAM}	N_{1024QAM}	Data rate {Mb/s}		
										0.8 μ sec GI	1.6 μ sec GI	3.2 μ sec GI
0	1	BPSK	1/4	1	996	16	5880	1,470	1	108.1	102.1	91.9
0	0		1/2	1			5880	2,940	1	216.2	204.2	183.8
1	1	QPSK	1/4	2			11760	2,940	1	216.2	204.2	183.8
1	0		1/2	2			11760	5,880	1	432.4	408.3	367.5
2	N/A		3/4	2			11760	8,820	1	648.5	612.5	551.3
3	1	16-QAM	1/4	4			23520	5,880	1	432.4	408.3	367.5
3	0		1/2	4			23520	11,760	1	864.7	816.7	735.0
4	1		3/8	4			23520	8,820	1	648.5	612.5	551.3
4	0		3/4	4			23520	17,640	1	1,297.1	1,225.0	1,102.5
5	N/A	64-QAM	2/3	6			35280	23,520	1	1,729.4	1,633.3	1,470.0
6			3/4	6			35280	35,460	1	1,945.6	1,837.5	1,653.8
7			5/6	6			35280	29,400	1	2,161.8	2,041.7	1,837.5
8		256-QAM	3/4	8			47040	35,280	1	2,594.1	2,450.0	2,205.0
9			5/6	8			47040	39,200	1	2,882.4	2,722.2	2,450.0
10		1024-QAM	3/4	10			58800	44,100	1	3,242.6	3,062.5	2,756.3
11			5/6	10			58800	49,000	1	3,602.9	3,402.8	3,062.5

Table 26-90—HE-MCSs for mandatory 996-tone RU and mandatory non-OFDMA 80 MHz, $N_{ss} = 7$

HE-MCS Index	DCM	Modulation	R	$N_{\text{SS}}^{\text{MCS}}$	N_{SD}	N_{SP}	N_{CARS}	N_{OARS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	960	16	6860	1,715	1	126.1	119.1	107.2
0	0		1/2	1			6860	3,430	1	252.2	238.2	214.4
1	1	QPSK	1/4	2			13720	3,430	1	252.2	238.2	214.4
1	0		1/2	2			13720	6,860	1	504.4	476.4	428.8
2	N/A		3/4	2			13720	10,290	1	756.6	714.6	643.1
3	1	16-QAM	1/4	4			27440	6,860	1	504.4	476.4	428.8
3	0		1/2	4			27440	13,720	1	1,008.8	952.8	857.5
4	1		3/8	4			27440	10,290	1	756.6	714.6	643.1
4	0		3/4	4			27440	20,580	1	1,513.2	1,429.2	1,286.3
5	N/A	64-QAM	2/3	6			41160	27,440	1	2,017.6	1,905.6	1,715.0
6			3/4	6			41160	30,870	1	2,269.9	2,143.8	1,929.4
7			5/6	6			41160	34,300	1	2,522.1	2,381.9	2,143.8
8		256-QAM	3/4	8			54880	41,160	1	3,026.5	2,858.3	2,572.5
9			5/6	8			54880	45,733	1	3,362.7	3,175.9	2,858.3
10		1024-QAM	3/4	10			68600	51,450	1	3,783.1	3,572.9	3,215.6
11			5/6	10			68600	57,166	1	4,203.4	3,969.9	3,572.9

Table 26-91—HE-MCSs for mandatory 996-tone RU and mandatory non-OFDMA 80 MHz, $N_{\text{SS}} = 8$

HE-MCS Index	DCM	Modulation	R	$N_{\text{SS}}^{\text{MCS}}$	N_{SD}	N_{SP}	N_{CARS}	N_{OARS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	960	16	7840	1,960	1	144.1	136.1	122.5
0	0		1/2	1			7840	3,920	1	288.2	272.2	245.0
1	1	QPSK	1/4	2			15680	3,920	1	288.2	272.2	245.0
1	0		1/2	2			15680	7,840	1	576.5	544.4	490.0
2	N/A		3/4	2			15680	11,760	1	864.7	816.7	735.0
3	1	16-QAM	1/4	4			31360	7,840	1	576.5	544.4	490.0
3	0		1/2	4			31360	15,680	1	1,152.9	1,088.9	980.0
4	1		3/8	4			31360	11,760	1	864.7	816.7	735.0
4	0		3/4	4			31360	23,520	1	1,729.4	1,633.3	1,470.0
5	N/A	64-QAM	2/3	6			47040	31,360	1	2,305.9	2,177.8	1,960.0
6			3/4	6			47040	35,280	1	2,594.1	2,450.0	2,205.0
7			5/6	6			47040	39,200	1	2,882.4	2,722.2	2,450.0
8		256-QAM	3/4	8			62720	47,040	1	3,458.8	3,266.7	2,940.0
9			5/6	8			62720	52,266	1	3,843.1	3,629.6	3,266.6
10		1024-QAM	3/4	10			78400	58,800	1	4,323.5	4,083.3	3,675.0
11			5/6	10			78400	65,333	1	4,803.9	4,537.0	4,083.3

Table 26-92—HE-MCSs for optional non-OFDMA 160 MHz and 80+80 MHz, $N_{ss} = 1$

HE-MCS Index	DCM	Modulation	R	N_{BPSK}	N_{QPSK}	N_{16QAM}	N_{64QAM}	N_{256QAM}	N_{1024QAM}	Data rate (Mb/s)		
										0.8 μ sec GI	1.6 μ sec GI	3.2 μ sec GI
0	1	BPSK	1/4	1	1960	32	1960	490	1	36.0	34.0	30.6
0	0		1/2	1			1960	980	1	72.1	68.1	61.3
1	1	QPSK	1/4	2			3920	980	1	72.1	68.1	61.3
1	0		1/2	2			3920	1,960	1	144.1	136.1	122.5
2	N/A	16-QAM	3/4	2			3920	2,940	1	216.2	204.2	183.8
3	1		1/4	4			7840	1,960	1	144.1	136.1	122.5
3	0		1/2	4			7840	3,920	1	288.2	272.2	245.0
4	1		3/8	4			7840	2,940	1	216.2	204.2	183.8
4	0		3/4	4			7840	5,880	1	432.4	408.3	367.5
5	N/A	64-QAM	2/3	6			11760	7,840	1	576.5	544.4	490.0
5			3/4	6			11760	8,820	1	648.5	612.5	551.3
7		256-QAM	5/8	6			11760	9,800	1	720.6	680.6	612.5
8			3/4	8			15680	11,760	1	864.7	816.7	735.0
9			5/8	8			15680	13,066	1	960.7	907.4	816.6
10			3/4	10			19600	14,700	1	1,080.9	1,020.8	918.8
11		1024-QAM	5/8	10			19600	16,333	1	1,201.0	1,134.2	1,020.8

Table 26-93—HE-MCSs for optional non-OFDMA 160 MHz and 80+80 MHz, $N_{ss} = 2$

HE-MCS Index	DCM	Modulation	R	N_{BPSK}	N_{QPSK}	N_{16QAM}	N_{64QAM}	N_{256QAM}	N_{1024QAM}	Data rate (Mb/s)		
										0.8 μ sec GI	1.6 μ sec GI	3.2 μ sec GI
0	1	BPSK	1/4	1	1960	32	3920	980	1	72.1	68.1	61.3
0	0		1/2	1			3920	1,960	1	144.1	136.1	122.5
1	1	QPSK	1/4	2			7840	1,960	1	144.1	136.1	122.5
1	0		1/2	2			7840	3,920	1	288.2	272.2	245.0
2	N/A	16-QAM	3/4	2			7840	5,880	1	432.4	408.3	367.5
3	1		1/4	4			15680	3,920	1	288.2	272.2	245.0
3	0		1/2	4			15680	7,840	1	576.5	544.4	490.0
4	1		3/8	4			15680	5,880	1	432.4	408.3	367.5
4	0		3/4	4			15680	11,760	1	864.7	816.7	735.0
5	N/A	64-QAM	2/3	6			23520	15,680	1	1,152.9	1,088.9	980.0
6			3/4	6			23520	17,640	1	1,297.1	1,225.0	1,102.5
7		256-QAM	5/8	6			23520	19,600	1	1,441.2	1,361.1	1,225.0
8			3/4	8			31360	23,520	1	1,729.4	1,633.3	1,470.0
9			5/8	8			31360	26,133	1	1,921.5	1,814.8	1,633.3
10			3/4	10			39200	29,400	1	2,161.8	2,041.7	1,837.5
11		1024-QAM	5/8	10			39200	32,666	1	2,401.9	2,268.5	2,041.6

Table 26-94—HE-MCSs for optional non-OFDMA 160 MHz and 80+80 MHz, $N_{SS} = 3$

HE-MCS Index	DCM	Modulation	R	N_{streams}	N_{STBC}	N_{SF}	N_{QAM}	N_{QAM}	N_{SS}	Data rate (Mb/s)		
										0.8 μsec GI	1.6 μsec GI	3.2 μsec GI
0	1	BPSK	1/4	1	1960	32	5680	1,470	1	108.1	102.1	91.9
0	0		1/2	1			5680	2,940	1	216.2	204.2	183.8
1	1	QPSK	1/4	2			11760	2,940	1	216.2	204.2	183.8
1	0		1/2	2			11760	5,880	1	432.4	408.3	367.5
2	N/A		3/4	2			11760	8,820	1	648.5	612.5	551.3
3	1	16-QAM	1/4	4			23520	5,880	1	432.4	408.3	367.5
3	0		1/2	4			23520	11,760	1	864.7	816.7	735.0
4	1		3/8	4			23520	8,820	1	648.5	612.5	551.3
4	0		3/4	4			23520	17,640	1	1,297.1	1,225.0	1,102.5
5	N/A	64-QAM	2/3	6			35280	23,520	1	1,729.4	1,633.3	1,470.0
6			3/4	6			35280	26,460	1	1,945.6	1,837.5	1,653.8
7			5/6	6			35280	29,400	1	2,161.8	2,041.7	1,837.5
8		256-QAM	3/4	8			47040	35,280	1	2,594.1	2,450.0	2,205.0
9			5/6	8			47040	39,200	1	2,882.4	2,722.2	2,450.0
10		1024-QAM	3/4	10			58800	44,100	1	3,242.6	3,062.5	2,756.3
11			5/6	10			58800	49,000	1	3,602.9	3,402.8	3,062.5

Table 26-95—HE-MCSs for optional non-OFDMA 160 MHz and 80+80 MHz, $N_{SS} = 4$

HE-MCS Index	DCM	Modulation	R	N_{streams}	N_{STBC}	N_{SF}	N_{QAM}	N_{QAM}	N_{SS}	Data rate (Mb/s)		
										0.8 μsec GI	1.6 μsec GI	3.2 μsec GI
0	1	BPSK	1/4	1	1960	32	7840	1,960	1	144.1	136.1	122.5
0	0		1/2	1			7840	3,920	1	288.2	272.2	245.0
1	1	QPSK	1/4	2			15680	3,920	1	288.2	272.2	245.0
1	0		1/2	2			15680	7,840	1	576.5	544.4	490.0
2	N/A		3/4	2			15680	11,760	1	864.7	816.7	735.0
3	1	16-QAM	1/4	4			31360	7,840	1	576.5	544.4	490.0
3	0		1/2	4			31360	15,680	1	1,152.9	1,088.9	980.0
4	1		3/8	4			31360	11,760	1	864.7	816.7	735.0
4	0		3/4	4			31360	23,520	1	1,729.4	1,633.3	1,470.0
5	N/A	64-QAM	2/3	6			47040	31,360	1	2,305.9	2,177.8	1,960.0
6			3/4	6			47040	35,280	1	2,594.1	2,450.0	2,205.0
7			5/6	6			47040	39,200	1	2,882.4	2,722.2	2,450.0
8		256-QAM	3/4	8			62720	47,040	1	3,458.8	3,266.7	2,940.0
9			5/6	8			62720	52,266	1	3,843.1	3,629.6	3,266.6
10		1024-QAM	3/4	10			78400	58,800	1	4,323.5	4,083.3	3,675.0
11			5/6	10			78400	65,333	1	4,803.9	4,537.0	4,083.3

Table 26-96—HE-MCSs for optional non-OFDMA 160 MHz and 80+80 MHz, $N_{SS} = 5$

HE-MCS Index	DCM	Modulation	R	$N_{SS,CS}$	N_{SD}	N_{SF}	N_{data}	N_{pilot}	N_{total}	Data rate (Mb/s)		
										0.8 μ sec GI	1.6 μ sec GI	3.2 μ sec GI
0	1	BPSK	1/4	1	1960	32	9800	2,450	1	180.1	170.1	153.1
0	0		1/2	1			9800	4,900	1	360.3	340.3	306.3
1	1	QPSK	1/4	2			19600	4,900	1	360.3	340.3	306.3
1	0		1/2	2			19600	9,800	1	720.6	680.6	612.5
2	N/A	16-QAM	3/4	2			19600	14,700	1	1,080.9	1,020.8	918.8
3	1		1/4	4			39200	9,800	1	720.6	680.6	612.5
3	0		1/2	4			39200	19,600	1	1,441.2	1,361.1	1,225.0
4	1		3/8	4			39200	14,700	1	1,080.9	1,020.8	918.8
4	0		3/4	4			39200	29,400	1	2,161.8	2,041.7	1,837.5
5	N/A	64-QAM	2/3	6			58800	59,200	1	2,882.4	2,722.2	2,450.0
6			3/4	6			58800	44,100	1	3,242.6	3,062.5	2,756.3
7			5/6	6			58800	49,000	1	3,602.9	3,402.8	3,062.5
8		256-QAM	3/4	8			78400	58,800	1	4,323.5	4,083.3	3,675.0
9			5/6	8			78400	65,333	1	4,803.9	4,537.0	4,083.3
10		1024-QAM	3/4	10			98000	73,500	1	5,404.4	5,104.2	4,593.8
11			5/6	10			98000	81,666	1	6,004.8	5,671.3	5,104.1

Table 26-97—HE-MCSs for optional non-OFDMA 160 MHz and 80+80 MHz, $N_{SS} = 6$

HE-MCS Index	DCM	Modulation	R	$N_{SS,CS}$	N_{SD}	N_{SF}	N_{data}	N_{pilot}	N_{total}	Data rate (Mb/s)		
										0.8 μ sec GI	1.6 μ sec GI	3.2 μ sec GI
0	1	BPSK	1/4	1	1960	32	11760	2,940	1	216.2	204.2	183.8
0	0		1/2	1			11760	5,880	1	432.4	408.3	367.5
1	1	QPSK	1/4	2			23520	5,880	1	432.4	408.3	367.5
1	0		1/2	2			23520	11,760	1	864.7	816.7	735.0
2	N/A	16-QAM	3/4	2			23520	17,640	1	1,297.1	1,225.0	1,102.5
3	1		1/4	4			47040	11,760	1	864.7	816.7	735.0
3	0		1/2	4			47040	23,520	1	1,729.4	1,633.3	1,470.0
4	1		3/8	4			47040	17,640	1	1,297.1	1,225.0	1,102.5
4	0		3/4	4			47040	35,280	1	2,594.1	2,450.0	2,205.0
5	N/A	64-QAM	2/3	6			70560	47,040	1	3,458.8	3,266.7	2,940.0
6			3/4	6			70560	52,920	1	3,891.2	3,675.0	3,307.5
7			5/6	6			70560	58,800	1	4,323.5	4,083.3	3,675.0
8		256-QAM	3/4	8			94080	70,560	1	5,168.2	4,900.0	4,410.0
9			5/6	8			94080	78,400	1	5,764.7	5,444.4	4,900.0
10		1024-QAM	3/4	10			117600	88,200	1	6,485.3	6,125.0	5,512.5
11			5/6	10			117600	98,000	1	7,205.9	6,805.6	6,125.0

Table 26-98—HE-MCSs for optional non-OFDMA 160 MHz and 80+80 MHz, $N_{SS} = 7$

HE-MCS Index	DCM	Modulation	R	N_{SS}/CS	N_{ST}/SC	N_{ST}/SC	N_{QAM}	N_{QAM}	N_{SS}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	1960	32	13720	3,430	1	252.2	238.2	214.4
0	0		1/2	1			13720	6,860	1	504.4	476.4	428.8
1	1	QPSK	1/4	2			27440	6,860	1	504.4	476.4	428.8
1	0		1/2	2			27440	13,720	1	1,008.8	952.8	857.5
2	N/A	16-QAM	3/4	2			27440	20,580	1	1,513.2	1,429.2	1,286.3
3	1		1/4	4			54880	13,720	1	1,008.8	952.8	857.5
3	0	64-QAM	1/2	4			54880	27,440	1	2,017.6	1,905.6	1,715.0
4	1		3/8	4			54880	20,580	1	1,513.2	1,429.2	1,286.3
4	0	256-QAM	3/4	4			54880	41,160	1	3,026.5	2,858.3	2,572.5
5	N/A		54-QAM	2/3			6	82320	54,880	1	4,035.3	3,811.1
6		3/4		6			82320	61,740	1	4,539.7	4,287.5	3,858.8
7		5/6		6			82320	68,600	1	5,044.1	4,763.9	4,287.5
8		256-QAM	3/4	8			109760	82,320	1	6,052.9	5,718.7	5,145.0
9			5/6	8			109760	91,466	1	6,725.4	6,351.8	5,716.6
10		1024-QAM	3/4	10			137200	102,900	1	7,566.2	7,145.8	6,431.3
11			5/6	10			137200	114,333	1	8,406.8	7,939.8	7,145.8

Table 26-99—HE-MCSs for optional non-OFDMA 160 MHz and 80+80 MHz, $N_{SS} = 8$

HE-MCS Index	DCM	Modulation	R	N_{SS}/CS	N_{ST}/SC	N_{ST}/SC	N_{QAM}	N_{QAM}	N_{SS}	Data rate {Mb/s}		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	1960	32	15680	3,920	1	288.2	272.2	245.0
0	0		1/2	1			15680	7,840	1	576.5	544.4	490.0
1	1	QPSK	1/4	2			31360	7,840	1	576.5	544.4	490.0
1	0		1/2	2			31360	15,680	1	1,152.9	1,088.9	980.0
2	N/A	16-QAM	3/4	2			31360	23,520	1	1,729.4	1,633.3	1,470.0
3	1		1/4	4			62720	15,680	1	1,152.9	1,088.9	980.0
3	0	64-QAM	1/2	4			62720	31,360	1	2,305.9	2,177.8	1,960.0
4	1		3/8	4			62720	23,520	1	1,729.4	1,633.3	1,470.0
4	0	256-QAM	3/4	4			62720	47,040	1	3,458.8	3,266.7	2,940.0
5	N/A		64-QAM	2/3			6	94080	62,720	1	4,611.8	4,355.6
6		3/4		6			94080	70,560	1	5,188.2	4,900.0	4,410.0
7	256-QAM	5/6	6	94080			78,400	1	5,764.7	5,444.4	4,900.0	
8		3/4	8	125440			94,080	1	6,917.6	6,533.3	5,880.0	
9	1024-QAM	5/6	8	125440			104,533	1	7,686.3	7,259.2	6,533.3	
10		3/4	10	156800			117,600	1	8,647.1	8,166.7	7,350.0	
11		5/6	10	156800			130,665	1	9,607.8	9,074.0	8,166.6	

