802.11 PHY调制与速率

The DSSS system uses baseband modulations of differential binary phase shift keying (DBPSK) and differential quadrature phase shift keying (DQPSK) to provide the 1 Mb/s and 2 Mb/s data rates
DSSS使用DBPSK 和 DQPSK,速率支持1M 2M

HR/DSSS PHY provide 5.5 Mb/s and 11 Mb/s, provide the higher rates, 8-chip complementary code keying (CCK) modulation scheme
HR/DSSS PHY CCK编码 5.5M,11M速率

Orthogonal frequency division multiplexing (OFDM) PHY
The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36,48, and 54 Mb/s
The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory.
The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM).
Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4.

Table 17-4—Modulation-dependent parameters

Modulation	Coding rate (R)	Coded bits per subcarrier (N_{BPSC})	Coded bits per OFDM symbol (N_{CBPS})	Data bits per OFDM symbol (N_{DBPS})	Data rate (Mb/s) (20 MHz channel spacing)	Data rate (Mb/s) (10 MHz channel spacing)	Data rate (Mb/s) (5 MHz channel spacing)
BPSK	1/2	1	48	24	6	3	1.5
BPSK	3/4	1	48	36	9	4.5	2.25
QPSK	1/2	2	96	48	12	6	3
QPSK	3/4	2	96	72	18	9	4.5
16-QAM	1/2	4	192	96	24	12	6
16-QAM	3/4	4	192	144	36	18	9
64-QAM	2/3	6	288	192	48	24	12
64-QAM	3/4	6	288	216	54	27	13.5

Extended Rate PHY (ERP)
The ERP builds on the payload data rates of 1 and 2 Mb/s, use DSSS modulation and builds on the payload data rates of 1, 2, 5.5, and 11 Mb/s。 provide additional payload data rates of 6, 9, 12, 18, 24,36, 48, and 54 Mb/s. Of these rates, transmission and reception capability for 1, 2, 5.5, 6, 11, 12, and 24 Mb/s data rates is mandatory.
是前面三个的融合

High-throughput (HT) PHY
high-throughput (HT) orthogonal frequency division multiplexing (OFDM) system
The HT PHY data subcarriers are modulated using binary phase shift keying (BPSK), quadrature phase shift keying (QPSK), 16-quadrature amplitude modulation (16-QAM), or 64-QAM. Forward error correction(FEC) coding (convolutional coding) is used with a coding rate of 1/2, 2/3, 3/4, or 5/6. LDPC codes are added as an optional feature.
Other optional features at both transmit and receive sides are 400 ns (short) guard interval (GI), transmit beamforming, HT-greenfield format, and STBC.
前向纠错编码，LDPC编码,400ns Short GI,波束成形发射,HT-GreenField,STBC等新特性 强制支持的速率参考Table 19-27 MCS0-MCS7

Table 19-27—MCS parameters for mandatory 20 MHz, N_{SS} = 1, N_{ES} = 1

MCS Index	Modulation	R	$N_{BPSCS}(i_{SS})$	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	Data rate (Mb/s) 800 ns GI	Data rate (Mb/s) 400 ns GI (see NOTE)
0	BPSK	1/2	1	52	4	52	26	6.5	7.2
1	QPSK	1/2	2	52	4	104	52	13.0	14.4
2	QPSK	3/4	2	52	4	104	78	19.5	21.7
3	16-QAM	1/2	4	52	4	208	104	26.0	28.9
4	16-QAM	3/4	4	52	4	208	156	39.0	43.3
5	64-QAM	2/3	6	52	4	312	208	52.0	57.8
6	64-QAM	3/4	6	52	4	312	234	58.5	65.0
7	64-QAM	5/6	6	52	4	312	260	65.0	72.2

NOTE—Support of 400 ns GI is optional on transmit and receive.

Table 19-28—MCS parameters for optional 20 MHz, N_{SS} = 2, N_{ES} = 1, EQM

MCS Index	Modulation	R	$N_{BPSCS}(i_{SS})$	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	Data rate (Mb/s) 800 ns GI	Data rate (Mb/s) 400 ns GI
8	BPSK	1/2	1	52	4	104	52	13.0	14.4
9	QPSK	1/2	2	52	4	208	104	26.0	28.9
10	QPSK	3/4	2	52	4	208	156	39.0	43.3
11	16-QAM	1/2	4	52	4	416	208	52.0	57.8
12	16-QAM	3/4	4	52	4	416	312	78.0	86.7
13	64-QAM	2/3	6	52	4	624	416	104.0	115.6
14	64-QAM	3/4	6	52	4	624	468	117.0	130.0
15	64-QAM	5/6	6	52	4	624	520	130.0	144.4

Table 19-31—MCS parameters for optional 40 MHz, N_{SS} = 1, N_{ES} = 1

MCS Index	Modulation	R	$N_{BPSCS}(i_{SS})$	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	Data rate (Mb/s) 800 ns GI	Data rate (Mb/s) 400 ns GI
0	BPSK	1/2	1	108	6	108	54	13.5	15.0
1	QPSK	1/2	2	108	6	216	108	27.0	30.0
2	QPSK	3/4	2	108	6	216	162	40.5	45.0
3	16-QAM	1/2	4	108	6	432	216	54.0	60.0
4	16-QAM	3/4	4	108	6	432	324	81.0	90.0
5	64-QAM	2/3	6	108	6	648	432	108.0	120.0
6	64-QAM	3/4	6	108	6	648	486	121.5	135.0
7	64-QAM	5/6	6	108	6	648	540	135.0	150.0

Table 19-32—MCS parameters for optional 40 MHz, N_{SS} = 2, N_{ES} = 1, EQM

MCS Index	Modulation	R	$N_{BPSCS}(i_{SS})$	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	Data rate (Mb/s) 800 ns GI	Data rate (Mb/s) 400 ns GI
8	BPSK	1/2	1	108	6	216	108	27.0	30.0
9	QPSK	1/2	2	108	6	432	216	54.0	60.0
10	QPSK	3/4	2	108	6	432	324	81.0	90.0
11	16-QAM	1/2	4	108	6	864	432	108.0	120.0
12	16-QAM	3/4	4	108	6	864	648	162.0	180.0
13	64-QAM	2/3	6	108	6	1296	864	216.0	240.0
14	64-QAM	3/4	6	108	6	1296	972	243.0	270.0
15	64-QAM	5/6	6	108	6	1296	1080	270.0	300.0

Directional multi-gigabit (DMG) PHY
The DMG PHY supports three modulation methods:
— A control modulation using MCS 0 (the DMG control mode; see 20.4)
— A single carrier (SC) modulation using MCS 1 to MCS 12, MCS 9.1, 12.1, 12.2, 12.3, 12.4, 12.5 and 12.6 (the DMG SC mode; see 20.6) and MCS 25 to MCS 31
— An OFDM modulation using MCS 13 to MCS 24 (the DMG OFDM mode; see 20.5)
Table 20-19—DMG SC mode modulation and coding schemes

very high throughput (VHT) orthogonal frequency division multiplexing (OFDM) system
The VHT PHY data subcarriers are modulated using binary phase shift keying (BPSK), quadrature phase shift keying (QPSK), 16-quadrature amplitude modulation (16-QAM), 64-QAM, and 256-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. 多了256-QAM

Table 21-24—Allowed relative constellation error versus constellation size and coding rate

Modulation	Coding rate	Relative constellation error (dB)
BPSK	1/2	–5
QPSK	1/2	–10
QPSK	3/4	–13
16-QAM	1/2	–16
16-QAM	3/4	–19
64-QAM	2/3	–22
64-QAM	3/4	–25
64-QAM	5/6	–27
256-QAM	3/4	–30
256-QAM	5/6	–32

Table 21-30—VHT-MCSs for mandatory 20 MHz, N_{SS} = 1

VHT-MCS Index	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s) 800 ns GI	Data rate (Mb/s) 400 ns GI (See NOTE)
0	BPSK	1/2	1	52	4	52	26	1	6.5	7.2
1	QPSK	1/2	2	52	4	104	52	1	13.0	14.4
2	QPSK	3/4	2	52	4	104	78	1	19.5	21.7
3	16-QAM	1/2	4	52	4	208	104	1	26.0	28.9
4	16-QAM	3/4	4	52	4	208	156	1	39.0	43.3
5	64-QAM	2/3	6	52	4	312	208	1	52.0	57.8
6	64-QAM	3/4	6	52	4	312	234	1	58.5	65.0
7	64-QAM	5/6	6	52	4	312	260	1	65.0	72.2
8	256-QAM	3/4	8	52	4	416	312	1	78.0	86.7
9	Not valid									

NOTE—Support of 400 ns GI is optional on transmit and receive.

Table 21-38—VHT-MCSs for mandatory 40 MHz, N_{SS} = 1

VHT-MCS Index	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s) 800 ns GI	Data rate (Mb/s) 400 ns GI (See NOTE)
0	BPSK	1/2	1	108	6	108	54	1	13.5	15.0
1	QPSK	1/2	2	108	6	216	108	1	27.0	30.0
2	QPSK	3/4	2	108	6	216	162	1	40.5	45.0
3	16-QAM	1/2	4	108	6	432	216	1	54.0	60.0
4	16-QAM	3/4	4	108	6	432	324	1	81.0	90.0
5	64-QAM	2/3	6	108	6	648	432	1	108.0	120.0
6	64-QAM	3/4	6	108	6	648	486	1	121.5	135.0
7	64-QAM	5/6	6	108	6	648	540	1	135.0	150.0
8	256-QAM	3/4	8	108	6	864	648	1	162.0	180.0
9	256-QAM	5/6	8	108	6	864	720	1	180.0	200.0

NOTE—Support of 400 ns GI is optional on transmit and receive.

Table 21-46—VHT-MCSs for mandatory 80 MHz, N_{SS} = 1

VHT-MCS Index	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s) 800 ns GI	Data rate (Mb/s) 400 ns GI (See NOTE)
0	BPSK	1/2	1	234	8	234	117	1	29.3	32.5
1	QPSK	1/2	2	234	8	468	234	1	58.5	65.0
2	QPSK	3/4	2	234	8	468	351	1	87.8	97.5
3	16-QAM	1/2	4	234	8	936	468	1	117.0	130.0
4	16-QAM	3/4	4	234	8	936	702	1	175.5	195.0
5	64-QAM	2/3	6	234	8	1404	936	1	234.0	260.0
6	64-QAM	3/4	6	234	8	1404	1053	1	263.3	292.5
7	64-QAM	5/6	6	234	8	1404	1170	1	292.5	325.0
8	256-QAM	3/4	8	234	8	1872	1404	1	351.0	390.0
9	256-QAM	5/6	8	234	8	1872	1560	1	390.0	433.3

NOTE—Support of 400 ns GI is optional on transmit and receive.

Table 21-54—VHT-MCSs for optional 160 MHz and 80+80 MHz, N_{SS} = 1

VHT-MCS Index	Modulation	R	N_{BPSCS}	$N_{SD} \cdot N_{Seg}$	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s) 800 ns GI	Data rate (Mb/s) 400 ns GI
0	BPSK	1/2	1	468	16	468	234	1	58.5	65.0
1	QPSK	1/2	2	468	16	936	468	1	117.0	130.0
2	QPSK	3/4	2	468	16	936	702	1	175.5	195.0
3	16-QAM	1/2	4	468	16	1872	936	1	234.0	260.0
4	16-QAM	3/4	4	468	16	1872	1404	1	351.0	390.0
5	64-QAM	2/3	6	468	16	2808	1872	1	468.0	520.0
6	64-QAM	3/4	6	468	16	2808	2106	1	526.5	585.0
7	64-QAM	5/6	6	468	16	2808	2340	2	585.0	650.0
8	256-QAM	3/4	8	468	16	3744	2808	2	702.0	780.0
9	256-QAM	5/6	8	468	16	3744	3120	2	780.0	866.7

high efficiency (HE) orthogonal frequency division multiplexing (OFDM) system
The HE PHY data subcarriers are modulated using BPSK, BPSK DCM, QPSK, QPSK DCM, 16-QAM, 16-QAM DCM, 64-QAM, 256-QAM and 1024-QAM 还有DCM. Forward error correction (FEC) coding (convolutional or LDPC coding) is used with coding rates of 1/2, 2/3, 3/4 and 5/6.

The HE PHY extends the maximum number of users supported for DL MU-MIMO transmissions to eight per RU and provides support for DL and UL orthogonal frequency division multiple access (OFDMA) as well as for UL MU-MIMO. Both DL and UL MU-MIMO transmissions are supported on portions of the PPDU bandwidth (on resource units greater than or equal to 106 tones).
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.
支持OFDMA ,支持MIMO多入多出(空分复用)

The HE PHY provides support for 0.8 μs, 1.6 μs and 3.2 μs guard interval durations 支持的GI

Table 28-5—Maximum number of RUs for each channel width

RU type	CBW20	CBW40	CBW80	CBW80+80 and CBW160
26-tone RU	9	18	37	74
52-tone RU	4	8	16	32
106-tone RU	2	4	8	16
242-tone RU	1	2	4	8
484-tone RU	N/A	1	2	4
996-tone RU	N/A	N/A	1	2
2×996 tone RU	N/A	N/A	N/A	1

An HE MU PPDU using OFDMA transmission can carry a mixture of 26-, 52-, 106-, 242-, 484-, and 996-tone RUs.

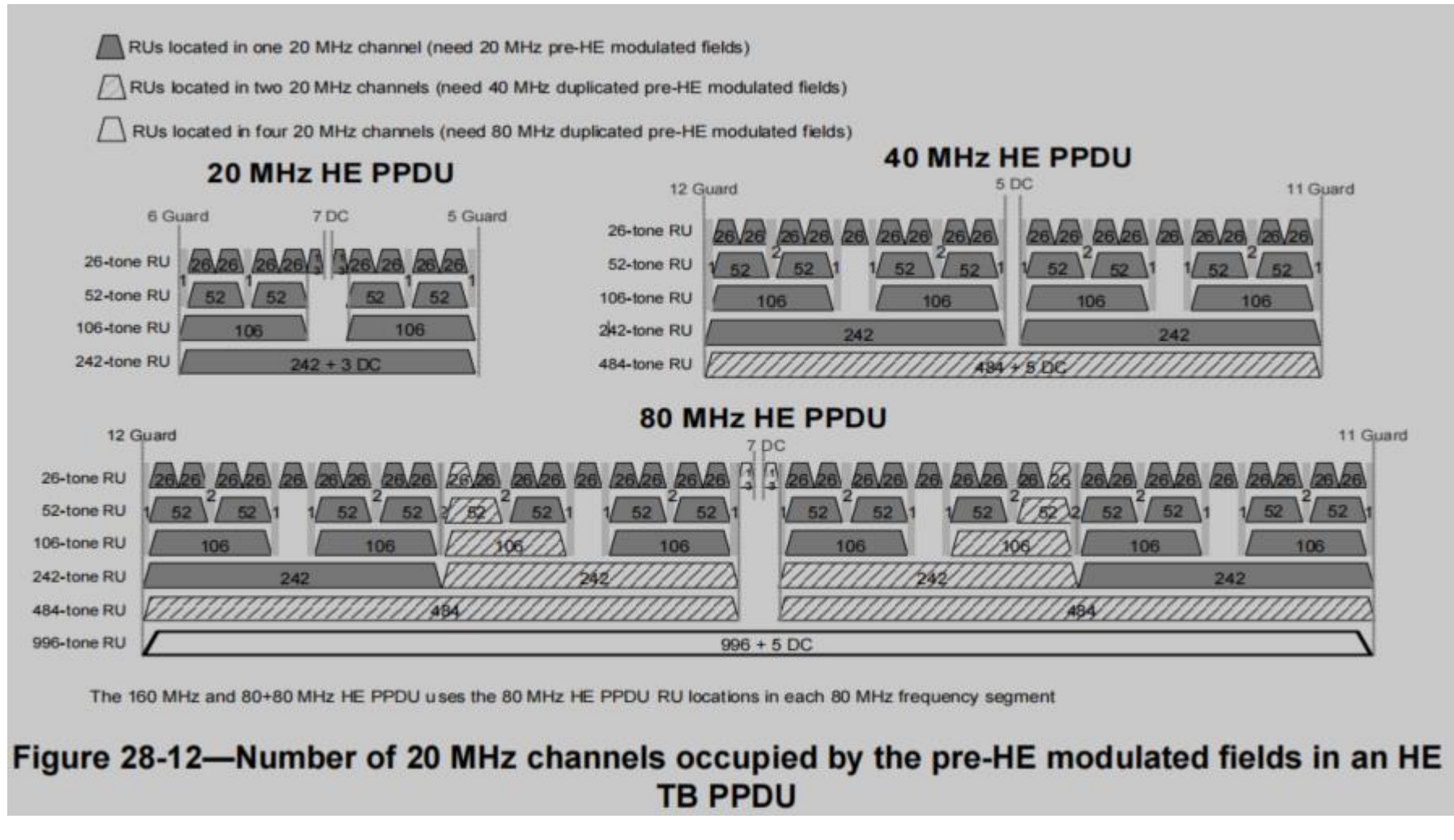

Figure 28-12—Number of 20 MHz channels occupied by the pre-HE modulated fields in an HE TB PPDU

Table 28-52—HE-MCSs for 26-tone RU, N_{SS} = 1

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{CBPS}	N_{DBPS}	Data rate (Mb/s) 0.8 μs GI	Data rate (Mb/s) 1.6 μs GI	Data rate (Mb/s) 3.2 μs GI
0	1	BPSK	1/2	1	12	12	6	0.4	0.4	0.4
	0		1/2		24	24	12	0.9	0.8	0.8
1	1	QPSK	1/2	2	12	24	12	0.9	0.8	0.8
	0		1/2		24	48	24	1.8	1.7	1.5
2	N/A		3/4		24	48	36	2.6	2.5	2.3
3	1	16-QAM	1/2	4	12	48	24	1.8	1.7	1.5
	0		1/2		24	96	48	3.5	3.3	3.0
4	1		3/4		12	48	36	2.6	2.5	2.3
	0		3/4		24	96	72	5.3	5.0	4.5
5	N/A	64-QAM	2/3	6	24	144	96	7.1	6.7	6.0
6			3/4				108	7.9	7.5	6.8
7			5/6				120	8.8	8.3	7.5
8		256-QAM	3/4	8		192	144	10.6	10.0	9.0
9			5/6				160	11.8	11.1	10.0
10		1024-QAM	3/4	10		240	180	13.2	12.5	11.3
11			5/6				200	14.7	13.9	12.5

Table 28-60—HE-MCSs for 52-tone RU, N_{SS} = 1

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{CBPS}	N_{DBPS}	Data rate (Mb/s) 0.8 μs GI	Data rate (Mb/s) 1.6 μs GI	Data rate (Mb/s) 3.2 μs GI
0	1	BPSK	1/2	1	24	24	12	0.9	0.8	0.8
	0		1/2		48	48	24	1.8	1.7	1.5
1	1	QPSK	1/2	2	24	48	24	1.8	1.7	1.5
	0		1/2		48	96	48	3.5	3.3	3.0
2	N/A		3/4		48	96	72	5.3	5.0	4.5
3	1	16-QAM	1/2	4	24	96	48	3.5	3.3	3.0
	0		1/2		48	192	96	7.1	6.7	6.0
4	1		3/4		24	96	72	5.3	5.0	4.5
	0		3/4		48	192	144	10.6	10.0	9.0
5	N/A	64-QAM	2/3	6	48	288	192	14.1	13.3	12.0
6			3/4				216	15.9	15.0	13.5
7			5/6				240	17.6	16.7	15.0
8		256-QAM	3/4	8		384	288	21.2	20.0	18.0
9			5/6				320	23.5	22.2	20.0
10		1024-QAM	3/4	10		480	360	26.5	25.0	22.5
11			5/6				400	29.4	27.8	25.0

User Info field字段中的 RU Allocation字段表示RU类型

For a 20 MHz PPDU, the mapping of B19-B13 to RU allocation follows the RU index in Table 28-6 (Data and pilot subcarrier indices for RUs in a 20 MHz HE PPDU) in increasing order
For a 40 MHz PPDU, the mapping of B19-B13 to RU allocation follows the RU index in Table 28-7 (Data and pilot subcarrier indices for RUs in a 40 MHz HE PPDU) in increasing order.
For an 80 MHz, 160 MHz and 80+80 MHz PPDU, the mapping of B19-B13 to RU allocation follows the RU index in Table 28-8 (Data and pilot subcarrier indices for RUs in an 80 MHz HE PPDU) in increasing order

B0 B11	B12 B19	B20	B21 B24	B25	B26 B31	B32 B38	B39	
AID12	RU Allocation	UL FEC Coding Type	UL MCS	UL DCM	SS Allocation / RA-RU Information	UL Target RSSI	Reserved	Trigger Dependent User Info
12	8	1	4	1	6	7	1	variable

Figure 9-52g—User Info field

Table 9-25h—The encoding of B19–B13 of the RU Allocation subfield

B19 – B13	Description
0–36	Possible 26-tone RU cases in 80 MHz
37–52	Possible 52-tone RU cases in 80 MHz
53–60	Possible 106-tone RU cases in 80 MHz
61–64	Possible 242-tone RU cases in 80 MHz
65–66	Possible 484-tone RU cases in 80 MHz
67	996-tone RU cases in 80 MHz
68	2×996-tone RU case
69–127	Reserved

NOTE—These values are in binary form in PHY (for example, see Table 28-24 (RU Allocation subfield))

Table 28-6—Data and pilot subcarrier indices for RUs in a 20 MHz HE PPDU

RU type	RU index and subcarrier range				
26-tone RU	RU 1 [−121: −96]	RU 2 [−95: −70]	RU 3 [−68: −43]	RU 4 [−42: −17]	RU 5 [−16: −4, 4: 16]
	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]				