

U.S. Patent No. 10,715,235 (“’235 Patent”)

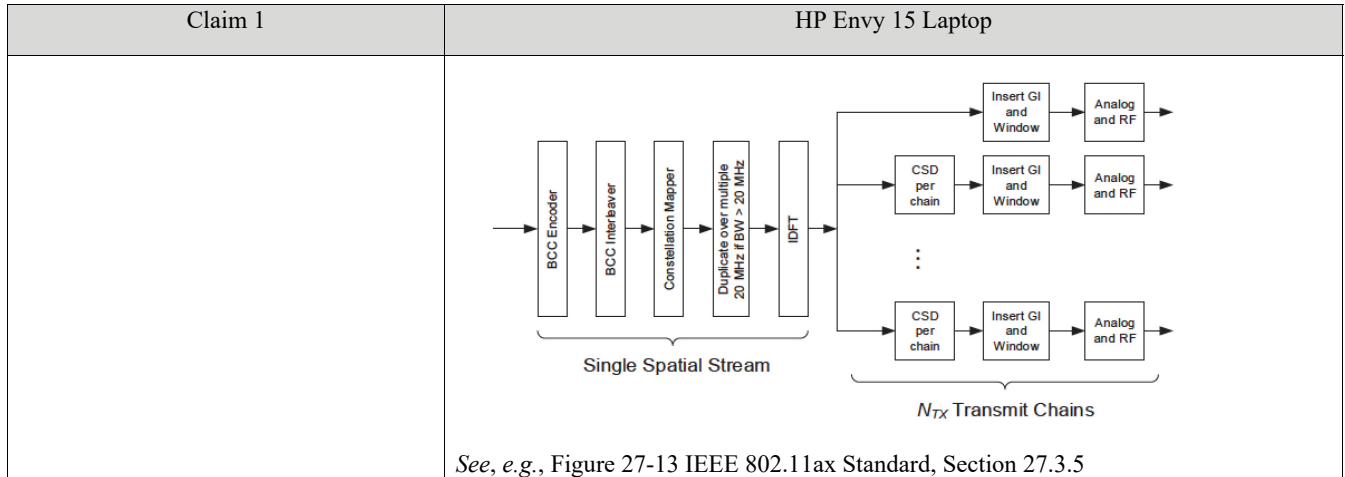
Accused Products

HP products utilizing the IEEE 802.11ac wave 2 standard alone, or the 802.11ac wave 2 standard and/or the 802.11ax or “Wi-Fi 6” standard supporting MIMO and/or MU-MIMO technologies, including without limitation the Envy Series, Envy x360 Series, Pavilion Series, Pavilion Gaming Series, Pavilion x360 Convertible Series, Spectre x360 Convertible Series, Omen Series, Chromebook x360 Series, Chromebook 11a Series, Chromebook 14b Series, Chromebook Clamshell Series, Chromebook x360 Series, ProBook Series, Elite DragonFly Series, Elite Folio Series, ZBook Series, Elite x2 Series, and EliteBook Series; Defendant’s Desktop computers, including all variations and configurations thereof, such as: Pavilion Gaming Series, All-in-One Series, Envy Series, Pavilion Series, OMEN Series, ProDesk Series, EliteOne Series, z2 Mini Workstation Series, ProOne Series, EliteDesk Series, Elite Slice Series, Chromebox Series, Z2 Small Form Factor Workstation Series, and Z2 Tower Workstation Series (“Accused Products”) infringe at least Claims 1, 2, 4, 8, 9, 11, 12, 15, and 16 of the ’235 Patent. The infringement chart below is based on the HP Envy 15 Laptop (“Envy 15 Laptop”) supporting MIMO and/or MU-MIMO utilizing the 802.11ac wave 2 and/or 802.11ax standard, which is exemplary of the infringement of the ’235 Patent.

Claim 1

Claim 1	HP Envy 15 Laptop
<p>[1pre]. A receiver for use in a wireless communications system, the receiver comprising:</p>	<p>To the extent the preamble is limiting, the Envy 15 Laptop includes a receiver for use in a wireless communications system.</p> <p>For example, the Envy 15 Laptop supports MU-MIMO technology.</p> <hr/> <p>Wireless connectivity</p> <ul style="list-style-type: none"> • Intel® Wi-Fi 6 AX 201 (2x2)^(19e) and Bluetooth® 5 combo⁽²⁶⁾ (Supporting Gigabit file transfer speeds)⁽⁷⁾ • MU-MIMO supported <hr/> <p>See HP Envy Laptop Datasheet at p. 2 available at https://h20195.www2.hp.com/v2/getpdf.aspx/4aa7-8007enuc.pdf</p> <p>Each Accused Product operates as a communicating device or station in a Wi-Fi network. Each Accused Product that supports or utilizes Wi-Fi 6 infringes in substantially the same manner as the Envy 15 Laptop according to the exemplary descriptions of Wi-Fi 6 / 802.11ax functionality cited below. Each Accused Product that supports or utilizes MIMO / MU-MIMO technologies pursuant to IEEE 802.11ac</p>

Claim 1	HP Envy 15 Laptop
	<p>wave 2 infringes in substantially the same manner as the Envy 15 Laptop according to the exemplary descriptions of 802.11ac wave 2 functionality cited below.</p>
<p>[1a] an antenna, wherein the antenna comprises a first antenna element and a second antenna element;</p>	<p>The Envy 15 Laptop includes an antenna, wherein the antenna comprises a first antenna element and a second antenna element.</p> <p>For example, Envy 15 Laptop transmits MU-MIMO signal through multiple antennas.</p> <p>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.</p> <p><i>See, e.g., IEEE 802.11ax Standard, Section 27.3.3.2.1.</i></p> <p><i>See, e.g., IEEE 802.11ax Standard, at Sections 26.5, 26.5.1, 26.5.2, 26.5.3, 27.1.1, 27.3.1, 27.3.2.5, 27.3.2.6, 27.3.5, 27.3.6.11.4, 27.3.10.7, 27.3.10.8, 27.3.10.9, 27.3.15, including Tables 27-19, 27-20, 27-21, 27-24, 27-25, 27-26, 27-27, 27-28, 27-29, Figures 27-19, 27-20, and other transmitter block diagrams for MU-MIMO transmission.</i></p> <p><i>See, e.g., 802.11ac Standard Clause 22.3, 22.3.1, 22.3.2, 22.3.3, 22.3.4, 22.3.4.1, 22.3.4.2, 22.3.4.3, 22.3.4.4, 22.3.4.5, 22.3.4.6, 22.3.4.7, 22.3.4.8, 22.3.4.9, 22.3.4.10, 22.3.5, including Tables, Figures 22-1, 22-2, 22-3, 22-4, 22-5, 22-6, 22-7, 22-8, 22-9, 22-10, 22-11, 22-12, 22-13, 22-14, 22-15, 22-16, and other transmitter block diagrams for MIMO transmission.</i></p>
<p>[1b] a transceiver operatively coupled to the antenna and configured to transmit and receive electromagnetic signals using the antenna; and</p>	<p>The Envy 15 Laptop includes a transceiver operatively coupled to the antenna and configured to transmit and receive electromagnetic signals using the antenna.</p> <p>For example, the Envy 15 Laptop includes a transmitter that is connected to the array of antennas and is configured to transmit and receive RF signals using the transmit and receive chains.</p>



Claim 1

HP Envoy 15 Laptop

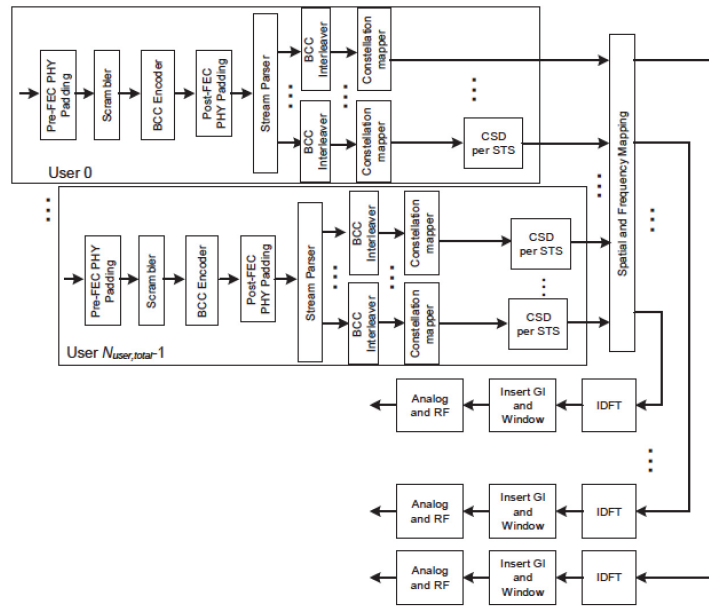
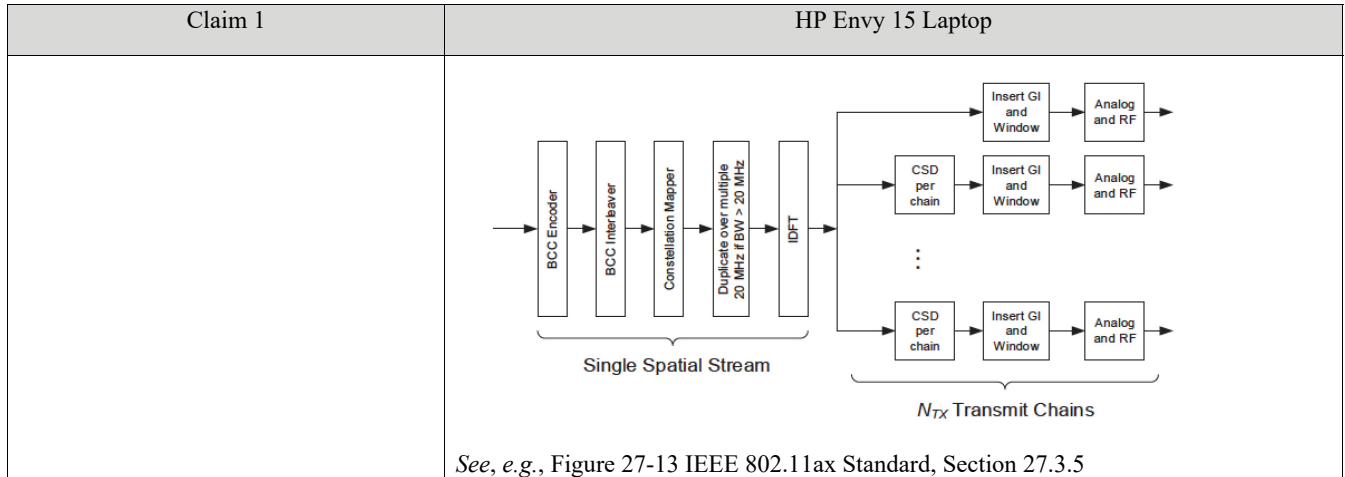


Figure 27-19—Transmitter block diagram for the Data field of an HE DL MU-MIMO transmission in a 106-, 242-, 484- or 996-tone RU with BCC encoding
See, e.g., Figure 27-19 IEEE 802.11ax Standard, Section 27.3.5

Claim 1	HP Envy 15 Laptop
	<p>The per user data is combined as follows:</p> <ol style="list-style-type: none"> a) Spatial mapping: The Q matrix is applied as described in 27.3.11.14 (OFDM modulation). The combining of all user data of an RU is done in this block. b) IDFT: Compute the inverse discrete Fourier transform. c) Insert GI and apply windowing: Prepend a GI determined by the TXVECTOR parameter GI_TYPE and apply windowing as described in 27.3.9 (Mathematical description of signals). d) Analog and RF: Upconvert the resulting complex baseband waveform with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 27.3.9 (Mathematical description of signals) and 27.3.10 (HE preamble) for details. <p><i>See, e.g., IEEE 802.11ax Standard, Section 27.3.6.11.4</i></p> <p>SU-MIMO and DL MU-MIMO beamforming are techniques used by a STA with multiple antennas (the beamformer) to steer signals using knowledge of the channel to improve throughput. With SU-MIMO beamforming all space-time streams in the transmitted signal are intended for reception at a single STA in an</p> <p>RU. With DL MU-MIMO beamforming, disjoint subsets of the space-time streams are intended for reception at different STAs in an RU of size greater than or equal to 106-tones.</p> <p><i>See, e.g., IEEE 802.11ax Standard, Section 27.3.15.1</i></p> <p>Transmit beamforming and DL-MU-MIMO require knowledge of the channel state to compute a steering matrix that is applied to the transmitted signal to optimize reception at one or more receivers. The STA transmitting using the steering matrix is called the VHT beamformer and a STA for which reception is optimized is called a VHT beamformee. An explicit feedback mechanism is used where the VHT beamformee directly measures the channel from the training symbols transmitted by the VHT beamformer and sends back a transformed estimate of the channel state to the VHT beamformer. The VHT beamformer then uses this estimate, perhaps combining estimates from multiple VHT beamformees, to derive the steering matrix.</p> <p><i>See, e.g., IEEE 802.11ac Standard Clause 9.31.5.1</i></p> <p>During transmission, a PSDU (in the SU case) or one or more PSDUs (in the MU case) are processed (i.e., scrambled and coded) and appended to the PHY preamble to create the PPDU. At the receiver, the PHY preamble is processed to aid in the detection, demodulation, and delivery of the PSDU.</p> <p><i>See, e.g., IEEE 802.11ax Standard, Section 27.3.1</i></p>

Claim 1	HP Envy 15 Laptop
	<p style="text-align: center;">Figure 27-61—PHY receive procedure for an HE MU PPDU</p>
<p>[1c] a processor operatively coupled to the transceiver, the processor configured to:</p>	<p>The Envy 15 Laptop includes a processor operatively coupled to the transceiver.</p> <p>For example, Envy 15 Laptop includes a digital signal processor.</p>



Claim 1

HP Envoy 15 Laptop

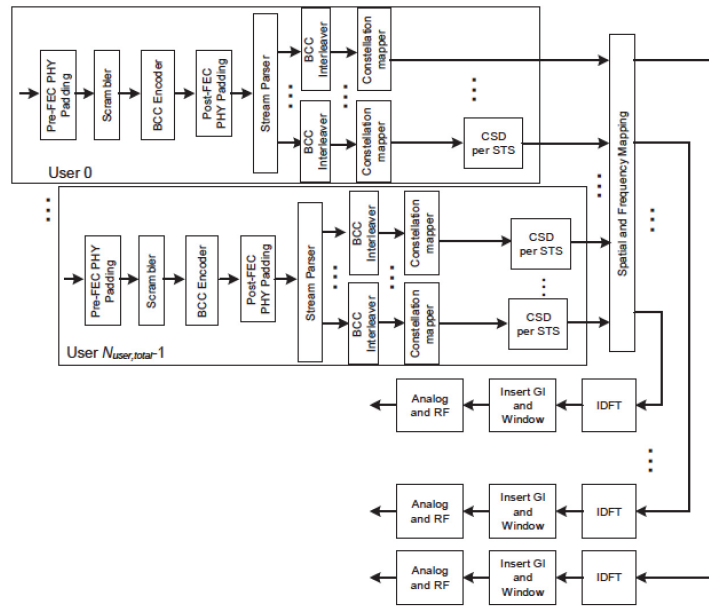


Figure 27-19—Transmitter block diagram for the Data field of an HE DL MU-MIMO transmission in a 106-, 242-, 484- or 996-tone RU with BCC encoding
See, e.g., Figure 27-19 IEEE 802.11ax Standard, Section 27.3.5

Claim 1	HP Envy 15 Laptop
	<p>The generation of each field in an HE PPDU uses many of the following blocks:</p> <ul style="list-style-type: none"> 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) Replication over multiple 20 MHz (for BW > 20 MHz) l) Multiplication by 1st column of P_{HE-LTF} m) LDPC tone mapper n) Segment deparser o) Space time block code (STBC) encoder for one spatial stream p) Cyclic shift diversity (CSD) per STS insertion q) Spatial mapper r) Frequency mapping s) Inverse discrete Fourier transform (IDFT) t) Cyclic shift diversity (CSD) per chain insertion u) Guard interval (GI) insertion v) Windowing <p>See, e.g., Figure 27-19 IEEE 802.11ax Standard, Section 27.3.5</p>

Claim 1	HP Envy 15 Laptop
	<p><i>See, e.g., 802.11ac Standard Clause 22.3, 22.3.1, 22.3.2, 22.3.3, 22.3.4, 22.3.4.1, 22.3.4.2, 22.3.4.3, 22.3.4.4, 22.3.4.5, 22.3.4.6, 22.3.4.7, 22.3.4.8, 22.3.4.9, 22.3.4.10, 22.3.5, including Tables, Figures 22-1, 22-2, 22-3, 22-4, 22-5, 22-6, 22-7, 22-8, 22-9, 22-10, 22-11, 22-12, 22-13, 22-14, 22-15, 22-16, and other transmitter block diagrams for MIMO transmission.</i></p>
<p>[1d] receive a first signal transmission from a remote station via the first antenna element and a second signal transmission from the remote station via the second antenna element simultaneously;</p>	<p>The processor in Envy 15 Laptop receives a first signal transmission from a remote station via the first antenna element and a second signal transmission from the remote station via the second antenna element simultaneously.</p> <p>For example, the Envy 15 Laptop receives a first signal transmission from a remote station, such as a Wi-Fi Access Point, via a first antenna element of an antenna and a second signal transmission from the remote station via a second antenna element of the antenna simultaneously.</p> <p>For example, the Envy 15 Laptop receives a first signal transmission from a remote station, such as a Wi-Fi Access Point, via a first antenna element of an antenna and a second signal transmission from the remote station via a second antenna element of the antenna simultaneously, such as when the Envy 15 Laptop receives first and second signals with its first and second antenna elements that contain training fields of a null data packet used for MU-MIMO sounding and channel estimation procedures.</p> <p>The HE PHY supports OFDMA transmissions, both in the DL and the UL where different users can occupy different RUs in a PPDU (see 27.3.9 (Mathematical description of signals)). The transmission within an RU in a PPDU may be single stream to one user, spatially multiplexed to one user (SU-MIMO), or spatially multiplexed 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).</p> <p><i>See, e.g., IEEE 802.11ax Standard, Section 27.3.1.1</i></p>

Claim 1	HP Envy 15 Laptop
	<p> tured. The number of users in the MU-MIMO group is indicated in the Number Of HE-SIG-B Symbols Or MU-MIMO Users field in HE-SIG-A. The allocated spatial streams for each user and the total number of spatial streams are indicated in the Spatial Configuration field of User field in HE-SIG-B containing the STA-ID of the designated MU-MIMO STA as defined in Table 27-29 (Spatial Configuration subfield encoding). <i>See, e.g., IEEE 802.11ax Standard, Section 27.3.2.5</i> </p> <p> If there is only one User field (see Table 27-27 (User field format for a non-MU-MIMO allocation)) for an RU in the HE-SIG-B content channel, then the number of spatial streams for the user in the RU is indicated by the NSTS field in the User field. </p> <p> If there is more than one User field (see Table 27-28 (User field for an MU-MIMO allocation)) for an RU in the HE-SIG-B content channel, then the number of allocated spatial streams for each user in the RU is indicated by the Spatial Configuration field of the User field in HE-SIG-B. Note that for an RU with 484 or <i>See, e.g., IEEE 802.11ax Standard, Section 27.3.2.5</i> </p> <p> UL MU transmissions are preceded by a Trigger frame or frame carrying a TRS Control subfield from the AP. The Trigger frame or frame carrying the TRS Control subfield indicates the parameters, such as the duration of the HE TB PPDU, RU allocation, target RSSI and MCS (see 9.3.1.22 (Trigger frame format), 9.2.4.6a.1 (TRS Control) and 26.5.3.3 (Non-AP STA behavior for UL MU operation)), required to transmit an HE TB PPDU. <i>See, e.g., IEEE 802.11ax Standard, Section 27.3.2.6</i> </p> <p> The HE-SIG-B field provides the OFDMA and DL MU-MIMO resource allocation information to allow the STAs to look up the corresponding resources to be used in the data portion of the frame. The integer fields of the HE-SIG-B field are transmitted in unsigned binary format, LSB first, where the LSB is in the lowest numbered bit position. <i>See, e.g., IEEE 802.11ax Standard, Section 27.3.10.8</i> </p> <p> SU-MIMO and DL MU-MIMO beamforming are techniques used by a STA with multiple antennas (the beamformer) to steer signals using knowledge of the channel to improve throughput. With SU-MIMO beamforming all space-time streams in the transmitted signal are intended for reception at a single STA in an </p>

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	<p>RU. With DL MU-MIMO beamforming, disjoint subsets of the space-time streams are intended for reception at different STAs in an RU of size greater than or equal to 106-tones.</p> <p><i>See, e.g., IEEE 802.11ax Standard, Section 27.3.15.1</i></p> <p>The User Specific field consists of multiple User fields. The User fields follow the Common field of HE-SIG-B. The RU Allocation field in the Common field and the position of the User field in the User Specific field together identify the RU used to transmit a STA's data. Multiple RUs addressed to a single STA shall</p> <p><i>See, e.g., IEEE 802.11ax Standard, Section 27.3.10.8.5</i></p> <p>Transmit beamforming and DL-MU-MIMO require knowledge of the channel state to compute a steering matrix that is applied to the transmitted signal to optimize reception at one or more receivers. The STA transmitting using the steering matrix is called the VHT beamformer and a STA for which reception is optimized is called a VHT beamformee. An explicit feedback mechanism is used where the VHT beamformee directly measures the channel from the training symbols transmitted by the VHT beamformer and sends back a transformed estimate of the channel state to the VHT beamformer. The VHT beamformer then uses this estimate, perhaps combining estimates from multiple VHT beamformees, to derive the steering matrix.</p> <p><i>See, e.g., IEEE 802.11ac Standard Clause 9.31.5.1</i></p> <p>A VHT beamformer shall initiate a sounding feedback sequence by transmitting a VHT NDP Announcement frame followed by a VHT NDP after a SIFS. The VHT beamformer shall include in the VHT NDP Announcement frame one STA Info field for each VHT beamformee that is expected to prepare VHT Compressed Beamforming feedback and shall identify the VHT beamformee by including the VHT beamformee's AID in the AID subfield of the STA Info field. The VHT NDP Announcement frame shall include at least one STA Info field.</p> <p><i>See, e.g., IEEE 802.11ac Standard Clause 9.31.5.2</i></p> <p>A non-AP VHT beamformee that receives a VHT NDP Announcement frame from a VHT beamformer with which it is associated or has an established DLS or TDLS session and that contains the VHT beamformee's AID in the AID subfield of a STA Info field that is not the first STA Info field shall transmit its VHT Compressed Beamforming feedback a SIFS after receiving a Beamforming Report Poll with RA matching its MAC address and a non-bandwidth signaling TA obtained from the TA field matching the MAC address of the VHT beamformer. If the RXVECTOR parameter CH_BANDWIDTH_IN_NON_HT of the received</p> <p><i>See, e.g., IEEE 802.11ac Standard Clause 9.31.5.2</i></p>

Claim 1	HP Envy 15 Laptop												
	<p>The VHT Compressed Beamforming frame is an Action No Ack frame of category VHT. The Action field of a VHT Compressed Beamforming frame contains the information shown in Table 8-281ai.</p> <p style="text-align: center;">Table 8-281ai—VHT Compressed Beamforming frame Action field format</p> <table border="1" data-bbox="678 768 1377 993"> <thead> <tr> <th data-bbox="678 768 824 814">Order</th> <th data-bbox="824 768 1377 814">Information</th> </tr> </thead> <tbody> <tr> <td data-bbox="678 814 824 848">1</td> <td data-bbox="824 814 1377 848">Category</td> </tr> <tr> <td data-bbox="678 848 824 882">2</td> <td data-bbox="824 848 1377 882">VHT Action</td> </tr> <tr> <td data-bbox="678 882 824 915">3</td> <td data-bbox="824 882 1377 915">VHT MIMO Control (see 8.4.1.47)</td> </tr> <tr> <td data-bbox="678 915 824 949">4</td> <td data-bbox="824 915 1377 949">VHT Compressed Beamforming Report (see 8.4.1.48)</td> </tr> <tr> <td data-bbox="678 949 824 993">5</td> <td data-bbox="824 949 1377 993">MU Exclusive Beamforming Report (see 8.4.1.49)</td> </tr> </tbody> </table> <p><i>See, e.g., IEEE 802.11ac Standard Clause 8.5.23.2</i></p> <p>The VHT MIMO Control field is always present in the frame. The presence and contents of the VHT Compressed Beamforming Report field and the MU Exclusive Beamforming Report field are dependent on the values of the Feedback Type, Remaining Feedback Segments, and First Feedback Segment subfields of the VHT MIMO Control field (see 8.4.1.47, 8.4.1.48, 8.4.1.49, and 9.31.5).</p> <p><i>See, e.g., IEEE 802.11ac Standard Clause 8.5.23.2</i></p> <p><i>See Tables 8-53(d)-(h) in IEEE 802.11ac Standard Clause 8.4.1.48</i></p> <p>The $AvgSNR_i$ in Table 8-53h is found by computing the SNR per subcarrier in decibels for the subcarriers identified in Table 8-53g, and then computing the arithmetic mean of those values. Each SNR value per tone in stream i (before being averaged) corresponds to the SNR associated with the column i of the beamforming feedback matrix V determined at the beamformee. Each SNR corresponds to the predicted SNR at the beamformee when the beamformer applies all columns of the matrix V.</p> <p><i>See, e.g., IEEE 802.11ac Standard Clause 8.4.1.48</i></p>	Order	Information	1	Category	2	VHT Action	3	VHT MIMO Control (see 8.4.1.47)	4	VHT Compressed Beamforming Report (see 8.4.1.48)	5	MU Exclusive Beamforming Report (see 8.4.1.49)
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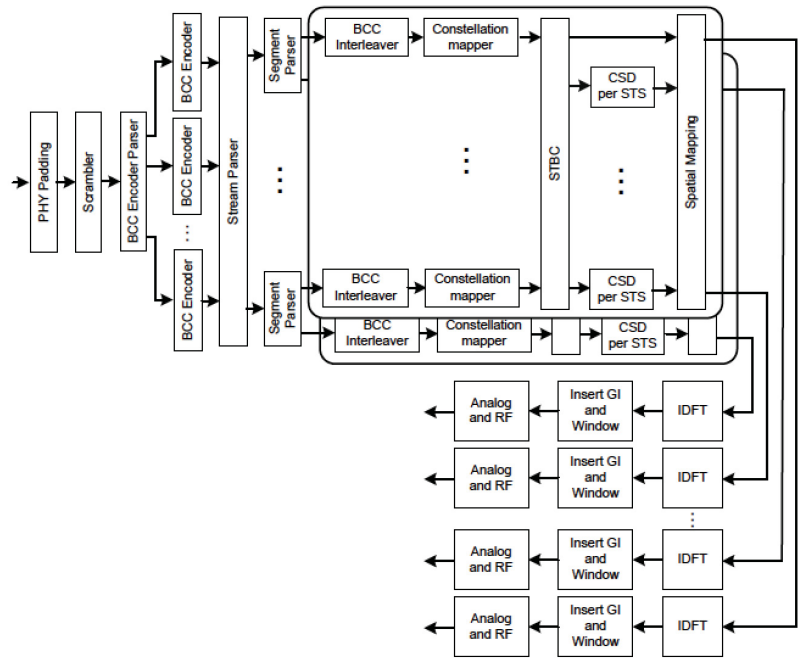
Claim 1	HP Envy 15 Laptop																								
	<p>The MU Exclusive Beamforming Report field is used by the VHT Compressed Beamforming feedback (see 8.5.23.2) to carry explicit feedback information in the form of delta SNRs. The information in the VHT Compressed Beamforming Report field and the MU Exclusive Beamforming Report field can be used by the transmit MU beamformer to determine steering matrices Q, as described in 9.29.3, 20.3.12.3, and Table 22.3.11.</p> <p>See, e.g., IEEE 802.11ac Standard Clause 8.4.1.49</p> <table border="1" data-bbox="609 783 1458 1199"> <thead> <tr> <th data-bbox="609 783 943 842">Field</th> <th data-bbox="943 783 1019 842">Size (Bits)</th> <th data-bbox="1019 783 1458 842">Meaning</th> </tr> </thead> <tbody> <tr> <td data-bbox="609 842 943 905">Delta SNR for space-time stream 1 for subcarrier $k = sscidx(0)$</td> <td data-bbox="943 842 1019 905">4</td> <td data-bbox="1019 842 1458 905">$\Delta SNR_{sscidx(0),1}$ as defined in Equation (8-2)</td> </tr> <tr> <td data-bbox="609 905 943 936">...</td> <td data-bbox="943 905 1019 936">...</td> <td data-bbox="1019 905 1458 936">...</td> </tr> <tr> <td data-bbox="609 936 943 999">Delta SNR for space-time stream N_c for subcarrier $k = sscidx(0)$</td> <td data-bbox="943 936 1019 999">4</td> <td data-bbox="1019 936 1458 999">$\Delta SNR_{sscidx(0),N_c}$ as defined in Equation (8-2)</td> </tr> <tr> <td data-bbox="609 999 943 1062">Delta SNR for space-time stream 1 for subcarrier $k = sscidx(1)$</td> <td data-bbox="943 999 1019 1062">4</td> <td data-bbox="1019 999 1458 1062">$\Delta SNR_{sscidx(1),1}$ as defined in Equation (8-2)</td> </tr> <tr> <td data-bbox="609 1062 943 1094">...</td> <td data-bbox="943 1062 1019 1094">...</td> <td data-bbox="1019 1062 1458 1094">...</td> </tr> <tr> <td data-bbox="609 1094 943 1157">Delta SNR for space-time stream N_c for subcarrier $k = sscidx(1)$</td> <td data-bbox="943 1094 1019 1157">4</td> <td data-bbox="1019 1094 1458 1157">$\Delta SNR_{sscidx(1),N_c}$ as defined in Equation (8-2)</td> </tr> <tr> <td data-bbox="609 1157 943 1199">...</td> <td data-bbox="943 1157 1019 1199">...</td> <td data-bbox="1019 1157 1458 1199">...</td> </tr> </tbody> </table>	Field	Size (Bits)	Meaning	Delta SNR for space-time stream 1 for subcarrier $k = sscidx(0)$	4	$\Delta SNR_{sscidx(0),1}$ as defined in Equation (8-2)	Delta SNR for space-time stream N_c for subcarrier $k = sscidx(0)$	4	$\Delta SNR_{sscidx(0),N_c}$ as defined in Equation (8-2)	Delta SNR for space-time stream 1 for subcarrier $k = sscidx(1)$	4	$\Delta SNR_{sscidx(1),1}$ as defined in Equation (8-2)	Delta SNR for space-time stream N_c for subcarrier $k = sscidx(1)$	4	$\Delta SNR_{sscidx(1),N_c}$ as defined in Equation (8-2)
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Claim 1	HP Envy 15 Laptop		
	Field	Size (Bits)	Meaning
	Delta SNR for space-time stream 1 for subcarrier $k = sscidx(Ns'-1)$	4	$\Delta SNR_{sscidx(Ns'-1),1}$ as defined in Equation (8-2)

	Delta SNR for space-time stream Nc for subcarrier $k = sscidx(Ns'-1)$	4	$\Delta SNR_{sscidx(Ns'-1),Nc}$ as defined in Equation (8-2)
	NOTE— $sscidx()$ is defined in Table 8-53j.		
	<p>In Table 8-53i, Ns' is the number of subcarriers for which the Delta SNR subfield is sent back to the beamformer. Table 8-53j shows Ns', the exact subcarrier indices and their order for which the Delta SNR is sent back.</p> <p>See, e.g., Table 8-53i IEEE 802.11ac Standard Clause 8.4.1.48</p> <p>Transmit beamforming and DL-MU-MIMO require knowledge of the channel state to compute a steering matrix that is applied to the transmitted signal to optimize reception at one or more receivers. The STA transmitting using the steering matrix is called the VHT beamformer and a STA for which reception is optimized is called a VHT beamformee. An explicit feedback mechanism is used where the VHT beamformee directly measures the channel from the training symbols transmitted by the VHT beamformer and sends back a transformed estimate of the channel state to the VHT beamformer. The VHT beamformer then uses this estimate, perhaps combining estimates from multiple VHT beamformees, to derive the steering matrix.</p> <p>See, e.g., IEEE 802.11ac Standard Clause 9.31.5.1</p>		

Claim 1

HP Envy 15 Laptop



See, e.g., IEEE 802.11ac Standard Clause 22.3.4.6(d)

Claim 1	HP Envy 15 Laptop
	<p>The VHT-SIG-B field is constructed per-user as follows:</p> <ol style="list-style-type: none"> a) Obtain the VHT-MCS (for MU only) and APEP_LENGTH from the TXVECTOR. b) VHT-SIG-B bits: Set the VHT-MCS (for MU only) and VHT-SIG-B Length field as described in 22.3.8.3.6. Add the reserved bits (for SU only) and N_{tail} bits of tail. For an NDP set VHT-SIG-B to the fixed bit pattern for the bandwidth used as described in 22.3.8.3.6. c) VHT-SIG-B Bit Repetition: Repeat the VHT-SIG-B bits as a function of CH_BANDWIDTH as defined in 22.3.8.3.6. d) BCC encoder: Encode the VHT-SIG-B field using BCC at rate $R=1/2$ as described in 18.3.5.6. e) Segment parser (if needed): For a contiguous 160 MHz or noncontiguous 80+80 MHz transmission, divide the output bits of the BCC encoder into two frequency subblocks as described in 22.3.10.7. This block is bypassed for 20 MHz, 40 MHz, and 80 MHz VHT PPDU transmissions. f) BCC interleaver: Interleave as described in 22.3.10.8. g) Constellation mapper: Map to a BPSK constellation as defined in 18.3.5.8. h) Segment deparser (if needed): For a contiguous 160 MHz transmission, merge the two frequency subblocks into one frequency segment as described in 22.3.10.9.3. This block is bypassed for 20 MHz, 40 MHz, 80 MHz, and 80+80 MHz VHT PPDU transmissions. i) Pilot insertion: Insert pilots following the steps described in 22.3.10.10. j) P_{VHTLTF} matrix mapping: Apply the mapping of the 1st column of the P_{VHTLTF} matrix to the data subcarriers as described in 22.3.8.3.6. The total number of data and pilot subcarriers is the same as in the Data field. k) CSD: Apply CSD for each space-time stream and frequency segment as described in 22.3.8.3.2. l) Spatial mapping: Apply the Q matrix as described in 22.3.10.11.1. m) Phase rotation: Apply the appropriate phase rotations for each 20 MHz subchannel as described in 22.3.7.4 and 22.3.7.5. n) IDFT: Compute the inverse discrete Fourier transform. o) Insert GI and apply windowing: Prepend a GI (LONG_GI) and apply windowing as described in 22.3.7.4. p) Analog and RF: Up-convert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 22.3.7.4 and 22.3.8 for details. <p>See, e.g., IEEE 802.11ac Standard Clauses 22.3.4.8(l) and 22.3.4.9.1(m), 22.3.4.9.2(m), 22.3.4.10.4(a).</p>

Claim 1	HP Envy 15 Laptop
	<p>The DL-MU-MIMO steering matrix $Q_k = [Q_{k,0}, Q_{k,1}, \dots, Q_{k,N_{user}-1}]$ can be determined by the beamformer using the beamforming feedback matrices for subcarrier k from beamformee u, $V_{k,u}$, and SNR information for subcarrier k from beamformee u, $SNR_{k,u}$, where $u = 0, 1, \dots, N_{user} - 1$. The steering matrix that is computed (or updated) using new beamforming feedback matrices and new SNR information from some or all of participating beamformees might replace the existing steering matrix Q_k for the next DL-MU-MIMO data transmission. The beamformee group for the MU transmission is signaled using the Group ID field in VHT-SIG-A (see 22.3.8.3.3 and 22.3.11.4).</p> <p><i>See, e.g., IEEE 802.11ac Standard Clause 22.3.11.1</i></p> <p>Upon receipt of a VHT NDP sounding PPDU, the beamformee shall remove the space-time stream CSD in Table 22-11 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 shall be compressed in the form of angles using the method described in 20.3.12.3.6. The angles, $\phi(k,u)$ and $\psi(k,u)$, are quantized according to Table 8-53e. The number of bits for quantization is chosen by the beamformee, based on the indication from the beamformer as to whether the feedback is requested for SU-MIMO beamforming or DL-MU-MIMO beamforming. The compressed beamforming feedback using 20.3.12.3.6 is the only Clause 22 beamforming feedback format defined.</p> <p>The beamformee shall generate the beamforming feedback matrices with the number of rows (N_r) equal to the N_{STS} of the NDP.</p> <p>After receiving the angle information, $\phi(k,u)$ and $\psi(k,u)$, the beamformer reconstructs $V_{k,u}$ using Equation (20-79). For SU-MIMO beamforming, the beamformer can use this $V_{k,0}$ matrix to determine the steering matrix Q_k. For DL-MU-MIMO beamforming, the beamformer may calculate a steering matrix $Q_k = [Q_{k,0}, Q_{k,1}, \dots, Q_{k,N_{user}-1}]$ using $V_{k,u}$ and $SNR_{k,u}$ ($0 \leq u \leq N_{user} - 1$) in order to suppress crosstalk between participating beamformees. The method used by the beamformer to calculate the steering matrix Q_k is implementation specific.</p> <p><i>See, e.g., IEEE 802.11ac Standard Clause 22.3.11.2</i></p>
[1e] determine first signal information for the first signal transmission;	<p>The processor in the Envy 15 Laptop determines first signal information for the first signal transmission.</p> <p>For example, the Envy 15 Laptop determines the first signal information for the first signal transmission, by determining symbols corresponding to e.g. a first space-time stream using e.g. the training fields of a null data packet for MU-MIMO sounding and</p>

Claim 1	HP Envy 15 Laptop
	<p>channel estimation, which allows for determining, e.g., an estimate of the channel state, e.g., a transformed estimate of the channel state to be transmitted in a compressed beamforming report, e.g., the parameters in the beamforming feedback matrix.</p> <p>Transmit beamforming and DL MU-MIMO require knowledge of the channel state to compute a steering matrix that is applied to the transmit signal to optimize reception at one or more receivers. HE STAs use the HE sounding protocol to determine the channel state information. The HE sounding protocol provides explicit feedback mechanisms, defined as HE non-trigger-based (non-TB) sounding and HE trigger-based (TB) sounding, where the HE beamformee measures the channel using a training signal (i.e., an HE sounding NDP) transmitted by the HE beamformer and sends back a transformed estimate of the channel state. The HE beamformer uses this estimate to derive the steering matrix.</p> <p>The HE beamformee returns an estimate of the channel state in an HE compressed beamforming/CQI report carried in one or more HE Compressed Beamforming/CQI frames. There are three types of HE compressed beamforming/CQI report:</p> <p><i>See, e.g., IEEE 802.11ax Standard, Section 26.7.1</i></p> <p>An HE beamformee that receives an HE NDP Announcement frame from an HE beamformer with which it is associated and that contains the HE beamformee's MAC address in the RA field and also receives an HE sounding NDP a SIFS after the HE NDP Announcement frame shall transmit its HE compressed beamforming/CQI report a SIFS after the HE sounding NDP. The TXVECTOR parameter CH_BANDWIDTH for the PDU containing the HE compressed beamforming/CQI report shall be set to indicate a bandwidth not wider than that indicated by the RXVECTOR parameter CH_BANDWIDTH of the HE sounding NDP.</p> <p><i>See, e.g., IEEE 802.11ax Standard, Section 26.7.3</i></p> <p>An HE beamformee that receives an HE NDP Announcement frame as part of an HE TB sounding sequence with a STA Info field addressed to it soliciting SU or MU feedback shall generate an HE compressed beamforming/CQI report using the feedback type, N_g and codebook size indicated in the STA Info field. If the HE beamformee then receives a BFRP Trigger frame with a User Info field addressed to it, the HE beamformee transmits an HE TB PDU containing the HE compressed beamforming/CQI report following the rules defined in 26.5.3.3 (Non-AP STA behavior for UL MU operation). If the HE NDP Announcement frame has</p> <p><i>See, e.g., IEEE 802.11ax Standard, Section 26.7.3</i></p> <p>UL MU operation allows an AP to solicit simultaneous immediate response frames from one or more non-AP HE STAs. A non-AP HE STA shall follow the rules in this subclause for the transmission of response</p> <p><i>See, e.g., IEEE 802.11ax Standard, Section 26.5.3</i></p>

Claim 1	HP Envy 15 Laptop
	<p>The HE-LTF field 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 and HE ER SU PPDU, the transmitter provides training for N_{STS} space-time streams (spatial mapper inputs) used for the transmission of the PSDU. In an HE MU PPDU, the transmitter provides training for $N_{STS,r,total}$ space-time streams used for the transmission of the PSDU(s) in the r-th RU. In an HE TB 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. An 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 subcarriers of each HE-LTF symbol are multiplied by the entries of a</p> <p><i>See, e.g., IEEE 802.11ax Standard, Section 27.3.10.10</i></p> <p>In an HE SU PPDU, HE MU PPDU and HE ER SU PPDU, the combination of HE-LTF type and GI duration is indicated in HE-SIG-A field. In an HE TB PPDU, the combination of HE-LTF type and GI duration is indicated in the Trigger frame that triggers the transmission of the PPDU. If an HE PPDU is an HE sounding NDP, the combinations of HE-LTF types and GI durations are listed in 27.3.18 (Transmit specification). If an HE PPDU is an HE TB feedback NDP, the combinations of types and GI durations are listed in 27.3.4 (HE PPDU formats).</p> <p><i>See, e.g., IEEE 802.11ax Standard, Section 27.3.10.10</i></p> <p>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 9.4.1.65 (HE Compressed Beamforming Report field) and 9.4.1.66 (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.</p> <p>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 9.4.1.65 (HE Compressed Beamforming Report field).</p> <p><i>See, e.g., IEEE 802.11ax Standard, Section 27.3.15.1</i></p>

Claim 1	HP Envy 15 Laptop
	<p>Transmit beamforming and DL-MU-MIMO require knowledge of the channel state to compute a steering matrix that is applied to the transmitted signal to optimize reception at one or more receivers. The STA transmitting using the steering matrix is called the VHT beamformer and a STA for which reception is optimized is called a VHT beamformee. An explicit feedback mechanism is used where the VHT beamformee directly measures the channel from the training symbols transmitted by the VHT beamformer and sends back a transformed estimate of the channel state to the VHT beamformer. The VHT beamformer then uses this estimate, perhaps combining estimates from multiple VHT beamformees, to derive the steering matrix.</p> <p><i>See, e.g., IEEE 802.11ac Standard Clause 9.31.5.1</i></p> <p>A VHT beamformer shall initiate a sounding feedback sequence by transmitting a VHT NDP Announcement frame followed by a VHT NDP after a SIFS. The VHT beamformer shall include in the VHT NDP Announcement frame one STA Info field for each VHT beamformee that is expected to prepare VHT Compressed Beamforming feedback and shall identify the VHT beamformee by including the VHT beamformee's AID in the AID subfield of the STA Info field. The VHT NDP Announcement frame shall include at least one STA Info field.</p> <p><i>See, e.g., IEEE 802.11ac Standard Clause 9.31.5.2</i></p> <p>A non-AP VHT beamformee that receives a VHT NDP Announcement frame from a VHT beamformer with which it is associated or has an established DLS or TDLS session and that contains the VHT beamformee's AID in the AID subfield of a STA Info field that is not the first STA Info field shall transmit its VHT Compressed Beamforming feedback a SIFS after receiving a Beamforming Report Poll with RA matching its MAC address and a non-bandwidth signaling TA obtained from the TA field matching the MAC address of the VHT beamformer. If the RXVECTOR parameter CH_BANDWIDTH_IN_NON_HT of the received</p> <p><i>See, e.g., IEEE 802.11ac Standard Clause 9.31.5.2</i></p>

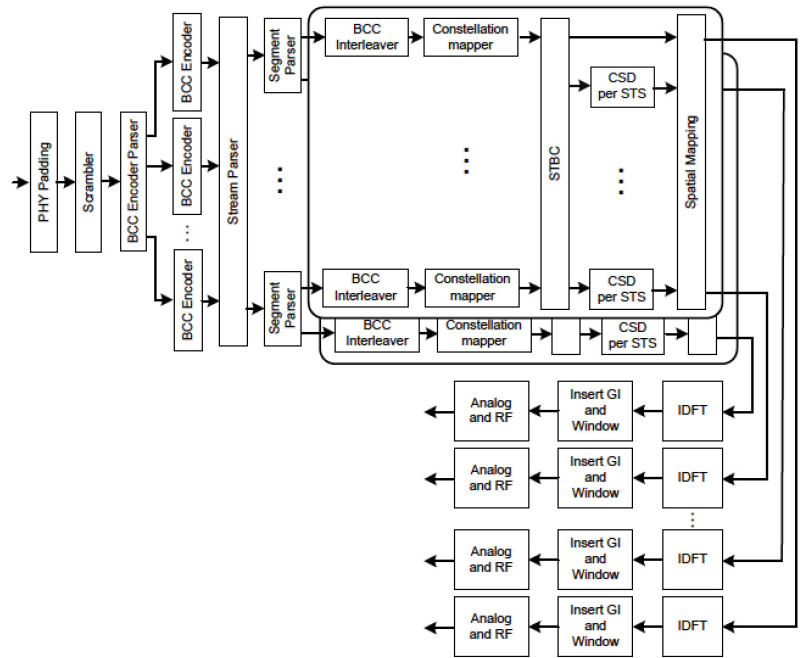
Claim 1	HP Envy 15 Laptop												
	<p data-bbox="704 627 1357 651">Table 8-281ai—VHT Compressed Beamforming frame Action field format</p> <table border="1" data-bbox="699 674 1359 884"> <thead> <tr> <th data-bbox="699 674 841 716">Order</th> <th data-bbox="841 674 1359 716">Information</th> </tr> </thead> <tbody> <tr> <td data-bbox="699 716 841 747">1</td> <td data-bbox="841 716 1359 747">Category</td> </tr> <tr> <td data-bbox="699 747 841 779">2</td> <td data-bbox="841 747 1359 779">VHT Action</td> </tr> <tr> <td data-bbox="699 779 841 810">3</td> <td data-bbox="841 779 1359 810">VHT MIMO Control (see 8.4.1.47)</td> </tr> <tr> <td data-bbox="699 810 841 842">4</td> <td data-bbox="841 810 1359 842">VHT Compressed Beamforming Report (see 8.4.1.48)</td> </tr> <tr> <td data-bbox="699 842 841 884">5</td> <td data-bbox="841 842 1359 884">MU Exclusive Beamforming Report (see 8.4.1.49)</td> </tr> </tbody> </table> <p data-bbox="623 930 1159 953">The Category field is set to the value for VHT, specified in Table 8-38.</p> <p data-bbox="623 976 1419 999">The VHT Action field is set to the value for VHT Compressed Beamforming, specified in Table 8-281ah.</p> <p data-bbox="623 1022 1438 1108">The VHT MIMO Control field is always present in the frame. The presence and contents of the VHT Compressed Beamforming Report field and the MU Exclusive Beamforming Report field are dependent on the values of the Feedback Type, Remaining Feedback Segments, and First Feedback Segment subfields of the VHT MIMO Control field (see 8.4.1.47, 8.4.1.48, 8.4.1.49, and 9.31.5).</p> <p data-bbox="594 1115 1089 1138"><i>See, e.g.</i>, IEEE 802.11ac Standard Clause 8.5.23.2</p> <p data-bbox="594 1144 1252 1167"><i>See</i> Tables 8-53(d)-(h) in IEEE 802.11ac Standard Clause 8.4.1.48</p> <p data-bbox="594 1236 1455 1352">The $AvgSNR_i$ in Table 8-53h is found by computing the SNR per subcarrier in decibels for the subcarriers identified in Table 8-53g, and then computing the arithmetic mean of those values. Each SNR value per tone in stream i (before being averaged) corresponds to the SNR associated with the column i of the beamforming feedback matrix V determined at the beamformee. Each SNR corresponds to the predicted SNR at the beamformee when the beamformer applies all columns of the matrix V.</p> <p data-bbox="594 1358 1089 1381"><i>See, e.g.</i>, IEEE 802.11ac Standard Clause 8.4.1.48</p>	Order	Information	1	Category	2	VHT Action	3	VHT MIMO Control (see 8.4.1.47)	4	VHT Compressed Beamforming Report (see 8.4.1.48)	5	MU Exclusive Beamforming Report (see 8.4.1.49)
Order	Information												
1	Category												
2	VHT Action												
3	VHT MIMO Control (see 8.4.1.47)												
4	VHT Compressed Beamforming Report (see 8.4.1.48)												
5	MU Exclusive Beamforming Report (see 8.4.1.49)												

Claim 1	HP Envy 15 Laptop																								
	<p>The MU Exclusive Beamforming Report field is used by the VHT Compressed Beamforming feedback (see 8.5.23.2) to carry explicit feedback information in the form of delta SNRs. The information in the VHT Compressed Beamforming Report field and the MU Exclusive Beamforming Report field can be used by the transmit MU beamformer to determine steering matrices Q, as described in 9.29.3, 20.3.12.3, and Table 22.3.11.</p> <p>See, e.g., IEEE 802.11ac Standard Clause 8.4.1.49</p> <table border="1" data-bbox="609 781 1458 1201"> <thead> <tr> <th data-bbox="609 781 943 842">Field</th> <th data-bbox="943 781 1019 842">Size (Bits)</th> <th data-bbox="1019 781 1458 842">Meaning</th> </tr> </thead> <tbody> <tr> <td data-bbox="609 842 943 903">Delta SNR for space-time stream 1 for subcarrier $k = sscidx(0)$</td> <td data-bbox="943 842 1019 903">4</td> <td data-bbox="1019 842 1458 903">$\Delta SNR_{sscidx(0),1}$ as defined in Equation (8-2)</td> </tr> <tr> <td data-bbox="609 903 943 938">...</td> <td data-bbox="943 903 1019 938">...</td> <td data-bbox="1019 903 1458 938">...</td> </tr> <tr> <td data-bbox="609 938 943 999">Delta SNR for space-time stream N_c for subcarrier $k = sscidx(0)$</td> <td data-bbox="943 938 1019 999">4</td> <td data-bbox="1019 938 1458 999">$\Delta SNR_{sscidx(0),N_c}$ as defined in Equation (8-2)</td> </tr> <tr> <td data-bbox="609 999 943 1060">Delta SNR for space-time stream 1 for subcarrier $k = sscidx(1)$</td> <td data-bbox="943 999 1019 1060">4</td> <td data-bbox="1019 999 1458 1060">$\Delta SNR_{sscidx(1),1}$ as defined in Equation (8-2)</td> </tr> <tr> <td data-bbox="609 1060 943 1096">...</td> <td data-bbox="943 1060 1019 1096">...</td> <td data-bbox="1019 1060 1458 1096">...</td> </tr> <tr> <td data-bbox="609 1096 943 1157">Delta SNR for space-time stream N_c for subcarrier $k = sscidx(1)$</td> <td data-bbox="943 1096 1019 1157">4</td> <td data-bbox="1019 1096 1458 1157">$\Delta SNR_{sscidx(1),N_c}$ as defined in Equation (8-2)</td> </tr> <tr> <td data-bbox="609 1157 943 1197">...</td> <td data-bbox="943 1157 1019 1197">...</td> <td data-bbox="1019 1157 1458 1197">...</td> </tr> </tbody> </table>	Field	Size (Bits)	Meaning	Delta SNR for space-time stream 1 for subcarrier $k = sscidx(0)$	4	$\Delta SNR_{sscidx(0),1}$ as defined in Equation (8-2)	Delta SNR for space-time stream N_c for subcarrier $k = sscidx(0)$	4	$\Delta SNR_{sscidx(0),N_c}$ as defined in Equation (8-2)	Delta SNR for space-time stream 1 for subcarrier $k = sscidx(1)$	4	$\Delta SNR_{sscidx(1),1}$ as defined in Equation (8-2)	Delta SNR for space-time stream N_c for subcarrier $k = sscidx(1)$	4	$\Delta SNR_{sscidx(1),N_c}$ as defined in Equation (8-2)
Field	Size (Bits)	Meaning																							
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	<table border="1" data-bbox="597 632 1442 884"> <thead> <tr> <th data-bbox="602 638 930 690">Field</th> <th data-bbox="935 638 1003 690">Size (Bits)</th> <th data-bbox="1008 638 1437 690">Meaning</th> </tr> </thead> <tbody> <tr> <td data-bbox="602 697 930 749">Delta SNR for space-time stream 1 for subcarrier $k = sscidx(Ns'-1)$</td> <td data-bbox="935 697 1003 749">4</td> <td data-bbox="1008 697 1437 749">$\Delta SNR_{sscidx(Ns'-1),1}$ as defined in Equation (8-2)</td> </tr> <tr> <td data-bbox="602 756 930 783">...</td> <td data-bbox="935 756 1003 783">...</td> <td data-bbox="1008 756 1437 783">...</td> </tr> <tr> <td data-bbox="602 789 930 842">Delta SNR for space-time stream Nc for subcarrier $k = sscidx(Ns'-1)$</td> <td data-bbox="935 789 1003 842">4</td> <td data-bbox="1008 789 1437 842">$\Delta SNR_{sscidx(Ns'-1),Nc}$ as defined in Equation (8-2)</td> </tr> </tbody> </table> <p data-bbox="602 848 1437 884">NOTE—$sscidx()$ is defined in Table 8-53j.</p> <p data-bbox="602 926 1437 995">In Table 8-53i, Ns' is the number of subcarriers for which the Delta SNR subfield is sent back to the beamformer. Table 8-53j shows Ns', the exact subcarrier indices and their order for which the Delta SNR is sent back.</p> <p data-bbox="602 1001 1437 1029"><i>See, e.g.,</i> Table 8-53i IEEE 802.11ac Standard Clause 8.4.1.48</p> <p data-bbox="602 1058 1437 1245">Transmit beamforming and DL-MU-MIMO require knowledge of the channel state to compute a steering matrix that is applied to the transmitted signal to optimize reception at one or more receivers. The STA transmitting using the steering matrix is called the VHT beamformer and a STA for which reception is optimized is called a VHT beamformee. An explicit feedback mechanism is used where the VHT beamformee directly measures the channel from the training symbols transmitted by the VHT beamformer and sends back a transformed estimate of the channel state to the VHT beamformer. The VHT beamformer then uses this estimate, perhaps combining estimates from multiple VHT beamformees, to derive the steering matrix.</p> <p data-bbox="602 1251 1437 1278"><i>See, e.g.,</i> IEEE 802.11ac Standard Clause 9.31.5.1</p>			Field	Size (Bits)	Meaning	Delta SNR for space-time stream 1 for subcarrier $k = sscidx(Ns'-1)$	4	$\Delta SNR_{sscidx(Ns'-1),1}$ as defined in Equation (8-2)	Delta SNR for space-time stream Nc for subcarrier $k = sscidx(Ns'-1)$	4	$\Delta SNR_{sscidx(Ns'-1),Nc}$ as defined in Equation (8-2)
Field	Size (Bits)	Meaning													
Delta SNR for space-time stream 1 for subcarrier $k = sscidx(Ns'-1)$	4	$\Delta SNR_{sscidx(Ns'-1),1}$ as defined in Equation (8-2)													
...													
Delta SNR for space-time stream Nc for subcarrier $k = sscidx(Ns'-1)$	4	$\Delta SNR_{sscidx(Ns'-1),Nc}$ as defined in Equation (8-2)													

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See, e.g., IEEE 802.11ac Standard Clause 22.3.4.6(d)

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	<p>The VHT-SIG-B field is constructed per-user as follows:</p> <ol style="list-style-type: none"> a) Obtain the VHT-MCS (for MU only) and APEP_LENGTH from the TXVECTOR. b) VHT-SIG-B bits: Set the VHT-MCS (for MU only) and VHT-SIG-B Length field as described in 22.3.8.3.6. Add the reserved bits (for SU only) and N_{tail} bits of tail. For an NDP set VHT-SIG-B to the fixed bit pattern for the bandwidth used as described in 22.3.8.3.6. c) VHT-SIG-B Bit Repetition: Repeat the VHT-SIG-B bits as a function of CH_BANDWIDTH as defined in 22.3.8.3.6. d) BCC encoder: Encode the VHT-SIG-B field using BCC at rate $R=1/2$ as described in 18.3.5.6. e) Segment parser (if needed): For a contiguous 160 MHz or noncontiguous 80+80 MHz transmission, divide the output bits of the BCC encoder into two frequency subblocks as described in 22.3.10.7. This block is bypassed for 20 MHz, 40 MHz, and 80 MHz VHT PPDU transmissions. f) BCC interleaver: Interleave as described in 22.3.10.8. g) Constellation mapper: Map to a BPSK constellation as defined in 18.3.5.8. h) Segment deparser (if needed): For a contiguous 160 MHz transmission, merge the two frequency subblocks into one frequency segment as described in 22.3.10.9.3. This block is bypassed for 20 MHz, 40 MHz, 80 MHz, and 80+80 MHz VHT PPDU transmissions. i) Pilot insertion: Insert pilots following the steps described in 22.3.10.10. j) P_{VHTLTF} matrix mapping: Apply the mapping of the 1st column of the P_{VHTLTF} matrix to the data subcarriers as described in 22.3.8.3.6. The total number of data and pilot subcarriers is the same as in the Data field. k) CSD: Apply CSD for each space-time stream and frequency segment as described in 22.3.8.3.2. l) Spatial mapping: Apply the Q matrix as described in 22.3.10.11.1. m) Phase rotation: Apply the appropriate phase rotations for each 20 MHz subchannel as described in 22.3.7.4 and 22.3.7.5. n) IDFT: Compute the inverse discrete Fourier transform. o) Insert GI and apply windowing: Prepend a GI (LONG_GI) and apply windowing as described in 22.3.7.4. p) Analog and RF: Up-convert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 22.3.7.4 and 22.3.8 for details. <p>See, e.g., IEEE 802.11ac Standard Clauses 22.3.4.8(l) and 22.3.4.9.1(m), 22.3.4.9.2(m), 22.3.4.10.4(a).</p>

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	<p>The DL-MU-MIMO steering matrix $Q_k = [Q_{k,0}, Q_{k,1}, \dots, Q_{k,N_{user}-1}]$ can be determined by the beamformer using the beamforming feedback matrices for subcarrier k from beamformee u, $V_{k,u}$, and SNR information for subcarrier k from beamformee u, $SNR_{k,u}$, where $u = 0, 1, \dots, N_{user} - 1$. The steering matrix that is computed (or updated) using new beamforming feedback matrices and new SNR information from some or all of participating beamformees might replace the existing steering matrix Q_k for the next DL-MU-MIMO data transmission. The beamformee group for the MU transmission is signaled using the Group ID field in VHT-SIG-A (see 22.3.8.3.3 and 22.3.11.4).</p> <p><i>See, e.g., IEEE 802.11ac Standard Clause 22.3.11.1</i></p> <p>Upon receipt of a VHT NDP sounding PPDU, the beamformee shall remove the space-time stream CSD in Table 22-11 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 shall be compressed in the form of angles using the method described in 20.3.12.3.6. The angles, $\phi(k,u)$ and $\psi(k,u)$, are quantized according to Table 8-53e. The number of bits for quantization is chosen by the beamformee, based on the indication from the beamformer as to whether the feedback is requested for SU-MIMO beamforming or DL-MU-MIMO beamforming. The compressed beamforming feedback using 20.3.12.3.6 is the only Clause 22 beamforming feedback format defined.</p> <p>The beamformee shall generate the beamforming feedback matrices with the number of rows (N_r) equal to the N_{STS} of the NDP.</p> <p>After receiving the angle information, $\phi(k,u)$ and $\psi(k,u)$, the beamformer reconstructs $V_{k,u}$ using Equation (20-79). For SU-MIMO beamforming, the beamformer can use this $V_{k,0}$ matrix to determine the steering matrix Q_k. For DL-MU-MIMO beamforming, the beamformer may calculate a steering matrix $Q_k = [Q_{k,0}, Q_{k,1}, \dots, Q_{k,N_{user}-1}]$ using $V_{k,u}$ and $SNR_{k,u}$ ($0 \leq u \leq N_{user} - 1$) in order to suppress crosstalk between participating beamformees. The method used by the beamformer to calculate the steering matrix Q_k is implementation specific.</p> <p><i>See, e.g., IEEE 802.11ac Standard Clause 22.3.11.2</i></p>
<p>[1f] determine second signal information for the second signal transmission, wherein the second signal information is different than the first signal information;</p>	<p>The processor in the Envy 15 Laptop determines second signal information for the second signal transmission, wherein the second signal information is different than the first signal information.</p>

Claim 1	HP Envy 15 Laptop
	<p>For example, the Envy 15 Laptop determines the second signal information for the second signal transmission, by determining symbols corresponding to e.g. a second space-time stream using e.g. the training fields of a null data packet for MU-MIMO sounding and channel estimation, which allows for determining , e.g., an estimate of the channel state, e.g., a transformed estimate of the channel state to be transmitted in a compressed beamforming report, e.g., the parameters in the beamforming feedback matrix.</p> <p>Transmit beamforming and DL MU-MIMO require knowledge of the channel state to compute a steering matrix that is applied to the transmit signal to optimize reception at one or more receivers. HE STAs use the HE sounding protocol to determine the channel state information. The HE sounding protocol provides explicit feedback mechanisms, defined as HE non-trigger-based (non-TB) sounding and HE trigger-based (TB) sounding, where the HE beamformee measures the channel using a training signal (i.e., an HE sounding NDP) transmitted by the HE beamformer and sends back a transformed estimate of the channel state. The HE beamformer uses this estimate to derive the steering matrix.</p> <p>The HE beamformee returns an estimate of the channel state in an HE compressed beamforming/CQI report carried in one or more HE Compressed Beamforming/CQI frames. There are three types of HE compressed beamforming/CQI report:</p> <p><i>See, e.g., IEEE 802.11ax Standard, Section 26.7.1</i></p> <p>An HE beamformee that receives an HE NDP Announcement frame from an HE beamformer with which it is associated and that contains the HE beamformee's MAC address in the RA field and also receives an HE sounding NDP a SIFS after the HE NDP Announcement frame shall transmit its HE compressed beamforming/CQI report a SIFS after the HE sounding NDP. The TXVECTOR parameter CH_BANDWIDTH for the PPDU containing the HE compressed beamforming/CQI report shall be set to indicate a bandwidth not wider than that indicated by the RXVECTOR parameter CH_BANDWIDTH of the HE sounding NDP.</p> <p><i>See, e.g., IEEE 802.11ax Standard, Section 26.7.3</i></p> <p>An HE beamformee that receives an HE NDP Announcement frame as part of an HE TB sounding sequence with a STA Info field addressed to it soliciting SU or MU feedback shall generate an HE compressed beamforming/CQI report using the feedback type, Ng and codebook size indicated in the STA Info field. If the HE beamformee then receives a BFRP Trigger frame with a User Info field addressed to it, the HE beamformee transmits an HE TB PPDU containing the HE compressed beamforming/CQI report following the rules defined in 26.5.3.3 (Non-AP STA behavior for UL MU operation). If the HE NDP Announcement frame has</p> <p><i>See, e.g., IEEE 802.11ax Standard, Section 26.7.3</i></p>

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	<p>UL MU operation allows an AP to solicit simultaneous immediate response frames from one or more non-AP HE STAs. A non-AP HE STA shall follow the rules in this subclause for the transmission of response <i>See, e.g., IEEE 802.11ax Standard, Section 26.5.3</i></p> <p>The HE-LTF field 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 and HE ER SU PPDU, the transmitter provides training for N_{STS} space-time streams (spatial mapper inputs) used for the transmission of the PSDU. In an HE MU PPDU, the transmitter provides training for $N_{STS,r,total}$ space-time streams used for the transmission of the PSDU(s) in the r-th RU. In an HE TB 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. An 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 subcarriers of each HE-LTF symbol are multiplied by the entries of a <i>See, e.g., IEEE 802.11ax Standard, Section 27.3.10.10</i></p> <p>In an HE SU PPDU, HE MU PPDU and HE ER SU PPDU, the combination of HE-LTF type and GI duration is indicated in HE-SIG-A field. In an HE TB PPDU, the combination of HE-LTF type and GI duration is indicated in the Trigger frame that triggers the transmission of the PPDU. If an HE PPDU is an HE sounding NDP, the combinations of HE-LTF types and GI durations are listed in 27.3.18 (Transmit specification). If an HE PPDU is an HE TB feedback NDP, the combinations of types and GI durations are listed in 27.3.4 (HE PPDU formats). <i>See, e.g., IEEE 802.11ax Standard, Section 27.3.10.10</i></p> <p>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 9.4.1.65 (HE Compressed Beamforming Report field) and 9.4.1.66 (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.</p> <p>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 9.4.1.65 (HE Compressed Beamforming Report field). <i>See, e.g., IEEE 802.11ax Standard, Section 27.3.15.1</i></p>

Claim 1	HP Envy 15 Laptop
	<p>Transmit beamforming and DL-MU-MIMO require knowledge of the channel state to compute a steering matrix that is applied to the transmitted signal to optimize reception at one or more receivers. The STA transmitting using the steering matrix is called the VHT beamformer and a STA for which reception is optimized is called a VHT beamformee. An explicit feedback mechanism is used where the VHT beamformee directly measures the channel from the training symbols transmitted by the VHT beamformer and sends back a transformed estimate of the channel state to the VHT beamformer. The VHT beamformer then uses this estimate, perhaps combining estimates from multiple VHT beamformees, to derive the steering matrix.</p> <p><i>See, e.g., IEEE 802.11ac Standard Clause 9.31.5.1</i></p> <p>A VHT beamformer shall initiate a sounding feedback sequence by transmitting a VHT NDP Announcement frame followed by a VHT NDP after a SIFS. The VHT beamformer shall include in the VHT NDP Announcement frame one STA Info field for each VHT beamformee that is expected to prepare VHT Compressed Beamforming feedback and shall identify the VHT beamformee by including the VHT beamformee's AID in the AID subfield of the STA Info field. The VHT NDP Announcement frame shall include at least one STA Info field.</p> <p><i>See, e.g., IEEE 802.11ac Standard Clause 9.31.5.2</i></p> <p>A non-AP VHT beamformee that receives a VHT NDP Announcement frame from a VHT beamformer with which it is associated or has an established DLS or TDLS session and that contains the VHT beamformee's AID in the AID subfield of a STA Info field that is not the first STA Info field shall transmit its VHT Compressed Beamforming feedback a SIFS after receiving a Beamforming Report Poll with RA matching its MAC address and a non-bandwidth signaling TA obtained from the TA field matching the MAC address of the VHT beamformer. If the RXVECTOR parameter CH_BANDWIDTH_IN_NON_HT of the received</p> <p><i>See, e.g., IEEE 802.11ac Standard Clause 9.31.5.2</i></p>

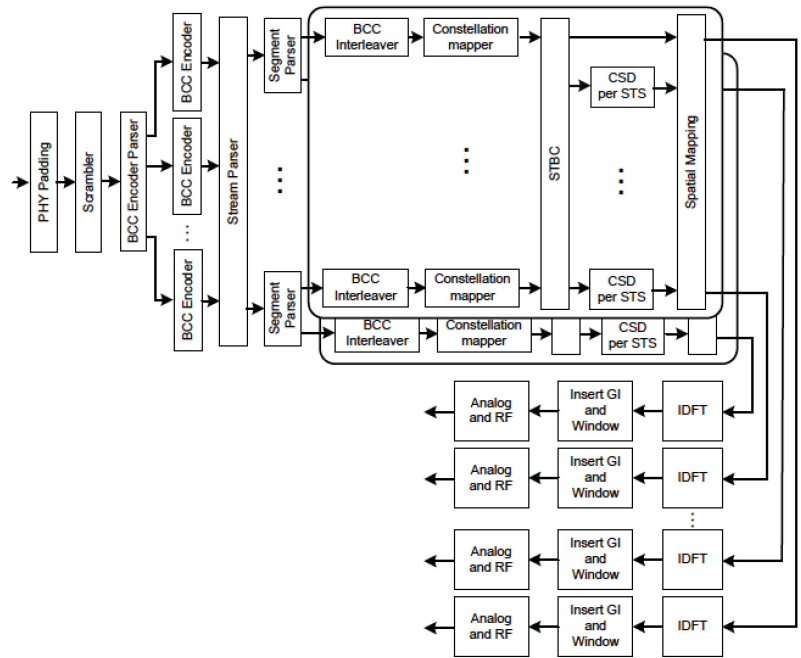
Claim 1	HP Envy 15 Laptop												
	<p data-bbox="704 627 1357 651">Table 8-281ai—VHT Compressed Beamforming frame Action field format</p> <table border="1" data-bbox="699 674 1359 884"> <thead> <tr> <th data-bbox="699 674 841 716">Order</th> <th data-bbox="841 674 1359 716">Information</th> </tr> </thead> <tbody> <tr> <td data-bbox="699 716 841 747">1</td> <td data-bbox="841 716 1359 747">Category</td> </tr> <tr> <td data-bbox="699 747 841 779">2</td> <td data-bbox="841 747 1359 779">VHT Action</td> </tr> <tr> <td data-bbox="699 779 841 810">3</td> <td data-bbox="841 779 1359 810">VHT MIMO Control (see 8.4.1.47)</td> </tr> <tr> <td data-bbox="699 810 841 842">4</td> <td data-bbox="841 810 1359 842">VHT Compressed Beamforming Report (see 8.4.1.48)</td> </tr> <tr> <td data-bbox="699 842 841 884">5</td> <td data-bbox="841 842 1359 884">MU Exclusive Beamforming Report (see 8.4.1.49)</td> </tr> </tbody> </table> <p data-bbox="623 930 1159 953">The Category field is set to the value for VHT, specified in Table 8-38.</p> <p data-bbox="623 976 1419 999">The VHT Action field is set to the value for VHT Compressed Beamforming, specified in Table 8-281ah.</p> <p data-bbox="623 1022 1438 1108">The VHT MIMO Control field is always present in the frame. The presence and contents of the VHT Compressed Beamforming Report field and the MU Exclusive Beamforming Report field are dependent on the values of the Feedback Type, Remaining Feedback Segments, and First Feedback Segment subfields of the VHT MIMO Control field (see 8.4.1.47, 8.4.1.48, 8.4.1.49, and 9.31.5).</p> <p data-bbox="594 1115 1089 1138"><i>See, e.g.,</i> IEEE 802.11ac Standard Clause 8.5.23.2</p> <p data-bbox="594 1144 1252 1167"><i>See</i> Tables 8-53(d)-(h) in IEEE 802.11ac Standard Clause 8.4.1.48</p> <p data-bbox="594 1236 1455 1352">The $AvgSNR_i$ in Table 8-53h is found by computing the SNR per subcarrier in decibels for the subcarriers identified in Table 8-53g, and then computing the arithmetic mean of those values. Each SNR value per tone in stream i (before being averaged) corresponds to the SNR associated with the column i of the beamforming feedback matrix V determined at the beamformee. Each SNR corresponds to the predicted SNR at the beamformee when the beamformer applies all columns of the matrix V.</p> <p data-bbox="594 1358 1089 1381"><i>See, e.g.,</i> IEEE 802.11ac Standard Clause 8.4.1.48</p>	Order	Information	1	Category	2	VHT Action	3	VHT MIMO Control (see 8.4.1.47)	4	VHT Compressed Beamforming Report (see 8.4.1.48)	5	MU Exclusive Beamforming Report (see 8.4.1.49)
Order	Information												
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	<p>The MU Exclusive Beamforming Report field is used by the VHT Compressed Beamforming feedback (see 8.5.23.2) to carry explicit feedback information in the form of delta SNRs. The information in the VHT Compressed Beamforming Report field and the MU Exclusive Beamforming Report field can be used by the transmit MU beamformer to determine steering matrices Q, as described in 9.29.3, 20.3.12.3, and Table 22.3.11.</p> <p>See, e.g., IEEE 802.11ac Standard Clause 8.4.1.49</p> <table border="1" data-bbox="609 781 1458 1201"> <thead> <tr> <th data-bbox="609 781 943 842">Field</th> <th data-bbox="943 781 1019 842">Size (Bits)</th> <th data-bbox="1019 781 1458 842">Meaning</th> </tr> </thead> <tbody> <tr> <td data-bbox="609 842 943 903">Delta SNR for space-time stream 1 for subcarrier $k = sscidx(0)$</td> <td data-bbox="943 842 1019 903">4</td> <td data-bbox="1019 842 1458 903">$\Delta SNR_{sscidx(0),1}$ as defined in Equation (8-2)</td> </tr> <tr> <td data-bbox="609 903 943 940">...</td> <td data-bbox="943 903 1019 940">...</td> <td data-bbox="1019 903 1458 940">...</td> </tr> <tr> <td data-bbox="609 940 943 1001">Delta SNR for space-time stream N_c for subcarrier $k = sscidx(0)$</td> <td data-bbox="943 940 1019 1001">4</td> <td data-bbox="1019 940 1458 1001">$\Delta SNR_{sscidx(0),N_c}$ as defined in Equation (8-2)</td> </tr> <tr> <td data-bbox="609 1001 943 1062">Delta SNR for space-time stream 1 for subcarrier $k = sscidx(1)$</td> <td data-bbox="943 1001 1019 1062">4</td> <td data-bbox="1019 1001 1458 1062">$\Delta SNR_{sscidx(1),1}$ as defined in Equation (8-2)</td> </tr> <tr> <td data-bbox="609 1062 943 1100">...</td> <td data-bbox="943 1062 1019 1100">...</td> <td data-bbox="1019 1062 1458 1100">...</td> </tr> <tr> <td data-bbox="609 1100 943 1161">Delta SNR for space-time stream N_c for subcarrier $k = sscidx(1)$</td> <td data-bbox="943 1100 1019 1161">4</td> <td data-bbox="1019 1100 1458 1161">$\Delta SNR_{sscidx(1),N_c}$ as defined in Equation (8-2)</td> </tr> <tr> <td data-bbox="609 1161 943 1201">...</td> <td data-bbox="943 1161 1019 1201">...</td> <td data-bbox="1019 1161 1458 1201">...</td> </tr> </tbody> </table>	Field	Size (Bits)	Meaning	Delta SNR for space-time stream 1 for subcarrier $k = sscidx(0)$	4	$\Delta SNR_{sscidx(0),1}$ as defined in Equation (8-2)	Delta SNR for space-time stream N_c for subcarrier $k = sscidx(0)$	4	$\Delta SNR_{sscidx(0),N_c}$ as defined in Equation (8-2)	Delta SNR for space-time stream 1 for subcarrier $k = sscidx(1)$	4	$\Delta SNR_{sscidx(1),1}$ as defined in Equation (8-2)	Delta SNR for space-time stream N_c for subcarrier $k = sscidx(1)$	4	$\Delta SNR_{sscidx(1),N_c}$ as defined in Equation (8-2)
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	<table border="1"> <thead> <tr> <th data-bbox="602 638 925 688">Field</th> <th data-bbox="928 638 1003 688">Size (Bits)</th> <th data-bbox="1006 638 1442 688">Meaning</th> </tr> </thead> <tbody> <tr> <td data-bbox="602 695 925 747">Delta SNR for space-time stream 1 for subcarrier $k = sscidx(Ns'-1)$</td> <td data-bbox="928 695 1003 747">4</td> <td data-bbox="1006 695 1442 747">$\Delta SNR_{sscidx(Ns'-1),1}$ as defined in Equation (8-2)</td> </tr> <tr> <td data-bbox="602 753 925 785">...</td> <td data-bbox="928 753 1003 785">...</td> <td data-bbox="1006 753 1442 785">...</td> </tr> <tr> <td data-bbox="602 791 925 844">Delta SNR for space-time stream Nc for subcarrier $k = sscidx(Ns'-1)$</td> <td data-bbox="928 791 1003 844">4</td> <td data-bbox="1006 791 1442 844">$\Delta SNR_{sscidx(Ns'-1),Nc}$ as defined in Equation (8-2)</td> </tr> </tbody> </table>	Field	Size (Bits)	Meaning	Delta SNR for space-time stream 1 for subcarrier $k = sscidx(Ns'-1)$	4	$\Delta SNR_{sscidx(Ns'-1),1}$ as defined in Equation (8-2)	Delta SNR for space-time stream Nc for subcarrier $k = sscidx(Ns'-1)$	4	$\Delta SNR_{sscidx(Ns'-1),Nc}$ as defined in Equation (8-2)		
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NOTE— $sscidx()$ is defined in Table 8-53j.															
<p>In Table 8-53i, Ns' is the number of subcarriers for which the Delta SNR subfield is sent back to the beamformer. Table 8-53j shows Ns', the exact subcarrier indices and their order for which the Delta SNR is sent back.</p> <p>See, e.g., Table 8-53i IEEE 802.11ac Standard Clause 8.4.1.48</p> <p>Transmit beamforming and DL-MU-MIMO require knowledge of the channel state to compute a steering matrix that is applied to the transmitted signal to optimize reception at one or more receivers. The STA transmitting using the steering matrix is called the VHT beamformer and a STA for which reception is optimized is called a VHT beamformee. An explicit feedback mechanism is used where the VHT beamformee directly measures the channel from the training symbols transmitted by the VHT beamformer and sends back a transformed estimate of the channel state to the VHT beamformer. The VHT beamformer then uses this estimate, perhaps combining estimates from multiple VHT beamformees, to derive the steering matrix.</p> <p>See, e.g., IEEE 802.11ac Standard Clause 9.31.5.1</p>															

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See, e.g., IEEE 802.11ac Standard Clause 22.3.4.6(d)

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	<p>The VHT-SIG-B field is constructed per-user as follows:</p> <ol style="list-style-type: none"> a) Obtain the VHT-MCS (for MU only) and APEP_LENGTH from the TXVECTOR. b) VHT-SIG-B bits: Set the VHT-MCS (for MU only) and VHT-SIG-B Length field as described in 22.3.8.3.6. Add the reserved bits (for SU only) and N_{tail} bits of tail. For an NDP set VHT-SIG-B to the fixed bit pattern for the bandwidth used as described in 22.3.8.3.6. c) VHT-SIG-B Bit Repetition: Repeat the VHT-SIG-B bits as a function of CH_BANDWIDTH as defined in 22.3.8.3.6. d) BCC encoder: Encode the VHT-SIG-B field using BCC at rate $R=1/2$ as described in 18.3.5.6. e) Segment parser (if needed): For a contiguous 160 MHz or noncontiguous 80+80 MHz transmission, divide the output bits of the BCC encoder into two frequency subblocks as described in 22.3.10.7. This block is bypassed for 20 MHz, 40 MHz, and 80 MHz VHT PPDU transmissions. f) BCC interleaver: Interleave as described in 22.3.10.8. g) Constellation mapper: Map to a BPSK constellation as defined in 18.3.5.8. h) Segment deparser (if needed): For a contiguous 160 MHz transmission, merge the two frequency subblocks into one frequency segment as described in 22.3.10.9.3. This block is bypassed for 20 MHz, 40 MHz, 80 MHz, and 80+80 MHz VHT PPDU transmissions. i) Pilot insertion: Insert pilots following the steps described in 22.3.10.10. j) P_{VHTLTF} matrix mapping: Apply the mapping of the 1st column of the P_{VHTLTF} matrix to the data subcarriers as described in 22.3.8.3.6. The total number of data and pilot subcarriers is the same as in the Data field. k) CSD: Apply CSD for each space-time stream and frequency segment as described in 22.3.8.3.2. l) Spatial mapping: Apply the Q matrix as described in 22.3.10.11.1. m) Phase rotation: Apply the appropriate phase rotations for each 20 MHz subchannel as described in 22.3.7.4 and 22.3.7.5. n) IDFT: Compute the inverse discrete Fourier transform. o) Insert GI and apply windowing: Prepend a GI (LONG_GI) and apply windowing as described in 22.3.7.4. p) Analog and RF: Up-convert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 22.3.7.4 and 22.3.8 for details. <p>See, e.g., IEEE 802.11ac Standard Clauses 22.3.4.8(l) and 22.3.4.9.1(m), 22.3.4.9.2(m), 22.3.4.10.4(a).</p>

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	<p>The DL-MU-MIMO steering matrix $Q_k = [Q_{k,0}, Q_{k,1}, \dots, Q_{k,N_{user}-1}]$ can be determined by the beamformer using the beamforming feedback matrices for subcarrier k from beamformee u, $V_{k,u}$, and SNR information for subcarrier k from beamformee u, $SNR_{k,u}$, where $u = 0, 1, \dots, N_{user} - 1$. The steering matrix that is computed (or updated) using new beamforming feedback matrices and new SNR information from some or all of participating beamformees might replace the existing steering matrix Q_k for the next DL-MU-MIMO data transmission. The beamformee group for the MU transmission is signaled using the Group ID field in VHT-SIG-A (see 22.3.8.3.3 and 22.3.11.4).</p> <p><i>See, e.g., IEEE 802.11ac Standard Clause 22.3.11.1</i></p> <p>Upon receipt of a VHT NDP sounding PPDU, the beamformee shall remove the space-time stream CSD in Table 22-11 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 shall be compressed in the form of angles using the method described in 20.3.12.3.6. The angles, $\phi(k,u)$ and $\psi(k,u)$, are quantized according to Table 8-53e. The number of bits for quantization is chosen by the beamformee, based on the indication from the beamformer as to whether the feedback is requested for SU-MIMO beamforming or DL-MU-MIMO beamforming. The compressed beamforming feedback using 20.3.12.3.6 is the only Clause 22 beamforming feedback format defined.</p> <p>The beamformee shall generate the beamforming feedback matrices with the number of rows (N_r) equal to the N_{STS} of the NDP.</p> <p>After receiving the angle information, $\phi(k,u)$ and $\psi(k,u)$, the beamformer reconstructs $V_{k,u}$ using Equation (20-79). For SU-MIMO beamforming, the beamformer can use this $V_{k,0}$ matrix to determine the steering matrix Q_k. For DL-MU-MIMO beamforming, the beamformer may calculate a steering matrix $Q_k = [Q_{k,0}, Q_{k,1}, \dots, Q_{k,N_{user}-1}]$ using $V_{k,u}$ and $SNR_{k,u}$ ($0 \leq u \leq N_{user} - 1$) in order to suppress crosstalk between participating beamformees. The method used by the beamformer to calculate the steering matrix Q_k is implementation specific.</p> <p><i>See, e.g., IEEE 802.11ac Standard Clause 22.3.11.2</i></p>
<p>[1 g] determine a set of weighting values based on the first signal information and the second signal information, wherein the set of weighting values is configured to be used by the transceiver to construct</p>	<p>The processor in the Envy 15 Laptop determine a set of weighting values based on the first signal information and the second signal information, wherein the set of weighting values is configured to be used by the transceiver to construct one or more beam-formed transmission signals.</p>

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<p>one or more beam-formed transmission signals;</p>	<p>For example, the Envy 15 Laptop determines an estimate of the channel state (e.g., by measuring the channel using a training signal) that includes a set of weighting values based on the first signal information and the second signal information. A transformed estimate of the channel state will ultimately be sent in a compressed beamforming report, e.g., the parameters of the beamforming feedback matrix. The Envy 15 Laptop uses the derived estimate of the channel state, which includes the set of weighting values (e.g. data relevant to describe the MIMO channel), by configuring the set of weighting values to be used by the transceiver to construct one or more beam-formed transmission signals, e.g., by supporting multiple uplink spatial streams (e.g., 2x2 or more streams) and/or transmit beamforming (“TxBF”) to steer transmissions.</p> <p>Transmit beamforming and DL MU-MIMO require knowledge of the channel state to compute a steering matrix that is applied to the transmit signal to optimize reception at one or more receivers. HE STAs use the HE sounding protocol to determine the channel state information. The HE sounding protocol provides explicit feedback mechanisms, defined as HE non-trigger-based (non-TB) sounding and HE trigger-based (TB) sounding, where the HE beamformee measures the channel using a training signal (i.e., an HE sounding NDP) transmitted by the HE beamformer and sends back a transformed estimate of the channel state. The HE beamformer uses this estimate to derive the steering matrix.</p> <p>The HE beamformee returns an estimate of the channel state in an HE compressed beamforming/CQI report carried in one or more HE Compressed Beamforming/CQI frames. There are three types of HE compressed beamforming/CQI report:</p> <p><i>See, e.g., IEEE 802.11ax Standard, Section 26.7.1</i></p> <p>An HE beamformee that receives an HE NDP Announcement frame from an HE beamformer with which it is associated and that contains the HE beamformee's MAC address in the RA field and also receives an HE sounding NDP a SIFS after the HE NDP Announcement frame shall transmit its HE compressed beamforming/CQI report a SIFS after the HE sounding NDP. The TXVECTOR parameter CH_BANDWIDTH for the PPDU containing the HE compressed beamforming/CQI report shall be set to indicate a bandwidth not wider than that indicated by the RXVECTOR parameter CH_BANDWIDTH of the HE sounding NDP.</p> <p><i>See, e.g., IEEE 802.11ax Standard, Section 26.7.3</i></p>

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	<p>An HE beamformee that receives an HE NDP Announcement frame as part of an HE TB sounding sequence with a STA Info field addressed to it soliciting SU or MU feedback shall generate an HE compressed beamforming/CQI report using the feedback type, N_g and codebook size indicated in the STA Info field. If the HE beamformee then receives a BFRP Trigger frame with a User Info field addressed to it, the HE beamformee transmits an HE TB PPDU containing the HE compressed beamforming/CQI report following the rules defined in 26.5.3.3 (Non-AP STA behavior for UL MU operation). If the HE NDP Announcement frame has <i>See, e.g., IEEE 802.11ax Standard, Section 26.7.3</i></p> <p>UL MU operation allows an AP to solicit simultaneous immediate response frames from one or more non-AP HE STAs. A non-AP HE STA shall follow the rules in this subclause for the transmission of response <i>See, e.g., IEEE 802.11ax Standard, Section 26.5.3</i></p> <p>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. <i>See, e.g., IEEE 802.11ax Standard, Section 27.3.3.2.1</i></p> <p>The HE-LTF field 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 and HE ER SU PPDU, the transmitter provides training for N_{STS} space-time streams (spatial mapper inputs) used for the transmission of the PSDU. In an HE MU PPDU, the transmitter provides training for $N_{STS,r,total}$ space-time streams used for the transmission of the PSDU(s) in the r-th RU. In an HE TB 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. An 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 subcarriers of each HE-LTF symbol are multiplied by the entries of a <i>See, e.g., IEEE 802.11ax Standard, Section 27.3.10.10</i></p> <p>In an HE SU PPDU, HE MU PPDU and HE ER SU PPDU, the combination of HE-LTF type and GI duration is indicated in HE-SIG-A field. In an HE TB PPDU, the combination of HE-LTF type and GI duration is indicated in the Trigger frame that triggers the transmission of the PPDU. If an HE PPDU is an HE sounding NDP, the combinations of HE-LTF types and GI durations are listed in 27.3.18 (Transmit specification). If an HE PPDU is an HE TB feedback NDP, the combinations of types and GI durations are listed in 27.3.4 (HE PPDU formats).</p>

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	<p data-bbox="592 625 1128 653"><i>See, e.g.</i>, IEEE 802.11ax Standard, Section 27.3.10.10</p> <p data-bbox="607 688 1438 827">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 9.4.1.65 (HE Compressed Beamforming Report field) and 9.4.1.66 (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.</p> <p data-bbox="607 852 1438 940">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 9.4.1.65 (HE Compressed Beamforming Report field).</p> <p data-bbox="592 949 1112 976"><i>See, e.g.</i>, IEEE 802.11ax Standard, Section 27.3.15.1</p> <p data-bbox="592 1010 1438 1194">Transmit beamforming and DL-MU-MIMO require knowledge of the channel state to compute a steering matrix that is applied to the transmitted signal to optimize reception at one or more receivers. The STA transmitting using the steering matrix is called the VHT beamformer and a STA for which reception is optimized is called a VHT beamformee. An explicit feedback mechanism is used where the VHT beamformee directly measures the channel from the training symbols transmitted by the VHT beamformer and sends back a transformed estimate of the channel state to the VHT beamformer. The VHT beamformer then uses this estimate, perhaps combining estimates from multiple VHT beamformees, to derive the steering matrix.</p> <p data-bbox="592 1205 1088 1232"><i>See, e.g.</i>, IEEE 802.11ac Standard Clause 9.31.5.1</p> <p data-bbox="607 1230 1450 1367">A VHT beamformer shall initiate a sounding feedback sequence by transmitting a VHT NDP Announcement frame followed by a VHT NDP after a SIFS. The VHT beamformer shall include in the VHT NDP Announcement frame one STA Info field for each VHT beamformee that is expected to prepare VHT Compressed Beamforming feedback and shall identify the VHT beamformee by including the VHT beamformee's AID in the AID subfield of the STA Info field. The VHT NDP Announcement frame shall include at least one STA Info field.</p> <p data-bbox="592 1375 1088 1402"><i>See, e.g.</i>, IEEE 802.11ac Standard Clause 9.31.5.2</p>

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	<p>A non-AP VHT beamformee that receives a VHT NDP Announcement frame from a VHT beamformer with which it is associated or has an established DLS or TDLS session and that contains the VHT beamformee's AID in the AID subfield of a STA Info field that is not the first STA Info field shall transmit its VHT Compressed Beamforming feedback a SIFS after receiving a Beamforming Report Poll with RA matching its MAC address and a non-bandwidth signaling TA obtained from the TA field matching the MAC address of the VHT beamformer. If the RXVECTOR parameter CH_BANDWIDTH_IN_NON_HT of the received</p> <p><i>See, e.g., IEEE 802.11ac Standard Clause 9.31.5.2</i></p> <p>Table 8-281ai—VHT Compressed Beamforming frame Action field format</p> <table border="1" data-bbox="699 831 1360 1045"> <thead> <tr> <th data-bbox="699 831 841 873">Order</th> <th data-bbox="841 831 1360 873">Information</th> </tr> </thead> <tbody> <tr> <td data-bbox="699 873 841 905">1</td> <td data-bbox="841 873 1360 905">Category</td> </tr> <tr> <td data-bbox="699 905 841 936">2</td> <td data-bbox="841 905 1360 936">VHT Action</td> </tr> <tr> <td data-bbox="699 936 841 968">3</td> <td data-bbox="841 936 1360 968">VHT MIMO Control (see 8.4.1.47)</td> </tr> <tr> <td data-bbox="699 968 841 999">4</td> <td data-bbox="841 968 1360 999">VHT Compressed Beamforming Report (see 8.4.1.48)</td> </tr> <tr> <td data-bbox="699 999 841 1045">5</td> <td data-bbox="841 999 1360 1045">MU Exclusive Beamforming Report (see 8.4.1.49)</td> </tr> </tbody> </table> <p>The Category field is set to the value for VHT, specified in Table 8-38.</p> <p>The VHT Action field is set to the value for VHT Compressed Beamforming, specified in Table 8-281ah.</p> <p>The VHT MIMO Control field is always present in the frame. The presence and contents of the VHT Compressed Beamforming Report field and the MU Exclusive Beamforming Report field are dependent on the values of the Feedback Type, Remaining Feedback Segments, and First Feedback Segment subfields of the VHT MIMO Control field (see 8.4.1.47, 8.4.1.48, 8.4.1.49, and 9.31.5).</p> <p><i>See, e.g., IEEE 802.11ac Standard Clause 8.5.23.2</i></p> <p><i>See Tables 8-53(d)-(h) in IEEE 802.11ac Standard Clause 8.4.1.48</i></p> <p>The $AvgSNR_i$ in Table 8-53h is found by computing the SNR per subcarrier in decibels for the subcarriers identified in Table 8-53g, and then computing the arithmetic mean of those values. Each SNR value per tone in stream i (before being averaged) corresponds to the SNR associated with the column i of the beamforming feedback matrix V determined at the beamformee. Each SNR corresponds to the predicted SNR at the beamformee when the beamformer applies all columns of the matrix V.</p>	Order	Information	1	Category	2	VHT Action	3	VHT MIMO Control (see 8.4.1.47)	4	VHT Compressed Beamforming Report (see 8.4.1.48)	5	MU Exclusive Beamforming Report (see 8.4.1.49)
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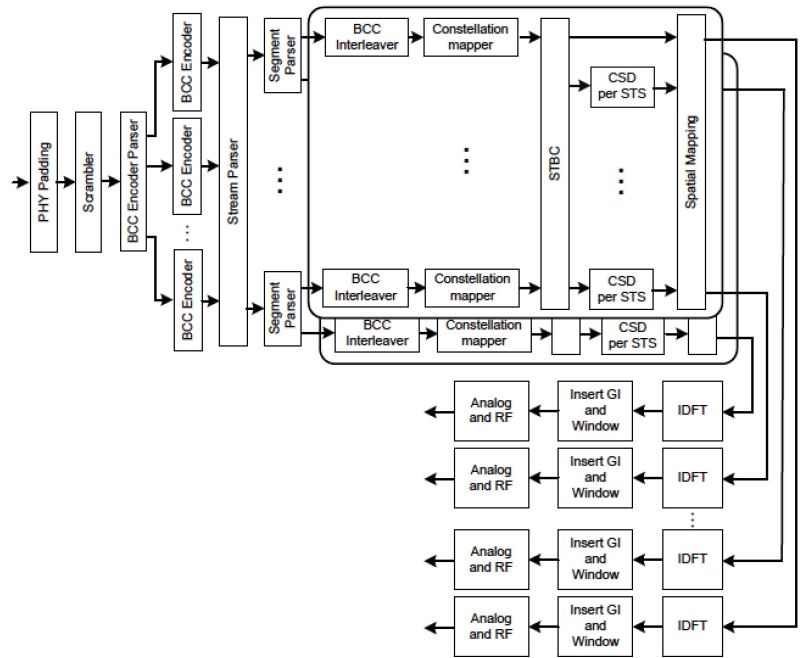
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	<p data-bbox="592 625 1089 653"><i>See, e.g., IEEE 802.11ac Standard Clause 8.4.1.48</i></p> <p data-bbox="592 684 1446 800">The MU Exclusive Beamforming Report field is used by the VHT Compressed Beamforming feedback (see 8.5.23.2) to carry explicit feedback information in the form of delta SNRs. The information in the VHT Compressed Beamforming Report field and the MU Exclusive Beamforming Report field can be used by the transmit MU beamformer to determine steering matrices Q, as described in 9.29.3, 20.3.12.3, and Table 22.3.11.</p> <p data-bbox="592 804 1089 831"><i>See, e.g., IEEE 802.11ac Standard Clause 8.4.1.49</i></p> <table border="1" data-bbox="609 840 1458 1255"> <thead> <tr> <th data-bbox="609 840 943 898">Field</th> <th data-bbox="943 840 1019 898">Size (Bits)</th> <th data-bbox="1019 840 1458 898">Meaning</th> </tr> </thead> <tbody> <tr> <td data-bbox="609 898 943 957">Delta SNR for space-time stream 1 for subcarrier $k = sscidx(0)$</td> <td data-bbox="943 898 1019 957">4</td> <td data-bbox="1019 898 1458 957">$\Delta SNR_{sscidx(0),1}$ as defined in Equation (8-2)</td> </tr> <tr> <td data-bbox="609 957 943 995">...</td> <td data-bbox="943 957 1019 995">...</td> <td data-bbox="1019 957 1458 995">...</td> </tr> <tr> <td data-bbox="609 995 943 1054">Delta SNR for space-time stream N_c for subcarrier $k = sscidx(0)$</td> <td data-bbox="943 995 1019 1054">4</td> <td data-bbox="1019 995 1458 1054">$\Delta SNR_{sscidx(0),N_c}$ as defined in Equation (8-2)</td> </tr> <tr> <td data-bbox="609 1054 943 1113">Delta SNR for space-time stream 1 for subcarrier $k = sscidx(1)$</td> <td data-bbox="943 1054 1019 1113">4</td> <td data-bbox="1019 1054 1458 1113">$\Delta SNR_{sscidx(1),1}$ as defined in Equation (8-2)</td> </tr> <tr> <td data-bbox="609 1113 943 1150">...</td> <td data-bbox="943 1113 1019 1150">...</td> <td data-bbox="1019 1113 1458 1150">...</td> </tr> <tr> <td data-bbox="609 1150 943 1209">Delta SNR for space-time stream N_c for subcarrier $k = sscidx(1)$</td> <td data-bbox="943 1150 1019 1209">4</td> <td data-bbox="1019 1150 1458 1209">$\Delta SNR_{sscidx(1),N_c}$ as defined in Equation (8-2)</td> </tr> <tr> <td data-bbox="609 1209 943 1255">...</td> <td data-bbox="943 1209 1019 1255">...</td> <td data-bbox="1019 1209 1458 1255">...</td> </tr> </tbody> </table>	Field	Size (Bits)	Meaning	Delta SNR for space-time stream 1 for subcarrier $k = sscidx(0)$	4	$\Delta SNR_{sscidx(0),1}$ as defined in Equation (8-2)	Delta SNR for space-time stream N_c for subcarrier $k = sscidx(0)$	4	$\Delta SNR_{sscidx(0),N_c}$ as defined in Equation (8-2)	Delta SNR for space-time stream 1 for subcarrier $k = sscidx(1)$	4	$\Delta SNR_{sscidx(1),1}$ as defined in Equation (8-2)	Delta SNR for space-time stream N_c for subcarrier $k = sscidx(1)$	4	$\Delta SNR_{sscidx(1),N_c}$ as defined in Equation (8-2)
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...																							

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	Field	Size (Bits)	Meaning
	Delta SNR for space-time stream 1 for subcarrier $k = sscidx(Ns'-1)$	4	$\Delta SNR_{sscidx(Ns'-1),1}$ as defined in Equation (8-2)

	Delta SNR for space-time stream Nc for subcarrier $k = sscidx(Ns'-1)$	4	$\Delta SNR_{sscidx(Ns'-1),Nc}$ as defined in Equation (8-2)
	NOTE— $sscidx()$ is defined in Table 8-53j.		
	<p>In Table 8-53i, Ns' is the number of subcarriers for which the Delta SNR subfield is sent back to the beamformer. Table 8-53j shows Ns', the exact subcarrier indices and their order for which the Delta SNR is sent back.</p> <p>See, e.g., Table 8-53i IEEE 802.11ac Standard Clause 8.4.1.48</p> <p>Transmit beamforming and DL-MU-MIMO require knowledge of the channel state to compute a steering matrix that is applied to the transmitted signal to optimize reception at one or more receivers. The STA transmitting using the steering matrix is called the VHT beamformer and a STA for which reception is optimized is called a VHT beamformee. An explicit feedback mechanism is used where the VHT beamformee directly measures the channel from the training symbols transmitted by the VHT beamformer and sends back a transformed estimate of the channel state to the VHT beamformer. The VHT beamformer then uses this estimate, perhaps combining estimates from multiple VHT beamformees, to derive the steering matrix.</p> <p>See, e.g., IEEE 802.11ac Standard Clause 9.31.5.1</p>		

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See, e.g., IEEE 802.11ac Standard Clause 22.3.4.6(d)

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	<p>The VHT-SIG-B field is constructed per-user as follows:</p> <ol style="list-style-type: none"> a) Obtain the VHT-MCS (for MU only) and APEP_LENGTH from the TXVECTOR. b) VHT-SIG-B bits: Set the VHT-MCS (for MU only) and VHT-SIG-B Length field as described in 22.3.8.3.6. Add the reserved bits (for SU only) and N_{tail} bits of tail. For an NDP set VHT-SIG-B to the fixed bit pattern for the bandwidth used as described in 22.3.8.3.6. c) VHT-SIG-B Bit Repetition: Repeat the VHT-SIG-B bits as a function of CH_BANDWIDTH as defined in 22.3.8.3.6. d) BCC encoder: Encode the VHT-SIG-B field using BCC at rate $R=1/2$ as described in 18.3.5.6. e) Segment parser (if needed): For a contiguous 160 MHz or noncontiguous 80+80 MHz transmission, divide the output bits of the BCC encoder into two frequency subblocks as described in 22.3.10.7. This block is bypassed for 20 MHz, 40 MHz, and 80 MHz VHT PPDU transmissions. f) BCC interleaver: Interleave as described in 22.3.10.8. g) Constellation mapper: Map to a BPSK constellation as defined in 18.3.5.8. h) Segment deparser (if needed): For a contiguous 160 MHz transmission, merge the two frequency subblocks into one frequency segment as described in 22.3.10.9.3. This block is bypassed for 20 MHz, 40 MHz, 80 MHz, and 80+80 MHz VHT PPDU transmissions. i) Pilot insertion: Insert pilots following the steps described in 22.3.10.10. j) P_{VHTLTF} matrix mapping: Apply the mapping of the 1st column of the P_{VHTLTF} matrix to the data subcarriers as described in 22.3.8.3.6. The total number of data and pilot subcarriers is the same as in the Data field. k) CSD: Apply CSD for each space-time stream and frequency segment as described in 22.3.8.3.2. l) Spatial mapping: Apply the Q matrix as described in 22.3.10.11.1. m) Phase rotation: Apply the appropriate phase rotations for each 20 MHz subchannel as described in 22.3.7.4 and 22.3.7.5. n) IDFT: Compute the inverse discrete Fourier transform. o) Insert GI and apply windowing: Prepend a GI (LONG_GI) and apply windowing as described in 22.3.7.4. p) Analog and RF: Up-convert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 22.3.7.4 and 22.3.8 for details. <p>See, e.g., IEEE 802.11ac Standard Clauses 22.3.4.8(l) and 22.3.4.9.1(m), 22.3.4.9.2(m), 22.3.4.10.4(a).</p>

Claim 1	HP Envy 15 Laptop
	<p>The DL-MU-MIMO steering matrix $Q_k = [Q_{k,0}, Q_{k,1}, \dots, Q_{k,N_{user}-1}]$ can be determined by the beamformer using the beamforming feedback matrices for subcarrier k from beamformee u, $V_{k,u}$, and SNR information for subcarrier k from beamformee u, $SNR_{k,u}$, where $u = 0, 1, \dots, N_{user} - 1$. The steering matrix that is computed (or updated) using new beamforming feedback matrices and new SNR information from some or all of participating beamformees might replace the existing steering matrix Q_k for the next DL-MU-MIMO data transmission. The beamformee group for the MU transmission is signaled using the Group ID field in VHT-SIG-A (see 22.3.8.3.3 and 22.3.11.4).</p> <p><i>See, e.g., IEEE 802.11ac Standard Clause 22.3.11.1</i></p> <p>Upon receipt of a VHT NDP sounding PPDU, the beamformee shall remove the space-time stream CSD in Table 22-11 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 shall be compressed in the form of angles using the method described in 20.3.12.3.6. The angles, $\phi(k,u)$ and $\psi(k,u)$, are quantized according to Table 8-53e. The number of bits for quantization is chosen by the beamformee, based on the indication from the beamformer as to whether the feedback is requested for SU-MIMO beamforming or DL-MU-MIMO beamforming. The compressed beamforming feedback using 20.3.12.3.6 is the only Clause 22 beamforming feedback format defined.</p> <p>The beamformee shall generate the beamforming feedback matrices with the number of rows (N_r) equal to the N_{STS} of the NDP.</p> <p>After receiving the angle information, $\phi(k,u)$ and $\psi(k,u)$, the beamformer reconstructs $V_{k,u}$ using Equation (20-79). For SU-MIMO beamforming, the beamformer can use this $V_{k,0}$ matrix to determine the steering matrix Q_k. For DL-MU-MIMO beamforming, the beamformer may calculate a steering matrix $Q_k = [Q_{k,0}, Q_{k,1}, \dots, Q_{k,N_{user}-1}]$ using $V_{k,u}$ and $SNR_{k,u}$ ($0 \leq u \leq N_{user} - 1$) in order to suppress crosstalk between participating beamformees. The method used by the beamformer to calculate the steering matrix Q_k is implementation specific.</p> <p><i>See, e.g., IEEE 802.11ac Standard Clause 22.3.11.2</i></p> <p>To the extent Defendant disputes that the foregoing shows literal infringement, there would also be infringement under the doctrine of equivalents. For example, determining weighting values (e.g. angle information) (e.g. the derived estimate of the channel state), which includes data relevant to describe the MIMO channel is insubstantially different from the claim requirement because it performs substantially the same function</p>

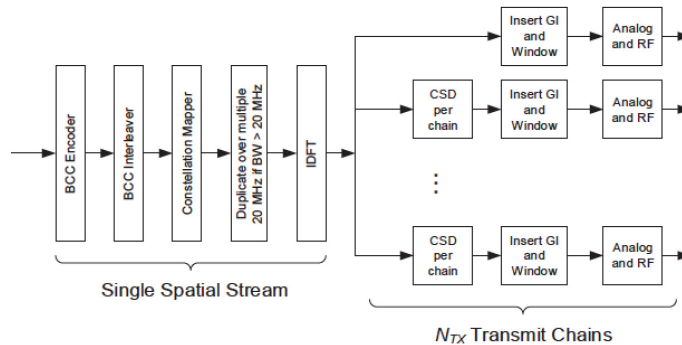
Claim 1	HP Envy 15 Laptop
	<p>(determine a set of weighting values) in substantially the same way (determine angle information describing MIMO channel) to achieve substantially the same result (beamforming).</p> <p>For further example, constructing one or more beamformed transmission signals by supporting multiple uplink spatial streams (e.g., 2x2 or more streams) and/or transmit beamforming (“TxBF”) to steer transmissions is insubstantially different from the claim requirement because it performs substantially the same function in substantially the same way to achieve substantially the same result.</p>
<p>[1h] cause the transceiver to transmit a third signal to the remote station via the antenna, the third signal comprising content based on the set of weighting values.</p>	<p>The processor in the Envy 15 Laptop causes the transceiver to transmit a third signal to the remote station via the antenna, the third signal comprising content based on the set of weighting values.</p> <p>For example, Envy 15 Laptop transmits to the remote station (e.g., a Wi-Fi access point) a signal that includes the beamforming feedback matrix.</p> <p>This subclause provides the procedure by which PSDUs are converted to and from transmissions on the wireless medium.</p> <p>During transmission, a PSDU (in the SU case) or one or more PSDUs (in the MU case) are processed (i.e., scrambled and coded) and appended to the PHY preamble to create the PPDU. At the receiver, the PHY preamble is processed to aid in the detection, demodulation, and delivery of the PSDU.</p> <p>See, e.g., IEEE 802.11ax Standard, Section 27.3.1</p> <p>DL MU transmission allows an AP to simultaneously transmit information to more than one non-AP STA. For a DL MU transmission, the AP uses the HE MU PPDU format and employs either DL OFDMA, DL MU-MIMO, or a mixture of both. UL MU transmission allows an AP to simultaneously receive information from more than one non-AP STA. UL MU transmissions are preceded by a Trigger frame or a frame carrying a TRS Control subfield from the AP. The non-AP STAs transmit using the HE TB PPDU format and employ either UL OFDMA, UL MU-MIMO, or a mixture of both.</p> <p>See, e.g., IEEE 802.11ax Standard, Section 27.3.1.1</p>

Claim 1

HP Envy 15 Laptop

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.

See, e.g., IEEE 802.11ax Standard, Section 27.3.3.2.1



See, e.g., Figure 27-13 IEEE 802.11ax Standard, Section 27.3.5

The per user data is combined as follows:

- Spatial mapping: The Q matrix is applied as described in 27.3.11.14 (OFDM modulation). The combining of all user data of an RU is done in this block.
- IDFT: Compute the inverse discrete Fourier transform.
- Insert GI and apply windowing: Prepend a GI determined by the TXVECTOR parameter GI_TYPE and apply windowing as described in 27.3.9 (Mathematical description of signals).
- Analog and RF: Upconvert the resulting complex baseband waveform with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 27.3.9 (Mathematical description of signals) and 27.3.10 (HE preamble) for details.

Claim 1	HP Envy 15 Laptop
	<p data-bbox="592 625 1133 653"><i>See, e.g.</i>, IEEE 802.11ax Standard, Section 27.3.6.11.4</p> <p data-bbox="592 699 1466 894">To the extent Defendant disputes that the foregoing shows literal infringement, there would also be infringement under the doctrine of equivalents. For example, the Accused Instrumentalities perform substantially the same function (transmit a third signal to the remote station via the antenna, the third signal comprising content based on the set of weighting values) in substantially the same way (transmit channel state estimate) to achieve substantially the same result (improve knowledge of the channel state to improve throughput).</p>

Claim 2

Claim 2	Accused Products
<p data-bbox="159 1018 560 1184">2. The receiver as recited in claim 1, wherein the first signal transmission and the second signal transmission comprise electromagnetic signals comprising one or more transmission peaks and one or more transmission nulls.</p>	<p data-bbox="592 1018 1453 1100">The Envy 15 Laptop includes the receiver as recited in claim 1, wherein the first signal transmission and the second signal transmission comprise electromagnetic signals comprising one or more transmission peaks and one or more transmission nulls.</p> <p data-bbox="592 1119 1458 1201"><i>See supra</i> claim element [1d], including discussion regarding MU-MIMO sounding and channel estimation procedures, which shows electromagnetic signals comprising one or more transmission peaks and one or more transmission nulls.</p>

Claim 4

Claim 4	Accused Products
<p data-bbox="159 1354 565 1486">4. The receiver as recited in claim 1, wherein the content comprises data configured to be used by the remote station to modify the placement of one or more transmission peaks and one or more</p>	<p data-bbox="592 1354 1450 1463">The Envy 15 Laptop includes the receiver as recited in claim 1, wherein the content comprises data configured to be used by the remote station to modify the placement of one or more transmission peaks and one or more transmission nulls in a subsequent signal transmission.</p>

Claim 4	Accused Products
transmission nulls in a subsequent signal transmission.	<i>See supra</i> claim element [1d], including discussion regarding MU-MIMO sounding and channel estimation procedures, which shows electromagnetic signals comprising one or more transmission peaks and one or more transmission nulls.

Claim 5

Claim 5	Accused Products
<p>5. The receiver as recited in claim 4, wherein the set of weighting values is further based on one or more of: a transmit power level, a data transmit rate, an antenna direction, quality of service data, or timing data.</p>	<p>The Envy 15 Laptop includes the receiver as recited in claim 4, wherein the set of weighting values is further based on one or more of: a transmit power level, a data transmit rate, an antenna direction, quality of service data, or timing data.</p> <p>For example, Envy 15 Laptop calculates weights based on at least the subcarrier frequency which is based on the data transmission rate and antenna array directions.</p> <p>The beamforming feedback matrix V is formed by the beamformee as follows. The beamformer transmits an NDP with $N_{STS,NDP}$ space-time streams, where $N_{STS,NDP}$ takes a value between 2 and 8. Based on this NDP, the beamformee estimates the $N_{RX,BFEE} \times N_{STS,NDP}$ channel, and based on that channel it determines a $N_r \times N_c$ orthogonal matrix V, where N_r and N_c satisfy Equation (9-1). $N_{RX,BFEE}$ is the number of receiver chains used to receive the NDP at the beamformee.</p> <p><i>See, e.g.</i>, IEEE 802.11ax Standard, Section 9.4.1.65</p>

Claim 5	Accused Products
	<p>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 19.3.12.3.6 (Compressed beamforming feedback matrix). The angles, $\phi(k,u)$ and $\psi(k,u)$, are quantized according to Table 9-68 (Quantization of angles). The number of bits for quantization, tone grouping factor, and the number of columns in the HE compressed beamforming feedback are set by the HE beamformer if the HE NDP Announcement frame contains more than one STA Info field that has a value in the AID11 field other than 2047. The number of bits for quantization, tone grouping factor, and the number of columns in the HE compressed beamforming feedback are determined by the beamformee only if the HE NDP Announcement frame contains a single STA Info field that has a value in the AID11 field other than 2047. The compressed beamforming feedback matrix as defined in 19.3.12.3.6 (Compressed beamforming feedback matrix) is the only Clause 27 (High Efficiency (HE) PHY specification) beamforming feedback matrix defined.</p> <p><i>See, e.g., IEEE 802.11ax Standard, Section 27.3.15.2</i></p> <p>$Q_{k,u}^{(i_{seg})}$ is the spatial mapping matrix for user u on subcarrier k in frequency segment i_{seg}. For HE modulated fields, $Q_{k,u}^{(i_{seg})}$ is a matrix with N_{TX} rows and $N_{STS,r,u}$ columns. For pre-HE modulated fields, $Q_{k,u}^{(i_{seg})}$ 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 defined in 27.3.10.2.1 (Cyclic shift for pre-HE modulated fields).</p> <p><i>See, e.g., IEEE 802.11ax Standard, Section 27.3.9</i></p>

Claim 8

Claim 8	HP Envy 15 Laptop
<p>[8pre] A method in a wireless communications system, the method comprising:</p>	<p>To the extent the preamble is limiting, each Accused Product practices the claimed method.</p> <p>For example, the Envy 15 Laptop supports MU-MIMO technology.</p>

Claim 8	HP Envy 15 Laptop
	<p>Wireless connectivity</p> <ul style="list-style-type: none"> • Intel® Wi-Fi 6 AX 201 (2x2)^(19e) and Bluetooth® 5 combo⁽²⁶⁾ (Supporting Gigabit file transfer speeds)⁽⁷⁾ • MU-MIMO supported <hr/> <p>See HP Envy Laptop Datasheet at p. 2 available at https://h20195.www2.hp.com/v2/getpdf.aspx/4aa7-8007enuc.pdf</p> <p>Each Accused Product operates as a communicating device or station in a Wi-Fi network. Each Accused Product that supports or utilizes Wi-Fi 6 infringes in substantially the same manner as the Envy 15 Laptop according to the exemplary descriptions of Wi-Fi 6 / 802.11ax functionality cited below. Each Accused Product that supports or utilizes MIMO / MU-MIMO technologies pursuant to IEEE 802.11ac wave 2 infringes in substantially the same manner as the Envy 15 Laptop according to the exemplary descriptions of 802.11ac wave 2 functionality cited below.</p>
<p>[8a] receiving a first signal transmission from a remote station via a first antenna element of an antenna and a second signal transmission from the remote station via a second antenna element of the antenna simultaneously, wherein the first signal transmission and the second signal transmission comprise electromagnetic signals comprising one or more transmission peaks and one or more transmission nulls;</p>	<p>The Envy 15 Laptop receives a first signal transmission from a remote station via a first antenna element of an antenna and a second signal transmission from the remote station via a second antenna element of the antenna simultaneously, wherein the first signal transmission and the second signal transmission comprise electromagnetic signals comprising one or more transmission peaks and one or more transmission nulls.</p> <p>For example, the Envy 15 Laptop receives a first signal transmission from a remote station, such as a Wi-Fi Access Point, via a first antenna element of an antenna and a second signal transmission from the remote station via a second antenna element of the antenna simultaneously.</p> <p>For example, the Envy 15 Laptop receives a first signal transmission from a remote station, such as a Wi-Fi Access Point, via a first antenna element of an antenna and a second signal transmission from the remote station via a second antenna element of the antenna simultaneously, such as when the Envy 15 Laptop receives first and second signals with its first and second antenna elements that contain training fields of a null data packet used for MU-MIMO sounding and channel estimation procedures.</p>

Claim 8	HP Envy 15 Laptop
	<p>The HE PHY supports OFDMA transmissions, both in the DL and the UL where different users can occupy different RUs in a PPDU (see 27.3.9 (Mathematical description of signals)). The transmission within an RU in a PPDU may be single stream to one user, spatially multiplexed to one user (SU-MIMO), or spatially multiplexed 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).</p> <p><i>See, e.g., IEEE 802.11ax Standard, Section 27.3.1.1</i></p> <p>tured. The number of users in the MU-MIMO group is indicated in the Number Of HE-SIG-B Symbols Or MU-MIMO Users field in HE-SIG-A. The allocated spatial streams for each user and the total number of spatial streams are indicated in the Spatial Configuration field of User field in HE-SIG-B containing the STA-ID of the designated MU-MIMO STA as defined in Table 27-29 (Spatial Configuration subfield encoding).</p> <p><i>See, e.g., IEEE 802.11ax Standard, Section 27.3.2.5</i></p> <p>If there is only one User field (see Table 27-27 (User field format for a non-MU-MIMO allocation)) for an RU in the HE-SIG-B content channel, then the number of spatial streams for the user in the RU is indicated by the NSTS field in the User field.</p> <p>If there is more than one User field (see Table 27-28 (User field for an MU-MIMO allocation)) for an RU in the HE-SIG-B content channel, then the number of allocated spatial streams for each user in the RU is indicated by the Spatial Configuration field of the User field in HE-SIG-B. Note that for an RU with 484 or</p> <p><i>See, e.g., IEEE 802.11ax Standard, Section 27.3.2.5</i></p> <p>UL MU transmissions are preceded by a Trigger frame or frame carrying a TRS Control subfield from the AP. The Trigger frame or frame carrying the TRS Control subfield indicates the parameters, such as the duration of the HE TB PPDU, RU allocation, target RSSI and MCS (see 9.3.1.22 (Trigger frame format), 9.2.4.6a.1 (TRS Control) and 26.5.3.3 (Non-AP STA behavior for UL MU operation)), required to transmit an HE TB PPDU.</p> <p><i>See, e.g., IEEE 802.11ax Standard, Section 27.3.2.6</i></p>

Claim 8	HP Envy 15 Laptop
	<p>The HE-SIG-B field provides the OFDMA and DL MU-MIMO resource allocation information to allow the STAs to look up the corresponding resources to be used in the data portion of the frame. The integer fields of the HE-SIG-B field are transmitted in unsigned binary format, LSB first, where the LSB is in the lowest numbered bit position.</p> <p><i>See, e.g., IEEE 802.11ax Standard, Section 27.3.10.8</i></p> <p>SU-MIMO and DL MU-MIMO beamforming are techniques used by a STA with multiple antennas (the beamformer) to steer signals using knowledge of the channel to improve throughput. With SU-MIMO beamforming all space-time streams in the transmitted signal are intended for reception at a single STA in an RU. With DL MU-MIMO beamforming, disjoint subsets of the space-time streams are intended for reception at different STAs in an RU of size greater than or equal to 106-tones.</p> <p><i>See, e.g., IEEE 802.11ax Standard, Section 27.3.15.1</i></p> <p>The User Specific field consists of multiple User fields. The User fields follow the Common field of HE-SIG-B. The RU Allocation field in the Common field and the position of the User field in the User Specific field together identify the RU used to transmit a STA's data. Multiple RUs addressed to a single STA shall</p> <p><i>See, e.g., IEEE 802.11ax Standard, Section 27.3.10.8.5</i></p> <p>Transmit beamforming and DL-MU-MIMO require knowledge of the channel state to compute a steering matrix that is applied to the transmitted signal to optimize reception at one or more receivers. The STA transmitting using the steering matrix is called the VHT beamformer and a STA for which reception is optimized is called a VHT beamformee. An explicit feedback mechanism is used where the VHT beamformee directly measures the channel from the training symbols transmitted by the VHT beamformer and sends back a transformed estimate of the channel state to the VHT beamformer. The VHT beamformer then uses this estimate, perhaps combining estimates from multiple VHT beamformees, to derive the steering matrix.</p> <p><i>See, e.g., IEEE 802.11ac Standard Clause 9.31.5.1</i></p>

Claim 8

HP Envy 15 Laptop

A VHT beamformer shall initiate a sounding feedback sequence by transmitting a VHT NDP Announcement frame followed by a VHT NDP after a SIFS. The VHT beamformer shall include in the VHT NDP Announcement frame one STA Info field for each VHT beamformee that is expected to prepare VHT Compressed Beamforming feedback and shall identify the VHT beamformee by including the VHT beamformee's AID in the AID subfield of the STA Info field. The VHT NDP Announcement frame shall include at least one STA Info field.

See, e.g., IEEE 802.11ac Standard Clause 9.31.5.2

A non-AP VHT beamformee that receives a VHT NDP Announcement frame from a VHT beamformer with which it is associated or has an established DLS or TDLS session and that contains the VHT beamformee's AID in the AID subfield of a STA Info field that is not the first STA Info field shall transmit its VHT Compressed Beamforming feedback a SIFS after receiving a Beamforming Report Poll with RA matching its MAC address and a non-bandwidth signaling TA obtained from the TA field matching the MAC address of the VHT beamformer. If the RXVECTOR parameter CH_BANDWIDTH_IN_NON_HT of the received

See, e.g., IEEE 802.11ac Standard Clause 9.31.5.2

The VHT Compressed Beamforming frame is an Action No Ack frame of category VHT. The Action field of a VHT Compressed Beamforming frame contains the information shown in Table 8-281ai.

Table 8-281ai—VHT Compressed Beamforming frame Action field format

Order	Information
1	Category
2	VHT Action
3	VHT MIMO Control (see 8.4.1.47)
4	VHT Compressed Beamforming Report (see 8.4.1.48)
5	MU Exclusive Beamforming Report (see 8.4.1.49)

See, e.g., IEEE 802.11ac Standard Clause 8.5.23.2

The VHT MIMO Control field is always present in the frame. The presence and contents of the VHT Compressed Beamforming Report field and the MU Exclusive Beamforming Report field are dependent on the values of the Feedback Type, Remaining Feedback Segments, and First Feedback Segment subfields of the VHT MIMO Control field (see 8.4.1.47, 8.4.1.48, 8.4.1.49, and 9.31.5).

Claim 8	HP Envy 15 Laptop
	<p data-bbox="594 625 1089 653"><i>See, e.g.</i>, IEEE 802.11ac Standard Clause 8.5.23.2</p> <p data-bbox="594 680 1252 707"><i>See</i> Tables 8-53(d)-(h) in IEEE 802.11ac Standard Clause 8.4.1.48</p> <p data-bbox="594 774 1455 892">The <i>AvgSNR_i</i> in Table 8-53h is found by computing the SNR per subcarrier in decibels for the subcarriers identified in Table 8-53g, and then computing the arithmetic mean of those values. Each SNR value per tone in stream <i>i</i> (before being averaged) corresponds to the SNR associated with the column <i>i</i> of the beamforming feedback matrix <i>V</i> determined at the beamformee. Each SNR corresponds to the predicted SNR at the beamformee when the beamformer applies all columns of the matrix <i>V</i>.</p> <p data-bbox="594 898 1089 926"><i>See, e.g.</i>, IEEE 802.11ac Standard Clause 8.4.1.48</p> <p data-bbox="594 957 1455 1075">The MU Exclusive Beamforming Report field is used by the VHT Compressed Beamforming feedback (see 8.5.23.2) to carry explicit feedback information in the form of delta SNRs. The information in the VHT Compressed Beamforming Report field and the MU Exclusive Beamforming Report field can be used by the transmit MU beamformer to determine steering matrices <i>Q_i</i>, as described in 9.29.3, 20.3.12.3, and Table 22.3.11.</p> <p data-bbox="594 1077 1089 1104"><i>See, e.g.</i>, IEEE 802.11ac Standard Clause 8.4.1.49</p>

Claim 8	HP Envy 15 Laptop		
	Field	Size (Bits)	Meaning
	Delta SNR for space-time stream 1 for subcarrier $k = sscidx(0)$	4	$\Delta SNR_{sscidx(0),1}$ as defined in Equation (8-2)

	Delta SNR for space-time stream Nc for subcarrier $k = sscidx(0)$	4	$\Delta SNR_{sscidx(0),Nc}$ as defined in Equation (8-2)
	Delta SNR for space-time stream 1 for subcarrier $k = sscidx(1)$	4	$\Delta SNR_{sscidx(1),1}$ as defined in Equation (8-2)

	Delta SNR for space-time stream Nc for subcarrier $k = sscidx(1)$	4	$\Delta SNR_{sscidx(1),Nc}$ as defined in Equation (8-2)

		Size (Bits)	Meaning
	Delta SNR for space-time stream 1 for subcarrier $k = sscidx(Ns'-1)$	4	$\Delta SNR_{sscidx(Ns'-1),1}$ as defined in Equation (8-2)

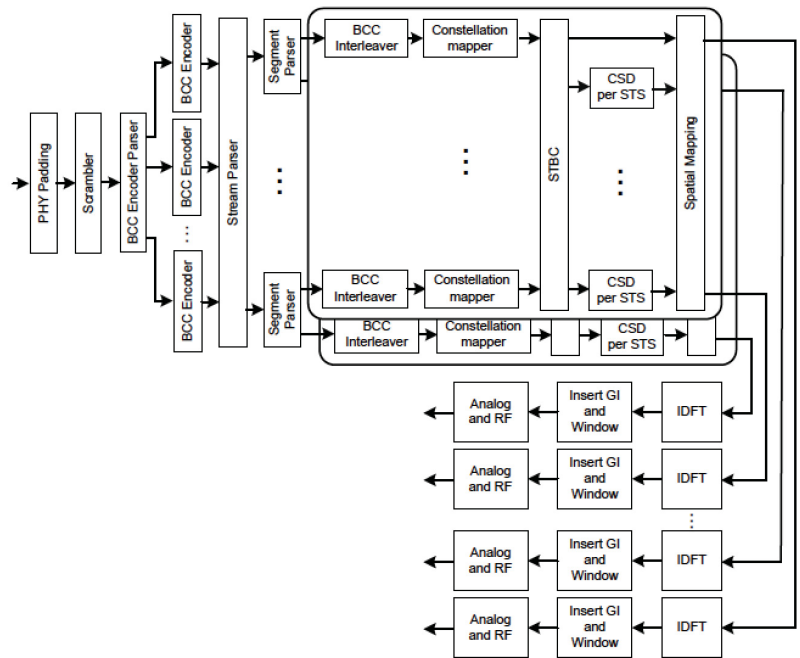
	Delta SNR for space-time stream Nc for subcarrier $k = sscidx(Ns'-1)$	4	$\Delta SNR_{sscidx(Ns'-1),Nc}$ as defined in Equation (8-2)
	NOTE— $sscidx()$ is defined in Table 8-53j.		
	<p>In Table 8-53i, Ns' is the number of subcarriers for which the Delta SNR subfield is sent back to the beamformer. Table 8-53j shows Ns', the exact subcarrier indices and their order for which the Delta SNR is sent back.</p> <p>See, e.g., Table 8-53i IEEE 802.11ac Standard Clause 8.4.1.48</p>		

Claim 8

HP Envy 15 Laptop

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

See, e.g., IEEE 802.11ac Standard Clause 9.31.5.1



Claim 8	HP Envy 15 Laptop
	<p data-bbox="592 653 1117 680">See, e.g., IEEE 802.11ac Standard Clause 22.3.4.6(d)</p> <p data-bbox="605 693 1045 716">The VHT-SIG-B field is constructed per-user as follows:</p> <ol style="list-style-type: none"> <li data-bbox="625 722 1308 745">a) Obtain the VHT-MCS (for MU only) and APEP_LENGTH from the TXVECTOR. <li data-bbox="625 751 1442 821">b) VHT-SIG-B bits: Set the VHT-MCS (for MU only) and VHT-SIG-B Length field as described in 22.3.8.3.6. Add the reserved bits (for SU only) and N_{tail} bits of tail. For an NDP set VHT-SIG-B to the fixed bit pattern for the bandwidth used as described in 22.3.8.3.6. <li data-bbox="625 827 1442 873">c) VHT-SIG-B Bit Repetition: Repeat the VHT-SIG-B bits as a function of CH_BANDWIDTH as defined in 22.3.8.3.6. <li data-bbox="625 879 1398 903">d) BCC encoder: Encode the VHT-SIG-B field using BCC at rate $R=1/2$ as described in 18.3.5.6. <li data-bbox="625 909 1442 978">e) Segment parser (if needed): For a contiguous 160 MHz or noncontiguous 80+80 MHz transmission, divide the output bits of the BCC encoder into two frequency subblocks as described in 22.3.10.7. This block is bypassed for 20 MHz, 40 MHz, and 80 MHz VHT PPDU transmissions. <li data-bbox="625 984 1081 1008">f) BCC interleaver: Interleave as described in 22.3.10.8. <li data-bbox="625 1014 1243 1037">g) Constellation mapper: Map to a BPSK constellation as defined in 18.3.5.8. <li data-bbox="625 1043 1442 1113">h) Segment deparser (if needed): For a contiguous 160 MHz transmission, merge the two frequency subblocks into one frequency segment as described in 22.3.10.9.3. This block is bypassed for 20 MHz, 40 MHz, 80 MHz, and 80+80 MHz VHT PPDU transmissions. <li data-bbox="625 1119 1219 1142">i) Pilot insertion: Insert pilots following the steps described in 22.3.10.10. <li data-bbox="625 1148 1442 1218">j) P_{VHTLTF} matrix mapping: Apply the mapping of the 1st column of the P_{VHTLTF} matrix to the data subcarriers as described in 22.3.8.3.6. The total number of data and pilot subcarriers is the same as in the Data field. <li data-bbox="625 1224 1406 1247">k) CSD: Apply CSD for each space-time stream and frequency segment as described in 22.3.8.3.2. <li data-bbox="625 1253 1208 1276">l) Spatial mapping: Apply the Q matrix as described in 22.3.10.11.1. <li data-bbox="625 1283 1442 1329">m) Phase rotation: Apply the appropriate phase rotations for each 20 MHz subchannel as described in 22.3.7.4 and 22.3.7.5. <li data-bbox="625 1335 1089 1358">n) IDFT: Compute the inverse discrete Fourier transform. <li data-bbox="625 1365 1442 1411">o) Insert GI and apply windowing: Prepend a GI (LONG_GI) and apply windowing as described in 22.3.7.4. <li data-bbox="625 1417 1442 1486">p) Analog and RF: Up-convert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 22.3.7.4 and 22.3.8 for details.

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	<p data-bbox="592 625 1466 682"><i>See, e.g.</i>, IEEE 802.11ac Standard Clauses 22.3.4.8(l) and 22.3.4.9.1(m), 22.3.4.9.2(m), 22.3.4.10.4(a).</p> <p data-bbox="621 716 1398 890">The DL-MU-MIMO steering matrix $Q_k = [Q_{k,0}, Q_{k,1}, \dots, Q_{k,N_{user}-1}]$ can be determined by the beamformer using the beamforming feedback matrices for subcarrier k from beamformee u, $V_{k,u}$, and SNR information for subcarrier k from beamformee u, $SNR_{k,u}$, where $u = 0, 1, \dots, N_{user} - 1$. The steering matrix that is computed (or updated) using new beamforming feedback matrices and new SNR information from some or all of participating beamformees might replace the existing steering matrix Q_k for the next DL-MU-MIMO data transmission. The beamformee group for the MU transmission is signaled using the Group ID field in VHT-SIG-A (see 22.3.8.3.3 and 22.3.11.4).</p> <p data-bbox="592 905 1101 932"><i>See, e.g.</i>, IEEE 802.11ac Standard Clause 22.3.11.1</p> <p data-bbox="602 968 1453 1157">Upon receipt of a VHT NDP sounding PPDU, the beamformee shall remove the space-time stream CSD in Table 22-11 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 shall be compressed in the form of angles using the method described in 20.3.12.3.6. The angles, $\phi(k,u)$ and $\psi(k,u)$, are quantized according to Table 8-53e. The number of bits for quantization is chosen by the beamformee, based on the indication from the beamformer as to whether the feedback is requested for SU-MIMO beamforming or DL-MU-MIMO beamforming. The compressed beamforming feedback using 20.3.12.3.6 is the only Clause 22 beamforming feedback format defined.</p> <p data-bbox="602 1178 1453 1226">The beamformee shall generate the beamforming feedback matrices with the number of rows (N_r) equal to the N_{STS} of the NDP.</p> <p data-bbox="602 1247 1453 1388">After receiving the angle information, $\phi(k,u)$ and $\psi(k,u)$, the beamformer reconstructs $V_{k,u}$ using Equation (20-79). For SU-MIMO beamforming, the beamformer can use this $V_{k,0}$ matrix to determine the steering matrix Q_k. For DL-MU-MIMO beamforming, the beamformer may calculate a steering matrix $Q_k = [Q_{k,0}, Q_{k,1}, \dots, Q_{k,N_{user}-1}]$ using $V_{k,u}$ and $SNR_{k,u}$ ($0 \leq u \leq N_{user} - 1$) in order to suppress crosstalk between participating beamformees. The method used by the beamformer to calculate the steering matrix Q_k is implementation specific.</p> <p data-bbox="592 1388 1109 1415"><i>See, e.g.</i>, IEEE 802.11ac Standard Clause 22.3.11.2.</p>
[8b] determining first signal information for the first signal transmission;	The Envy 15 Laptop determines first signal information for the first signal transmission.

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	<p>For example, the Envy 15 Laptop determines the first signal information for the first signal transmission, by determining symbols corresponding to e.g. a first space-time stream using e.g. the training fields of a null data packet for MU-MIMO sounding and channel estimation to, which allows for determining, e.g., an estimate of the channel state, e.g., a transformed estimate of the channel state to be transmitted in a compressed beamforming report, e.g., the parameters in the beamforming feedback matrix.</p> <p>Transmit beamforming and DL MU-MIMO require knowledge of the channel state to compute a steering matrix that is applied to the transmit signal to optimize reception at one or more receivers. HE STAs use the HE sounding protocol to determine the channel state information. The HE sounding protocol provides explicit feedback mechanisms, defined as HE non-trigger-based (non-TB) sounding and HE trigger-based (TB) sounding, where the HE beamformee measures the channel using a training signal (i.e., an HE sounding NDP) transmitted by the HE beamformer and sends back a transformed estimate of the channel state. The HE beamformer uses this estimate to derive the steering matrix.</p> <p>The HE beamformee returns an estimate of the channel state in an HE compressed beamforming/CQI report carried in one or more HE Compressed Beamforming/CQI frames. There are three types of HE compressed beamforming/CQI report:</p> <p><i>See, e.g., IEEE 802.11ax Standard, Section 26.7.1</i></p> <p>An HE beamformee that receives an HE NDP Announcement frame from an HE beamformer with which it is associated and that contains the HE beamformee's MAC address in the RA field and also receives an HE sounding NDP a SIFS after the HE NDP Announcement frame shall transmit its HE compressed beamforming/CQI report a SIFS after the HE sounding NDP. The TXVECTOR parameter CH_BANDWIDTH for the PPDU containing the HE compressed beamforming/CQI report shall be set to indicate a bandwidth not wider than that indicated by the RXVECTOR parameter CH_BANDWIDTH of the HE sounding NDP.</p> <p><i>See, e.g., IEEE 802.11ax Standard, Section 26.7.3</i></p> <p>An HE beamformee that receives an HE NDP Announcement frame as part of an HE TB sounding sequence with a STA Info field addressed to it soliciting SU or MU feedback shall generate an HE compressed beamforming/CQI report using the feedback type, N_g and codebook size indicated in the STA Info field. If the HE beamformee then receives a BFRP Trigger frame with a User Info field addressed to it, the HE beamformee transmits an HE TB PPDU containing the HE compressed beamforming/CQI report following the rules defined in 26.5.3.3 (Non-AP STA behavior for UL MU operation). If the HE NDP Announcement frame has</p> <p><i>See, e.g., IEEE 802.11ax Standard, Section 26.7.3</i></p> <p>UL MU operation allows an AP to solicit simultaneous immediate response frames from one or more non-AP HE STAs. A non-AP HE STA shall follow the rules in this subclause for the transmission of response</p>

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	<p data-bbox="594 625 1084 653"><i>See, e.g.</i>, IEEE 802.11ax Standard, Section 26.5.3</p> <p data-bbox="594 657 1451 890">The HE-LTF field 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 and HE ER SU PPDU, the transmitter provides training for N_{STS} space-time streams (spatial mapper inputs) used for the transmission of the PSDU. In an HE MU PPDU, the transmitter provides training for $N_{STS,r,total}$ space-time streams used for the transmission of the PSDU(s) in the r-th RU. In an HE TB 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. An 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 subcarriers of each HE-LTF symbol are multiplied by the entries of a</p> <p data-bbox="594 894 1130 921"><i>See, e.g.</i>, IEEE 802.11ax Standard, Section 27.3.10.10</p> <p data-bbox="594 953 1451 1092">In an HE SU PPDU, HE MU PPDU and HE ER SU PPDU, the combination of HE-LTF type and GI duration is indicated in HE-SIG-A field. In an HE TB PPDU, the combination of HE-LTF type and GI duration is indicated in the Trigger frame that triggers the transmission of the PPDU. If an HE PPDU is an HE sounding NDP, the combinations of HE-LTF types and GI durations are listed in 27.3.18 (Transmit specification). If an HE PPDU is an HE TB feedback NDP, the combinations of types and GI durations are listed in 27.3.4 (HE PPDU formats).</p> <p data-bbox="594 1096 1130 1123"><i>See, e.g.</i>, IEEE 802.11ax Standard, Section 27.3.10.10</p> <p data-bbox="594 1161 1451 1299">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 9.4.1.65 (HE Compressed Beamforming Report field) and 9.4.1.66 (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.</p> <p data-bbox="594 1325 1451 1415">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 9.4.1.65 (HE Compressed Beamforming Report field).</p> <p data-bbox="594 1419 1117 1446"><i>See, e.g.</i>, IEEE 802.11ax Standard, Section 27.3.15.1</p>

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	<p>Transmit beamforming and DL-MU-MIMO require knowledge of the channel state to compute a steering matrix that is applied to the transmitted signal to optimize reception at one or more receivers. The STA transmitting using the steering matrix is called the VHT beamformer and a STA for which reception is optimized is called a VHT beamformee. An explicit feedback mechanism is used where the VHT beamformee directly measures the channel from the training symbols transmitted by the VHT beamformer and sends back a transformed estimate of the channel state to the VHT beamformer. The VHT beamformer then uses this estimate, perhaps combining estimates from multiple VHT beamformees, to derive the steering matrix.</p> <p><i>See, e.g., IEEE 802.11ac Standard Clause 9.31.5.1</i></p> <p>A VHT beamformer shall initiate a sounding feedback sequence by transmitting a VHT NDP Announcement frame followed by a VHT NDP after a SIFS. The VHT beamformer shall include in the VHT NDP Announcement frame one STA Info field for each VHT beamformee that is expected to prepare VHT Compressed Beamforming feedback and shall identify the VHT beamformee by including the VHT beamformee's AID in the AID subfield of the STA Info field. The VHT NDP Announcement frame shall include at least one STA Info field.</p> <p><i>See, e.g., IEEE 802.11ac Standard Clause 9.31.5.2</i></p> <p>A non-AP VHT beamformee that receives a VHT NDP Announcement frame from a VHT beamformer with which it is associated or has an established DLS or TDLS session and that contains the VHT beamformee's AID in the AID subfield of a STA Info field that is not the first STA Info field shall transmit its VHT Compressed Beamforming feedback a SIFS after receiving a Beamforming Report Poll with RA matching its MAC address and a non-bandwidth signaling TA obtained from the TA field matching the MAC address of the VHT beamformer. If the RXVECTOR parameter CH_BANDWIDTH_IN_NON_HT of the received</p> <p><i>See, e.g., IEEE 802.11ac Standard Clause 9.31.5.2</i></p>

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Table 8-281ai—VHT Compressed Beamforming frame Action field format

Order	Information
1	Category
2	VHT Action
3	VHT MIMO Control (see 8.4.1.47)
4	VHT Compressed Beamforming Report (see 8.4.1.48)
5	MU Exclusive Beamforming Report (see 8.4.1.49)

The Category field is set to the value for VHT, specified in Table 8-38.

The VHT Action field is set to the value for VHT Compressed Beamforming, specified in Table 8-281ah.

The VHT MIMO Control field is always present in the frame. The presence and contents of the VHT Compressed Beamforming Report field and the MU Exclusive Beamforming Report field are dependent on the values of the Feedback Type, Remaining Feedback Segments, and First Feedback Segment subfields of the VHT MIMO Control field (see 8.4.1.47, 8.4.1.48, 8.4.1.49, and 9.31.5).

See, e.g., IEEE 802.11ac Standard Clause 8.5.23.2

See Tables 8-53(d)-(h) in IEEE 802.11ac Standard Clause 8.4.1.48

The $AvgSNR_i$ in Table 8-53h is found by computing the SNR per subcarrier in decibels for the subcarriers identified in Table 8-53g, and then computing the arithmetic mean of those values. Each SNR value per tone in stream i (before being averaged) corresponds to the SNR associated with the column i of the beamforming feedback matrix V determined at the beamformee. Each SNR corresponds to the predicted SNR at the beamformee when the beamformer applies all columns of the matrix V .

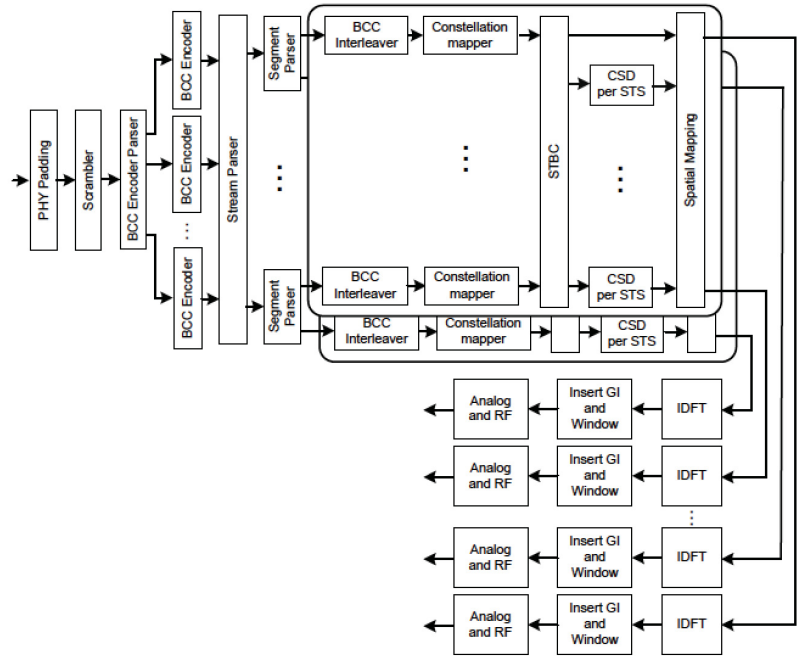
See, e.g., IEEE 802.11ac Standard Clause 8.4.1.48

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	<p>The MU Exclusive Beamforming Report field is used by the VHT Compressed Beamforming feedback (see 8.5.23.2) to carry explicit feedback information in the form of delta SNRs. The information in the VHT Compressed Beamforming Report field and the MU Exclusive Beamforming Report field can be used by the transmit MU beamformer to determine steering matrices Q, as described in 9.29.3, 20.3.12.3, and Table 22.3.11.</p> <p>See, e.g., IEEE 802.11ac Standard Clause 8.4.1.49</p> <table border="1" data-bbox="609 783 1458 1199"> <thead> <tr> <th data-bbox="609 783 943 842">Field</th> <th data-bbox="943 783 1019 842">Size (Bits)</th> <th data-bbox="1019 783 1458 842">Meaning</th> </tr> </thead> <tbody> <tr> <td data-bbox="609 842 943 905">Delta SNR for space-time stream 1 for subcarrier $k = sscidx(0)$</td> <td data-bbox="943 842 1019 905">4</td> <td data-bbox="1019 842 1458 905">$\Delta SNR_{sscidx(0),1}$ as defined in Equation (8-2)</td> </tr> <tr> <td data-bbox="609 905 943 936">...</td> <td data-bbox="943 905 1019 936">...</td> <td data-bbox="1019 905 1458 936">...</td> </tr> <tr> <td data-bbox="609 936 943 999">Delta SNR for space-time stream N_c for subcarrier $k = sscidx(0)$</td> <td data-bbox="943 936 1019 999">4</td> <td data-bbox="1019 936 1458 999">$\Delta SNR_{sscidx(0),N_c}$ as defined in Equation (8-2)</td> </tr> <tr> <td data-bbox="609 999 943 1062">Delta SNR for space-time stream 1 for subcarrier $k = sscidx(1)$</td> <td data-bbox="943 999 1019 1062">4</td> <td data-bbox="1019 999 1458 1062">$\Delta SNR_{sscidx(1),1}$ as defined in Equation (8-2)</td> </tr> <tr> <td data-bbox="609 1062 943 1094">...</td> <td data-bbox="943 1062 1019 1094">...</td> <td data-bbox="1019 1062 1458 1094">...</td> </tr> <tr> <td data-bbox="609 1094 943 1157">Delta SNR for space-time stream N_c for subcarrier $k = sscidx(1)$</td> <td data-bbox="943 1094 1019 1157">4</td> <td data-bbox="1019 1094 1458 1157">$\Delta SNR_{sscidx(1),N_c}$ as defined in Equation (8-2)</td> </tr> <tr> <td data-bbox="609 1157 943 1199">...</td> <td data-bbox="943 1157 1019 1199">...</td> <td data-bbox="1019 1157 1458 1199">...</td> </tr> </tbody> </table>	Field	Size (Bits)	Meaning	Delta SNR for space-time stream 1 for subcarrier $k = sscidx(0)$	4	$\Delta SNR_{sscidx(0),1}$ as defined in Equation (8-2)	Delta SNR for space-time stream N_c for subcarrier $k = sscidx(0)$	4	$\Delta SNR_{sscidx(0),N_c}$ as defined in Equation (8-2)	Delta SNR for space-time stream 1 for subcarrier $k = sscidx(1)$	4	$\Delta SNR_{sscidx(1),1}$ as defined in Equation (8-2)	Delta SNR for space-time stream N_c for subcarrier $k = sscidx(1)$	4	$\Delta SNR_{sscidx(1),N_c}$ as defined in Equation (8-2)
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	<table border="1"> <thead> <tr> <th data-bbox="602 638 925 688">Field</th> <th data-bbox="930 638 1003 688">Size (Bits)</th> <th data-bbox="1008 638 1442 688">Meaning</th> </tr> </thead> <tbody> <tr> <td data-bbox="602 695 925 751">Delta SNR for space-time stream 1 for subcarrier $k = sscidx(Ns'-1)$</td> <td data-bbox="930 695 1003 751">4</td> <td data-bbox="1008 695 1442 751">$\Delta SNR_{sscidx(Ns'-1),1}$ as defined in Equation (8-2)</td> </tr> <tr> <td data-bbox="602 758 925 785">...</td> <td data-bbox="930 758 1003 785">...</td> <td data-bbox="1008 758 1442 785">...</td> </tr> <tr> <td data-bbox="602 791 925 848">Delta SNR for space-time stream Nc for subcarrier $k = sscidx(Ns'-1)$</td> <td data-bbox="930 791 1003 848">4</td> <td data-bbox="1008 791 1442 848">$\Delta SNR_{sscidx(Ns'-1),Nc}$ as defined in Equation (8-2)</td> </tr> </tbody> </table>	Field	Size (Bits)	Meaning	Delta SNR for space-time stream 1 for subcarrier $k = sscidx(Ns'-1)$	4	$\Delta SNR_{sscidx(Ns'-1),1}$ as defined in Equation (8-2)	Delta SNR for space-time stream Nc for subcarrier $k = sscidx(Ns'-1)$	4	$\Delta SNR_{sscidx(Ns'-1),Nc}$ as defined in Equation (8-2)		
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NOTE— $sscidx()$ is defined in Table 8-53j.															
<p>In Table 8-53i, Ns' is the number of subcarriers for which the Delta SNR subfield is sent back to the beamformer. Table 8-53j shows Ns', the exact subcarrier indices and their order for which the Delta SNR is sent back.</p> <p>See, e.g., Table 8-53i IEEE 802.11ac Standard Clause 8.4.1.48</p>															
<p>Transmit beamforming and DL-MU-MIMO require knowledge of the channel state to compute a steering matrix that is applied to the transmitted signal to optimize reception at one or more receivers. The STA transmitting using the steering matrix is called the VHT beamformer and a STA for which reception is optimized is called a VHT beamformee. An explicit feedback mechanism is used where the VHT beamformee directly measures the channel from the training symbols transmitted by the VHT beamformer and sends back a transformed estimate of the channel state to the VHT beamformer. The VHT beamformer then uses this estimate, perhaps combining estimates from multiple VHT beamformees, to derive the steering matrix.</p> <p>See, e.g., IEEE 802.11ac Standard Clause 9.31.5.1</p>															

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See, e.g., IEEE 802.11ac Standard Clause 22.3.4.6(d)

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	<p>The VHT-SIG-B field is constructed per-user as follows:</p> <ol style="list-style-type: none"> a) Obtain the VHT-MCS (for MU only) and APEP_LENGTH from the TXVECTOR. b) VHT-SIG-B bits: Set the VHT-MCS (for MU only) and VHT-SIG-B Length field as described in 22.3.8.3.6. Add the reserved bits (for SU only) and N_{tail} bits of tail. For an NDP set VHT-SIG-B to the fixed bit pattern for the bandwidth used as described in 22.3.8.3.6. c) VHT-SIG-B Bit Repetition: Repeat the VHT-SIG-B bits as a function of CH_BANDWIDTH as defined in 22.3.8.3.6. d) BCC encoder: Encode the VHT-SIG-B field using BCC at rate $R=1/2$ as described in 18.3.5.6. e) Segment parser (if needed): For a contiguous 160 MHz or noncontiguous 80+80 MHz transmission, divide the output bits of the BCC encoder into two frequency subblocks as described in 22.3.10.7. This block is bypassed for 20 MHz, 40 MHz, and 80 MHz VHT PPDU transmissions. f) BCC interleaver: Interleave as described in 22.3.10.8. g) Constellation mapper: Map to a BPSK constellation as defined in 18.3.5.8. h) Segment deparser (if needed): For a contiguous 160 MHz transmission, merge the two frequency subblocks into one frequency segment as described in 22.3.10.9.3. This block is bypassed for 20 MHz, 40 MHz, 80 MHz, and 80+80 MHz VHT PPDU transmissions. i) Pilot insertion: Insert pilots following the steps described in 22.3.10.10. j) P_{VHTLTF} matrix mapping: Apply the mapping of the 1st column of the P_{VHTLTF} matrix to the data subcarriers as described in 22.3.8.3.6. The total number of data and pilot subcarriers is the same as in the Data field. k) CSD: Apply CSD for each space-time stream and frequency segment as described in 22.3.8.3.2. l) Spatial mapping: Apply the Q matrix as described in 22.3.10.11.1. m) Phase rotation: Apply the appropriate phase rotations for each 20 MHz subchannel as described in 22.3.7.4 and 22.3.7.5. n) IDFT: Compute the inverse discrete Fourier transform. o) Insert GI and apply windowing: Prepend a GI (LONG_GI) and apply windowing as described in 22.3.7.4. p) Analog and RF: Up-convert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 22.3.7.4 and 22.3.8 for details. <p>See, e.g., IEEE 802.11ac Standard Clauses 22.3.4.8(l) and 22.3.4.9.1(m), 22.3.4.9.2(m), 22.3.4.10.4(a).</p>

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	<p>The DL-MU-MIMO steering matrix $Q_k = [Q_{k,0}, Q_{k,1}, \dots, Q_{k,N_{user}-1}]$ can be determined by the beamformer using the beamforming feedback matrices for subcarrier k from beamformee u, $V_{k,u}$, and SNR information for subcarrier k from beamformee u, $SNR_{k,u}$, where $u = 0, 1, \dots, N_{user} - 1$. The steering matrix that is computed (or updated) using new beamforming feedback matrices and new SNR information from some or all of participating beamformees might replace the existing steering matrix Q_k for the next DL-MU-MIMO data transmission. The beamformee group for the MU transmission is signaled using the Group ID field in VHT-SIG-A (see 22.3.8.3.3 and 22.3.11.4).</p> <p><i>See, e.g., IEEE 802.11ac Standard Clause 22.3.11.1</i></p> <p>Upon receipt of a VHT NDP sounding PPDU, the beamformee shall remove the space-time stream CSD in Table 22-11 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 shall be compressed in the form of angles using the method described in 20.3.12.3.6. The angles, $\phi(k,u)$ and $\psi(k,u)$, are quantized according to Table 8-53e. The number of bits for quantization is chosen by the beamformee, based on the indication from the beamformer as to whether the feedback is requested for SU-MIMO beamforming or DL-MU-MIMO beamforming. The compressed beamforming feedback using 20.3.12.3.6 is the only Clause 22 beamforming feedback format defined.</p> <p>The beamformee shall generate the beamforming feedback matrices with the number of rows (N_r) equal to the N_{STS} of the NDP.</p> <p>After receiving the angle information, $\phi(k,u)$ and $\psi(k,u)$, the beamformer reconstructs $V_{k,u}$ using Equation (20-79). For SU-MIMO beamforming, the beamformer can use this $V_{k,0}$ matrix to determine the steering matrix Q_k. For DL-MU-MIMO beamforming, the beamformer may calculate a steering matrix $Q_k = [Q_{k,0}, Q_{k,1}, \dots, Q_{k,N_{user}-1}]$ using $V_{k,u}$ and $SNR_{k,u}$ ($0 \leq u \leq N_{user} - 1$) in order to suppress crosstalk between participating beamformees. The method used by the beamformer to calculate the steering matrix Q_k is implementation specific.</p> <p><i>See, e.g., IEEE 802.11ac Standard Clause 22.3.11.2</i></p> <p>.</p>
[8c] determining second signal information for the second signal transmission, wherein the second signal	The Envy 15 Laptop determines second signal information for the second signal transmission, wherein the second signal information is different than the first signal information.

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<p>information is different than the first signal information;</p>	<p>For example, the Envy 15 Laptop determines the second signal information for the second signal transmission, by determining symbols corresponding to e.g. a second space-time stream using e.g. the training fields of a null data packet for MU-MIMO sounding and channel estimation to, which allows for determining , e.g., an estimate of the channel state, e.g., a transformed estimate of the channel state to be transmitted in a compressed beamforming report, e.g., the parameters in the beamforming feedback matrix.</p> <p>Transmit beamforming and DL MU-MIMO require knowledge of the channel state to compute a steering matrix that is applied to the transmit signal to optimize reception at one or more receivers. HE STAs use the HE sounding protocol to determine the channel state information. The HE sounding protocol provides explicit feedback mechanisms, defined as HE non-trigger-based (non-TB) sounding and HE trigger-based (TB) sounding, where the HE beamformee measures the channel using a training signal (i.e., an HE sounding NDP) transmitted by the HE beamformer and sends back a transformed estimate of the channel state. The HE beamformer uses this estimate to derive the steering matrix.</p> <p>The HE beamformee returns an estimate of the channel state in an HE compressed beamforming/CQI report carried in one or more HE Compressed Beamforming/CQI frames. There are three types of HE compressed beamforming/CQI report:</p> <p><i>See, e.g., IEEE 802.11ax Standard, Section 26.7.1</i></p> <p>An HE beamformee that receives an HE NDP Announcement frame from an HE beamformer with which it is associated and that contains the HE beamformee's MAC address in the RA field and also receives an HE sounding NDP a SIFS after the HE NDP Announcement frame shall transmit its HE compressed beamforming/CQI report a SIFS after the HE sounding NDP. The TXVECTOR parameter CH_BANDWIDTH for the PPDU containing the HE compressed beamforming/CQI report shall be set to indicate a bandwidth not wider than that indicated by the RXVECTOR parameter CH_BANDWIDTH of the HE sounding NDP.</p> <p><i>See, e.g., IEEE 802.11ax Standard, Section 26.7.3</i></p> <p>An HE beamformee that receives an HE NDP Announcement frame as part of an HE TB sounding sequence with a STA Info field addressed to it soliciting SU or MU feedback shall generate an HE compressed beamforming/CQI report using the feedback type, Ng and codebook size indicated in the STA Info field. If the HE beamformee then receives a BFRP Trigger frame with a User Info field addressed to it, the HE beamformee transmits an HE TB PPDU containing the HE compressed beamforming/CQI report following the rules defined in 26.5.3.3 (Non-AP STA behavior for UL MU operation). If the HE NDP Announcement frame has</p> <p><i>See, e.g., IEEE 802.11ax Standard, Section 26.7.3</i></p>

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	<p>UL MU operation allows an AP to solicit simultaneous immediate response frames from one or more non-AP HE STAs. A non-AP HE STA shall follow the rules in this subclause for the transmission of response <i>See, e.g., IEEE 802.11ax Standard, Section 26.5.3</i></p> <p>The HE-LTF field 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 and HE ER SU PPDU, the transmitter provides training for N_{STS} space-time streams (spatial mapper inputs) used for the transmission of the PSDU. In an HE MU PPDU, the transmitter provides training for $N_{STS,r,total}$ space-time streams used for the transmission of the PSDU(s) in the r-th RU. In an HE TB 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. An 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 subcarriers of each HE-LTF symbol are multiplied by the entries of a <i>See, e.g., IEEE 802.11ax Standard, Section 27.3.10.10</i></p> <p>In an HE SU PPDU, HE MU PPDU and HE ER SU PPDU, the combination of HE-LTF type and GI duration is indicated in HE-SIG-A field. In an HE TB PPDU, the combination of HE-LTF type and GI duration is indicated in the Trigger frame that triggers the transmission of the PPDU. If an HE PPDU is an HE sounding NDP, the combinations of HE-LTF types and GI durations are listed in 27.3.18 (Transmit specification). If an HE PPDU is an HE TB feedback NDP, the combinations of types and GI durations are listed in 27.3.4 (HE PPDU formats). <i>See, e.g., IEEE 802.11ax Standard, Section 27.3.10.10</i></p> <p>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 9.4.1.65 (HE Compressed Beamforming Report field) and 9.4.1.66 (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.</p> <p>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 9.4.1.65 (HE Compressed Beamforming Report field). <i>See, e.g., IEEE 802.11ax Standard, Section 27.3.15.1</i></p>

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	<p>Transmit beamforming and DL-MU-MIMO require knowledge of the channel state to compute a steering matrix that is applied to the transmitted signal to optimize reception at one or more receivers. The STA transmitting using the steering matrix is called the VHT beamformer and a STA for which reception is optimized is called a VHT beamformee. An explicit feedback mechanism is used where the VHT beamformee directly measures the channel from the training symbols transmitted by the VHT beamformer and sends back a transformed estimate of the channel state to the VHT beamformer. The VHT beamformer then uses this estimate, perhaps combining estimates from multiple VHT beamformees, to derive the steering matrix.</p> <p><i>See, e.g., IEEE 802.11ac Standard Clause 9.31.5.1</i></p> <p>A VHT beamformer shall initiate a sounding feedback sequence by transmitting a VHT NDP Announcement frame followed by a VHT NDP after a SIFS. The VHT beamformer shall include in the VHT NDP Announcement frame one STA Info field for each VHT beamformee that is expected to prepare VHT Compressed Beamforming feedback and shall identify the VHT beamformee by including the VHT beamformee's AID in the AID subfield of the STA Info field. The VHT NDP Announcement frame shall include at least one STA Info field.</p> <p><i>See, e.g., IEEE 802.11ac Standard Clause 9.31.5.2</i></p> <p>A non-AP VHT beamformee that receives a VHT NDP Announcement frame from a VHT beamformer with which it is associated or has an established DLS or TDLS session and that contains the VHT beamformee's AID in the AID subfield of a STA Info field that is not the first STA Info field shall transmit its VHT Compressed Beamforming feedback a SIFS after receiving a Beamforming Report Poll with RA matching its MAC address and a non-bandwidth signaling TA obtained from the TA field matching the MAC address of the VHT beamformer. If the RXVECTOR parameter CH_BANDWIDTH_IN_NON_HT of the received</p> <p><i>See, e.g., IEEE 802.11ac Standard Clause 9.31.5.2</i></p>

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Table 8-281ai—VHT Compressed Beamforming frame Action field format

Order	Information
1	Category
2	VHT Action
3	VHT MIMO Control (see 8.4.1.47)
4	VHT Compressed Beamforming Report (see 8.4.1.48)
5	MU Exclusive Beamforming Report (see 8.4.1.49)

The Category field is set to the value for VHT, specified in Table 8-38.

The VHT Action field is set to the value for VHT Compressed Beamforming, specified in Table 8-281ah.

The VHT MIMO Control field is always present in the frame. The presence and contents of the VHT Compressed Beamforming Report field and the MU Exclusive Beamforming Report field are dependent on the values of the Feedback Type, Remaining Feedback Segments, and First Feedback Segment subfields of the VHT MIMO Control field (see 8.4.1.47, 8.4.1.48, 8.4.1.49, and 9.31.5).

See, e.g., IEEE 802.11ac Standard Clause 8.5.23.2

See Tables 8-53(d)-(h) in IEEE 802.11ac Standard Clause 8.4.1.48

The $AvgSNR_i$ in Table 8-53h is found by computing the SNR per subcarrier in decibels for the subcarriers identified in Table 8-53g, and then computing the arithmetic mean of those values. Each SNR value per tone in stream i (before being averaged) corresponds to the SNR associated with the column i of the beamforming feedback matrix V determined at the beamformee. Each SNR corresponds to the predicted SNR at the beamformee when the beamformer applies all columns of the matrix V .

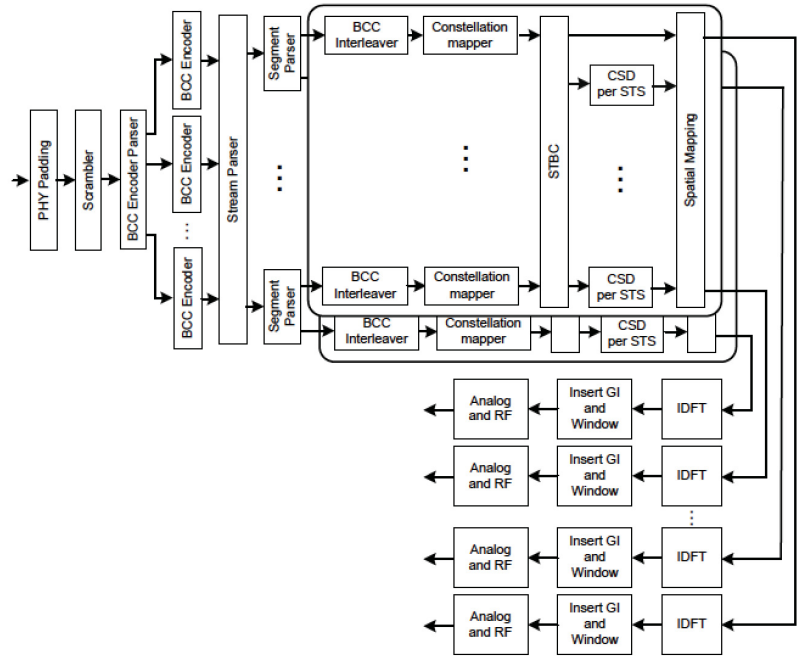
See, e.g., IEEE 802.11ac Standard Clause 8.4.1.48

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	<p>The MU Exclusive Beamforming Report field is used by the VHT Compressed Beamforming feedback (see 8.5.23.2) to carry explicit feedback information in the form of delta SNRs. The information in the VHT Compressed Beamforming Report field and the MU Exclusive Beamforming Report field can be used by the transmit MU beamformer to determine steering matrices Q, as described in 9.29.3, 20.3.12.3, and Table 22.3.11.</p> <p>See, e.g., IEEE 802.11ac Standard Clause 8.4.1.49</p> <table border="1" data-bbox="610 783 1458 1199"> <thead> <tr> <th data-bbox="610 783 943 842">Field</th> <th data-bbox="943 783 1019 842">Size (Bits)</th> <th data-bbox="1019 783 1458 842">Meaning</th> </tr> </thead> <tbody> <tr> <td data-bbox="610 842 943 905">Delta SNR for space-time stream 1 for subcarrier $k = sscidx(0)$</td> <td data-bbox="943 842 1019 905">4</td> <td data-bbox="1019 842 1458 905">$\Delta SNR_{sscidx(0),1}$ as defined in Equation (8-2)</td> </tr> <tr> <td data-bbox="610 905 943 936">...</td> <td data-bbox="943 905 1019 936">...</td> <td data-bbox="1019 905 1458 936">...</td> </tr> <tr> <td data-bbox="610 936 943 999">Delta SNR for space-time stream N_c for subcarrier $k = sscidx(0)$</td> <td data-bbox="943 936 1019 999">4</td> <td data-bbox="1019 936 1458 999">$\Delta SNR_{sscidx(0),N_c}$ as defined in Equation (8-2)</td> </tr> <tr> <td data-bbox="610 999 943 1062">Delta SNR for space-time stream 1 for subcarrier $k = sscidx(1)$</td> <td data-bbox="943 999 1019 1062">4</td> <td data-bbox="1019 999 1458 1062">$\Delta SNR_{sscidx(1),1}$ as defined in Equation (8-2)</td> </tr> <tr> <td data-bbox="610 1062 943 1094">...</td> <td data-bbox="943 1062 1019 1094">...</td> <td data-bbox="1019 1062 1458 1094">...</td> </tr> <tr> <td data-bbox="610 1094 943 1157">Delta SNR for space-time stream N_c for subcarrier $k = sscidx(1)$</td> <td data-bbox="943 1094 1019 1157">4</td> <td data-bbox="1019 1094 1458 1157">$\Delta SNR_{sscidx(1),N_c}$ as defined in Equation (8-2)</td> </tr> <tr> <td data-bbox="610 1157 943 1199">...</td> <td data-bbox="943 1157 1019 1199">...</td> <td data-bbox="1019 1157 1458 1199">...</td> </tr> </tbody> </table>	Field	Size (Bits)	Meaning	Delta SNR for space-time stream 1 for subcarrier $k = sscidx(0)$	4	$\Delta SNR_{sscidx(0),1}$ as defined in Equation (8-2)	Delta SNR for space-time stream N_c for subcarrier $k = sscidx(0)$	4	$\Delta SNR_{sscidx(0),N_c}$ as defined in Equation (8-2)	Delta SNR for space-time stream 1 for subcarrier $k = sscidx(1)$	4	$\Delta SNR_{sscidx(1),1}$ as defined in Equation (8-2)	Delta SNR for space-time stream N_c for subcarrier $k = sscidx(1)$	4	$\Delta SNR_{sscidx(1),N_c}$ as defined in Equation (8-2)
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	<table border="1"> <thead> <tr> <th data-bbox="602 638 925 688">Field</th> <th data-bbox="930 638 1003 688">Size (Bits)</th> <th data-bbox="1008 638 1442 688">Meaning</th> </tr> </thead> <tbody> <tr> <td data-bbox="602 695 925 751">Delta SNR for space-time stream 1 for subcarrier $k = sscidx(Ns'-1)$</td> <td data-bbox="930 695 1003 751">4</td> <td data-bbox="1008 695 1442 751">$\Delta SNR_{sscidx(Ns'-1),1}$ as defined in Equation (8-2)</td> </tr> <tr> <td data-bbox="602 758 925 785">...</td> <td data-bbox="930 758 1003 785">...</td> <td data-bbox="1008 758 1442 785">...</td> </tr> <tr> <td data-bbox="602 791 925 848">Delta SNR for space-time stream Nc for subcarrier $k = sscidx(Ns'-1)$</td> <td data-bbox="930 791 1003 848">4</td> <td data-bbox="1008 791 1442 848">$\Delta SNR_{sscidx(Ns'-1),Nc}$ as defined in Equation (8-2)</td> </tr> </tbody> </table>	Field	Size (Bits)	Meaning	Delta SNR for space-time stream 1 for subcarrier $k = sscidx(Ns'-1)$	4	$\Delta SNR_{sscidx(Ns'-1),1}$ as defined in Equation (8-2)	Delta SNR for space-time stream Nc for subcarrier $k = sscidx(Ns'-1)$	4	$\Delta SNR_{sscidx(Ns'-1),Nc}$ as defined in Equation (8-2)		
	Field	Size (Bits)	Meaning												
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NOTE— $sscidx()$ is defined in Table 8-53j.															
<p>In Table 8-53i, Ns' is the number of subcarriers for which the Delta SNR subfield is sent back to the beamformer. Table 8-53j shows Ns', the exact subcarrier indices and their order for which the Delta SNR is sent back.</p> <p>See, e.g., Table 8-53i IEEE 802.11ac Standard Clause 8.4.1.48</p> <p>Transmit beamforming and DL-MU-MIMO require knowledge of the channel state to compute a steering matrix that is applied to the transmitted signal to optimize reception at one or more receivers. The STA transmitting using the steering matrix is called the VHT beamformer and a STA for which reception is optimized is called a VHT beamformee. An explicit feedback mechanism is used where the VHT beamformee directly measures the channel from the training symbols transmitted by the VHT beamformer and sends back a transformed estimate of the channel state to the VHT beamformer. The VHT beamformer then uses this estimate, perhaps combining estimates from multiple VHT beamformees, to derive the steering matrix.</p> <p>See, e.g., IEEE 802.11ac Standard Clause 9.31.5.1</p>															

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See, e.g., IEEE 802.11ac Standard Clause 22.3.4.6(d)

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	<p>The VHT-SIG-B field is constructed per-user as follows:</p> <ol style="list-style-type: none"> a) Obtain the VHT-MCS (for MU only) and APEP_LENGTH from the TXVECTOR. b) VHT-SIG-B bits: Set the VHT-MCS (for MU only) and VHT-SIG-B Length field as described in 22.3.8.3.6. Add the reserved bits (for SU only) and N_{tail} bits of tail. For an NDP set VHT-SIG-B to the fixed bit pattern for the bandwidth used as described in 22.3.8.3.6. c) VHT-SIG-B Bit Repetition: Repeat the VHT-SIG-B bits as a function of CH_BANDWIDTH as defined in 22.3.8.3.6. d) BCC encoder: Encode the VHT-SIG-B field using BCC at rate $R=1/2$ as described in 18.3.5.6. e) Segment parser (if needed): For a contiguous 160 MHz or noncontiguous 80+80 MHz transmission, divide the output bits of the BCC encoder into two frequency subblocks as described in 22.3.10.7. This block is bypassed for 20 MHz, 40 MHz, and 80 MHz VHT PPDU transmissions. f) BCC interleaver: Interleave as described in 22.3.10.8. g) Constellation mapper: Map to a BPSK constellation as defined in 18.3.5.8. h) Segment deparser (if needed): For a contiguous 160 MHz transmission, merge the two frequency subblocks into one frequency segment as described in 22.3.10.9.3. This block is bypassed for 20 MHz, 40 MHz, 80 MHz, and 80+80 MHz VHT PPDU transmissions. i) Pilot insertion: Insert pilots following the steps described in 22.3.10.10. j) P_{VHTLTF} matrix mapping: Apply the mapping of the 1st column of the P_{VHTLTF} matrix to the data subcarriers as described in 22.3.8.3.6. The total number of data and pilot subcarriers is the same as in the Data field. k) CSD: Apply CSD for each space-time stream and frequency segment as described in 22.3.8.3.2. l) Spatial mapping: Apply the Q matrix as described in 22.3.10.11.1. m) Phase rotation: Apply the appropriate phase rotations for each 20 MHz subchannel as described in 22.3.7.4 and 22.3.7.5. n) IDFT: Compute the inverse discrete Fourier transform. o) Insert GI and apply windowing: Prepend a GI (LONG_GI) and apply windowing as described in 22.3.7.4. p) Analog and RF: Up-convert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 22.3.7.4 and 22.3.8 for details. <p>See, e.g., IEEE 802.11ac Standard Clauses 22.3.4.8(l) and 22.3.4.9.1(m), 22.3.4.9.2(m), 22.3.4.10.4(a).</p>

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	<p>The DL-MU-MIMO steering matrix $Q_k = [Q_{k,0}, Q_{k,1}, \dots, Q_{k,N_{user}-1}]$ can be determined by the beamformer using the beamforming feedback matrices for subcarrier k from beamformee u, $V_{k,u}$, and SNR information for subcarrier k from beamformee u, $SNR_{k,u}$, where $u = 0, 1, \dots, N_{user} - 1$. The steering matrix that is computed (or updated) using new beamforming feedback matrices and new SNR information from some or all of participating beamformees might replace the existing steering matrix Q_k for the next DL-MU-MIMO data transmission. The beamformee group for the MU transmission is signaled using the Group ID field in VHT-SIG-A (see 22.3.8.3.3 and 22.3.11.4).</p> <p><i>See, e.g., IEEE 802.11ac Standard Clause 22.3.11.1</i></p> <p>Upon receipt of a VHT NDP sounding PPDU, the beamformee shall remove the space-time stream CSD in Table 22-11 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 shall be compressed in the form of angles using the method described in 20.3.12.3.6. The angles, $\phi(k,u)$ and $\psi(k,u)$, are quantized according to Table 8-53e. The number of bits for quantization is chosen by the beamformee, based on the indication from the beamformer as to whether the feedback is requested for SU-MIMO beamforming or DL-MU-MIMO beamforming. The compressed beamforming feedback using 20.3.12.3.6 is the only Clause 22 beamforming feedback format defined.</p> <p>The beamformee shall generate the beamforming feedback matrices with the number of rows (N_r) equal to the N_{STS} of the NDP.</p> <p>After receiving the angle information, $\phi(k,u)$ and $\psi(k,u)$, the beamformer reconstructs $V_{k,u}$ using Equation (20-79). For SU-MIMO beamforming, the beamformer can use this $V_{k,0}$ matrix to determine the steering matrix Q_k. For DL-MU-MIMO beamforming, the beamformer may calculate a steering matrix $Q_k = [Q_{k,0}, Q_{k,1}, \dots, Q_{k,N_{user}-1}]$ using $V_{k,u}$ and $SNR_{k,u}$ ($0 \leq u \leq N_{user} - 1$) in order to suppress crosstalk between participating beamformees. The method used by the beamformer to calculate the steering matrix Q_k is implementation specific.</p> <p><i>See, e.g., IEEE 802.11ac Standard Clause 22.3.11.2</i></p> <p>.</p>

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<p>[8d] determining a set of weighting values based on the first signal information and the second signal information, wherein the set of weighting values is configured to be used by the remote station to construct one or more beam-formed transmission signals; and</p>	<p>The Envy 15 Laptop determines a set of weighting values based on the first signal information and the second signal information, wherein the set of weighting values is configured to be used by the remote station to construct one or more beam-formed transmission signals.</p> <p>For example, the Envy 15 Laptop determines an estimate of the channel state (e.g., by measuring the channel using a training signal) that includes a set of weighting values based on the first signal information and the second signal information. A transformed estimate of the channel state will ultimately be sent in a compressed beamforming report, e.g., the parameters of the beamforming feedback matrix, which include weighting values configured to be used by the remote station (e.g., a Wi-Fi access point) to construct one or more beamformed transmission signals.</p> <p>Transmit beamforming and DL MU-MIMO require knowledge of the channel state to compute a steering matrix that is applied to the transmit signal to optimize reception at one or more receivers. HE STAs use the HE sounding protocol to determine the channel state information. The HE sounding protocol provides explicit feedback mechanisms, defined as HE non-trigger-based (non-TB) sounding and HE trigger-based (TB) sounding, where the HE beamformee measures the channel using a training signal (i.e., an HE sounding NDP) transmitted by the HE beamformer and sends back a transformed estimate of the channel state. The HE beamformer uses this estimate to derive the steering matrix.</p> <p>The HE beamformee returns an estimate of the channel state in an HE compressed beamforming/CQI report carried in one or more HE Compressed Beamforming/CQI frames. There are three types of HE compressed beamforming/CQI report:</p> <p><i>See, e.g., IEEE 802.11ax Standard, Section 26.7.1</i></p> <p>An HE beamformee that receives an HE NDP Announcement frame from an HE beamformer with which it is associated and that contains the HE beamformee's MAC address in the RA field and also receives an HE sounding NDP a SIFS after the HE NDP Announcement frame shall transmit its HE compressed beamforming/CQI report a SIFS after the HE sounding NDP. The TXVECTOR parameter CH_BANDWIDTH for the PPDU containing the HE compressed beamforming/CQI report shall be set to indicate a bandwidth not wider than that indicated by the RXVECTOR parameter CH_BANDWIDTH of the HE sounding NDP.</p> <p><i>See, e.g., IEEE 802.11ax Standard, Section 26.7.3</i></p>

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	<p>An HE beamformee that receives an HE NDP Announcement frame as part of an HE TB sounding sequence with a STA Info field addressed to it soliciting SU or MU feedback shall generate an HE compressed beamforming/CQI report using the feedback type, N_g and codebook size indicated in the STA Info field. If the HE beamformee then receives a BFRP Trigger frame with a User Info field addressed to it, the HE beamformee transmits an HE TB PPDU containing the HE compressed beamforming/CQI report following the rules defined in 26.5.3.3 (Non-AP STA behavior for UL MU operation). If the HE NDP Announcement frame has <i>See, e.g., IEEE 802.11ax Standard, Section 26.7.3</i></p> <p>UL MU operation allows an AP to solicit simultaneous immediate response frames from one or more non-AP HE STAs. A non-AP HE STA shall follow the rules in this subclause for the transmission of response <i>See, e.g., IEEE 802.11ax Standard, Section 26.5.3</i></p> <p>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. <i>See, e.g., IEEE 802.11ax Standard, Section 27.3.3.2.1</i></p> <p>The HE-LTF field 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 and HE ER SU PPDU, the transmitter provides training for N_{STS} space-time streams (spatial mapper inputs) used for the transmission of the PSDU. In an HE MU PPDU, the transmitter provides training for $N_{STS,r,total}$ space-time streams used for the transmission of the PSDU(s) in the r-th RU. In an HE TB 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. An 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 subcarriers of each HE-LTF symbol are multiplied by the entries of a <i>See, e.g., IEEE 802.11ax Standard, Section 27.3.10.10</i></p> <p>In an HE SU PPDU, HE MU PPDU and HE ER SU PPDU, the combination of HE-LTF type and GI duration is indicated in HE-SIG-A field. In an HE TB PPDU, the combination of HE-LTF type and GI duration is indicated in the Trigger frame that triggers the transmission of the PPDU. If an HE PPDU is an HE sounding NDP, the combinations of HE-LTF types and GI durations are listed in 27.3.18 (Transmit specification). If an HE PPDU is an HE TB feedback NDP, the combinations of types and GI durations are listed in 27.3.4 (HE PPDU formats).</p>

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	<p data-bbox="592 625 1128 653"><i>See, e.g.</i>, IEEE 802.11ax Standard, Section 27.3.10.10</p> <p data-bbox="609 688 1442 827">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 9.4.1.65 (HE Compressed Beamforming Report field) and 9.4.1.66 (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.</p> <p data-bbox="609 852 1442 940">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 9.4.1.65 (HE Compressed Beamforming Report field).</p> <p data-bbox="592 951 1112 978"><i>See, e.g.</i>, IEEE 802.11ax Standard, Section 27.3.15.1</p> <p data-bbox="592 1010 1442 1194">Transmit beamforming and DL-MU-MIMO require knowledge of the channel state to compute a steering matrix that is applied to the transmitted signal to optimize reception at one or more receivers. The STA transmitting using the steering matrix is called the VHT beamformer and a STA for which reception is optimized is called a VHT beamformee. An explicit feedback mechanism is used where the VHT beamformee directly measures the channel from the training symbols transmitted by the VHT beamformer and sends back a transformed estimate of the channel state to the VHT beamformer. The VHT beamformer then uses this estimate, perhaps combining estimates from multiple VHT beamformees, to derive the steering matrix.</p> <p data-bbox="592 1205 1088 1232"><i>See, e.g.</i>, IEEE 802.11ac Standard Clause 9.31.5.1</p> <p data-bbox="609 1232 1451 1367">A VHT beamformer shall initiate a sounding feedback sequence by transmitting a VHT NDP Announcement frame followed by a VHT NDP after a SIFS. The VHT beamformer shall include in the VHT NDP Announcement frame one STA Info field for each VHT beamformee that is expected to prepare VHT Compressed Beamforming feedback and shall identify the VHT beamformee by including the VHT beamformee's AID in the AID subfield of the STA Info field. The VHT NDP Announcement frame shall include at least one STA Info field.</p> <p data-bbox="592 1377 1088 1404"><i>See, e.g.</i>, IEEE 802.11ac Standard Clause 9.31.5.2</p>

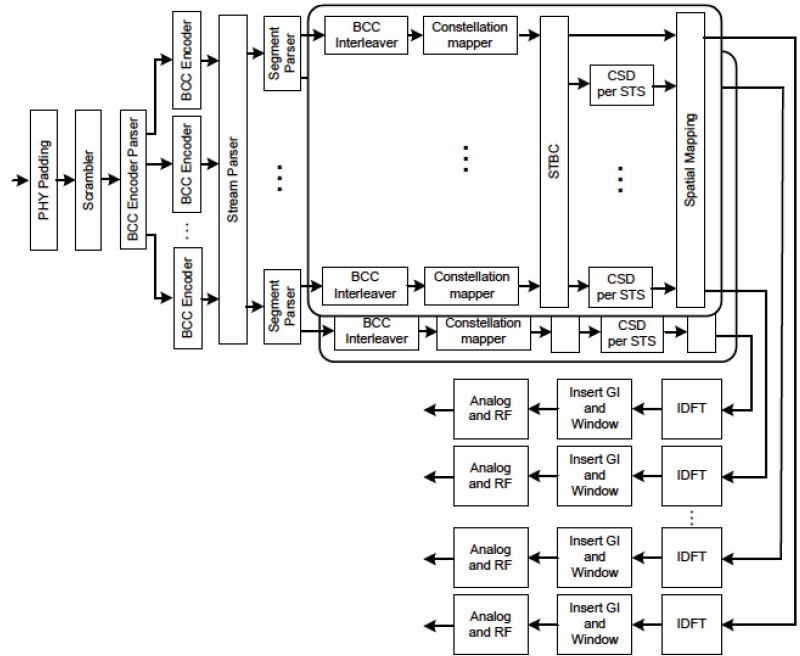
Claim 8	HP Envy 15 Laptop												
	<p>A non-AP VHT beamformee that receives a VHT NDP Announcement frame from a VHT beamformer with which it is associated or has an established DLS or TDLS session and that contains the VHT beamformee's AID in the AID subfield of a STA Info field that is not the first STA Info field shall transmit its VHT Compressed Beamforming feedback a SIFS after receiving a Beamforming Report Poll with RA matching its MAC address and a non-bandwidth signaling TA obtained from the TA field matching the MAC address of the VHT beamformer. If the RXVECTOR parameter CH_BANDWIDTH_IN_NON_HT of the received</p> <p><i>See, e.g., IEEE 802.11ac Standard Clause 9.31.5.2</i></p> <p>Table 8-281ai—VHT Compressed Beamforming frame Action field format</p> <table border="1" data-bbox="699 831 1360 1045"> <thead> <tr> <th>Order</th> <th>Information</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>Category</td> </tr> <tr> <td>2</td> <td>VHT Action</td> </tr> <tr> <td>3</td> <td>VHT MIMO Control (see 8.4.1.47)</td> </tr> <tr> <td>4</td> <td>VHT Compressed Beamforming Report (see 8.4.1.48)</td> </tr> <tr> <td>5</td> <td>MU Exclusive Beamforming Report (see 8.4.1.49)</td> </tr> </tbody> </table> <p>The Category field is set to the value for VHT, specified in Table 8-38.</p> <p>The VHT Action field is set to the value for VHT Compressed Beamforming, specified in Table 8-281ah.</p> <p>The VHT MIMO Control field is always present in the frame. The presence and contents of the VHT Compressed Beamforming Report field and the MU Exclusive Beamforming Report field are dependent on the values of the Feedback Type, Remaining Feedback Segments, and First Feedback Segment subfields of the VHT MIMO Control field (see 8.4.1.47, 8.4.1.48, 8.4.1.49, and 9.31.5).</p> <p><i>See, e.g., IEEE 802.11ac Standard Clause 8.5.23.2</i></p> <p><i>See Tables 8-53(d)-(h) in IEEE 802.11ac Standard Clause 8.4.1.48</i></p> <p>The $AvgSNR_i$ in Table 8-53h is found by computing the SNR per subcarrier in decibels for the subcarriers identified in Table 8-53g, and then computing the arithmetic mean of those values. Each SNR value per tone in stream i (before being averaged) corresponds to the SNR associated with the column i of the beamforming feedback matrix V determined at the beamformee. Each SNR corresponds to the predicted SNR at the beamformee when the beamformer applies all columns of the matrix V.</p>	Order	Information	1	Category	2	VHT Action	3	VHT MIMO Control (see 8.4.1.47)	4	VHT Compressed Beamforming Report (see 8.4.1.48)	5	MU Exclusive Beamforming Report (see 8.4.1.49)
Order	Information												
1	Category												
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	<p data-bbox="592 625 1089 653"><i>See, e.g.</i>, IEEE 802.11ac Standard Clause 8.4.1.48</p> <p data-bbox="592 684 1446 800">The MU Exclusive Beamforming Report field is used by the VHT Compressed Beamforming feedback (see 8.5.23.2) to carry explicit feedback information in the form of delta SNRs. The information in the VHT Compressed Beamforming Report field and the MU Exclusive Beamforming Report field can be used by the transmit MU beamformer to determine steering matrices Q, as described in 9.29.3, 20.3.12.3, and Table 22.3.11.</p> <p data-bbox="592 804 1089 831"><i>See, e.g.</i>, IEEE 802.11ac Standard Clause 8.4.1.49</p> <table border="1" data-bbox="609 840 1458 1257"> <thead> <tr> <th data-bbox="609 840 943 898">Field</th> <th data-bbox="943 840 1019 898">Size (Bits)</th> <th data-bbox="1019 840 1458 898">Meaning</th> </tr> </thead> <tbody> <tr> <td data-bbox="609 898 943 957">Delta SNR for space-time stream 1 for subcarrier $k = sscidx(0)$</td> <td data-bbox="943 898 1019 957">4</td> <td data-bbox="1019 898 1458 957">$\Delta SNR_{sscidx(0),1}$ as defined in Equation (8-2)</td> </tr> <tr> <td data-bbox="609 957 943 995">...</td> <td data-bbox="943 957 1019 995">...</td> <td data-bbox="1019 957 1458 995">...</td> </tr> <tr> <td data-bbox="609 995 943 1054">Delta SNR for space-time stream N_c for subcarrier $k = sscidx(0)$</td> <td data-bbox="943 995 1019 1054">4</td> <td data-bbox="1019 995 1458 1054">$\Delta SNR_{sscidx(0),N_c}$ as defined in Equation (8-2)</td> </tr> <tr> <td data-bbox="609 1054 943 1113">Delta SNR for space-time stream 1 for subcarrier $k = sscidx(1)$</td> <td data-bbox="943 1054 1019 1113">4</td> <td data-bbox="1019 1054 1458 1113">$\Delta SNR_{sscidx(1),1}$ as defined in Equation (8-2)</td> </tr> <tr> <td data-bbox="609 1113 943 1150">...</td> <td data-bbox="943 1113 1019 1150">...</td> <td data-bbox="1019 1113 1458 1150">...</td> </tr> <tr> <td data-bbox="609 1150 943 1209">Delta SNR for space-time stream N_c for subcarrier $k = sscidx(1)$</td> <td data-bbox="943 1150 1019 1209">4</td> <td data-bbox="1019 1150 1458 1209">$\Delta SNR_{sscidx(1),N_c}$ as defined in Equation (8-2)</td> </tr> <tr> <td data-bbox="609 1209 943 1257">...</td> <td data-bbox="943 1209 1019 1257">...</td> <td data-bbox="1019 1209 1458 1257">...</td> </tr> </tbody> </table>	Field	Size (Bits)	Meaning	Delta SNR for space-time stream 1 for subcarrier $k = sscidx(0)$	4	$\Delta SNR_{sscidx(0),1}$ as defined in Equation (8-2)	Delta SNR for space-time stream N_c for subcarrier $k = sscidx(0)$	4	$\Delta SNR_{sscidx(0),N_c}$ as defined in Equation (8-2)	Delta SNR for space-time stream 1 for subcarrier $k = sscidx(1)$	4	$\Delta SNR_{sscidx(1),1}$ as defined in Equation (8-2)	Delta SNR for space-time stream N_c for subcarrier $k = sscidx(1)$	4	$\Delta SNR_{sscidx(1),N_c}$ as defined in Equation (8-2)
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	<table border="1"> <thead> <tr> <th data-bbox="602 638 925 688">Field</th> <th data-bbox="930 638 1003 688">Size (Bits)</th> <th data-bbox="1008 638 1442 688">Meaning</th> </tr> </thead> <tbody> <tr> <td data-bbox="602 695 925 751">Delta SNR for space-time stream 1 for subcarrier $k = sscidx(Ns'-1)$</td> <td data-bbox="930 695 1003 751">4</td> <td data-bbox="1008 695 1442 751">$\Delta SNR_{sscidx(Ns'-1),1}$ as defined in Equation (8-2)</td> </tr> <tr> <td data-bbox="602 758 925 785">...</td> <td data-bbox="930 758 1003 785">...</td> <td data-bbox="1008 758 1442 785">...</td> </tr> <tr> <td data-bbox="602 791 925 848">Delta SNR for space-time stream Nc for subcarrier $k = sscidx(Ns'-1)$</td> <td data-bbox="930 791 1003 848">4</td> <td data-bbox="1008 791 1442 848">$\Delta SNR_{sscidx(Ns'-1),Nc}$ as defined in Equation (8-2)</td> </tr> </tbody> </table>	Field	Size (Bits)	Meaning	Delta SNR for space-time stream 1 for subcarrier $k = sscidx(Ns'-1)$	4	$\Delta SNR_{sscidx(Ns'-1),1}$ as defined in Equation (8-2)	Delta SNR for space-time stream Nc for subcarrier $k = sscidx(Ns'-1)$	4	$\Delta SNR_{sscidx(Ns'-1),Nc}$ as defined in Equation (8-2)		
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NOTE— $sscidx()$ is defined in Table 8-53j.															
<p>In Table 8-53i, Ns' is the number of subcarriers for which the Delta SNR subfield is sent back to the beamformer. Table 8-53j shows Ns', the exact subcarrier indices and their order for which the Delta SNR is sent back.</p> <p>See, e.g., Table 8-53i IEEE 802.11ac Standard Clause 8.4.1.48</p> <p>Transmit beamforming and DL-MU-MIMO require knowledge of the channel state to compute a steering matrix that is applied to the transmitted signal to optimize reception at one or more receivers. The STA transmitting using the steering matrix is called the VHT beamformer and a STA for which reception is optimized is called a VHT beamformee. An explicit feedback mechanism is used where the VHT beamformee directly measures the channel from the training symbols transmitted by the VHT beamformer and sends back a transformed estimate of the channel state to the VHT beamformer. The VHT beamformer then uses this estimate, perhaps combining estimates from multiple VHT beamformees, to derive the steering matrix.</p> <p>See, e.g., IEEE 802.11ac Standard Clause 9.31.5.1</p>															

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See, e.g., IEEE 802.11ac Standard Clause 22.3.4.6(d)

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	<p>The VHT-SIG-B field is constructed per-user as follows:</p> <ol style="list-style-type: none"> a) Obtain the VHT-MCS (for MU only) and APEP_LENGTH from the TXVECTOR. b) VHT-SIG-B bits: Set the VHT-MCS (for MU only) and VHT-SIG-B Length field as described in 22.3.8.3.6. Add the reserved bits (for SU only) and N_{tail} bits of tail. For an NDP set VHT-SIG-B to the fixed bit pattern for the bandwidth used as described in 22.3.8.3.6. c) VHT-SIG-B Bit Repetition: Repeat the VHT-SIG-B bits as a function of CH_BANDWIDTH as defined in 22.3.8.3.6. d) BCC encoder: Encode the VHT-SIG-B field using BCC at rate $R=1/2$ as described in 18.3.5.6. e) Segment parser (if needed): For a contiguous 160 MHz or noncontiguous 80+80 MHz transmission, divide the output bits of the BCC encoder into two frequency subblocks as described in 22.3.10.7. This block is bypassed for 20 MHz, 40 MHz, and 80 MHz VHT PPDU transmissions. f) BCC interleaver: Interleave as described in 22.3.10.8. g) Constellation mapper: Map to a BPSK constellation as defined in 18.3.5.8. h) Segment deparser (if needed): For a contiguous 160 MHz transmission, merge the two frequency subblocks into one frequency segment as described in 22.3.10.9.3. This block is bypassed for 20 MHz, 40 MHz, 80 MHz, and 80+80 MHz VHT PPDU transmissions. i) Pilot insertion: Insert pilots following the steps described in 22.3.10.10. j) P_{VHTLTF} matrix mapping: Apply the mapping of the 1st column of the P_{VHTLTF} matrix to the data subcarriers as described in 22.3.8.3.6. The total number of data and pilot subcarriers is the same as in the Data field. k) CSD: Apply CSD for each space-time stream and frequency segment as described in 22.3.8.3.2. l) Spatial mapping: Apply the Q matrix as described in 22.3.10.11.1. m) Phase rotation: Apply the appropriate phase rotations for each 20 MHz subchannel as described in 22.3.7.4 and 22.3.7.5. n) IDFT: Compute the inverse discrete Fourier transform. o) Insert GI and apply windowing: Prepend a GI (LONG_GI) and apply windowing as described in 22.3.7.4. p) Analog and RF: Up-convert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 22.3.7.4 and 22.3.8 for details. <p>See, e.g., IEEE 802.11ac Standard Clauses 22.3.4.8(l) and 22.3.4.9.1(m), 22.3.4.9.2(m), 22.3.4.10.4(a).</p>

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	<p>The DL-MU-MIMO steering matrix $Q_k = [Q_{k,0}, Q_{k,1}, \dots, Q_{k,N_{user}-1}]$ can be determined by the beamformer using the beamforming feedback matrices for subcarrier k from beamformee u, $V_{k,u}$, and SNR information for subcarrier k from beamformee u, $SNR_{k,u}$, where $u = 0, 1, \dots, N_{user} - 1$. The steering matrix that is computed (or updated) using new beamforming feedback matrices and new SNR information from some or all of participating beamformees might replace the existing steering matrix Q_k for the next DL-MU-MIMO data transmission. The beamformee group for the MU transmission is signaled using the Group ID field in VHT-SIG-A (see 22.3.8.3.3 and 22.3.11.4).</p> <p><i>See, e.g., IEEE 802.11ac Standard Clause 22.3.11.1</i></p> <p>Upon receipt of a VHT NDP sounding PPDU, the beamformee shall remove the space-time stream CSD in Table 22-11 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 shall be compressed in the form of angles using the method described in 20.3.12.3.6. The angles, $\phi(k,u)$ and $\psi(k,u)$, are quantized according to Table 8-53e. The number of bits for quantization is chosen by the beamformee, based on the indication from the beamformer as to whether the feedback is requested for SU-MIMO beamforming or DL-MU-MIMO beamforming. The compressed beamforming feedback using 20.3.12.3.6 is the only Clause 22 beamforming feedback format defined.</p> <p>The beamformee shall generate the beamforming feedback matrices with the number of rows (N_r) equal to the N_{STS} of the NDP.</p> <p>After receiving the angle information, $\phi(k,u)$ and $\psi(k,u)$, the beamformer reconstructs $V_{k,u}$ using Equation (20-79). For SU-MIMO beamforming, the beamformer can use this $V_{k,0}$ matrix to determine the steering matrix Q_k. For DL-MU-MIMO beamforming, the beamformer may calculate a steering matrix $Q_k = [Q_{k,0}, Q_{k,1}, \dots, Q_{k,N_{user}-1}]$ using $V_{k,u}$ and $SNR_{k,u}$ ($0 \leq u \leq N_{user} - 1$) in order to suppress crosstalk between participating beamformees. The method used by the beamformer to calculate the steering matrix Q_k is implementation specific.</p> <p><i>See, e.g., IEEE 802.11ac Standard Clause 22.3.11.2</i></p> <p>.</p> <p>To the extent Defendant disputes that the foregoing shows literal infringement, there would also be infringement under the doctrine of equivalents. For example, determining weighting values (e.g. angle information) (e.g. the derived estimate of the channel state), which includes data relevant to describe the MIMO channel is insubstantially</p>

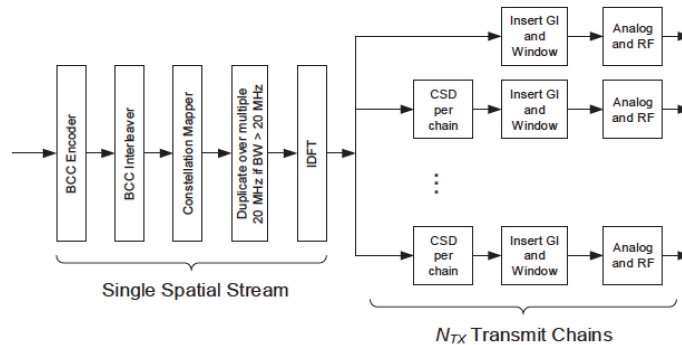
Claim 8	HP Envy 15 Laptop
	<p>different from the claim requirement because it performs substantially the same function (determine a set of weighting values) in substantially the same way (determine angle information describing MIMO channel) to achieve substantially the same result (beamforming).</p> <p>For further example, constructing one or more beamformed transmission signals by supporting multiple uplink spatial streams (<i>e.g.</i>, 2x2 or more streams) and/or transmit beamforming (“TxBF”) to steer transmissions is insubstantially different from the claim requirement because it performs substantially the same function in substantially the same way to achieve substantially the same result.</p>
<p>[8e] transmitting to the remote station a third signal comprising content based on the set of weighting values.</p>	<p>The Envy 15 Laptop transmits to the remote station a third signal comprising content based on the set of weighting values.</p> <p>For example, Envy 15 Laptop transmits to the remote station (<i>e.g.</i>, a Wi-Fi access point) a signal that includes the beamforming feedback matrix.</p> <p>This subclause provides the procedure by which PSDUs are converted to and from transmissions on the wireless medium.</p> <p>During transmission, a PSDU (in the SU case) or one or more PSDUs (in the MU case) are processed (<i>i.e.</i>, scrambled and coded) and appended to the PHY preamble to create the PPDU. At the receiver, the PHY preamble is processed to aid in the detection, demodulation, and delivery of the PSDU.</p> <p><i>See, e.g.</i>, IEEE 802.11ax Standard, Section 27.3.1</p> <p>DL MU transmission allows an AP to simultaneously transmit information to more than one non-AP STA. For a DL MU transmission, the AP uses the HE MU PPDU format and employs either DL OFDMA, DL MU-MIMO, or a mixture of both. UL MU transmission allows an AP to simultaneously receive information from more than one non-AP STA. UL MU transmissions are preceded by a Trigger frame or a frame carrying a TRS Control subfield from the AP. The non-AP STAs transmit using the HE TB PPDU format and employ either UL OFDMA, UL MU-MIMO, or a mixture of both.</p> <p><i>See, e.g.</i>, IEEE 802.11ax Standard, Section 27.3.1.1</p>

Claim 8

HP Envy 15 Laptop

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.

See, e.g., IEEE 802.11ax Standard, Section 27.3.3.2.1



See, e.g., Figure 27-13 IEEE 802.11ax Standard, Section 27.3.5

The per user data is combined as follows:

- Spatial mapping: The Q matrix is applied as described in 27.3.11.14 (OFDM modulation). The combining of all user data of an RU is done in this block.
- IDFT: Compute the inverse discrete Fourier transform.
- Insert GI and apply windowing: Prepend a GI determined by the TXVECTOR parameter GI_TYPE and apply windowing as described in 27.3.9 (Mathematical description of signals).
- Analog and RF: Upconvert the resulting complex baseband waveform with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 27.3.9 (Mathematical description of signals) and 27.3.10 (HE preamble) for details.

Claim 8	HP Envy 15 Laptop
	<p data-bbox="592 625 1133 653"><i>See, e.g.</i>, IEEE 802.11ax Standard, Section 27.3.6.11.4</p> <p data-bbox="592 699 1468 894">To the extent Defendant disputes that the foregoing shows literal infringement, there would also be infringement under the doctrine of equivalents. For example, the Accused Instrumentalities perform substantially the same function (transmit a third signal to the remote station via the antenna, the third signal comprising content based on the set of weighting values) in substantially the same way (transmit channel state estimate) to achieve substantially the same result (improve knowledge of the channel state to improve throughput).</p>

Claim 9

Claim 9	Accused Products
<p data-bbox="159 1018 570 1129">9. The method as recited in claim 8, further comprising: transmitting the third signal to the remote station via the antenna.</p>	<p data-bbox="592 1018 1463 1073">Envy 15 Laptop performs the method of claim 8 and further transmits the third signal to the remote station via the antenna.</p> <p data-bbox="592 1129 889 1157"><i>See supra</i> claim element [1h].</p>

Claim 11

Claim 11	Accused Products
<p data-bbox="159 1371 570 1482">11. The method as recited in claim 8, wherein the set of weighting values is further based on one or more of: a transmit power level, a data transmit rate,</p>	<p data-bbox="592 1371 1468 1457">The Envy 15 Laptop performs the method of claim 8, wherein the set of weighting values is further based on one or more of: a transmit power level, a data transmit rate, an antenna direction, quality of service data, or timing data.</p>

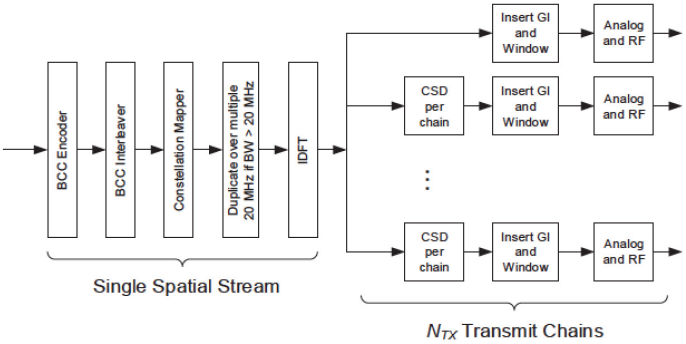
Claim 11	Accused Products
an antenna direction, quality of service data, or timing data.	<i>See supra</i> claim 5.

Claim 12

Claim 12	Accused Products
12. The method as recited in claim 11, wherein the content comprises data configured to be used by the remote station to modify the placement of one or more transmission peaks and one or more transmission nulls in a subsequent signal transmission.	<p>The Envy 15 Laptop performs the method of claim 11, wherein the content comprises data configured to be used by the remote station to modify the placement of one or more transmission peaks and one or more transmission nulls in a subsequent signal transmission.</p> <p><i>See supra</i> claims 4, 11, including discussion regarding MU-MIMO sounding and channel estimation procedures, which shows electromagnetic signals comprising one or more transmission peaks and one or more transmission nulls.</p>

Claim 15

Claim 15	Accused Products
[15pre] An apparatus for use in a wireless communications system, the apparatus comprising:	<p>To the extent the preamble is limiting, the Envy 15 Laptop includes an apparatus for use in a wireless communications system.</p> <p><i>See supra</i> claim element [1pre].</p>

Claim 15	Accused Products
	 <p style="text-align: center;"><i>See, e.g., Figure 27-13 IEEE 802.11ax Standard, Section 27.3.5</i></p>
[15a] an antenna;	<p>The Envy 15 Laptop includes an antenna.</p> <p><i>See supra</i> claim element [1a].</p>
[15b] a transceiver operatively coupled to the antenna; and	<p>The Envy 15 Laptop includes a transceiver operatively coupled to the antenna.</p> <p><i>See supra</i> claim elements [1a] and [1b].</p>

Claim 15	Accused Products
[15c] a processor operatively coupled to the transceiver, the processor configured to:	The Envy 15 Laptop includes a processor operatively coupled to the transceiver. The <i>See supra</i> claim element [1c].
[15d] receive a first signal transmission from a remote station via the antenna,	The processor in the Envy 15 Laptop receives a first signal transmission from a remote station via the antenna. <i>See supra</i> claim element [1d].
[15e] the first signal transmission comprising first signal information, wherein the first signal information comprises one or more of: a transmit power level, a data transmit rate, an antenna direction, quality of service data, or timing data;	The Envy 15 Laptop the first signal transmission comprising first signal information, wherein the first signal information comprises one or more of: a transmit power level, a data transmit rate, an antenna direction, quality of service data, or timing data. <i>See supra</i> claim element [1e].
[15f] receive a second signal transmission from the remote station via the antenna, the second signal transmission comprising second signal information;	The processor in the Envy 15 Laptop receives a second signal transmission from the remote station via the antenna, the second signal transmission comprising second signal information. <i>See supra</i> claim element [1f].
[15g] determine a set of weighting values based on the first signal information and the second signal information, wherein the set of weighting values is configured to be used by the transceiver to construct one or more beam-formed transmission signals;	The processor in the Envy 15 Laptop determines a set of weighting values based on the first signal information and the second signal information, wherein the set of weighting values is configured to be used by the transceiver to construct one or more beam-formed transmission signals. <i>See supra</i> claim element [1g].

Claim 15	Accused Products
<p>[15h] cause the transceiver to generate a third signal comprising content based on the set of weighting values.</p>	<p>The processor in the Envy 15 Laptop causes the transceiver to generate a third signal comprising content based on the set of weighting values.</p> <p><i>See supra</i> claim element [1h].</p>

Claim 16

Claim 16	Accused Products
<p>16. The apparatus as recited in claim 15, wherein the first signal transmission and the second signal transmission comprise electromagnetic signals comprising one or more transmission peaks and one or more transmission nulls.</p>	<p>The Envy 15 Laptop includes the apparatus as recited in claim 15, wherein the first signal transmission and the second signal transmission comprise electromagnetic signals comprising one or more transmission peaks and one or more transmission nulls.</p> <p><i>See supra</i> claim element [1d], including discussion regarding MU-MIMO sounding and channel estimation procedures, which shows electromagnetic signals comprising one or more transmission peaks and one or more transmission nulls.</p>