

U.S. Pat. No. 9,814,071	<u>Accused Products</u>
1. A method for enabling a receiving node to distinguish information simultaneously received from a plurality of transmitting nodes on a shared communication channel of a wireless digital network, the method comprising:	<u>Cellular</u> To the extent the preamble is construed as a limitation, the Accused LTE/5G Base Stations use a method for enabling a receiving node to distinguish information simultaneously received from a plurality of transmitting nodes (e.g., UEs) on a shared communication channel of a wireless digital network. See e.g., 3GPP TS 36.300 V10.12.0 (2014-12): 4 Overall architecture The E-UTRAN consists of eNBs, providing the E-UTRA user plane (PDCP/RLC/MAC/PHY) and control plane (RRC) protocol terminations towards the UE. The eNBs are interconnected with each other by means of the X2 interface. The eNBs are also connected by means of the S1 interface to the EPC (Evolved Packet Core), more specifically to the MME (Mobility Management Entity) by means of the S1-MME interface and to the Serving Gateway (S-GW) by means of the S1-U interface. The S1 interface supports a many-to-many relation between MMEs / Serving Gateways and eNBs. The E-UTRAN architecture is illustrated in Figure 4 below.

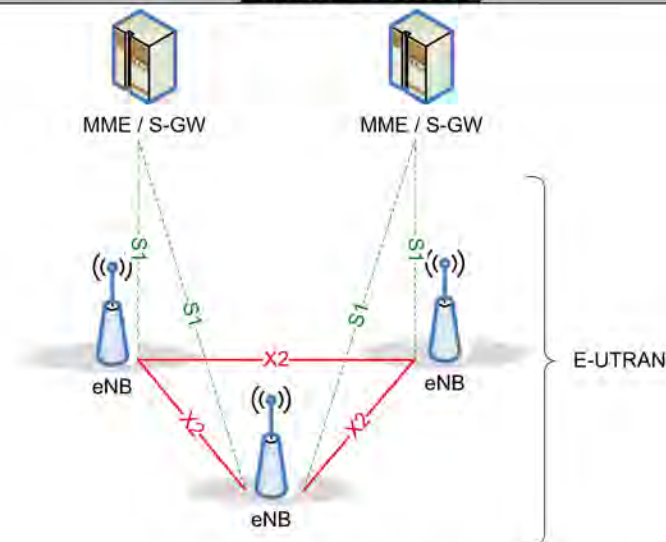


Figure 4-1: Overall Architecture

4.1 Functional Split

The eNB hosts the following functions:

- Functions for Radio Resource Management: Radio Bearer Control, Radio Admission Control, Connection Mobility Control, Dynamic allocation of resources to UEs in both uplink and downlink (scheduling);

[...]

5.2.6 Uplink multi-antenna transmission

The antenna configuration for uplink supports both SU-MIMO and MU-MIMO.

[3]

5.1.1 Physical channels

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	An uplink physical channel corresponds to a set of resource elements carrying information originating from higher layers and is the interface defined between 36.212 and 36.211. The following uplink physical channels are defined: - Physical Uplink Shared Channel, PUSCH - Physical Uplink Control Channel, PUCCH - Physical Random Access Channel, PRACH 5.1.2 Physical signals An uplink physical signal is used by the physical layer but does not carry information originating from higher layers. The following uplink physical signals are defined: - Reference signal See e.g., 3GPP TS 36.300 V10.12.0 (2014-12): 4.1 Overall Architecture An NG-RAN node is either: - a gNB, providing NR user plane and control plane protocol terminations towards the UE; or - an ng-eNB, providing E-UTRA user plane and control plane protocol terminations towards the UE. The gNBs and ng-eNBs are interconnected with each other by means of the Xn interface. The gNBs and ng-eNBs are also connected by means of the NG interfaces to the 5GC, more specifically to the AMF (Access and Mobility Management Function) by means of the NG-C interface and to the UPF (User Plane Function) by means of the NG-U interface (see TS 23.501 [3]). NOTE: The architecture and the F1 interface for a functional split are defined in TS 38.401 [4]. The NG-RAN architecture is illustrated in Figure 4.1-1 below.

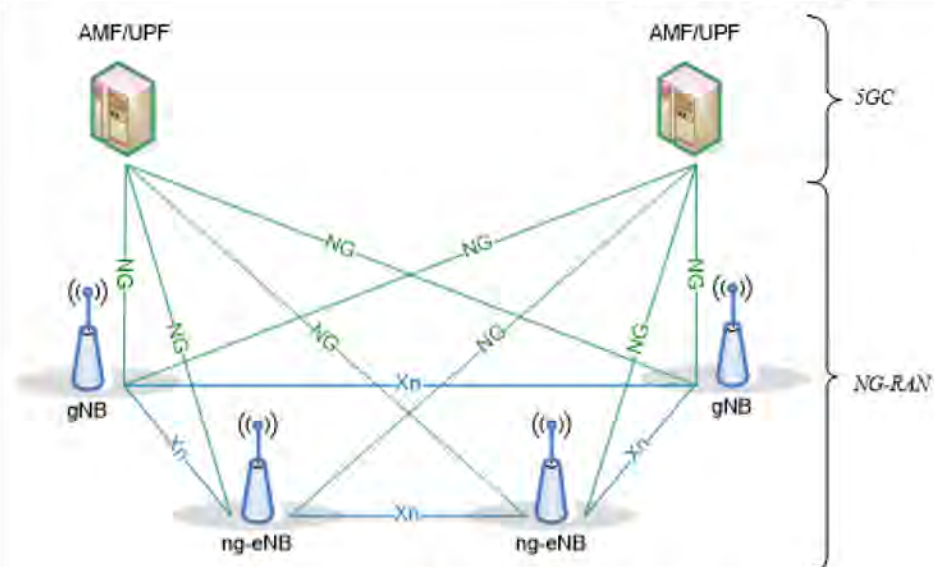


Figure 4.1-1: Overall Architecture

4.2 Functional Split

The **gNB** and **ng-eNB** host the following functions:

- Functions for Radio Resource Management: Radio Bearer Control, Radio Admission Control, Connection Mobility Control, Dynamic allocation of resources to UEs in both uplink and downlink (scheduling);

To the extent the preamble is construed as a limitation, the Accused LTE/5G UEs use a method for enabling a receiving node to distinguish information simultaneously received from a plurality of transmitting nodes (e.g., UEs) on a shared communication channel of a wireless digital network.

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	<u>TS 36.211 v12.5.0:</u> 6.4 <u>Physical downlink shared channel</u> The physical downlink shared channel shall be processed and mapped to resource elements as described in clause 6.3 with the following additions and exceptions: - In resource blocks in which UE-specific reference signals are not transmitted, the PDSCH shall be transmitted on the same set of antenna ports as the PBCH, which is one of $\{0\}$, $\{0,1\}$, or $\{0,1,2,3\}$. - <u>In resource blocks in which UE-specific reference signals are transmitted, the PDSCH shall be transmitted on antenna port(s) $\{5\}$, $\{7\}$, $\{8\}$, or $p \in \{7,8,\dots,v+6\}$, where v is the number of layers used for transmission of the PDSCH.</u> - If PDSCH is transmitted in MBSFN subframes as defined in 3GPP TS 36.213 [4], the PDSCH shall be transmitted on one or several of antenna port(s) $p \in \{7,8,\dots,v+6\}$, where v is the number of layers used for transmission of the PDSCH. - PDSCH is not mapped to resource elements used for UE-specific reference signals associated with PDSCH - In mapping to resource elements, the positions of the cell-specific reference signals are given by clause 6.10.1.2 with the number of antenna ports and the frequency shift of the cell-specific reference signals derived as described in clause 6.10.1.2, unless other values for these parameters are provided by clause 7.1.9 in 3GPP TS 36.213 [4], in which case these values are used in the resource blocks indicated by the relevant DCI. - If the DCI associated with the PDSCH uses the C-RNTI or semi-persistent C-RNTI, the PDSCH is not mapped to resource elements assumed by the UE to be used for transmission of: - zero-power CSI reference signals, where the positions of the CSI reference signals are given by clause 6.10.5.2. The configuration for zero power CSI reference signals is - obtained as described in clause 6.10.5.2, unless other values for these parameters are provided by clause 7.1.9 in 3GPP TS 36.213 [4], in which case these values are used in the resource blocks indicated by the relevant DCI, and - obtained by higher-layer configuration of up to five reserved CSI-RS resources as part of the discovery signal configuration following the procedure for zero-power CSI-RS in clause 6.10.5.2. - non-zero-power CSI reference signals for CSI reporting, where the positions of the non-zero-power CSI reference signals for CSI reporting are given by clause 6.10.5.2. The configuration for non-zero power CSI reference signals is obtained as described in clause 6.10.5.2.

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	TS 38.211 v15.8.0: 7.3 Physical channels 7.3.1 <u>Physical downlink shared channel</u> 7.3.1.1 Scrambling Up to two codewords $q \in \{0,1\}$ can be transmitted. In case of single-codeword transmission, $q = 0$. For each codeword q, the UE shall assume the block of bits $b^{(q)}(0), \dots, b^{(q)}(M_{\text{bit}}^{(q)} - 1)$, where $M_{\text{bit}}^{(q)}$ is the number of bits in codeword q transmitted on the physical channel, are scrambled prior to modulation, resulting in a block of scrambled bits $\tilde{b}^{(q)}(0), \dots, \tilde{b}^{(q)}(M_{\text{bit}}^{(q)} - 1)$ according to $\tilde{b}^{(q)}(i) = (b^{(q)}(i) + c^{(q)}(i)) \bmod 2$ where the scrambling sequence $c^{(q)}(i)$ is given by clause 5.2.1. The scrambling sequence generator shall be initialized with $c_{\text{init}} = n_{\text{RNTI}} \cdot 2^{15} + q \cdot 2^{14} + n_{\text{ID}}$ where - $n_{\text{ID}} \in \{0,1,\dots,1023\}$ equals the higher-layer parameter <i>dataScramblingIdentityPDSCH</i> if configured and the RNTI equals the C-RNTI, MCS-C-RNTI, or CS-RNTI, and the transmission is not scheduled using DCI format 1_0 in a common search space, - $n_{\text{ID}} = N_{\text{ID}}^{\text{cell}}$ otherwise and where n_{RNTI} corresponds to the RNTI associated with the PDSCH transmission as described in clause 5.1 of [6, TS 38.214]. 7.3.1.3 <u>Layer mapping</u> The UE shall assume that complex-valued modulation symbols for each of the codewords to be transmitted are mapped onto one or several layers according to Table 7.3.1.3-1. <u>Complex-valued modulation symbols $d^{(q)}(0), \dots, d^{(q)}(M_{\text{symb}}^{(q)} - 1)$ for codeword q shall be mapped onto the layers $x(i) = [x^{(0)}(i) \dots x^{(v-1)}(i)]^T, i = 0, 1, \dots, M_{\text{symb}}^{\text{layer}} - 1$ where v is the number of layers and $M_{\text{symb}}^{\text{layer}}$ is the number of modulation symbols per layer.</u>

Table 6.3.3.2-1: Codeword-to-layer mapping for spatial multiplexing

Number of layers	Number of codewords	Codeword-to-layer mapping $i = 0, 1, \dots, M_{\text{symb}}^{\text{layer}} - 1$
1	1	$x^{(0)}(i) = d^{(0)}(i)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)}$
2	1	$x^{(0)}(i) = d^{(0)}(2i)$ $x^{(1)}(i) = d^{(0)}(2i+1)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 2$
2	2	$x^{(0)}(i) = d^{(0)}(i)$ $x^{(1)}(i) = d^{(1)}(i)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} = M_{\text{symb}}^{(1)}$
3	1	$x^{(0)}(i) = d^{(0)}(3i)$ $x^{(1)}(i) = d^{(0)}(3i+1)$ $x^{(2)}(i) = d^{(0)}(3i+2)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 3$
3	2	$x^{(0)}(i) = d^{(0)}(i)$ $x^{(1)}(i) = d^{(1)}(2i)$ $x^{(2)}(i) = d^{(1)}(2i+1)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} = M_{\text{symb}}^{(1)} / 2$
4	1	$x^{(0)}(i) = d^{(0)}(4i)$ $x^{(1)}(i) = d^{(0)}(4i+1)$ $x^{(2)}(i) = d^{(0)}(4i+2)$ $x^{(3)}(i) = d^{(0)}(4i+3)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 4$
4	2	$x^{(0)}(i) = d^{(0)}(2i)$ $x^{(1)}(i) = d^{(0)}(2i+1)$ $x^{(2)}(i) = d^{(1)}(2i)$ $x^{(3)}(i) = d^{(1)}(2i+1)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 2 = M_{\text{symb}}^{(1)} / 2$
5	2	$x^{(0)}(i) = d^{(0)}(2i)$ $x^{(1)}(i) = d^{(0)}(2i+1)$ $x^{(2)}(i) = d^{(1)}(3i)$ $x^{(3)}(i) = d^{(1)}(3i+1)$ $x^{(4)}(i) = d^{(1)}(3i+2)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 2 = M_{\text{symb}}^{(1)} / 3$
6	2	$x^{(0)}(i) = d^{(0)}(3i)$ $x^{(1)}(i) = d^{(0)}(3i+1)$ $x^{(2)}(i) = d^{(0)}(3i+2)$ $x^{(3)}(i) = d^{(1)}(3i)$ $x^{(4)}(i) = d^{(1)}(3i+1)$ $x^{(5)}(i) = d^{(1)}(3i+2)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 3 = M_{\text{symb}}^{(1)} / 3$
7	2	$x^{(0)}(i) = d^{(0)}(3i)$ $x^{(1)}(i) = d^{(0)}(3i+1)$ $x^{(2)}(i) = d^{(0)}(3i+2)$ $x^{(3)}(i) = d^{(1)}(4i)$ $x^{(4)}(i) = d^{(1)}(4i+1)$ $x^{(5)}(i) = d^{(1)}(4i+2)$ $x^{(6)}(i) = d^{(1)}(4i+3)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 3 = M_{\text{symb}}^{(1)} / 4$

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	The Accused Instrumentalities (WiFi) practice a method for enabling a receiving node to distinguish information simultaneously received from a plurality of transmitting nodes on a shared communication channel of a wireless digital network. <u>WiFi Access Points</u> IEEE Standard 802.11ac (AP) The accused AP devices are equipped with IEEE 802.11ac support as well as multiple-input multiple-output (MIMO) capabilities. Each accused instrumentality includes multiple Wi-Fi antennas such that the device may receive at least two spatial streams simultaneously. This occurs during SU-MIMO for user devices. For example, a user device may receive a single digital data stream from a user device that comprises two or more spatial streams. Citation 1: Stations support SU-MIMO

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	21.3.11 SU-MIMO and DL-MU-MIMO Beamforming 21.3.11.1 General 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. With DL-MU-MIMO beamforming, disjoint subsets of the space-time streams are intended for reception at different STAs. 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. The feedback report format is described in 9.4.1.49. For DL-MU-MIMO beamforming, the receive signal vector in subcarrier k at beamformee u, $y_{k,u} = [y_{k,0}, y_{k,1}, \dots, y_{k,N_{RX}-1}]^T$, is shown in Equation (21-101), where $x_k = [x_{k,0}^T, x_{k,1}^T, \dots, x_{k,N_{user}-1}^T]^T$ denotes the transmit signal vector in subcarrier k for all N_{user} beamformees, with $x_{k,u} = [x_{k,0}, x_{k,1}, \dots, x_{k,N_{RX,u}-1}]^T$ being the transmit signal for beamformee u. $y_{k,u} = H_{k,u} \times [Q_{k,0}, Q_{k,1}, \dots, Q_{k,N_{user}-1}] \times x_k + n \quad (21-101)$ where $H_{k,u}$ is the channel matrix from the beamformer to beamformee u in subcarrier k with dimensions $N_{RX_u} \times N_{TX}$ FIG. 1 Source: https://ieeexplore.ieee.org/document/7786995, Page 2579, last accessed Mar 07, 2024, Exhibit B The accused product exchanges its capabilities (e.g., VHT capabilities) with mobile devices to initiate the connection in Probe request/response frames. The access point informs the mobile terminal about its capabilities through the Probe response frame. These capabilities include information about if the access point supports SU-beamformer, SU-beamformee, MU-beamformer, MU-beamformee, etc.

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	The mobile terminal sends the VHT NDP announcement frame to an access point. An access point responds with the action frame containing the Beamforming feedback matrix. The Beamforming feedback matrix field comprises a Compressed beamforming feedback matrix and the mobile device processes the received beams. A VHT NDP announcement frame contains a Feedback Type subfield in the STA info field. The mobile device marks the Feedback Type subfield as “0” or “1” to request the access point to send the SU feedback as shown in FIG. 2. Citation 2: STA information subfield Table 9-25—STA Info subfields <table><tr><th>Field</th><th>Description</th></tr><tr><td>AID12</td><td>Contains the 12 least significant bits of the AID of a STA expected to process the following VHT NDP and prepare the sounding feedback. Equal to 0 if the STA is an AP, mesh STA, or STA that is a member of an IBSS.</td></tr><tr><td>Feedback Type</td><td>Indicates the type of feedback requested. Set to 0 for SU. Set to 1 for MU.</td></tr><tr><td>Nc Index</td><td>If the Feedback Type field indicates MU, then Nc Index indicates the number of columns, N_c, in the Compressed Beamforming Feedback Matrix subfield minus 1: Set to 0 to request $N_c = 1$ Set to 1 to request $N_c = 2$... Set to 7 to request $N_c = 8$ Reserved if the Feedback Type field indicates SU.</td></tr></table> FIG. 2 Source: https://ieeexplore.ieee.org/document/7786995, Page 687, last accessed Mar 07, 2024, Exhibit B	Field	Description	AID12	Contains the 12 least significant bits of the AID of a STA expected to process the following VHT NDP and prepare the sounding feedback. Equal to 0 if the STA is an AP, mesh STA, or STA that is a member of an IBSS.	Feedback Type	Indicates the type of feedback requested. Set to 0 for SU. Set to 1 for MU.	Nc Index	If the Feedback Type field indicates MU, then Nc Index indicates the number of columns, N_c , in the Compressed Beamforming Feedback Matrix subfield minus 1: Set to 0 to request $N_c = 1$ Set to 1 to request $N_c = 2$... Set to 7 to request $N_c = 8$ Reserved if the Feedback Type field indicates SU.
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	Citation 3: Beamforming Feedback Matrix and its use to compute Steering matrix. 22.3.11.2 Beamforming Feedback Matrix V 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. The beamformee shall generate the beamforming feedback matrices with the number of rows (N_r) equal to the N_{STS} of the NDP. After receiving the angle information, $\phi(k,u)$ 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. FIG. 3 Source: https://ieeexplore.ieee.org/document/7786995, Page 2580, last accessed Feb 20, 2024, Exhibit B IEEE Standard 802.11ax (AP) The accused AP devices are equipped with IEEE 802.11ax support as well as multiple-input multiple-output (MIMO) capabilities. The Wi-Fi Standard 802.11ax uses a method for enabling a receiving node to distinguish information simultaneously received from a plurality of transmitting nodes (e.g., STAs) on a shared communication channel of a wireless digital network.

U.S. Pat. No. 9,814,071	Accused Products
	Citation 4: UL MU Operation 26.5.2 UL MU operation 26.5.2.1 General 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 frames in an HE TB PPDU unless the Trigger frame is an MU-RTS Trigger frame, in which case the response is a CTS frame sent in a non-HT PPDU (see 26.2.6 (MU-RTS Trigger/CTS frame exchange procedure)). Fig 1 Source: https://ieeexplore.ieee.org/document/9442429, Page 342, last accessed March 05, 2024, Exhibit C Citation 5: High Efficiency (HE) PHY specification IEEE P802.11ax/D6.0, November 2019 27. High Efficiency (HE) PHY specification 27.1 Introduction 27.1.1 Introduction to the HE PHY Clause 27 (High Efficiency (HE) PHY specification) specifies the PHY entity for a high efficiency (HE) orthogonal frequency division multiplexing (OFDM) system. In addition to the requirements in Clause 27 (High Efficiency (HE) PHY specification), an HE STA shall be capable of transmitting and receiving PPDUs that are compliant with the mandatory requirements of the following PHY specifications: Fig 2

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	Source: https://ieeexplore.ieee.org/document/9442429, Page 466, last accessed March 05, 2024, Exhibit C Citation 6: Features supported by High Efficiency (HE) AP An HE AP may support the following features: — MU-MIMO transmission on an RU in an HE MU PPDU where the RU does not span the entire PPDU bandwidth (DL MU-MIMO within OFDMA). — MU-MIMO reception on an RU in an HE TB PPDU where the RU spans the entire PPDU bandwidth (UL MU-MIMO). — MU-MIMO reception on an RU in an HE TB PPDU where the RU does not span the entire PPDU bandwidth (UL MU-MIMO within OFDMA). — Reception of the payload on an RU in an HE MU PPDU where RU spans the entire PPDU bandwidth or a 106-tone RU within 20 MHz PPDU bandwidth. — 40 MHz channel width in the 2.4 GHz band (transmit and receive). If it is supported then all RU sizes and locations applicable to 40 MHz channel width are supported in 2.4 GHz band (transmit and receive). Fig 3 Source: https://ieeexplore.ieee.org/document/9442429, Page 468, last accessed March 05, 2024, Exhibit C Citation 7: UL MU-MIMO

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	27.3.3.2 UL MU-MIMO 27.3.3.2.1 Introduction UL MU-MIMO is a technique to allow multiple STAs to transmit simultaneously over the same frequency resource to the receiver. The concept is very similar to SU-MIMO where multiple space-time streams are transmitted simultaneously over the same frequency resource utilizing spatial multiplexing through multiple antennas at the transmitter and receiver. The key difference from SU-MIMO is that in UL MU-MIMO, the transmitted streams originate from multiple STAs. Fig 4 Source: https://ieeexplore.ieee.org/document/9442429, Page 510, last accessed March 05, 2024, Exhibit C <u>Wi-Fi UEs</u> IEEE Standard 802.11ac (UE) The accused UE devices (User equipment i.e., UE) are equipped with IEEE 802.11ac support as well as multiple-input multiple-output (MIMO) capabilities. Each accused instrumentality includes multiple Wi-Fi antennas such that the device may receive at least two spatial streams simultaneously. This occurs during SU-MIMO for user devices. For example, a user device may receive a single digital data stream from a user device that comprises two or more spatial streams. Citation 8: Stations support DL-MU-MIMO

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	21.3.11 SU-MIMO and DL-MU-MIMO Beamforming 21.3.11.1 General 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. With DL-MU-MIMO beamforming, disjoint subsets of the space-time streams are intended for reception at different STAs. 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. The feedback report format is described in 9.4.1.49. For DL-MU-MIMO beamforming, the receive signal vector in subcarrier k at beamformee u, $y_{k,u} = [y_{k,0}, y_{k,1}, \dots, y_{k,N_{RX,u}-1}]^T$, is shown in Equation (21-101), where $x_k = [x_{k,0}^T, x_{k,1}^T, \dots, x_{k,N_{user}-1}^T]^T$ denotes the transmit signal vector in subcarrier k for all N_{user} beamformees, with $x_{k,u} = [x_{k,0}, x_{k,1}, \dots, x_{k,N_{STS,u}-1}]^T$ being the transmit signal for beamformee u. $y_{k,u} = H_{k,u} \times [Q_{k,0}, Q_{k,1}, \dots, Q_{k,N_{user}-1}] \times x_k + n \quad (21-101)$ where $H_{k,u}$ is the channel matrix from the beamformer to beamformee u in subcarrier k with dimensions $N_{RX,u} \times N_{TX}$ $N_{RX,u}$ is the number of receive antennas at beamformee u $Q_{k,u}$ is a steering matrix for beamformee u in subcarrier k with dimensions $N_{TX} \times N_{STS,u}$ N_{user} is the number of VHT MU PPDU recipients (see Table 21-6) n is a vector of additive noise and may include interference The DL-MU-MIMO steering matrix $Q_k = [Q_{k,0}, Q_{k,1}, \dots, Q_{k,N_{user}-1}]$ 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 21.3.8.3.3 and 21.3.11.4). FIG. 4 Source: https://ieeexplore.ieee.org/document/7786995, Pages 2579 & 2580, last accessed Mar 15, 2024, Exhibit B

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	The accused product exchanges its capabilities (e.g., VHT capabilities) with mobile devices to initiate the connection in Probe request/response frames. The user equipment informs the mobile terminal about its capabilities through the Probe response frame. These capabilities include information about whether the user equipment supports DL-MU-MIMO and SU-MIMO. The mobile terminal sends the VHT NDP announcement frame to an access point. An access point responds with the action frame containing the Beamforming feedback matrix. The Beamforming feedback matrix field comprises a Compressed beamforming feedback matrix and the mobile device processes the received beams. Citation 9: STA information subfield Table 9-25—STA Info subfields <table border="1"> <thead> <tr> <th>Field</th><th>Description</th></tr> </thead> <tbody> <tr> <td>AID12</td><td>Contains the 12 least significant bits of the AID of a STA expected to process the following VHT NDP and prepare the sounding feedback. Equal to 0 if the STA is an AP, mesh STA, or STA that is a member of an IBSS.</td></tr> <tr> <td>Feedback Type</td><td>Indicates the type of feedback requested. Set to 0 for SU. Set to 1 for MU.</td></tr> <tr> <td>Nc Index</td><td>If the Feedback Type field indicates MU, then Nc Index indicates the number of columns, N_c, in the Compressed Beamforming Feedback Matrix subfield minus 1: Set to 0 to request $N_c = 1$ Set to 1 to request $N_c = 2$... Set to 7 to request $N_c = 8$ Reserved if the Feedback Type field indicates SU.</td></tr> </tbody> </table> FIG. 5	Field	Description	AID12	Contains the 12 least significant bits of the AID of a STA expected to process the following VHT NDP and prepare the sounding feedback. Equal to 0 if the STA is an AP, mesh STA, or STA that is a member of an IBSS.	Feedback Type	Indicates the type of feedback requested. Set to 0 for SU. Set to 1 for MU.	Nc Index	If the Feedback Type field indicates MU, then Nc Index indicates the number of columns, N_c , in the Compressed Beamforming Feedback Matrix subfield minus 1: Set to 0 to request $N_c = 1$ Set to 1 to request $N_c = 2$... Set to 7 to request $N_c = 8$ Reserved if the Feedback Type field indicates SU.
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Nc Index	If the Feedback Type field indicates MU, then Nc Index indicates the number of columns, N_c , in the Compressed Beamforming Feedback Matrix subfield minus 1: Set to 0 to request $N_c = 1$ Set to 1 to request $N_c = 2$... Set to 7 to request $N_c = 8$ Reserved if the Feedback Type field indicates SU.								

U.S. Pat. No. 9,814,071	Accused Products
	Source: https://ieeexplore.ieee.org/document/7786995, Page 687, last accessed Mar 15, 2024, Exhibit B Citation 10: Beamforming Feedback Matrix and its use to compute Steering matrix 22.3.11.2 Beamforming Feedback Matrix V 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. The beamformee shall generate the beamforming feedback matrices with the number of rows (N_r) equal to the N_{STS} of the NDP. After receiving the angle information, $\phi(k,u)$ 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. FIG. 6 Source: https://ieeexplore.ieee.org/document/7786995, Page 2580, last accessed Mar 15, 2024, Exhibit B IEEE Standard 802.11ax (UE) The accused UE devices (i.e., user equipment) are equipped with IEEE 802.11ax support as well as multiple-input multiple-output (MIMO) capabilities.

U.S. Pat. No. 9,814,071	Accused Products
	The user equipment (UE) supporting Wi-Fi Standard 802.11ax uses a method for enabling a receiving node to distinguish information simultaneously received from a plurality of transmitting nodes (e.g., APs) on a shared communication channel of a wireless digital network. Citation 11: HE DL MU Operation 26.5.1 HE DL MU operation 26.5.1.1 General HE DL MU operation allows an AP to transmit simultaneously to one or more non-AP STAs in DL OFDMA, DL MU-MIMO, or both. The PSDU on each RU in an HE MU PPDU shall be padded to end at the same time, indicated by the L-SIG field as described in 27.3.11.5. Fig 5 Source: https://ieeexplore.ieee.org/document/9442429, Page 339, last accessed March 15, 2024, Exhibit C Citation 12: High Efficiency (HE) PHY specification IEEE P802.11ax/D6.0, November 2019 27. High Efficiency (HE) PHY specification 27.1 Introduction 27.1.1 Introduction to the HE PHY Clause 27 (High Efficiency (HE) PHY specification) specifies the PHY entity for a high efficiency (HE) orthogonal frequency division multiplexing (OFDM) system. In addition to the requirements in Clause 27 (High Efficiency (HE) PHY specification), an HE STA shall be capable of transmitting and receiving PPDU's that are compliant with the mandatory requirements of the following PHY specifications:

U.S. Pat. No. 9,814,071	Accused Products
	Fig 6 Source: https://ieeexplore.ieee.org/document/9442429, Page 466, last accessed March 15, 2024, Exhibit C Citation 13: Features supported by non- AP High Efficiency (HE) STA A non-AP HE STA shall support the following features: — Reception of an HE MU PPDU where the RU allocated to the non-AP STA is not utilizing MU-MIMO (DL OFDMA). — Transmission of an HE TB PPDU where the RU allocated to the non-AP STA is not utilizing MU-MIMO (UL OFDMA). — Reception of an HE MU PPDU consisting of a single RU spanning the entire PPDU bandwidth and utilizing MU-MIMO (DL MU-MIMO). The maximum number of spatial streams per user the non-AP STA can receive in the DL MU-MIMO transmission shall be equal to the minimum of 4 and the maximum number of spatial streams supported for reception of HE SU PPDUs. The non-AP STA shall be able to receive its intended spatial streams in a DL MU-MIMO transmission with a total number of spatial streams across all users of at least 4. — Reception of an HE MU PPDU with up to 4 HE-LTF OFDM symbols, where the RU allocated to the non-AP STA does not span the entire PPDU bandwidth. — Responding with the requested beamforming feedback in an HE sounding procedure with the maximum number of space-time streams in the HE sounding NDP that the non-AP STA can respond to being at least 4. — Reception of the HE-SIG-B field in an HE MU PPDU at HE-MCSs 0 to 5. — Single spatial stream HE-MCSs 0 to 7 in all supported channel widths and RU sizes for HE MU PPDUs (receive) or HE TB PPDUs (transmit). — 40 MHz and 80 MHz channel widths and all RU sizes and locations applicable to the 40 MHz and 80 MHz channel widths in the 5 GHz band (transmit and receive), except for a 20 MHz-only non-AP HE STA in which case the 40 MHz and 80 MHz channel widths, 996-tone RU, and 484-tone RU sizes in the 5 GHz and 6 GHz bands are not applicable. — Reception of an HE MU PPDU with a 2x HE-LTF and 0.8 μs GI duration on the HE-LTF and Data field OFDM symbols.

U.S. Pat. No. 9,814,071	Accused Products
	— Reception of an HE MU PPDU with a 2x HE-LTF and 1.6 μs GI duration on the HE-LTF and Data field OFDM symbols. — Transmission of an HE TB PPDU with a 2x HE-LTF and 1.6 μs GI duration on the HE-LTF and Data field OFDM symbols. — Reception of an HE MU PPDU with a 4x HE-LTF and 3.2 μs GI duration on the HE-LTF and Data field OFDM symbols. — Transmission of an HE TB PPDU with a 4x HE-LTF and 3.2 μs GI duration on the HE-LTF and Data field OFDM symbols. — Reception of an HE MU PPDU with a 4x HE-LTF and 0.8 μs GI duration on the HE-LTF and the Data field OFDM symbols if the non-AP HE STA supports HE ER SU PPDU with the same HE-LTF and GI combinations. — 26-, 52-, and 106-tone RU sizes on locations allowed in 27.3.2.8 in the primary 20 MHz channel within 40 MHz channel width if the non-AP HE STA is a 20 MHz operating non-AP HE STA and that is capable of supporting 40 MHz channel width (B0 of the Supported Channel Width Set subfield in the HE PHY Capabilities Information field in the HE Capabilities element is 1) (transmit and receive). — 26-, 52-, and 106-tone RU sizes on locations allowed in 27.3.2.8 in the primary 20 MHz channel within 80 MHz channel width if the non-AP HE STA is a 20 MHz operating non-AP HE STA and is operating in the 5 GHz or 6 GHz bands (transmit and receive). Fig 7 Source: https://ieeexplore.ieee.org/document/9442429, Pages 469 & 470, last accessed March 15, 2024, Exhibit C Citation 14: DL MU-MIMO 27.3.3.1 DL MU-MIMO 27.3.3.1.1 Supported RU sizes in DL MU-MIMO A STA that sets the Partial Bandwidth DL MU-MIMO subfield of the HE PHY Capabilities Information field in the HE Capabilities element that it transmits to 1 shall support receiving an RU in an HE MU PPDU where MU-MIMO is employed in the RU, the RU size is greater than or equal to 106 tones, and the RU does not span the entire PPDU bandwidth.

U.S. Pat. No. 9,814,071	<u>Accused Products</u>
	Fig 8 Source: https://ieeexplore.ieee.org/document/9442429, Page 509, last accessed March 15, 2024, Exhibit C

providing a plurality of parameter channels on the network in addition to the shared communication channel;

Cellular

The Accused LTE/5G Base Stations provide a plurality of parameter channels on the network in addition to the shared communication channel (e.g., data portion of a frame).

See e.g., 3GPP TS 36.211 V10.7.0 (2013-02):

5.5.2 Demodulation reference signal

5.5.2.1 Demodulation reference signal for PUSCH

5.5.2.1.1 Reference signal sequence

The PUSCH demodulation reference signal sequence $r_{\text{PUSCH}}^{(\lambda)}(\cdot)$ associated with layer $\lambda \in \{0,1,\dots,\nu-1\}$ is defined by

$$r_{\text{PUSCH}}^{(\lambda)}(m \cdot M_{\text{sc}}^{\text{RS}} + n) = w^{(\lambda)}(m) r_{u,v}^{(\alpha_\lambda)}(n)$$

where

$$m = 0,1$$

$$n = 0,\dots,M_{\text{sc}}^{\text{RS}} - 1$$

and

$$M_{\text{sc}}^{\text{RS}} = M_{\text{sc}}^{\text{PUSCH}}$$

Section 5.5.1 defines the sequence $r_{u,v}^{(\alpha_\lambda)}(0),\dots,r_{u,v}^{(\alpha_\lambda)}(M_{\text{sc}}^{\text{RS}} - 1)$. The orthogonal sequence $w^{(\lambda)}(m)$ is given by $[w^\lambda(0) \ w^\lambda(1)] = [1 \ 1]$ for DCI format 0 if the higher-layer parameter *Activate-DMRS-with OCC* is not set or if the temporary C-RNTI was used to transmit the most recent uplink-related DCI for the transport block associated with the corresponding PUSCH transmission, otherwise it is given by Table 5.5.2.1.1-1 using the cyclic shift field in most recent uplink-related DCI [3] for the transport block associated with the corresponding PUSCH transmission.

The cyclic shift α_λ in a slot n_s is given as $\alpha_\lambda = 2m_{\text{cs},\lambda}/12$ with

$$n_{\text{cs},\lambda} = (n_{\text{DMRS}}^{(1)} + n_{\text{DMRS},\lambda}^{(2)} + n_{\text{PN}}(n_s)) \bmod 12$$

where the values of $n_{\text{DMRS}}^{(1)}$ is given by Table 5.5.2.1.1-2 according to the parameter *cyclicShift* provided by higher layers, $n_{\text{DMRS},\lambda}^{(2)}$ is given by the cyclic shift for DMRS field in most recent uplink-related DCI [3] for the transport block associated with the corresponding PUSCH transmission where the value of $n_{\text{DMRS},\lambda}^{(2)}$ is given in Table 5.5.2.1.1-1.

TS 38.211 v15.10.0:

6.4.1.1 Demodulation reference signal for PUSCH

6.4.1.1.1 Sequence generation

6.4.1.1.1.1 Sequence generation when transform precoding is disabled

If transform precoding for PUSCH is not enabled, the sequence $r(n)$ shall be generated according to

$$r(n) = \frac{1}{\sqrt{2}}(1 - 2 \cdot c(2n)) + j \frac{1}{\sqrt{2}}(1 - 2 \cdot c(2n+1)).$$

where the pseudo-random sequence $c(i)$ is defined in clause 5.2.1. The pseudo-random sequence generator shall be initialized with

$$c_{\text{init}} = \left(2^{17} \left(N_{\text{synb}}^{\text{slot}} n_{\text{s,f}}^{\mu} + l + 1 \right) \left(2N_{\text{ID}}^{\text{scid}} + 1 \right) + 2N_{\text{ID}}^{\text{scid}} + n_{\text{scid}} \right) \bmod 2^{31}$$

where l is the OFDM symbol number within the slot, $n_{\text{s,f}}^{\mu}$ is the slot number within a frame, and

- $N_{\text{ID}}^0, N_{\text{ID}}^1 \in \{0, 1, \dots, 65535\}$ are given by the higher-layer parameters *scramblingID0* and *scramblingID1*, respectively, in the *DMRS-UplinkConfig* IE if provided and the PUSCH is scheduled by DCI format 0_1 or by a PUSCH transmission with a configured grant;
- $N_{\text{ID}}^0 \in \{0, 1, \dots, 65535\}$ is given by the higher-layer parameter *scramblingID0* in the *DMRS-UplinkConfig* IE if provided and the PUSCH is scheduled by DCI format 0_0 with the CRC scrambled by C-RNTI, MCS-C-RNTI, or CS-RNTI;
- $N_{\text{ID}}^{\text{scid}} = N_{\text{ID}}^{\text{cell}}$ otherwise.

	The quantity $n_{\text{SCID}} \in \{0,1\}$ is indicated by the DM-RS initialization field, if present, either in the DCI associated with the PUSCH transmission if DCI format 0_1 in [4, TS 38.212] is used or by the higher layer parameter <i>dmrs-SeqInitialization</i>, if present, for a Type 1 PUSCH transmission with a configured grant, otherwise $n_{\text{SCID}} = 0$.
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	The Accused LTE/5G UEs provide a plurality of parameter channels on the network in addition to the shared communication channel (e.g., data portion of a frame).
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TS 36.211 v12.5.0:

6.10.3 UE-specific reference signals associated with PDSCH

UE-specific reference signals associated with PDSCH

- are transmitted on antenna port(s) $p = 5$, $p = 7$, $p = 8$ or $p = 7, 8, \dots, v+6$, where v is the number of layers used for transmission of the PDSCH;
- are present and are a valid reference for PDSCH demodulation only if the PDSCH transmission is associated with the corresponding antenna port according to clause 7.1 of 3GPP TS 36.213 [4];
- are transmitted only on the physical resource blocks upon which the corresponding PDSCH is mapped.

A UE-specific reference signal associated with PDSCH is not transmitted in resource elements (k, l) in which one of the physical channels or physical signals other than the UE-specific reference signals defined in 6.1 are transmitted using resource elements with the same index pair (k, l) regardless of their antenna port p .

6.10.3.1 Sequence generation

For antenna port 5, the UE-specific reference-signal sequence $r_{n_s}(m)$ is defined by

$$r_{n_s}(m) = \frac{1}{\sqrt{2}}(1 - 2 \cdot c(2m)) + j \frac{1}{\sqrt{2}}(1 - 2 \cdot c(2m+1)), \quad m = 0, 1, \dots, 12N_{\text{RB}}^{\text{PDSCH}} - 1$$

where $N_{\text{RB}}^{\text{PDSCH}}$ denotes the assigned bandwidth in resource blocks of the corresponding PDSCH transmission. The pseudo-random sequence $c(i)$ is defined in clause 7.2. The pseudo-random sequence generator shall be initialised with $c_{\text{init}} = (\lfloor n_s/2 \rfloor + 1) \cdot (2N_{\text{ID}}^{\text{cell}} + 1) \cdot 2^{16} + n_{\text{RNTI}}$ at the start of each subframe where n_{RNTI} is as described in clause 7.1 3GPP TS 36.213 [4].

For any of the antenna ports $p \in \{7, 8, \dots, v+6\}$, the reference-signal sequence $r(m)$ is defined by

$$r(m) = \frac{1}{\sqrt{2}}(1 - 2 \cdot c(2m)) + j \frac{1}{\sqrt{2}}(1 - 2 \cdot c(2m+1)), \quad m = \begin{cases} 0, 1, \dots, 12N_{\text{RB}}^{\text{max,DL}} - 1 & \text{normal cyclic prefix} \\ 0, 1, \dots, 16N_{\text{RB}}^{\text{max,DL}} - 1 & \text{extended cyclic prefix} \end{cases}$$

TS 38.211 v15.8.0:

7.4.1.1 Demodulation reference signals for PDSCH

7.4.1.1.1 Sequence generation

The UE shall assume the sequence $r(n)$ is defined by

$$r(n) = \frac{1}{\sqrt{2}}(1 - 2 \cdot c(2n)) + j \frac{1}{\sqrt{2}}(1 - 2 \cdot c(2n+1))$$

where the pseudo-random sequence $c(i)$ is defined in clause 5.2.1. The pseudo-random sequence generator shall be initialized with

$$c_{\text{init}} = \left(2^{17} \left(N_{\text{synch}}^{\text{slot}} n_{\text{s},f}^{\mu} + l + 1 \right) \left(2N_{\text{ID}}^{\text{SCID}} + 1 \right) + 2N_{\text{ID}}^{\text{SCID}} + n_{\text{SCID}} \right) \bmod 2^{31}$$

where l is the OFDM symbol number within the slot, $n_{\text{s},f}^{\mu}$ is the slot number within a frame, and

- $N_{\text{ID}}^0, N_{\text{ID}}^1 \in \{0, 1, \dots, 65535\}$ are given by the higher-layer parameters *scramblingID0* and *scramblingID1*, respectively, in the *DMRS-DownlinkConfig* IE if provided and the PDSCH is scheduled by PDCCH using DCI format 1_1 with the CRC scrambled by C-RNTI, MCS-C-RNTI, or CS-RNTI
- $N_{\text{ID}}^0 \in \{0, 1, \dots, 65535\}$ is given by the higher-layer parameter *scramblingID0* in the *DMRS-DownlinkConfig* IE if provided and the PDSCH is scheduled by PDCCH using DCI format 1_0 with the CRC scrambled by C-RNTI, MCS-C-RNTI, or CS-RNTI;
- $N_{\text{ID}}^{\text{SCID}} = N_{\text{ID}}^{\text{cell}}$ otherwise;

The quantity $n_{\text{SCID}} \in \{0, 1\}$ is given by the DM-RS sequence initialization field, in the DCI associated with the PDSCH transmission if DCI format 1_1 in [4, TS 38.212] is used, otherwise $n_{\text{SCID}} = 0$.

7.4.1.1.2 Mapping to physical resources

The UE shall assume the PDSCH DM-RS being mapped to physical resources according to configuration type 1 or configuration type 2 as given by the higher-layer parameter *dmrs-Type*.

Wi-Fi Access Points

The Accused Instrumentalities (WiFi) practice a method of providing a plurality of parameter channels on the network in addition to the shared communication channel.

Access Point

IEEE Standard 802.11ac (AP)

The Accused Wi-Fi Router Instrumentalities provide a plurality of parameter channels (e.g., orthogonal codes applied to training fields including L-STF, L-LTF, VHT-STF, VHT-LTF) on the network in addition to the shared communication channel (e.g., the data portion of a frame).

The 802.11ac frame format is shown in Figure 4 and begins as expected with a preamble. The first 3 fields are L-STF (Short Training Field), L-LTF (Long Training Field), and L-SIG (Signal). The L-STF and L-LTF contain information that allows the device to detect the signal, perform frequency offset estimation, timing synchronization, etc.

Citation 15: VHT PPDU frame with VHT-LTF Field

21.3.2 VHT PPDU format

A single PPDU format is defined for this PHY: the VHT PPDU format. Figure 21-4 shows the VHT PPDU format.

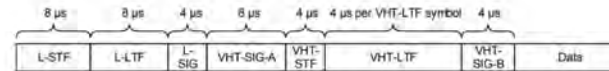


Figure 21-4—VHT PPDU format

The fields of the VHT PPDU format are summarized in Table 21-4.

Table 21-4—Fields of the VHT PPDU

Field	Description
L-STF	Non-HT Short Training field
L-LTF	Non-HT Long Training field
L-SIG	Non-HT SIGNAL field
VHT-SIG-A	VHT Signal A field
VHT-STF	VHT Short Training field
VHT-LTF	VHT Long Training field
VHT-SIG-B	VHT Signal B field
Data	The Data field carrying the PSDU(s)

FIG. 7

Source: <https://ieeexplore.ieee.org/document/7786995>, Page 2514, last accessed Mar 07, 2024, Exhibit B

The VHT LTF (long training fields) are used by the receiver to estimate the MIMO channel and equalize the received signal. The number of LTF symbols sent in a packet depends on the number of space-time streams: one LTF for one space-time stream, two LTFs for two space-time streams, four LTFs for three or four space-time streams, six LTFs for five or six space-time streams, eight LTFs for seven or eight space-time streams.

Each accused Instrumentality must determine an initial amplitude estimate corresponding to the received VHT-LTF to produce an initial MIMO channel estimate.

Citation 16: VHT-LTF

21.3.8.3.5 VHT-LTF definition

The VHT Long Training field (VHT-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. The transmitter provides training for $N_{STS,total}$ space-time streams (spatial mapper inputs) used for the transmission of the PSDU(s). For each tone, the MIMO channel that can be estimated is an $N_{RX} \times N_{STS,total}$ matrix. A VHT transmission has a preamble that contains VHT-LTF symbols, where the data tones of each VHT-LTF symbol are multiplied by entries belonging to a matrix $P_{VHT-LTF}$, to enable channel estimation at the receiver. The pilot tones of each VHT-LTF symbol are multiplied by the entries of a matrix $R_{VHT-LTF}$ defined in the following text. The multiplication of the pilot tones in the VHT-LTF symbol by the $R_{VHT-LTF}$ matrix instead of the $P_{VHT-LTF}$ matrix allows receivers to track phase and frequency offset during MIMO channel estimation using the VHT-LTF. The number of VHT-LTF symbols, $N_{VHT-LTF}$, is a function of the total number of space-time streams $N_{STS,total}$ as shown in Table 21-13. As a result the VHT-LTF field consists of one, two, four, six or eight symbols.

Table 21-13—Number of VHT-LTFs required for different numbers of space-time streams

$N_{STS,total}$	$N_{VHT-LTF}$
1	1
2	2
3	4
4	4
5	6
6	6
7	8
8	8

FIG. 8

Source: <https://ieeexplore.ieee.org/document/7786995>, Page 2549, last accessed Mar 07, 2024, Exhibit B

IEEE Standard 802.11ax (AP)

The accused product supporting Wi-Fi Standard 802.11ax provides a plurality of parameter channels (e.g., orthogonal codes applied to training fields including L-STF, L-LTF, HE-STF, HE-LTF) on the network in addition to the shared communication channel (e.g., the data portion of a frame).

Citation 17: HE TB PPDU Format

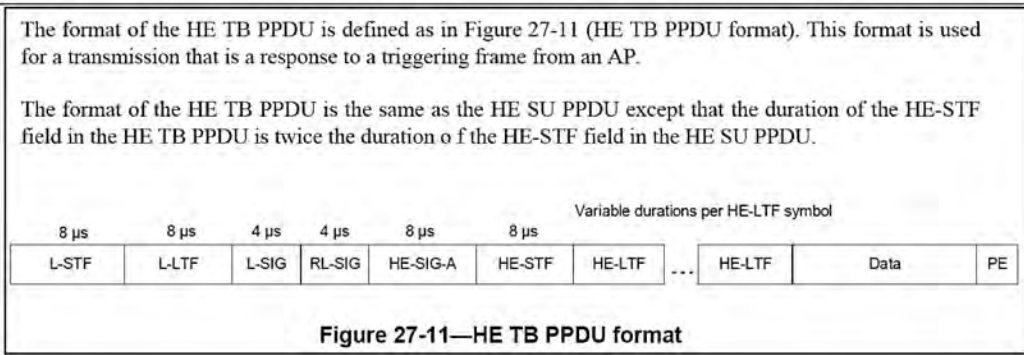


Fig 9

Source: <https://ieeexplore.ieee.org/document/9442429>, Page 512, last accessed March 05, 2024, Exhibit C

Citation 18: Channels occupied in an HE TB PPDU

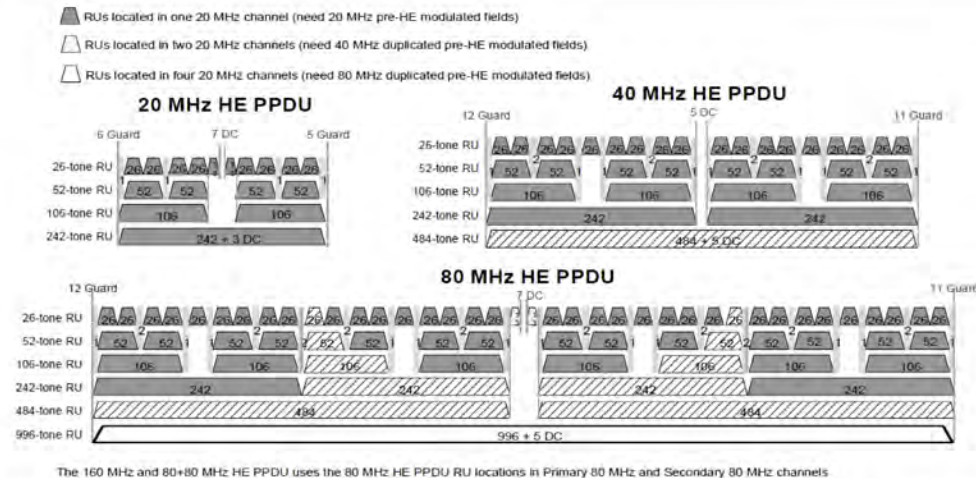


Figure 27-12—Number of 20 MHz channels occupied by the pre-HE modulated fields in an HE TB PPDU

Fig 10

Source: <https://ieeexplore.ieee.org/document/9442429>, Page 513, last accessed March 05, 2024, Exhibit C

Wi-Fi User Equipment

IEEE Standard 802.11ac (UE)

The user equipment (UE) supporting Wi-Fi standard 802.11ac provides a plurality of parameter channels (e.g., orthogonal codes applied to training fields including L-STF, L-LTF, VHT-STF, VHT-LTF) on the network in addition to the shared communication channel (e.g., the data portion of a frame).

The 802.11ac frame format is shown in Figure 4 and begins as expected with a preamble. The first 3 fields are L-STF (Short Training Field), L-LTF (Long Training Field), and L-SIG (Signal). The L-STF and L-LTF contain information that allows the device to detect the signal, perform frequency offset estimation, etc.

Citation 19: VHT PPDU frame with VHT-LTF Field

21.3.2 VHT PPDU format

A single PPDU format is defined for this PHY: the VHT PPDU format. Figure 21-4 shows the VHT PPDU format.

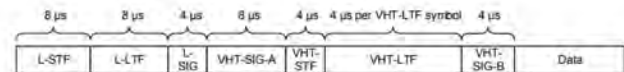


Figure 21-4—VHT PPDU format

The fields of the VHT PPDU format are summarized in Table 21-4.

Table 21-4—Fields of the VHT PPDU

Field	Description
L-STF	Non-HT Short Training field
L-LTF	Non-HT Long Training field
L-SIG	Non-HT SIGNAL field
VHT-SIG-A	VHT Signal A field
VHT-STF	VHT Short Training field
VHT-LTF	VHT Long Training field
VHT-SIG-B	VHT Signal B field
Data	The Data field carrying the PSDU(s)

FIG. 9

Source: <https://ieeexplore.ieee.org/document/7786995>, Page 2514, last accessed Mar 15, 2024, Exhibit B

The VHT LTF (long training fields) are used by the receiver to estimate the MIMO channel and equalize the received signal. The number of LTF symbols sent in a packet depends on the number of space-time streams: one LTF for one space-time stream, two LTFs for two space-time streams, four LTFs for three or four space-time streams, six LTFs for five or six space-time streams, eight LTFs for seven or eight space-time streams.

Each user equipment (UE) must determine an initial amplitude estimate corresponding to the received VHT-LTF to produce an initial MIMO channel estimate.

Citation 20: VHT-LTF

21.3.8.3.5 VHT-LTF definition

The VHT Long Training field (VHT-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. The transmitter provides training for $N_{STS,total}$ space-time streams (spatial mapper inputs) used for the transmission of the PSDU(s). For each tone, the MIMO channel that can be estimated is an $N_{RX} \times N_{STS,total}$ matrix. A VHT transmission has a preamble that contains VHT-LTF symbols, where the data tones of each VHT-LTF symbol are multiplied by entries belonging to a matrix $P_{VHT-LTF}$, to enable channel estimation at the receiver. The pilot tones of each VHT-LTF symbol are multiplied by the entries of a matrix $R_{VHT-LTF}$ defined in the following text. The multiplication of the pilot tones in the VHT-LTF symbol by the $R_{VHT-LTF}$ matrix instead of the $P_{VHT-LTF}$ matrix allows receivers to track phase and frequency offset during MIMO channel estimation using the VHT-LTF. The number of VHT-LTF symbols, $N_{VHT-LTF}$, is a function of the total number of space-time streams $N_{STS,total}$ as shown in Table 21-13. As a result the VHT-LTF field consists of one, two, four, six or eight symbols.

Table 21-13—Number of VHT-LTFs required for different numbers of space-time streams

$N_{STS,total}$	$N_{VHT-LTF}$
1	1
2	2
3	4
4	4
5	6
6	6
7	8
8	8

FIG. 10

Source: <https://ieeexplore.ieee.org/document/7786995>, Page 2549, last accessed Mar 15, 2024, Exhibit B
IEEE Standard 802.11ax (UE)

The user equipment (UE) supporting Wi-Fi Standard 802.11ax provides a plurality of parameter channels (e.g., orthogonal codes applied to training fields including L-STF, L-LTF, HE-STF, HE-LTF) on the network in addition to the shared communication channel (e.g., the data portion of a frame).

Citation 21: HE TB PPDU Format

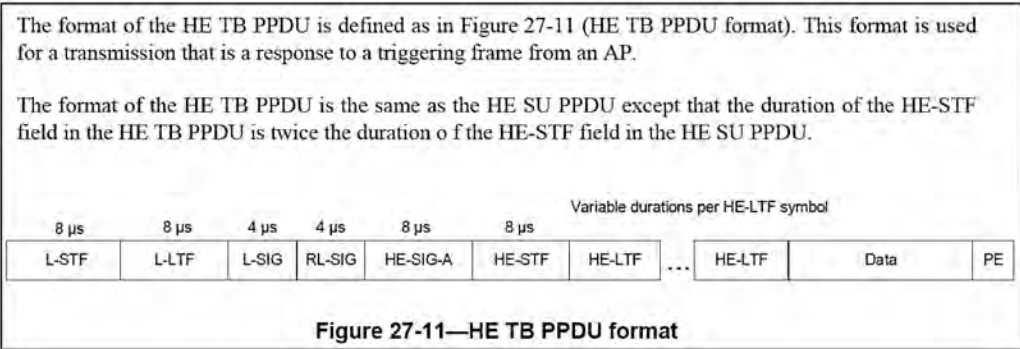


Fig 11

Source: <https://ieeexplore.ieee.org/document/9442429>, Page 512, last accessed March 15, 2024, Exhibit C

Citation 22: Channels occupied in an HE TB PPDU

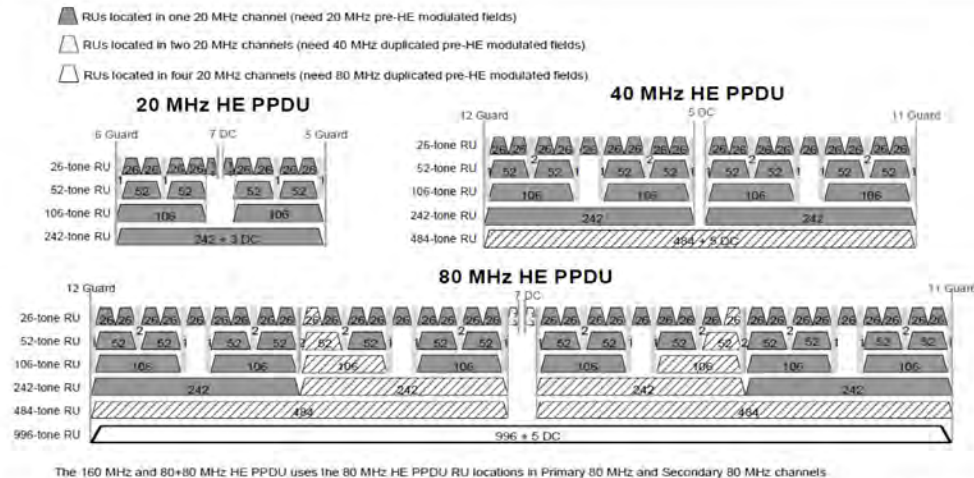


Figure 27-12—Number of 20 MHz channels occupied by the pre-HE modulated fields in an HE TB PPDU

Fig 12

Source: <https://ieeexplore.ieee.org/document/9442429>, Page 513, last accessed March 15, 2024, Exhibit C

If this element is not literally satisfied by the disclosures cited herein, it is satisfied under the doctrine of equivalents by the disclosures cited herein because the accused functionality would be insubstantially different from or function in the same way to provide the same result as the relevant claim element.

requiring each transmitting node to transmit a parameter-estimating signal on an

Cellular

The Accused LTE/5G Base Stations require each transmitting node to transmit a parameter-estimating signal on an unshared said parameter channel.

unshared said parameter channel;	See e.g., 3GPP TS 36.211 V10.7.0 (2013-02): 5.5.2 Demodulation reference signal 5.5.2.1 Demodulation reference signal for PUSCH 5.5.2.1.1 Reference signal sequence The PUSCH demodulation reference signal sequence $r_{\text{PUSCH}}^{(\lambda)}(\cdot)$ associated with layer $\lambda \in \{0,1,\dots,\nu-1\}$ is defined by $r_{\text{PUSCH}}^{(\lambda)}(m \cdot M_{\text{sc}}^{\text{RS}} + n) = w^{(\lambda)}(m) r_{u,v}^{(\alpha_\lambda)}(n)$ where $m = 0,1$ $n = 0,\dots,M_{\text{sc}}^{\text{RS}} - 1$ and $M_{\text{sc}}^{\text{RS}} = M_{\text{sc}}^{\text{PUSCH}}$ Section 5.5.1 defines the sequence $r_{u,v}^{(\alpha_\lambda)}(0),\dots,r_{u,v}^{(\alpha_\lambda)}(M_{\text{sc}}^{\text{RS}} - 1)$. The orthogonal sequence $w^{(\lambda)}(m)$ is given by $\begin{bmatrix} w^{(\lambda)}(0) & w^{(\lambda)}(1) \end{bmatrix} = \begin{bmatrix} 1 & 1 \end{bmatrix}$ for DCI format 0 if the higher-layer parameter <i>Activate-DMRS-with OCC</i> is not set or if the temporary C-RNTI was used to transmit the most recent uplink-related DCI for the transport block associated with the corresponding PUSCH transmission, otherwise it is given by Table 5.5.2.1.1-1 using the cyclic shift field in most recent uplink-related DCI [3] for the transport block associated with the corresponding PUSCH transmission. The cyclic shift α_λ in a slot n_s is given as $\alpha_\lambda = 2\pi n_{\text{cs},\lambda}/12$ with $n_{\text{cs},\lambda} = \left(n_{\text{DMRS}}^{(1)} + n_{\text{DMRS},\lambda}^{(2)} + n_{\text{PN}}(n_s) \right) \bmod 12$ where the values of $n_{\text{DMRS}}^{(1)}$ is given by Table 5.5.2.1.1-2 according to the parameter <i>cyclicShift</i> provided by higher layers, $n_{\text{DMRS},\lambda}^{(2)}$ is given by the cyclic shift for DMRS field in most recent uplink-related DCI [3] for the transport block associated with the corresponding PUSCH transmission where the value of $n_{\text{DMRS},\lambda}^{(2)}$ is given in Table 5.5.2.1.1-1.
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The first row of Table 5.5.2.1.1-1 shall be used to obtain $n_{\text{DMRS},0}^{(2)}$ and $w^{(\lambda)}(m)$ if there is no uplink-related DCI for the same transport block associated with the corresponding PUSCH transmission, and

- if the initial PUSCH for the same transport block is semi-persistently scheduled, or
- if the initial PUSCH for the same transport block is scheduled by the random access response grant.

The quantity $n_{\text{PN}}(n_s)$ is given by

$$n_{\text{PN}}(n_s) = \sum_{i=0}^7 c(8N_{\text{symb}}^{\text{UL}} \cdot n_s + i) \cdot 2^i$$

where the pseudo-random sequence $c(i)$ is defined by section 7.2. The application of $c(i)$ is cell-specific. The pseudo-random sequence generator shall be initialized with $c_{\text{init}} = \left\lfloor \frac{N_{\text{ID}}^{\text{cell}}}{30} \right\rfloor \cdot 2^5 + f_{\text{ss}}^{\text{PUSCH}}$ at the beginning of each radio frame.

The vector of reference signals shall be precoded according to

$$\begin{bmatrix} \tilde{r}_{\text{PUSCH}}^{(0)} \\ \vdots \\ \tilde{r}_{\text{PUSCH}}^{(P-1)} \end{bmatrix} = W \begin{bmatrix} r_{\text{PUSCH}}^{(0)} \\ \vdots \\ r_{\text{PUSCH}}^{(\nu-1)} \end{bmatrix}$$

where P is the number of antenna ports used for PUSCH transmission.

For PUSCH transmission using a single antenna port, $P = 1$, $W = 1$ and $\nu = 1$.

For spatial multiplexing, $P = 2$ or $P = 4$ and the precoding matrix W shall be identical to the precoding matrix used in Section 5.3.3A.2 for precoding of the PUSCH in the same subframe.

Table 5.5.2.1.1-1: Mapping of Cyclic Shift Field in uplink-related DCI format to $n_{\text{DMRS},\lambda}^{(2)}$ and $[w^{(\lambda)}(0) \ w^{(\lambda)}(1)]$.

Cyclic Shift Field in uplink-related DCI format [3]	$n_{\text{DMRS},\lambda}^{(2)}$				$[w^{(\lambda)}(0) \ w^{(\lambda)}(1)]$			
	$\lambda = 0$	$\lambda = 1$	$\lambda = 2$	$\lambda = 3$	$\lambda = 0$	$\lambda = 1$	$\lambda = 2$	$\lambda = 3$
000	0	6	3	9	$[1 \ 1]$	$[1 \ 1]$	$[1 \ -1]$	$[1 \ -1]$
001	6	0	9	3	$[1 \ -1]$	$[1 \ -1]$	$[1 \ 1]$	$[1 \ 1]$
010	3	9	6	0	$[1 \ -1]$	$[1 \ -1]$	$[1 \ 1]$	$[1 \ 1]$
011	4	10	7	1	$[1 \ 1]$	$[1 \ 1]$	$[1 \ 1]$	$[1 \ 1]$
100	2	8	5	11	$[1 \ 1]$	$[1 \ 1]$	$[1 \ 1]$	$[1 \ 1]$
101	8	2	11	5	$[1 \ -1]$	$[1 \ -1]$	$[1 \ -1]$	$[1 \ -1]$
110	10	4	1	7	$[1 \ -1]$	$[1 \ -1]$	$[1 \ -1]$	$[1 \ -1]$
111	9	3	0	6	$[1 \ 1]$	$[1 \ 1]$	$[1 \ -1]$	$[1 \ -1]$

Table 5.5.2.1.1-2: Mapping of *cyclicShift* to $n_{\text{DMRS}}^{(1)}$ values.

<i>cyclicShift</i>	$n_{\text{DMRS}}^{(1)}$
0	0
1	2
2	3
3	4
4	6
5	8
6	9
7	10

5.5.2.1.2 Mapping to physical resources

For each antenna port used for transmission of the PUSCH, the sequence $\tilde{r}_{\text{PUSCH}}^{(\tilde{p})}(\cdot)$ shall be multiplied with the amplitude scaling factor β_{PUSCH} and mapped in sequence starting with $\tilde{r}_{\text{PUSCH}}^{(\tilde{p})}(0)$ to the resource blocks. The set of physical resource blocks used in the mapping process and the relation between the index $\tilde{p}$ and the antenna port number p shall be identical to the corresponding PUSCH transmission as defined in Section 5.3.4. The mapping to resource elements (k, l) , with $l = 3$ for normal cyclic prefix and $l = 2$ for extended cyclic prefix, in the subframe shall be in increasing order of first k , then the slot number.

See e.g., 3GPP TS 38.211 V18.0.0 (2023-09):

6.4.1.1.3 Precoding and mapping to physical resources

The sequence shall be mapped to the intermediate quantity $\tilde{a}_{k,l}^{(\tilde{p}_{j,\mu})}$ according to

- if transform precoding is not enabled,
- if the higher-layer parameter *dmrs-TypeEnh* is configured

$$\begin{aligned}\tilde{a}_{k,l}^{(p_{j,\mu})} &= w_f(k')w_t(l')r(4n + k') \\ k &= \begin{cases} 8n + 2k' + \Delta & \text{configuration type 1} \\ 12n + k' + \Delta & \text{configuration type 2, } k' = 0,1 \\ 12n + k' + \Delta + 4 & \text{configuration type 2, } k' = 2,3 \end{cases} \\ k' &= 0,1,2,3 \\ l &= \bar{l} + l' \\ n &= 0,1, \dots \\ j &= 0,1, \dots, v - 1\end{aligned}$$

- otherwise

$$\begin{aligned}\tilde{a}_{k,l}^{(p_{j,\mu})} &= w_f(k')w_t(l')r(2n + k') \\ k &= \begin{cases} 4n + 2k' + \Delta & \text{configuration type 1} \\ 6n + k' + \Delta & \text{configuration type 2} \end{cases} \\ k' &= 0,1 \\ l &= \bar{l} + l' \\ n &= 0,1, \dots \\ j &= 0,1, \dots, v - 1\end{aligned}$$

- if transform precoding is enabled

$$\begin{aligned}\tilde{a}_{k,l}^{(p_0,\mu)} &= w_f(k')w_t(l')r(2n+k') \\ k &= 4n+2k'+\Delta \\ k' &= 0,1 \\ l &= \bar{l}+l' \\ n &= 0,1,\dots\end{aligned}$$

Table 6.4.1.1.3-1: Parameters for PUSCH DM-RS configuration type 1.

$\tilde{p}$	CDM group λ	Δ	$[w_f(0) \dots w_f(3)]$	$[w_t(0) \ w_t(1)]$
0	0	0	[+1 +1 +1 +1]	[+1 +1]
1	0	0	[+1 -1 +1 -1]	[+1 +1]
2	1	1	[+1 +1 +1 +1]	[+1 +1]
3	1	1	[+1 -1 +1 -1]	[+1 +1]
4	0	0	[+1 +1 +1 +1]	[+1 -1]
5	0	0	[+1 -1 +1 -1]	[+1 -1]
6	1	1	[+1 +1 +1 +1]	[+1 -1]
7	1	1	[+1 -1 +1 -1]	[+1 -1]
8	0	0	[+1 +j -1 -j]	[+1 +1]
9	0	0	[+1 -j -1 +j]	[+1 +1]
10	1	1	[+1 +j -1 -j]	[+1 +1]
11	1	1	[+1 -j -1 +j]	[+1 +1]
12	0	0	[+1 +j -1 -j]	[+1 -1]
13	0	0	[+1 -j -1 +j]	[+1 -1]
14	1	1	[+1 +j -1 -j]	[+1 -1]
15	1	1	[+1 -j -1 +j]	[+1 -1]

Table 6.4.1.2.1.2-1: The orthogonal sequence ☐.

$n_{\text{RNTI}} \bmod N_{\text{samp}}^{\text{group}}$	$N_{\text{samp}}^{\text{group}} = 2$ $[w(0) \ w(1)]$	$N_{\text{samp}}^{\text{group}} = 4$ $[w(0) \ w(1) \ w(2) \ w(3)]$
0		
1		
2	-	

The Accused LTE/5G UEs require each transmitting node to transmit a parameter-estimating signal on an unshared said parameter channel.

TS 36.211 v12.5.0:

6.10.3 UE-specific reference signals associated with PDSCH

UE-specific reference signals associated with PDSCH

- are transmitted on antenna port(s) $p = 5$, $p = 7$, $p = 8$ or $p = 7, 8, \dots, v+6$, where v is the number of layers used for transmission of the PDSCH;
- are present and are a valid reference for PDSCH demodulation only if the PDSCH transmission is associated with the corresponding antenna port according to clause 7.1 of 3GPP TS 36.213 [4];
- are transmitted only on the physical resource blocks upon which the corresponding PDSCH is mapped.

A UE-specific reference signal associated with PDSCH is not transmitted in resource elements (k, l) in which one of the physical channels or physical signals other than the UE-specific reference signals defined in 6.1 are transmitted using resource elements with the same index pair (k, l) regardless of their antenna port p .

6.10.3.1 Sequence generation

For antenna port 5, the UE-specific reference-signal sequence $r_{n_s}(m)$ is defined by

$$r_{n_s}(m) = \frac{1}{\sqrt{2}}(1 - 2 \cdot c(2m)) + j \frac{1}{\sqrt{2}}(1 - 2 \cdot c(2m+1)), \quad m = 0, 1, \dots, 12N_{\text{RB}}^{\text{PDSCH}} - 1$$

where $N_{\text{RB}}^{\text{PDSCH}}$ denotes the assigned bandwidth in resource blocks of the corresponding PDSCH transmission. The pseudo-random sequence $c(i)$ is defined in clause 7.2. The pseudo-random sequence generator shall be initialised with $c_{\text{init}} = (\lfloor n_s/2 \rfloor + 1) \cdot (2N_{\text{ID}}^{\text{cell}} + 1) \cdot 2^{16} + n_{\text{RNTI}}$ at the start of each subframe where n_{RNTI} is as described in clause 7.1 3GPP TS 36.213 [4].

For any of the antenna ports $p \in \{7, 8, \dots, v+6\}$, the reference-signal sequence $r(m)$ is defined by

$$r(m) = \frac{1}{\sqrt{2}}(1 - 2 \cdot c(2m)) + j \frac{1}{\sqrt{2}}(1 - 2 \cdot c(2m+1)), \quad m = \begin{cases} 0, 1, \dots, 12N_{\text{RB}}^{\text{max,DL}} - 1 & \text{normal cyclic prefix} \\ 0, 1, \dots, 16N_{\text{RB}}^{\text{max,DL}} - 1 & \text{extended cyclic prefix} \end{cases}$$

TS 38.211 v15.8.0:

7.4.1.1 Demodulation reference signals for PDSCH

7.4.1.1.1 Sequence generation

The UE shall assume the sequence $r(n)$ is defined by

$$r(n) = \frac{1}{\sqrt{2}}(1 - 2 \cdot c(2n)) + j \frac{1}{\sqrt{2}}(1 - 2 \cdot c(2n+1))$$

where the pseudo-random sequence $c(i)$ is defined in clause 5.2.1. The pseudo-random sequence generator shall be initialized with

$$c_{\text{init}} = \left(2^{17} \left(N_{\text{synch}}^{\text{slot}} n_{s,f}^{\mu} + l + 1 \right) \left(2N_{\text{ID}}^{\text{SCID}} + 1 \right) + 2N_{\text{ID}}^{\text{SCID}} + n_{\text{SCID}} \right) \bmod 2^{31}$$

where l is the OFDM symbol number within the slot, $n_{s,f}^{\mu}$ is the slot number within a frame, and

- $N_{\text{ID}}^0, N_{\text{ID}}^1 \in \{0, 1, \dots, 65535\}$ are given by the higher-layer parameters *scramblingID0* and *scramblingID1*, respectively, in the *DMRS-DownlinkConfig* IE if provided and the PDSCH is scheduled by PDCCH using DCI format 1_1 with the CRC scrambled by C-RNTI, MCS-C-RNTI, or CS-RNTI
- $N_{\text{ID}}^0 \in \{0, 1, \dots, 65535\}$ is given by the higher-layer parameter *scramblingID0* in the *DMRS-DownlinkConfig* IE if provided and the PDSCH is scheduled by PDCCH using DCI format 1_0 with the CRC scrambled by C-RNTI, MCS-C-RNTI, or CS-RNTI;
- $N_{\text{ID}}^{\text{SCID}} = N_{\text{ID}}^{\text{cell}}$ otherwise;

The quantity $n_{\text{SCID}} \in \{0, 1\}$ is given by the DM-RS sequence initialization field, in the DCI associated with the PDSCH transmission if DCI format 1_1 in [4, TS 38.212] is used, otherwise $n_{\text{SCID}} = 0$.

7.4.1.1.2 Mapping to physical resources

The UE shall assume the PDSCH DM-RS being mapped to physical resources according to configuration type 1 or configuration type 2 as given by the higher-layer parameter *dmrs-Type*.

	The Accused Instrumentalities (WiFi) practice a method of requiring each transmitting node to transmit a parameter-estimating signal on an unshared said parameter channel. <u>Wi-Fi Access Point</u> IEEE Standard 802.11ac (AP) The Accused Wi-Fi Router Instrumentalities require each transmitting node to transmit a parameter-estimating signal (e.g., training field) on an unshared said parameter channel (e.g., orthogonal code applied to training field). The VHT LTF (long training fields) are used by the receiver to estimate the MIMO channel and equalize the received signal. The number of LTF symbols sent in a packet depends on the number of space-time streams: one LTF for one space-time stream, two LTFs for two space-time streams, four LTFs for three or four space-time streams, six LTFs for five or six space-time streams, eight LTFs for seven or eight space-time streams. Citation 23: VHT-LTF
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21.3.8.3.5 VHT-LTF definition

The VHT Long Training field (VHT-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. The transmitter provides training for $N_{STS, total}$ space-time streams (spatial mapper inputs) used for the transmission of the PSDU(s). For each tone, the MIMO channel that can be estimated is an $N_{RX} \times N_{STS, total}$ matrix. A VHT transmission has a preamble that contains VHT-LTF symbols, where the data tones of each VHT-LTF symbol are multiplied by entries belonging to a matrix $P_{VHT-LTF}$, to enable channel estimation at the receiver. The pilot tones of each VHT-LTF symbol are multiplied by the entries of a matrix $R_{VHT-LTF}$ defined in the following text. The multiplication of the pilot tones in the VHT-LTF symbol by the $R_{VHT-LTF}$ matrix instead of the $P_{VHT-LTF}$ matrix allows receivers to track phase and frequency offset during MIMO channel estimation using the VHT-LTF. The number of VHT-LTF symbols, $N_{VHT-LTF}$, is a function of the total number of space-time streams $N_{STS, total}$ as shown in Table 21-13. As a result the VHT-LTF field consists of one, two, four, six or eight symbols.

Table 21-13—Number of VHT-LTFs required for different numbers of space-time streams

$N_{STS, total}$	$N_{VHT-LTF}$
1	1
2	2
3	4
4	4
5	6
6	6
7	8
8	8

FIG. 11

Source: <https://ieeexplore.ieee.org/document/7786995>, Page 2549, last accessed Mar 07, 2024, Exhibit B

IEEE Standard 802.11ax (AP)

The accused product supporting Wi-Fi Standard 802.11ax requires each transmitting node to transmit a parameter-estimating signal (e.g., training field) on an unshared said parameter channel (e.g., orthogonal code applied to training field).

Citation 24: Using HE-LTF in an UL MU-MIMO transmission

In an UL MU-MIMO transmission using the HE masked HE-LTF sequence mode, the HE-LTF sequence per frequency segment is generated by masking the nonzero elements in the common HE-LTF sequence repeatedly with a distinct orthogonal code as defined by Equation (27-53).

$$HELTf_{k,u,m}^{\text{Mask}} = HELTF_k \cdot \left[P_{8 \times 8} \right]_{M_{r,u} + m, \left(\left(\left\lfloor \frac{k}{N_{\text{HE-LTF-Type}}} \right\rfloor - 1 \right) \bmod 8 \right) + 1} \quad (27-53)$$

where

$HELTf_k$ is the value of the common HE-LTF sequence on subcarrier k generated by one of the equations from Equation (27-41) to Equation (27-52) depending on the bandwidth and the HE-LTF type (excluding the 1x HE-LTF, which shall not be masked).

$\left[P_{8 \times 8} \right]$ is defined in Equation (21-46)

$M_{r,u} + m$ is the row index of the $\left[P_{8 \times 8} \right]$ corresponding to spatial time stream m of user u in the r -th RU

$$N_{\text{HE-LTF-Type}} = \begin{cases} 2, & \text{for 2x HE-LTF} \\ 1, & \text{for 4x HE-LTF} \end{cases}$$

Fig 13

Source: <https://ieeexplore.ieee.org/document/9442429>, Page 590, last accessed March 05, 2024, Exhibit C

Wi-Fi User Equipment

IEEE Standard 802.11ac (UE)

The user equipment (UE) requires each transmitting node to transmit a parameter-estimating signal (e.g., training field) on an unshared said parameter channel (e.g., orthogonal code applied to the training field).

The VHT LTF (long training fields) are used by the receiver to estimate the MIMO channel and equalize the received signal. The number of LTF symbols sent in a packet depends on the number of space-time streams: one LTF for one space-time stream, two LTFs for two space-time streams, four LTFs for three or four space-time streams, six LTFs for five or six space-time streams, eight LTFs for seven or eight space-time streams.

Citation 25: VHT-LTF

21.3.8.3.5 VHT-LTF definition

The VHT Long Training field (VHT-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. The transmitter provides training for $N_{STS,total}$ space-time streams (spatial mapper inputs) used for the transmission of the PSDU(s). For each tone, the MIMO channel that can be estimated is an $N_{RX} \times N_{STS,total}$ matrix. A VHT transmission has a preamble that contains VHT-LTF symbols, where the data tones of each VHT-LTF symbol are multiplied by entries belonging to a matrix $P_{VHT-LTF}$, to enable channel estimation at the receiver. The pilot tones of each VHT-LTF symbol are multiplied by the entries of a matrix $R_{VHT-LTF}$ defined in the following text. The multiplication of the pilot tones in the VHT-LTF symbol by the $R_{VHT-LTF}$ matrix instead of the $P_{VHT-LTF}$ matrix allows receivers to track phase and frequency offset during MIMO channel estimation using the VHT-LTF. The number of VHT-LTF symbols, $N_{VHT-LTF}$, is a function of the total number of space-time streams $N_{STS,total}$ as shown in Table 21-13. As a result the VHT-LTF field consists of one, two, four, six or eight symbols.

Table 21-13—Number of VHT-LTFs required for different numbers of space-time streams

$N_{STS,total}$	$N_{VHT-LTF}$
1	1
2	2
3	4
4	4
5	6
6	6
7	8
8	8

FIG. 12

Source: <https://ieeexplore.ieee.org/document/7786995>, Page 2549, last accessed Mar 15, 2024, Exhibit B

IEEE Standard 802.11ax (UE)

The user equipment (UE) supporting Wi-Fi Standard 802.11ax requires each transmitting node (i.e., Access point) to transmit a parameter-estimating signal (e.g., training field) on an unshared said parameter channel (e.g., orthogonal code applied to training field).

Citation 26: Using HE-LTF symbols in the DL HE MU PPDU

HE-LTF symbols in the DL HE MU PPDU are used to measure the channel for the space-time streams intended for the STA and can also be used to measure the channel for the interfering space-time streams. To successfully demodulate the space-time streams intended for the STA, it is recommended that the STA use the channel knowledge for all space-time streams to reduce the effect of space-time streams allocated to other users.

Fig 14

Source: <https://ieeexplore.ieee.org/document/9442429>, Page 507, last accessed March 15, 2024, Exhibit C

Citation 27: HE DL MU Operation

26.5.1 HE DL MU operation

26.5.1.1 General

HE DL MU operation allows an AP to transmit simultaneously to one or more non-AP STAs in DL OFDMA, DL MU-MIMO, or both.

The PSDU on each RU in an HE MU PPDU shall be padded to end at the same time, indicated by the L-SIG field as described in 27.3.11.5.

Fig 15

Source: <https://ieeexplore.ieee.org/document/9442429>, Page 339, last accessed March 15, 2024, Exhibit C

If this element is not literally satisfied by the disclosures cited herein, it is satisfied under the doctrine of equivalents by the disclosures cited herein because the accused functionality would be insubstantially different from or function in the same way to provide the same result as the relevant claim element.

detecting the parameter-estimating signals on the unshared parameter channels and estimating therefrom at least one unique signal parameter for each of the transmitting nodes; and	<u>Cellular</u> The Accused LTE/5G Base Stations detect the parameter-estimating signals on the unshared parameter channels and estimate therefrom at least one unique signal parameter for each of the transmitting nodes. See 3GPP R1-122385: The BSI and CSH pattern should be configured in a UE-specific manner in order to provide interference randomization among Receiving Points (RPs), in particular for supporting CoMP scenario 4. Uplink MU-MIMO requires orthogonal PUSCH DMRS sequences among the paired UEs. R1-164144: The uplink MU-MIMO has been discussed since Rel-8. The Zadoff-Chu sequence is used for DMRS sequence generation. Different UEs with fully overlapping bandwidth allocation can use the same sequence with different cyclic shifts. However, if the UEs are allocated with partial overlapping bandwidth, different DMRS sequences may be applied so that their DMRS are not orthogonal with different cyclic shifts. In Rel-10, the UL DMRS has been enhanced by applying time domain OCC to support 2 orthogonal DMRS for MU-MIMO with partially overlapping bandwidth allocation. The two scheduled UEs with partially overlapping bandwidth can still have orthogonal DMRS by using different OCC codes. See On Channel Estimation for Multi-User MIMO in LTE-A Uplink: Abstract: In 3GPP Long Term Evolution-Advanced (LTE-A), uplink multi-input-multi-output(MIMO) transmission have been introduced as a key technology to improve the spectrum efficiency. Both single-user MIMO (SU-MIMO) and multi-user MIMO (MU-MIMO) modes are supported. With UL-MIMO, multiple layers of data are mapped on the same set of resources and transmitted simultaneously. Accordingly, the demodulation reference signal (DMRS) in LTE-A applies both frequency domain code division multiplexing and time domain code division multiplexing to support channel estimation for each multiplexed layer. Discrete Fourier transform (DFT)-based channel estimation schemes and the applications for LTE UL-MIMO have been widely studied. However, the orthogonality among DMRS of different layers could be reduced due to the channel conditions. The effect is significant when the arrival times of the paired user equipment (UE) at the receiver are not strictly aligned if MU-
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MIMO is applied. Consequently, the performance of DFT-based channel estimation schemes is affected. In this paper, we demonstrate a novel DFT based channel estimation scheme that can restore the inter-layer orthogonality. Simulation results show that the proposed method provides significant improvement over conventional DFT-based channel estimation methods.

The performance of UL-MIMO depends heavily on the accuracy of channel estimation, which is based on DMRS. For each layer, a DMRS sequence is transmitted. When SM is used, multiple DMRS sequences are transmitted over the same set of single carrier-frequency division multiple access (SC-FDMA) symbols. Different sequence adopts a unique orthogonal cover code so that the receiver can de-multiplex these sequences and estimate the channel corresponding to each layer respectively. The degree of orthogonality preserved at the receiver depends on the channel condition and affects the accuracy of channel estimation.

Here $r_m^{(\lambda,u)}(n)$ is the DMRS sequence for layer λ of UE u in slot m , where $m \in \{0, 1\}$ and $\lambda \in \{0, 1, 2, 3\}$. $\bar{r}(n)$ is the base sequence. $e^{\frac{j2\pi n_{cs,\lambda,u}}{12}}$ can be viewed as the frequency domain orthogonal cover code applied. It is named as cyclic shift (CS) within LTE-A vocabulary, as the application is equivalent to applying a cyclic shift to the transmitted signal in the time domain. $n_{cs,\lambda,u} \in \{0, 1, 2, \dots, 11\}$ is the cyclic shift used for layer λ of UE u . $w^{(\lambda,u)}(m)$ is the time domain orthogonal cover code, it is referred to as orthogonal cover code (OCC) in LTE-A. $w^{(\lambda,u)}(m)$ can be selected from either $[+1, +1]$ or $[+1, -1]$. OCC is frequently used to ensure the orthogonality between DMRS transmissions from the different UEs involved in the MU-MIMO transmission. Compare to CS, OCC does not require the bandwidths allocated for paired UEs to be the same, and hence allows more flexibility in MU-MIMO scheduling.

See 5G NR: The Next Generation Wireless Access Technology, p. 186

these regions, the PDSCH mapping is slightly different than the PDSCH mapping.

Multiple orthogonal reference signals can be created in each DM-RS occasion. The different reference signals are separated in the frequency and code domains, and, in the case of a double-symbol DM-RS, additionally in the time domain. Two different types of demodulation reference signals can be configured, type 1 and type 2, differing in the mapping in the frequency domain and the maximum number of orthogonal reference signals. Type 1 can provide up to four orthogonal signals using a single-symbol DM-RS and up to eight orthogonal reference signals using a double-symbol DM-RS. The corresponding numbers for type 2 are six and twelve. The reference signal types (1 or 2) should not be confused with the mapping types (A or B); different mapping types can be combined with different reference signal types.

The Accused LTE/5G UEs detect the parameter-estimating signals on the unshared parameter channels and estimate therefrom at least one unique signal parameter for each of the transmitting nodes.

5Ghub Tutorial:

5G NR Downlink Physical channels

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Demodulation Reference Signals (DMRS)

Demodulation Reference Signals (DMRS) are used for downlink data demodulation (channel adaptation) and time-frequency synchronization.

PDSCH/PUSCH DM-RS signals are used for decoding the Physical Downlink Shared Channel (PDSCH), which contains the downlink user data. These signals can be divided into Front Loaded (FL) DMRS which occupies 1 to 2 symbols and Additional (Add) DRMS, which occupies 1 to 3 symbols, and is used in high-speed scenarios at the latter part of a slot.

Different DMRS types allow a different maximum number of ports: Type 1: Single-symbol: 4, dual-symbol: up to 8 orthogonal ports, used for SU-MIMO. Type 2: Single-symbol: 6, dual-symbol: up to 12 orthogonal ports, used for MU-MIMO.

DMRS time-frequency mapping position is divided into two different types, as well. Type A, starting from the 3rd or 4th symbol in the slot, and Type B, starting from 1st symbol on scheduled PDSCH and is practical only for cases there is no CORESET on the 1st OFDM symbol.

5G New Radio Paper:

A. Downlink and Uplink Demodulation Reference Signals (DMRS)

DMRS is used by the receiver to produce channel estimates for demodulation of the associated physical channel. The design of DMRS is specific for each physical channel – PBCH, PDCCH, PDSCH, PUSCH, and PUCCH. In all cases, DMRS is UE specific, transmitted on demand, and normally does not extend outside of the scheduled physical resource of the channel it supports. In the sequel, we focus on the DMRS for PDSCH and PUSCH when CP-OFDM is used.

The PDSCH/PUSCH DMRS structure supports a wide range of scenarios, UE capabilities, and use cases. The number of DMRS symbols in a PDSCH/PUSCH duration can be configured; this enables support for very high UE mobility, but also, low DMRS overhead when the scenario allows so. Similarly, the density of DMRS in the frequency domain is configurable to allow for an optimized overhead. The first DMRS instance comes early in the PDSCH/PUSCH transmission; this enables channel estimation to start early in the receiver, thereby reducing the processing latency. DMRS can be on a regular comb structure, and RB bundling is configurable. This is beneficial for efficient, high performance channel estimation. NR DMRS supports massive multi-user MIMO; it can be beamformed and supports up to 12 orthogonal layers. DMRS sequence for CP-OFDM is QPSK based on Gold sequences. For PUSCH with DFT-S-OFDM there is also a low PAPR Zadoff-Chu mode.

The Accused Instrumentalities (WiFi) practice a method comprising a step of detecting the parameter-estimating signals on the unshared parameter channels and estimating therefrom at least one unique signal parameter for each of the transmitting nodes.

Wi-Fi Access Point

IEEE Standard 802.11ac (AP)

The Accused Wi-Fi Router Instrumentalities detect the parameter-estimating signals (e.g., training fields) on the unshared parameter channels (e.g., orthogonal code applied to training field) and estimate therefrom at least one unique signal parameter for each of the transmitting nodes.

The accused product receives a digital data stream comprising multiple spatial streams, it includes a VHT Long Training Field (VHT-LTF). The VHT LTF (long training fields) are used by the receiver to estimate the MIMO channel and equalize the received signal. VHT-LTF allows the receiver to track Phase or Frequency offset during the MIMO channel estimation.

Citation 28: VHT-LTF

21.3.8.3.5 VHT-LTF definition

The VHT Long Training field (VHT-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. The transmitter provides training for $N_{STS,total}$ space-time streams (spatial mapper inputs) used for the transmission of the PSDU(s). For each tone, the MIMO channel that can be estimated is an $N_{RX} \times N_{STS,total}$ matrix. A VHT transmission has a preamble that contains VHT-LTF symbols, where the data tones of each VHT-LTF symbol are multiplied by entries belonging to a matrix $P_{VHT-LTF}$, to enable channel estimation at the receiver. The pilot tones of each VHT-LTF symbol are multiplied by the entries of a matrix $R_{VHT-LTF}$ defined in the following text. The multiplication of the pilot tones in the VHT-LTF symbol by the $R_{VHT-LTF}$ matrix instead of the $P_{VHT-LTF}$ matrix allows receivers to track phase and frequency offset during MIMO channel estimation using the VHT-LTF. The number of VHT-LTF symbols, $N_{VHT-LTF}$, is a function of the total number of space-time streams $N_{STS,total}$ as shown in Table 21-13. As a result the VHT-LTF field consists of one, two, four, six or eight symbols.

Table 21-13—Number of VHT-LTFs required for different numbers of space-time streams

$N_{STS,total}$	$N_{VHT-LTF}$
1	1
2	2
3	4
4	4
5	6
6	6
7	8
8	8

FIG. 13

Source: <https://ieeexplore.ieee.org/document/7786995>, Page 2549, last accessed Mar 07, 2024, Exhibit B

IEEE Standard 802.11ax (AP)

The Accused Wi-Fi Router Instrumentalities using the Wi-Fi Standard 802.11ax detect the parameter-estimating signals (e.g., training fields) on the unshared parameter channels (e.g., orthogonal code applied to training field) and estimate therefrom at least one unique signal parameter for each of the transmitting nodes.

The accused product receives a digital data stream comprising multiple spatial streams, it includes a High Efficiency Long Training Field (HE-LTF). The HE LTF (long training fields) are used by the receiver to estimate the MIMO channel and equalize the received signal.

Citation 29: HE-LTF

27.3.11.10 HE-LTF

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 subcarrier 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. When single stream pilot is used in HE-LTF, the pilot subcarriers of each HE-LTF symbol are multiplied by the entries of a matrix R_{HE-LTF} defined below to allow receivers to track phase and/or frequency offset during MIMO channel estimation using the HE-LTF. Single stream pilots shall be used in the HE-LTF field for SU, DL and UL OFDMA, DL MU-MIMO and partial bandwidth UL MU-MIMO transmissions. Single stream pilots shall be used in the HE-LTF field for a full bandwidth UL MU-MIMO transmission if single stream pilot HE-LTF mode is selected.

Fig 16

Source: <https://ieeexplore.ieee.org/document/9442429>, Page 580, last accessed March 05, 2024, Exhibit C

Wi-Fi User Equipment
IEEE Standard 802.11ac (UE)

The user equipment (UE) supporting 802.11ac detects the parameter-estimating signals (e.g., training fields) on the unshared parameter channels (e.g., orthogonal code applied to the training field) and estimates therefrom at least one unique signal parameter for each of the transmitting nodes.

The user equipment (UE) receives a digital data stream comprising multiple spatial streams, it includes a VHT Long Training Field (VHT-LTF). The VHT LTF (long training fields) are used by the receiver to estimate the MIMO channel and equalize the received signal. VHT-LTF allows the receiver to track Phase or Frequency offset during the MIMO channel estimation.

Citation 30: VHT-LTF

21.3.8.3.5 VHT-LTF definition

The VHT Long Training field (VHT-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. The transmitter provides training for $N_{STS,total}$ space-time streams (spatial mapper inputs) used for the transmission of the PSDU(s). For each tone, the MIMO channel that can be estimated is an $N_{RX} \times N_{STS,total}$ matrix. A VHT transmission has a preamble that contains VHT-LTF symbols, where the data tones of each VHT-LTF symbol are multiplied by entries belonging to a matrix $P_{VHT-LTF}$, to enable channel estimation at the receiver. The pilot tones of each VHT-LTF symbol are multiplied by the entries of a matrix $R_{VHT-LTF}$ defined in the following text. The multiplication of the pilot tones in the VHT-LTF symbol by the $R_{VHT-LTF}$ matrix instead of the $P_{VHT-LTF}$ matrix allows receivers to track phase and frequency offset during MIMO channel estimation using the VHT-LTF. The number of VHT-LTF symbols, $N_{VHT-LTF}$, is a function of the total number of space-time streams $N_{STS,total}$ as shown in Table 21-13. As a result the VHT-LTF field consists of one, two, four, six or eight symbols.

Table 21-13—Number of VHT-LTFs required for different numbers of space-time streams

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

FIG. 14

Source: <https://ieeexplore.ieee.org/document/7786995>, Page 2549, last accessed Mar 15, 2024, Exhibit B

IEEE Standard 802.11ax (UE)

The user equipment (UE) detects the parameter-estimating signals (e.g., training fields) on the unshared parameter channels (e.g., orthogonal code applied to training field) and estimate therefrom at least one unique signal parameter for each of the transmitting nodes.

The user equipment (UE) receives a digital data stream comprising multiple spatial streams, it includes a High Efficiency Long Training Field (HE-LTF). The HE LTF (long training fields) are used by the receiver to estimate the MIMO channel and equalize the received signal.

Citation 31: Using HE-LTF symbols in the DL HE MU PPDU

HE-LTF symbols in the DL HE MU PPDU are used to measure the channel for the space-time streams intended for the STA and can also be used to measure the channel for the interfering space-time streams. To successfully demodulate the space-time streams intended for the STA, it is recommended that the STA use the channel knowledge for all space-time streams to reduce the effect of space-time streams allocated to other users.

Fig 17

Source: <https://ieeexplore.ieee.org/document/9442429>, Page 507, last accessed March 15, 2024, Exhibit C

	Citation 32: HE-LTF 27.3.11.10 HE-LTF 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 subcarrier 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. When single stream pilot is used in HE-LTF, the pilot subcarriers of each HE-LTF symbol are multiplied by the entries of a matrix R_{HE-LTF} defined below to allow receivers to track phase and/or frequency offset during MIMO channel estimation using the HE-LTF. Single stream pilots shall be used in the HE-LTF field for SU, DL and UL OFDMA, DL MU-MIMO and partial bandwidth UL MU-MIMO transmissions. Single stream pilots shall be used in the HE-LTF field for a full bandwidth UL MU-MIMO transmission if single stream pilot HE-LTF mode is selected. Fig 18 Source: https://ieeexplore.ieee.org/document/9442429, Page 580, last accessed March 15, 2024, Exhibit C If this element is not literally satisfied by the disclosures cited herein, it is satisfied under the doctrine of equivalents by the disclosures cited herein because the accused functionality would be insubstantially different from or function in the same way to provide the same result as the relevant claim element.
detecting and distinguishing the information simultaneously received from each of the transmitting nodes	<u>Cellular</u> The Accused LTE/5G Base Stations detect and distinguish the information simultaneously received from each of the transmitting nodes according to their respective said unique estimated signal parameters. See Samsung Delivers the Promises of Massive MIMO:

according to their respective said unique estimated signal parameters.

Samsung's Massive MIMO Solution Benefits

Samsung Massive MIMO Unit (MMU): The key product in the solution is the Samsung Massive MIMO Unit (MMU), which is operating in the 2.5 GHz and CBRS (3.5 GHz) spectrum bands. This product also supports the following RAN technologies:

- 4G LTE
- 5G NR
- Co-deploy 4G LTE and 5G NR.

A key differentiator of Samsung's MMU is its ability to support LTE and 5G NR simultaneously. The "split mode" configuration allocates 32 of the 64 transmit-receiver pairs to each of the RAN technologies. This unique capability reduces the CAPEX spend by MNOs for co-deployment of LTE and 5G in those sites, as the existing equipment supports both technologies in the existing footprint.

High-Density Antenna System with Integrated Radio Control: The high-density antenna 64T64R option allows MNOs to reduce CAPEX as they now need fewer products to cover the same area. When operating in 2.5 GHz markets, the MMU leverages five 10 Gbps CPRI links, while the solution for CBRS markets uses four 10 Gbps CPRI links.

Carrier Aggregation: This MMU supports carrier aggregation and offers different options based on the deployment. For 2.5GHz, Carrier Aggregation supports up to three 20 MHz carriers, creating up to 60MHz of downlink bandwidth, while deployments in CBRS spectrum supports up to five 20MHz channels, offering up to 100 MHz of downlink bandwidth.

MIMO and MU-MIMO: In addition to supports 2x2 and 4x4 single-user MIMO, the MMU supports multi-user MIMO with by allowing up to 16 layers, or independent streams, of downlink transmission for up to 16 users. For 2.5 GHz deployments, the MMU supports up to 2 layers for uplink MU-MIMO transmissions for multi-user MIMO, while the CBRS solution in the 3.5 GHz spectrum allows up to 8 layers for uplink transmissions.

[1503.02192.pdf \(arxiv.org\)](#)

Uplink Performance Evaluation of Massive MU-MIMO Systems

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For uplink signal transmission, the received signal vector at a single BS, which we denote by $\mathbf{y} \in \mathbb{C}^{M \times 1}$ has the following expression:

$$\mathbf{y} = \sqrt{\rho} \mathbf{H} \mathbf{x} + \mathbf{n}, \quad (5)$$

where $\mathbf{x} \in \mathbb{C}^{K \times 1}$ is the signal vector being transmitted by all users, i.e., transmit antennas, $\mathbf{H} \in \mathbb{C}^{M \times K}$ is the uplink channel matrix defined in Eq. 2, $\mathbf{n} \in \mathbb{C}^{M \times 1}$ is a zero-mean noise vector with complex Gaussian distribution and identity covariance matrix, and ρ is the uplink transmit power.

In this paper we consider OFDM block-based transmissions where the frequency-domain data symbols are randomly and independently drawn from a QPSK alphabet with normalized average energy. The transmitted sample from the k -th user, x_k , is the k -th element of $\mathbf{x} = [x_1, \dots, x_K]^T$ with $E[|x_k|^2] = 1$, i.e., the OFDM symbols are normalized so that they present unit variance.

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III. UPLINK DETECTION

Detection techniques must be employed in order to separate each of the data streams transmitted by the various users in a massive MU-MIMO system.

Despite being the optimum detector, the maximum likelihood (ML) detector is highly complex. It has a complexity cost that grows exponentially with the number of transmit antennas, K , and modulation order used, which makes it very complex to be implemented in systems with hundreds of antennas as is the case with massive MIMO systems. Thus, when ML detection is impractical, we must resort to sub-optimal alternatives with reduced complexity [8].

Linear sub-optimal detectors with low complexity, such as MRC (also known as MF), ZF and MMSE detectors, are feasible candidates for the role in massive MIMO systems. In the case where M is much larger than K , i.e., $1 \ll K \ll M$, it is known that those linear detectors (MRC, ZF and MMSE) perform fairly well. They asymptotically achieve capacity as M grows [7] and therefore we will only consider those detectors in this paper.

We consider here the case where the BS has perfect CSI, i.e., it knows $\mathbf{H}$. Let $\mathbf{A}$ be an $M \times K$ linear detector matrix which depends on the channel $\mathbf{H}$. By using a linear detector, the received signal is separated into different data streams by multiplying it with $\mathbf{A}^H$ as follows

$$\mathbf{r} = \mathbf{A}^H \mathbf{y}, \quad (8)$$

where $\mathbf{r}$ is a $K \times 1$ signal vector containing the data streams of the K single-antenna devices.

As stated before, we consider three conventional linear detectors MRC, ZF and MMSE, i.e.,

$$\mathbf{A} = \begin{cases} \mathbf{H} & \text{for MRC} \\ \mathbf{H}(\mathbf{H}^H \mathbf{H})^{-1} & \text{for ZF} \\ \mathbf{H}(\mathbf{H}^H \mathbf{H} + \frac{\sigma_n^2}{\sigma_s^2} \mathbf{I})^{-1} & \text{for MMSE} \end{cases} \quad (9)$$

where σ_s^2 and σ_n^2 are the signal and noise variances, i.e., power, respectively.

See 5G NR: The Next Generation Wireless Access Technology, p. 184

- *Demodulation reference signals* (DM-RS) for PDSCH are intended for channel estimation at the device as part of coherent demodulation. They are present only in the resource blocks used for PDSCH transmission. Similarly, the DM-RS for PUSCH allows the gNB to coherently demodulate the PUSCH. The DM-RS for PDSCH and PUSCH is the focus of this section; DM-RS for PDCCH and PBCH is described in [Chapters 10 and 16](#), respectively.

The Accused LTE/5G UEs detect and distinguish the information simultaneously received from each of the transmitting nodes according to their respective said unique estimated signal parameters.

See e.g.:

5G New Radio Paper:

A. Downlink and Uplink Demodulation Reference Signals (DMRS)

DMRS is used by the receiver to produce channel estimates for demodulation of the associated physical channel. The design of DMRS is specific for each physical channel – PBCH, PDCCH, PDSCH, PUSCH, and PUCCH. In all cases, DMRS is UE specific, transmitted on demand, and normally does not extend outside of the scheduled physical resource of the channel it supports. In the sequel, we focus on the DMRS for PDSCH and PUSCH when CP-OFDM is used.

The PDSCH/PUSCH DMRS structure supports a wide range of scenarios, UE capabilities, and use cases. The number of DMRS symbols in a PDSCH/PUSCH duration can be configured; this enables support for very high UE mobility, but also, low DMRS overhead when the scenario allows so. Similarly, the density of DMRS in the frequency domain is configurable to allow for an optimized overhead. The first DMRS instance comes early in the PDSCH/PUSCH transmission; this enables channel estimation to start early in the receiver, thereby reducing the processing latency. DMRS can be on a regular comb structure, and RB bundling is configurable. This is beneficial for efficient, high performance channel estimation. NR DMRS supports massive multi-user MIMO; it can be beamformed and supports up to 12 orthogonal layers. DMRS sequence for CP-OFDM is QPSK based on Gold sequences. For PUSCH with DFT-S-OFDM there is also a low PAPR Zadoff-Chu mode.

5Ghub Tutorial:

5G NR Downlink Physical channels

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Demodulation Reference Signals (DMRS)

Demodulation Reference Signals (DMRS) are used for downlink data demodulation (channel adaptation) and time-frequency synchronization.

PDSCH/PUSCH DM-RS signals are used for decoding the Physical Downlink Shared Channel (PDSCH), which contains the downlink user data. These signals can be divided into Front Loaded (FL) DMRS which occupies 1 to 2 symbols and Additional (Add) DRMS, which occupies 1 to 3 symbols, and is used in high-speed scenarios at the latter part of a slot.

Different DMRS types allow a different maximum number of ports: Type 1: Single-symbol: 4, dual-symbol: up to 8 orthogonal ports, used for SU-MIMO. Type 2: Single-symbol: 6, dual-symbol: up to 12 orthogonal ports, used for MU-MIMO.

DMRS time-frequency mapping position is divided into two different types, as well. Type A, starting from the 3rd of 4th symbol in the slot, and Type B, starting from 1st symbol on scheduled PDSCH and is practical only for cases there is no CORESET on the 1st OFDM symbol.

TR 36.866 v12.0.1 (2014-03):

7.2 Interference Suppression (IS) receivers

IS receivers refer to receivers that apply linear filtering to the received signal to suppress the interference, as opposed to explicitly cancel the interference. Three types of IS receivers are identified:

- LMMSE-IRC:
 - It is baseline for Rel-11 MMSE-IRC study (refer to TR36.829).
 - No knowledge of interferer parameter(s) is required.
- Enhanced LMMSE-IRC (E-LMMSE-IRC):
 - MMSE-IRC that explicitly considers interferer channel estimates and other interferer knowledge.
 - Interference parameters that can enable interferer channel estimation are needed, including, for example, its DMRS or CRS with PMI/RI.
- Widely linear MMSE-IRC (WLMMSE-IRC):
 - WLMMSE-IRC exploits the additional degrees of freedom from the real and imaginary part of the received signal to enhance suppression of interference
 - Real-valued modulation may be used to increase performance of the WLMMSE-IRC receiver

7.3 Maximum Likelihood (ML) receivers

ML-type of receivers are non-linear in nature. Three types of ML receivers are also identified:

- ML:
 - Full-blown joint detection of useful and interference signals in accordance to the ML criterion
 - Interference parameters that can enable interferer channel estimation and interferer detection at symbol level (e.g. modulation) are needed.
- Reduced complexity ML (R-ML):

- Reduced complexity joint detection of useful and interference modulation symbols in accordance to the ML criterion (e.g. sphere decoding, QR-MLD, MLM, etc.)
- Same interference knowledge as for ML
- Iterative ML and Iterative R-ML:
 - Iterative MAP detection and decoding of useful and interference signals. Both successive and parallel processing implementations may be applied.
 - In addition to the interference knowledge needed for ML, interference knowledge that can enable code word demodulation and decoding is needed.
 - Additionally, assumptions on network coordination may be necessary.

7.4 Interference Cancellation (IC) receivers

IC-type of receivers are also non-linear in nature. Four types of IC receivers are identified

- Linear Code word level SIC (L-CWIC):
 - receiver utilizing successive application of linear detection (e.g.: LMMSE-IRC), decoding, re-encoding, and cancellation
 - May have iteration (e.g. Turbo L-CWIC)
 - May utilize CRC check (e.g. hard L-CWIC)
 - Same interference knowledge as Iterative ML and Iterative R-ML. Additionally, interferer RNTI knowledge may be needed.
 - Additionally, assumptions on network coordination may be necessary.
- ML-CWIC:
 - receiver utilizing successive application of ML or reduced complexity ML detection, decoding, re-encoding, and cancellation
 - May have iteration (e.g. Turbo ML-CWIC)

- May utilize CRC check (e.g. hard ML-CWIC)
- Same interference knowledge as L-CWIC
- Additionally, assumptions on network coordination may be necessary.
- Symbol level IC (SLIC):
 - successive cancellation receiver utilizing successive application of linear detection, reconstruction, and cancellation
 - May have iteration
 - Same interference knowledge as ML/R-ML.
- Parallel interference cancellation (PIC):
 - Parallel IC as opposed to successive IC, otherwise similar to SIC
 - PIC receivers can be categorized into L-CW-PIC, ML-CW-PIC or SL-PIC similar to SIC

The Accused Instrumentalities (WiFi) practice a method of detecting and distinguishing the information simultaneously received from each of the transmitting nodes according to their respective said unique estimated signal parameters.

Wi-Fi Access Point

IEEE Standard 802.11ac (AP)

The Accused Wi-Fi Router Instrumentalities detect and distinguish the information simultaneously received from each of the transmitting nodes (e.g., WiFi STAs) according to their respective said unique estimated signal parameters.

The accused product receives a digital data stream comprising multiple spatial streams, it includes a VHT Long Training Field (VHT-LTF). The VHT LTF (long training fields) are used by the receiver to estimate the MIMO channel and equalize the received signal. VHT-LTF allows the receiver to track Phase or Frequency offset during the MIMO channel estimation.

Citation 33: Stations support SU-MIMO

21.3.11 SU-MIMO and DL-MU-MIMO Beamforming

21.3.11.1 General

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. With DL-MU-MIMO beamforming, disjoint subsets of the space-time streams are intended for reception at different STAs.

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. The feedback report format is described in 9.4.1.49.

For DL-MU-MIMO beamforming, the receive signal vector in subcarrier k at beamformee u , $y_{k,u} = [y_{k,u,0}, y_{k,u,1}, \dots, y_{k,N_{STx}-1}]^T$, is shown in Equation (21-101), where $x_k = [x_{k,0}^T, x_{k,1}^T, \dots, x_{k,N_{STx}-1}^T]^T$ denotes the transmit signal vector in subcarrier k for all N_{user} beamformers, with $x_{k,u} = [x_{k,u,0}, x_{k,u,1}, \dots, x_{k,N_{STx}-1}]^T$ being the transmit signal for beamformee u .

$$y_{k,u} = H_{k,u} \times [Q_{k,0}, Q_{k,1}, \dots, Q_{k,N_{STx}-1}] \times x_k + n \quad (21-101)$$

where

$H_{k,u}$ is the channel matrix from the beamformer to beamformee u in subcarrier k with dimensions $N_{RX} \times N_{TX}$

FIG. 15

Source: <https://ieeexplore.ieee.org/document/7786995>, Page 2579, last accessed Mar 07, 2024, Exhibit B

Citation 34: VHT-LTF

21.3.8.3.5 VHT-LTF definition

The VHT Long Training field (VHT-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. The transmitter provides training for $N_{STS,total}$ space-time streams (spatial mapper inputs) used for the transmission of the PSDU(s). For each tone, the MIMO channel that can be estimated is an $N_{RX} \times N_{STS,total}$ matrix. A VHT transmission has a preamble that contains VHT-LTF symbols, where the data tones of each VHT-LTF symbol are multiplied by entries belonging to a matrix $P_{VHT-LTF}$, to enable channel estimation at the receiver. The pilot tones of each VHT-LTF symbol are multiplied by the entries of a matrix $R_{VHT-LTF}$ defined in the following text. The multiplication of the pilot tones in the VHT-LTF symbol by the $R_{VHT-LTF}$ matrix instead of the $P_{VHT-LTF}$ matrix allows receivers to track phase and frequency offset during MIMO channel estimation using the VHT-LTF. The number of VHT-LTF symbols, $N_{VHT-LTF}$, is a function of the total number of space-time streams $N_{STS,total}$ as shown in Table 21-13. As a result the VHT-LTF field consists of one, two, four, six or eight symbols.

Table 21-13—Number of VHT-LTFs required for different numbers of space-time streams

$N_{STS,total}$	$N_{VHT-LTF}$
1	1
2	2
3	4
4	4
5	6
6	6
7	8
8	8

FIG. 16

Source: <https://ieeexplore.ieee.org/document/7786995>, Page 2549, last accessed Mar 07, 2024, Exhibit B

IEEE Standard 802.11ax (AP)

The Wi-Fi Standard 802.11ax detects and distinguishes the information simultaneously received from each of the transmitting nodes (e.g., Wi-Fi STAs) according to their respective said unique estimated signal parameters.

Citation 35: High Efficiency (HE) PHY specification

27. High Efficiency (HE) PHY specification

27.1 Introduction

27.1.1 Introduction to the HE PHY

The HE PHY extends the maximum number of users supported for DL MU-MIMO transmissions to 8 users per resource unit (RU) and provides support for DL and UL orthogonal frequency division multiple access (OFDMA) as well as for UL MU-MIMO. Both DL and UL MU-MIMO transmissions are supported on portions of the PPDU bandwidth (on resource units greater than or equal to 106 tones). In an MU-MIMO resource unit, there is support for up to 8 users with up to 4 space-time streams per user with the total across all users not exceeding 8 space-time streams.

Fig 19

Source: <https://ieeexplore.ieee.org/document/9442429>, Page 466, last accessed March 05, 2024, Exhibit C

Citation 36: Features supported by High Efficiency (HE) AP

An HE AP may support the following features:

- MU-MIMO reception on an RU in an HE TB PPDU where the RU spans the entire PPDU bandwidth (UL MU-MIMO).
- MU-MIMO reception on an RU in an HE TB PPDU where the RU does not span the entire PPDU bandwidth (UL MU-MIMO within OFDMA).
- Reception of the payload on an RU in an HE MU PPDU where RU spans the entire PPDU bandwidth or a 106-tone RU within 20 MHz PPDU bandwidth.

Fig 20

Source: <https://ieeexplore.ieee.org/document/9442429>, Page 468, last accessed March 05, 2024, Exhibit C

Citation 37: RU support in UL MU-MIMO

27.3.3.2 UL MU-MIMO

27.3.3.2.1 Introduction

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

27.3.3.2.2 Supported RU sizes in UL MU-MIMO

An AP that sets the Partial Bandwidth UL MU-MIMO subfield of the HE PHY Capabilities Information field in the HE Capabilities element that it transmits to 1 shall support receiving an RU in an HE TB PPDU where MU-MIMO is employed in the RU, the RU size is greater than or equal to 106 tones, and the RU does not span the entire PPDU bandwidth.

A non-AP STA that sets the Partial Bandwidth UL MU-MIMO subfield of the HE PHY Capabilities Information field in the HE Capabilities element that it transmits to 1 shall support transmitting an RU in an HE TB PPDU where UL MU-MIMO is employed in the RU, the RU size is greater than or equal to 106 tones, and the RU does not span the entire PPDU bandwidth.

A STA that sets the Partial Bandwidth UL MU-MIMO subfield to 1 shall set the Full Bandwidth UL MU-MIMO subfield in the HE PHY Capabilities Information field to 1.

Fig 21

Source: <https://ieeexplore.ieee.org/document/9442429>, Page 510, last accessed March 05, 2024, Exhibit C

Wi-Fi User Equipment

IEEE Standard 802.11ac (UE)

The user equipment (UE) detect and distinguish the information simultaneously received from each of the transmitting nodes (e.g., APs) according to their respective said unique estimated signal parameters.

The user equipment (UE) receives a digital data stream comprising multiple spatial streams, it includes a VHT Long Training Field (VHT-LTF). The VHT LTF (long training fields) are used by the receiver to estimate the MIMO channel and equalize the received signal. VHT-LTF allows the receiver to track Phase or Frequency offset during the MIMO channel estimation.

Citation 38: Stations support DL-MU-MIMO

21.3.11 SU-MIMO and DL-MU-MIMO Beamforming

21.3.11.1 General

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. With DL-MU-MIMO beamforming, disjoint subsets of the space-time streams are intended for reception at different STAs.

For SU-MIMO beamforming, the steering matrix Q_k can be determined from the beamforming feedback matrix F_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. The feedback report format is described in 9.4.1.49.

For DL-MU-MIMO beamforming, the receive signal vector in subcarrier k at beamformee u , $y_{k,u} = [y_{k,0}, y_{k,1}, \dots, y_{k,N_{\text{ant}}-1}]^T$, is shown in Equation (21-101), where $x_k = [x_{k,0}, x_{k,1}, \dots, x_{k,N_{\text{ant}}-1}]^T$ denotes the transmit signal vector in subcarrier k for all N_{ant} beamformers, with $x_{k,u} = [x_{k,0}, x_{k,1}, \dots, x_{k,N_{\text{ant}}-1}]^T$ being the transmit signal for beamformee u .

$$y_{k,u} = H_{k,u} \times [Q_{k,0}, Q_{k,1}, \dots, Q_{k,N_{\text{ant}}-1}] \times x_k + n \quad (21-101)$$

where

$H_{k,u}$ is the channel matrix from the beamformer to beamformee u in subcarrier k with dimensions $N_{\text{RX}} \times N_{\text{TX}}$.

FIG. 17

Source: <https://ieeexplore.ieee.org/document/7786995>, Page 2579, last accessed Mar 15, 2024, Exhibit B

Citation 39: VHT-LTF

21.3.8.3.5 VHT-LTF definition

The VHT Long Training field (VHT-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. The transmitter provides training for $N_{STS,total}$ space-time streams (spatial mapper inputs) used for the transmission of the PSDU(s). For each tone, the MIMO channel that can be estimated is an $N_{RX} \times N_{STS,total}$ matrix. A VHT transmission has a preamble that contains VHT-LTF symbols, where the data tones of each VHT-LTF symbol are multiplied by entries belonging to a matrix $P_{VHT-LTF}$, to enable channel estimation at the receiver. The pilot tones of each VHT-LTF symbol are multiplied by the entries of a matrix $R_{VHT-LTF}$ defined in the following text. The multiplication of the pilot tones in the VHT-LTF symbol by the $R_{VHT-LTF}$ matrix instead of the $P_{VHT-LTF}$ matrix allows receivers to track phase and frequency offset during MIMO channel estimation using the VHT-LTF. The number of VHT-LTF symbols, $N_{VHT-LTF}$, is a function of the total number of space-time streams $N_{STS,total}$ as shown in Table 21-13. As a result the VHT-LTF field consists of one, two, four, six or eight symbols.

Table 21-13—Number of VHT-LTFs required for different numbers of space-time streams

$N_{STS,total}$	$N_{VHT-LTF}$
1	1
2	2
3	4
4	4
5	6
6	6
7	8
8	8

FIG. 18

Source: <https://ieeexplore.ieee.org/document/7786995>, Page 2549, last accessed Mar 15, 2024, Exhibit B

IEEE Standard 802.11ax (UE)

The user equipment (UE) supporting Wi-Fi Standard 802.11ax detects and distinguishes the information simultaneously received from each of the transmitting nodes (e.g., Wi-Fi STAs) according to their respective said unique estimated signal parameters (for e.g., Phase and/or Frequency offset etc).

Citation 40: High Efficiency (HE) PHY specification

27. High Efficiency (HE) PHY specification

27.1 Introduction

27.1.1 Introduction to the HE PHY

The HE PHY extends the maximum number of users supported for DL MU-MIMO transmissions to 8 users per resource unit (RU) and provides support for DL and UL orthogonal frequency division multiple access (OFDMA) as well as for UL MU-MIMO. Both DL and UL MU-MIMO transmissions are supported on portions of the PPDU bandwidth (on resource units greater than or equal to 106 tones). In an MU-MIMO resource unit, there is support for up to 8 users with up to 4 space-time streams per user with the total across all users not exceeding 8 space-time streams.

Fig 22

Source: <https://ieeexplore.ieee.org/document/9442429>, Page 466, last accessed March 15, 2024, Exhibit C

Citation 41: Features supported by non-AP High Efficiency (HE) STA

	A non-AP HE STA shall support the following features: — Reception of an HE MU PPDU where the RU allocated to the non-AP STA is not utilizing MU-MIMO (DL OFDMA). — Transmission of an HE TB PPDU where the RU allocated to the non-AP STA is not utilizing MU-MIMO (UL OFDMA). — Reception of an HE MU PPDU consisting of a single RU spanning the entire PPDU bandwidth and utilizing MU-MIMO (DL MU-MIMO). The maximum number of spatial streams per user the non-AP STA can receive in the DL MU-MIMO transmission shall be equal to the minimum of 4 and the maximum number of spatial streams supported for reception of HE SU PPDU. The non-AP STA shall be able to receive its intended spatial streams in a DL MU-MIMO transmission with a total number of spatial streams across all users of at least 4. — Reception of an HE MU PPDU with up to 4 HE-LTF OFDM symbols, where the RU allocated to the non-AP STA does not span the entire PPDU bandwidth. — Responding with the requested beamforming feedback in an HE sounding procedure with the maximum number of space-time streams in the HE sounding NDP that the non-AP STA can respond to being at least 4. — Reception of the HE-SIG-B field in an HE MU PPDU at HE-MCSs 0 to 5. — Single spatial stream HE-MCSs 0 to 7 in all supported channel widths and RU sizes for HE MU PPDU (receive) or HE TB PPDU (transmit). — 40 MHz and 80 MHz channel widths and all RU sizes and locations applicable to the 40 MHz and 80 MHz channel widths in the 5 GHz band (transmit and receive), except for a 20 MHz-only non-AP HE STA in which case the 40 MHz and 80 MHz channel widths, 996-tone RU, and 484-tone RU sizes in the 5 GHz and 6 GHz bands are not applicable. — Reception of an HE MU PPDU with a 2x HE-LTF and 0.8 μs GI duration on the HE-LTF and Data field OFDM symbols. — Reception of an HE MU PPDU with a 2x HE-LTF and 1.6 μs GI duration on the HE-LTF and Data field OFDM symbols. — Transmission of an HE TB PPDU with a 2x HE-LTF and 1.6 μs GI duration on the HE-LTF and Data field OFDM symbols. — Reception of an HE MU PPDU with a 4x HE-LTF and 3.2 μs GI duration on the HE-LTF and Data field OFDM symbols. — Transmission of an HE TB PPDU with a 4x HE-LTF and 3.2 μs GI duration on the HE-LTF and Data field OFDM symbols. — Reception of an HE MU PPDU with a 4x HE-LTF and 0.8 μs GI duration on the HE-LTF and the Data field OFDM symbols if the non-AP HE STA supports HE ER SU PPDU with the same HE-LTF and GI combinations. — 26-, 52-, and 106-tone RU sizes on locations allowed in 27.3.2.8 in the primary 20 MHz channel within 40 MHz channel width if the non-AP HE STA is a 20 MHz operating non-AP HE STA and
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that is capable of supporting 40 MHz channel width (B0 of the Supported Channel Width Set subfield in the HE PHY Capabilities Information field in the HE Capabilities element is 1) (transmit and receive).

- 26-, 52-, and 106-tone RU sizes on locations allowed in 27.3.2.8 in the primary 20 MHz channel within 80 MHz channel width if the non-AP HE STA is a 20 MHz operating non-AP HE STA and is operating in the 5 GHz or 6 GHz bands (transmit and receive).

Fig 23

Source: <https://ieeexplore.ieee.org/document/9442429>, Pages 469 & 470, last accessed March 15, 2024, Exhibit C

Citation 42: RU support in DL MU-MIMO

27.3.3.1 DL MU-MIMO

27.3.3.1.1 Supported RU sizes in DL MU-MIMO

A STA that sets the Partial Bandwidth DL MU-MIMO subfield of the HE PHY Capabilities Information field in the HE Capabilities element that it transmits to 1 shall support receiving an RU in an HE MU PPDU where MU-MIMO is employed in the RU, the RU size is greater than or equal to 106 tones, and the RU does not span the entire PPDU bandwidth.

Fig 24

Source: <https://ieeexplore.ieee.org/document/9442429>, Page 509, last accessed March 15, 2024, Exhibit C

Citation 43: HE-LTF

27.3.11.10 HE-LTF

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 subcarrier 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. When single stream pilot is used in HE-LTF, the pilot subcarriers of each HE-LTF symbol are multiplied by the entries of a matrix R_{HE-LTF} defined below to allow receivers to track phase and/or frequency offset during MIMO channel estimation using the HE-LTF. Single stream pilots shall be used in the HE-LTF field for SU, DL and UL OFDMA, DL MU-MIMO and partial bandwidth UL MU-MIMO transmissions. Single stream pilots shall be used in the HE-LTF field for a full bandwidth UL MU-MIMO transmission if single stream pilot HE-LTF mode is selected.

Fig 25

Source: <https://ieeexplore.ieee.org/document/9442429>, Page 580, last accessed March 15, 2024, Exhibit C

If this element is not literally satisfied by the disclosures cited herein, it is satisfied under the doctrine of equivalents by the disclosures cited herein because the accused functionality would be insubstantially different from or function in the same way to provide the same result as the relevant claim element.

'071 Claim 2	<u>Accused Products</u>
The method of claim 1 , <u>wherein said providing a plurality of parameter channels comprises using channel-spreading technology.</u>	<u>Cellular</u> The accused products include the method of claim 1, <i>see</i> Claim 1, wherein said providing a plurality of parameter channels comprises using channel-spreading technology. For example, in LTE and 5G the reference symbols on the uplink and on the downlink are constructed and then spread over multiple non overlapping Resource Elements (REs). <u>TS 38.211 v15.8.0:</u> 7.4.1 Reference signals 7.4.1.1 Demodulation reference signals for PDSCH 7.4.1.1.1 Sequence generation The UE shall assume the sequence $r(n)$ is defined by $r(n) = \frac{1}{\sqrt{2}}(1 - 2 \cdot c(2n)) + j \frac{1}{\sqrt{2}}(1 - 2 \cdot c(2n+1)).$

'071 Claim 2	<u>Accused Products</u>
	where the pseudo-random sequence $c(i)$ is defined in clause 5.2.1. The pseudo-random sequence generator shall be initialized with $c_{\text{init}} = \left(2^{17} \left(N_{\text{slot}}^{\text{slot}} n_{\text{s,f}}^{\mu} + l + 1 \right) \left(2N_{\text{ID}}^{\text{scid}} + 1 \right) + 2N_{\text{ID}}^{\text{scid}} + n_{\text{scid}} \right) \bmod 2^{31}$ where l is the OFDM symbol number within the slot, $n_{\text{s,f}}^{\mu}$ is the slot number within a frame, and - $N_{\text{ID}}^0, N_{\text{ID}}^1 \in \{0, 1, \dots, 65535\}$ are given by the higher-layer parameters <i>scramblingID0</i> and <i>scramblingID1</i>, respectively, in the <i>DMRS-DownlinkConfig</i> IE if provided and the PDSCH is scheduled by PDCCH using DCI format 1_1 with the CRC scrambled by C-RNTI, MCS-C-RNTI, or CS-RNTI - $N_{\text{ID}}^0 \in \{0, 1, \dots, 65535\}$ is given by the higher-layer parameter <i>scramblingID0</i> in the <i>DMRS-DownlinkConfig</i> IE if provided and the PDSCH is scheduled by PDCCH using DCI format 1_0 with the CRC scrambled by C-RNTI, MCS-C-RNTI, or CS-RNTI; - $N_{\text{ID}}^{\text{scid}} = N_{\text{ID}}^{\text{cell}}$ otherwise; The quantity $n_{\text{scid}} \in \{0, 1\}$ is given by the DM-RS sequence initialization field, in the DCI associated with the PDSCH transmission if DCI format 1_1 in [4, TS 38.212] is used, otherwise $n_{\text{scid}} = 0$. The quantity $n_{\text{scid}} \in \{0, 1\}$ is given by the DM-RS sequence initialization field, in the DCI associated with the PDSCH transmission if DCI format 1_1 in [4, TS 38.212] is used, otherwise $n_{\text{scid}} = 0$. 7.4.1.1.2 <u>Mapping to physical resources</u> The UE shall assume the PDSCH DM-RS being mapped to physical resources according to configuration type 1 or configuration type 2 as given by the higher-layer parameter <i>dmrs-Type</i>. The UE shall assume the sequence $r(m)$ is scaled by a factor $\beta_{\text{PDSCH}}^{\text{DMRS}}$ to conform with the transmission power specified in [6, TS 38.214] and mapped to resource elements $(k, l)_{p,\mu}$ according to

'071 Claim 2	<u>Accused Products</u>
	$a_{k,l}^{(p,\mu)} = \beta_{\text{PDSCH}}^{\text{DMRS}} w_f(k') w_t(l') r(2n + k')$ $k = \begin{cases} 4n + 2k' + \Delta & \text{Configuration type 1} \\ 6n + k' + \Delta & \text{Configuration type 2} \end{cases}$ $k' = 0,1$ $l = \bar{l} + l'$ $n = 0,1,\dots$ where $w_f(k')$, $w_t(l')$, and Δ are given by Tables 7.4.1.1.2-1 and 7.4.1.1.2-2 and the following conditions are fulfilled: - the resource elements are within the common resource blocks allocated for PDSCH transmission <u>TS 36.211 v11.5.</u>

'071 Claim 2	<u>Accused Products</u>
	6.10.3 <u>UE-specific reference signals associated with PDSCH</u> UE-specific reference signals associated with PDSCH - are transmitted on antenna port(s) $p = 5$, $p = 7$, $p = 8$ or $p = 7, 8, \dots, v+6$, where v is the number of layers used for transmission of the PDSCH; - are present and are a valid reference for PDSCH demodulation only if the PDSCH transmission is associated with the corresponding antenna port according to clause 7.1 of 3GPP TS 36.213 [4]; - are transmitted only on the physical resource blocks upon which the corresponding PDSCH is mapped. A UE-specific reference signal associated with PDSCH is not transmitted in resource elements (k, l) in which one of the physical channels or physical signals other than the UE-specific reference signals defined in 6.1 are transmitted using resource elements with the same index pair (k, l) regardless of their antenna port p. 6.10.3.1 Sequence generation For antenna port 5, the UE-specific reference-signal sequence $r_{n_s}(m)$ is defined by $r_{n_s}(m) = \frac{1}{\sqrt{2}}(1 - 2 \cdot c(2m)) + j \frac{1}{\sqrt{2}}(1 - 2 \cdot c(2m+1)), \quad m = 0, 1, \dots, 12N_{\text{RB}}^{\text{PDSCH}} - 1$ where $N_{\text{RB}}^{\text{PDSCH}}$ denotes the bandwidth in resource blocks of the corresponding PDSCH transmission. The pseudo-random sequence $c(i)$ is defined in clause 7.2. The pseudo-random sequence generator shall be initialised with $c_{\text{init}} = (\lfloor n_s/2 \rfloor + 1) \cdot (2N_{\text{ID}}^{\text{cell}} + 1) \cdot 2^{16} + n_{\text{RNTI}}$ at the start of each subframe where n_{RNTI} is as described in clause 7.1 3GPP TS 36.213 [4]. <u>TS 38.211 v15.8.0:</u>

'071 Claim 2	<u>Accused Products</u>
	7.3.1.3 <u>Layer mapping</u> The UE shall assume that complex-valued modulation symbols for each of the codewords to be transmitted are mapped onto one or several layers according to Table 7.3.1.3-1. Complex-valued modulation symbols $d^{(q)}(0), \dots, d^{(q)}(M_{\text{symb}}^{(q)} - 1)$ for codeword q shall be mapped onto the layers $x(i) = [x^{(0)}(i) \dots x^{(v-1)}(i)]^T, i = 0, 1, \dots, M_{\text{symb}}^{\text{layer}} - 1$ where v is the number of layers and $M_{\text{symb}}^{\text{layer}}$ is the number of modulation symbols per layer.

Table 6.3.3.2-1: Codeword-to-layer mapping for spatial multiplexing

Number of layers	Number of codewords	Codeword-to-layer mapping $i = 0, 1, \dots, M_{\text{symb}}^{\text{layer}} - 1$
1	1	$x^{(0)}(i) = d^{(0)}(i)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)}$
2	1	$x^{(0)}(i) = d^{(0)}(2i)$ $x^{(1)}(i) = d^{(0)}(2i+1)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 2$
2	2	$x^{(0)}(i) = d^{(0)}(i)$ $x^{(1)}(i) = d^{(1)}(i)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} = M_{\text{symb}}^{(1)}$
3	1	$x^{(0)}(i) = d^{(0)}(3i)$ $x^{(1)}(i) = d^{(0)}(3i+1)$ $x^{(2)}(i) = d^{(0)}(3i+2)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 3$
3	2	$x^{(0)}(i) = d^{(0)}(i)$ $x^{(1)}(i) = d^{(1)}(2i)$ $x^{(2)}(i) = d^{(1)}(2i+1)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} = M_{\text{symb}}^{(1)} / 2$
4	1	$x^{(0)}(i) = d^{(0)}(4i)$ $x^{(1)}(i) = d^{(0)}(4i+1)$ $x^{(2)}(i) = d^{(0)}(4i+2)$ $x^{(3)}(i) = d^{(0)}(4i+3)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 4$
4	2	$x^{(0)}(i) = d^{(0)}(2i)$ $x^{(1)}(i) = d^{(0)}(2i+1)$ $x^{(2)}(i) = d^{(1)}(2i)$ $x^{(3)}(i) = d^{(1)}(2i+1)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 2 = M_{\text{symb}}^{(1)} / 2$
5	2	$x^{(0)}(i) = d^{(0)}(2i)$ $x^{(1)}(i) = d^{(0)}(2i+1)$ $x^{(2)}(i) = d^{(1)}(3i)$ $x^{(3)}(i) = d^{(1)}(3i+1)$ $x^{(4)}(i) = d^{(1)}(3i+2)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 2 = M_{\text{symb}}^{(1)} / 3$
6	2	$x^{(0)}(i) = d^{(0)}(3i)$ $x^{(1)}(i) = d^{(0)}(3i+1)$ $x^{(2)}(i) = d^{(0)}(3i+2)$ $x^{(3)}(i) = d^{(1)}(3i)$ $x^{(4)}(i) = d^{(1)}(3i+1)$ $x^{(5)}(i) = d^{(1)}(3i+2)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 3 = M_{\text{symb}}^{(1)} / 3$
7	2	$x^{(0)}(i) = d^{(0)}(3i)$ $x^{(1)}(i) = d^{(0)}(3i+1)$ $x^{(2)}(i) = d^{(0)}(3i+2)$ $x^{(3)}(i) = d^{(1)}(4i)$ $x^{(4)}(i) = d^{(1)}(4i+1)$ $x^{(5)}(i) = d^{(1)}(4i+2)$ $x^{(6)}(i) = d^{(1)}(4i+3)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 3 = M_{\text{symb}}^{(1)} / 4$

'071 Claim 2	<u>Accused Products</u>
	TS 38.211 v15.8.0: 6.4.1 Reference signals 6.4.1.1 <u>Demodulation reference signal for PUSCH</u> 6.4.1.1.1 Sequence generation 6.4.1.1.1.1 Sequence generation when transform precoding is disabled If transform precoding for PUSCH is not enabled, the sequence $r(n)$ shall be generated according to $r(n) = \frac{1}{\sqrt{2}}(1 - 2 \cdot c(2n)) + j \frac{1}{\sqrt{2}}(1 - 2 \cdot c(2n+1))$ where the pseudo-random sequence $c(i)$ is defined in clause 5.2.1. The pseudo-random sequence generator shall be initialized with $c_{\text{init}} = \left(2^{17} \left(N_{\text{symbol}}^{\text{slot}} n_{s,f}^{\mu} + l + 1 \right) \left(2N_{\text{ID}}^{\text{scid}} + 1 \right) + 2N_{\text{ID}}^{\text{scid}} + n_{\text{scid}} \right) \bmod 2^{31}$ where l is the OFDM symbol number within the slot, $n_{s,f}^{\mu}$ is the slot number within a frame, and - $N_{\text{ID}}^0, N_{\text{ID}}^1 \in \{0, 1, \dots, 65535\}$ are given by the higher-layer parameters <i>scramblingID0</i> and <i>scramblingID1</i>, respectively, in the <i>DMRS-UplinkConfig</i> IE if provided and the PUSCH is scheduled by DCI format 0_1 or by a PUSCH transmission with a configured grant; - $N_{\text{ID}}^0 \in \{0, 1, \dots, 65535\}$ is given by the higher-layer parameter <i>scramblingID0</i> in the <i>DMRS-UplinkConfig</i> IE if provided and the PUSCH is scheduled by DCI format 0_0 with the CRC scrambled by C-RNTI, MCS-C-RNTI, or CS-RNTI; - $N_{\text{ID}}^{\text{scid}} = N_{\text{ID}}^{\text{cell}}$ otherwise. The quantity $n_{\text{scid}} \in \{0, 1\}$ is indicated by the DM-RS initialization field, if present, either in the DCI associated with the PUSCH transmission if DCI format 0_1 in [4, TS 38.212] is used or by the higher layer parameter <i>dmrs-SeqInitialization</i>, if present, for a Type 1 PUSCH transmission with a configured grant, otherwise $n_{\text{scid}} = 0$.

6.4.1.1.3 Precoding and mapping to physical resources

The sequence shall be mapped to the intermediate quantity $\tilde{a}_{k,l}^{(\tilde{p}_j, \mu)}$ according to

- if transform precoding is not enabled,

$$\begin{aligned}\tilde{a}_{k,l}^{(\tilde{p}_j, \mu)} &= w_r(k') w_t(l') r(2n + k') \\ k &= \begin{cases} 4n + 2k' + \Delta & \text{Configuration type 1} \\ 6n + k' + \Delta & \text{Configuration type 2} \end{cases} \\ k' &= 0, 1 \\ l &= \bar{l} + l' \\ n &= 0, 1, \dots \\ \bar{l} &= 0, 1, \dots, \nu - 1\end{aligned}$$

- if transform precoding is enabled

$$\begin{aligned}\tilde{a}_{k,l}^{(\tilde{p}_j, \mu)} &= w_r(k') w_t(l') r(2n + k') \\ k &= 4n + 2k' + \Delta \\ k' &= 0, 1 \\ l &= \bar{l} + l' \\ n &= 0, 1, \dots\end{aligned}$$

where $w_r(k')$, $w_t(l')$, and Δ are given by Tables 6.4.1.1.3-1 and 6.4.1.1.3-2 and the configuration type is given by the higher-layer parameter *DMRS-UplinkConfig*, and both k' and Δ correspond to $\tilde{p}_0, \dots, \tilde{p}_{\nu-1}$. The intermediate quantity $\tilde{a}_{k,l}^{(\tilde{p}_j, \mu)} = 0$ if Δ corresponds to any other antenna ports than $\tilde{p}_j$.

TS 36.211 v11.5.0

'071 Claim 2	<u>Accused Products</u>
	5.5.2 Demodulation reference signal 5.5.2.1 <u>Demodulation reference signal for PUSCH</u> 5.5.2.1.1 Reference signal sequence The PUSCH demodulation reference signal sequence $r_{\text{PUSCH}}^{(\lambda)}(\cdot)$ associated with layer $\lambda \in \{0,1,\dots,\nu-1\}$ is defined by $r_{\text{PUSCH}}^{(\lambda)}(m \cdot M_{\text{sc}}^{\text{RS}} + n) = w^{(\lambda)}(m) r_{u,v}^{(\alpha_\lambda)}(n)$ where $m = 0,1$ $n = 0,\dots,M_{\text{sc}}^{\text{RS}} - 1$ and $M_{\text{sc}}^{\text{RS}} = M_{\text{sc}}^{\text{PUSCH}}$ Subclause 5.5.1 defines the sequence $r_{u,v}^{(\alpha_\lambda)}(0),\dots,r_{u,v}^{(\alpha_\lambda)}(M_{\text{sc}}^{\text{RS}} - 1)$. The orthogonal sequence $w^{(\lambda)}(m)$ is given by $[w^{(\lambda)}(0) \ w^{(\lambda)}(1)] = [1 \ 1]$ for DCI format 0 if the higher-layer parameter <i>Activate-DMRS-with OCC</i> is not set or if the temporary C-RNTI was used to transmit the most recent uplink-related DCI for the transport block associated with the corresponding PUSCH transmission, otherwise it is given by Table 5.5.2.1.1-1 using the cyclic shift field in most recent uplink-related DCI 3GPP TS 36.212 [3] for the transport block associated with the corresponding PUSCH transmission. The cyclic shift α_λ in a slot n_s is given as $\alpha_\lambda = 2\pi n_{\text{cs},\lambda}/12$ with $n_{\text{cs},\lambda} = (n_{\text{DMRS}}^{(1)} + n_{\text{DMRS},\lambda}^{(2)} + n_{\text{PN}}(n_s)) \bmod 12$ where the values of $n_{\text{DMRS}}^{(1)}$ is given by Table 5.5.2.1.1-2 according to the parameter <i>cyclicShift</i> provided by higher layers, $n_{\text{DMRS},\lambda}^{(2)}$ is given by the cyclic shift for DMRS field in most recent uplink-related DCI 3GPP TS 36.212 [3] for the transport block associated with the corresponding PUSCH transmission where the value of $n_{\text{DMRS},\lambda}^{(2)}$ is given in Table 5.5.2.1.1-1.

5.3 Physical uplink shared channel

The baseband signal representing the physical uplink shared channel is defined in terms of the following steps:

- scrambling
- modulation of scrambled bits to generate complex-valued symbols
- mapping of the complex-valued modulation symbols onto one or several transmission layers
- transform precoding to generate complex-valued symbols
- precoding of the complex-valued symbols
- mapping of precoded complex-valued symbols to resource elements
- generation of complex-valued time-domain SC-FDMA signal for each antenna port

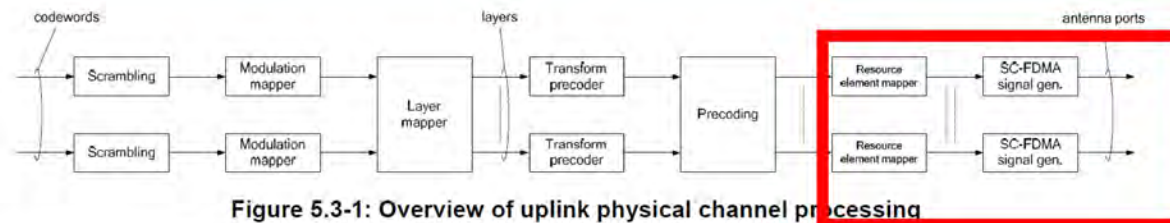


Figure 5.3-1: Overview of uplink physical channel processing

Wi-Fi Access Point

IEEE Standard 802.11ac (AP)

'071 Claim 2

Accused Products

The Accused Wi-Fi Router Instrumentalities provide a plurality of parameter channels (e.g., orthogonal codes applied to training fields including L-STF, L-LTF, VHT-STF, VHT-LTF) on the network in addition to the shared communication channel (e.g., data portion of a frame).

Citation 44: VHT PPDU frame with VHT-LTF Field

21.3.2 VHT PPDU format

A single PPDU format is defined for this PHY: the VHT PPDU format. Figure 21-4 shows the VHT PPDU format.

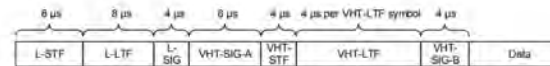


Figure 21-4—VHT PPDU format

The fields of the VHT PPDU format are summarized in Table 21-4.

Table 21-4—Fields of the VHT PPDU

Field	Description
L-STF	Non-HT Short Training field
L-LTF	Non-HT Long Training field
L-SIG	Non-HT SIGNAL field
VHT-SIG-A	VHT Signal A field
VHT-STF	VHT Short Training field
VHT-LTF	VHT Long Training field
VHT-SIG-B	VHT Signal B field
Data	The Data field carrying the PSDU(s)

FIG. 19

Source: <https://ieeexplore.ieee.org/document/7786995>, Page 2514, last accessed Mar 07, 2024, Exhibit B

The primary channel-spreading technology used by devices supporting 802.11ac is Orthogonal Frequency Division Multiplexing (OFDM). OFDM is a modulation technique that divides the available frequency spectrum into multiple subchannels, each using a different orthogonal carrier frequency. This enables parallel transmission of data streams over

'071 Claim 2	<u>Accused Products</u>
	these subchannels, improving spectral efficiency and providing resistance against frequency-selective fading and interference. Citation 45: VHT PPDU frame with VHT-LTF Field 17.3 OFDM PHY 17.3.1 Introduction Subclause 17.3 provides a convergence procedure in which PSDUs are converted to and from PPDU. During transmission, the PSDU shall be provided with a PHY preamble and header to create the PPDU. At the receiver, the PHY preamble and header are processed to aid in demodulation and delivery of the PSDU. 17.3.2 PPDU format 17.3.2.1 General Figure 17-1 shows the format for the PPDU including the OFDM PHY preamble, OFDM PHY header, PSDU, tail bits, and pad bits. The PHY header contains the following fields: LENGTH, RATE, a reserved bit, an even parity bit, and the SERVICE field. In terms of modulation, the LENGTH, RATE, reserved bit, and parity bit (with 6 zero tail bits appended) constitute a separate single OFDM symbol, denoted SIGNAL, which is transmitted with the most robust combination of BPSK modulation and a coding rate of $R = 1/2$. The SERVICE field of the PHY header and the PSDU (with 6 zero tail bits and pad bits appended), denoted as DATA, are transmitted at the data rate described in the RATE field and may constitute multiple OFDM symbols. The tail bits in the SIGNAL symbol enable decoding of the RATE and LENGTH fields immediately after the reception of the tail bits. The RATE and LENGTH fields are required for decoding the DATA part of the packet. In addition, the CCA mechanism is augmented by predicting the duration of the packet from the contents of the RATE and LENGTH fields, even if the data rate is not supported by the STA. Each of these fields is described in detail in 17.3.3, 17.3.4, and 17.3.5. FIG. 20 Source: https://ieeexplore.ieee.org/document/7786995, Page 2283, last accessed Mar 07, 2024, Exhibit B IEEE Standard 802.11ax (AP)

'071 Claim 2	Accused Products																						
	The Wi-Fi Standard 802.11ax provides a plurality of parameter channels (e.g., orthogonal codes applied to training fields including L-STF, L-LTF, HE-STF, HE-LTF) on the network which uses a spreading code. Citation 46: Parameter channels in HE TB PPDU Format The format of the HE TB PPDU is defined as in Figure 27-11 (HE TB PPDU format). This format is used for a transmission that is a response to a triggering frame from an AP. The format of the HE TB PPDU is the same as the HE SU PPDU except that the duration of the HE-STF field in the HE TB PPDU is twice the duration of the HE-STF field in the HE SU PPDU. <table><tr><td>8 μs</td><td>8 μs</td><td>4 μs</td><td>4 μs</td><td>8 μs</td><td>8 μs</td><td colspan="5">Variable durations per HE-LTF symbol</td></tr><tr><td>L-STF</td><td>L-LTF</td><td>L-SIG</td><td>RL-SIG</td><td>HE-SIG-A</td><td>HE-STF</td><td>HE-LTF</td><td>...</td><td>HE-LTF</td><td>Data</td><td>PE</td></tr></table> Figure 27-11—HE TB PPDU format Fig 26 Source: https://ieeexplore.ieee.org/document/9442429, Page 512, last accessed March 05, 2024, Exhibit C	8 μs	8 μs	4 μs	4 μs	8 μs	8 μs	Variable durations per HE-LTF symbol					L-STF	L-LTF	L-SIG	RL-SIG	HE-SIG-A	HE-STF	HE-LTF	...	HE-LTF	Data	PE
8 μs	8 μs	4 μs	4 μs	8 μs	8 μs	Variable durations per HE-LTF symbol																	
L-STF	L-LTF	L-SIG	RL-SIG	HE-SIG-A	HE-STF	HE-LTF	...	HE-LTF	Data	PE													

	Citation 47: Channels occupied by HE TB PDU
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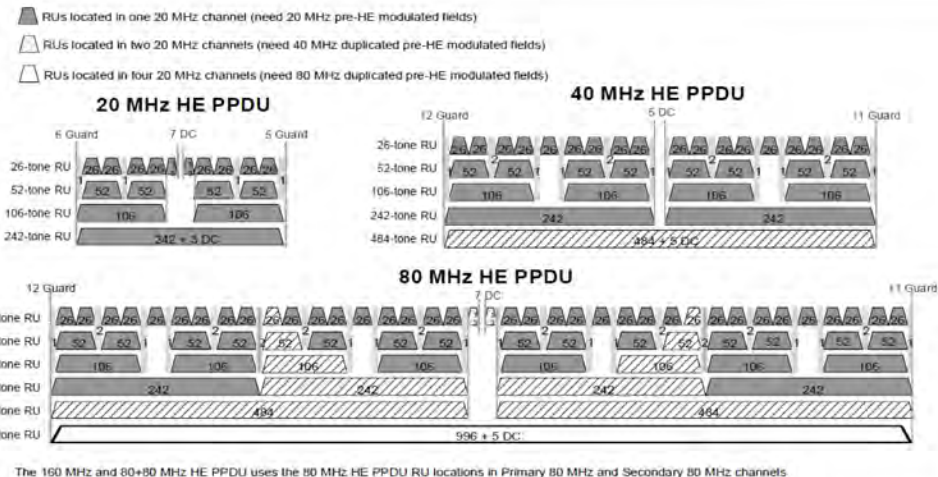


Figure 27-12—Number of 20 MHz channels occupied by the pre-HE modulated fields in an HE TB PPDU

Fig 27

Source: <https://ieeexplore.ieee.org/document/9442429>, Page 513, last accessed March 05, 2024, Exhibit C

OFDMA is a key feature introduced in 802.11ax. It extends the concept of OFDM by dividing each channel into smaller resource units called Resource Units (RUs). These RUs can be allocated to different users or devices simultaneously, enabling more efficient use of the available spectrum. OFDMA allows the access point (AP) to schedule transmissions to multiple clients within a single channel simultaneously, improving the network's ability to handle multiple devices and diverse traffic demands.

Citation 48: OFDMA in Channel-spreading

orthogonal frequency division multiple access (OFDMA) high-efficiency (HE) physical layer (PHY) protocol data unit (PPDU) (OFDMA HE PPDU): A 20 MHz HE PPDU with resource units (RUs) smaller than 242-tone, or a 40 MHz HE PPDU with RUs smaller than 484-tone, or an 80 MHz HE PPDU with RUs smaller than 996-tone, or a 160 MHz or 80+80 MHz HE PPDU with RUs smaller than 2×996-tone.

Fig 28

Source: <https://ieeexplore.ieee.org/document/9442429>, Page 44, last accessed March 05, 2024, Exhibit C

Citation 49: OFDMA in Channel-spreading

27.3.1.2 OFDMA

OFDMA is an OFDM-based multiple access scheme where different subsets of subcarriers are allocated to different users, and this scheme allows simultaneous data transmission to or from one or more users. In OFDMA, users are allocated different subsets of subcarriers that can change from one PPDU to the next. The difference between OFDM and OFDMA is illustrated in Figure 27-4. Similar to OFDM, OFDMA employs multiple subcarriers, but the subcarriers are divided into several groups where each group is referred to as an RU. With OFDMA, different transmit powers may be applied to different RUs.

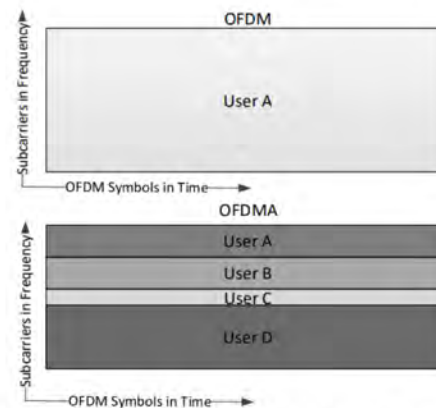


Figure 27-4—Illustration of OFDM and OFDMA concepts

Fig 29

'071 Claim 2**Accused Products**

Source: <https://ieeexplore.ieee.org/document/9442429>, Page 498, last accessed March 05, 2024, Exhibit C

Wi-Fi User Equipment**IEEE Standard 802.11ac (UE)**

The user equipment (UE) supporting 802.11ac provides a plurality of parameter channels (e.g., orthogonal codes applied to training fields including L-STF, L-LTF, VHT-STF, VHT-LTF) on the network in addition to the shared communication channel (e.g., the data portion of a frame).

Citation 50: VHT PPDU frame with VHT-LTF Field**21.3.2 VHT PPDU format**

A single PPDU format is defined for this PHY: the VHT PPDU format. Figure 21-4 shows the VHT PPDU format.

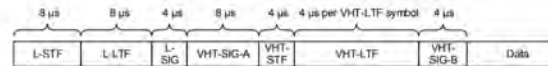


Figure 21-4—VHT PPDU format

The fields of the VHT PPDU format are summarized in Table 21-4.

Table 21-4—Fields of the VHT PPDU

Field	Description
L-STF	Non-HT Short Training field
L-LTF	Non-HT Long Training field
L-SIG	Non-HT SIGNAL field
VHT-SIG-A	VHT Signal A field
VHT-STF	VHT Short Training field
VHT-LTF	VHT Long Training field
VHT-SIG-B	VHT Signal B field
Data	The Data field carrying the PSDU(s)

FIG. 21

Source: <https://ieeexplore.ieee.org/document/7786995>, Page 2514, last accessed Mar 15, 2024, Exhibit B

'071 Claim 2	<u>Accused Products</u>
	The primary channel-spreading technology used by user equipment (UE) supporting 802.11ac is Orthogonal Frequency Division Multiplexing (OFDM). OFDM is a modulation technique that divides the available frequency spectrum into multiple subchannels, each using a different orthogonal carrier frequency. This enables parallel transmission of data streams over these subchannels, improving spectral efficiency and providing resistance against frequency-selective fading and interference.

Citation 51: VHT PPDU frame with VHT-LTF Field

17.3 OFDM PHY

17.3.1 Introduction

Subclause 17.3 provides a convergence procedure in which PSDUs are converted to and from PPDU. During transmission, the PSDU shall be provided with a PHY preamble and header to create the PPDU. At the receiver, the PHY preamble and header are processed to aid in demodulation and delivery of the PSDU.

17.3.2 PPDU format

17.3.2.1 General

Figure 17-1 shows the format for the PPDU including the OFDM PHY preamble, OFDM PHY header, PSDU, tail bits, and pad bits. The PHY header contains the following fields: LENGTH, RATE, a reserved bit, an even parity bit, and the SERVICE field. In terms of modulation, the LENGTH, RATE, reserved bit, and parity bit (with 6 zero tail bits appended) constitute a separate single OFDM symbol, denoted SIGNAL, which is transmitted with the most robust combination of BPSK modulation and a coding rate of $R = 1/2$. The SERVICE field of the PHY header and the PSDU (with 6 zero tail bits and pad bits appended), denoted as DATA, are transmitted at the data rate described in the RATE field and may constitute multiple OFDM symbols. The tail bits in the SIGNAL symbol enable decoding of the RATE and LENGTH fields immediately after the reception of the tail bits. The RATE and LENGTH fields are required for decoding the DATA part of the packet. In addition, the CCA mechanism is augmented by predicting the duration of the packet from the contents of the RATE and LENGTH fields, even if the data rate is not supported by the STA. Each of these fields is described in detail in 17.3.3, 17.3.4, and 17.3.5.

FIG. 22

Source: <https://ieeexplore.ieee.org/document/7786995>, Page 2283, last accessed Mar 15, 2024, Exhibit B

IEEE Standard 802.11ax (UE)

The user equipment (UE) supporting Wi-Fi Standard 802.11ax provides a plurality of parameter channels (e.g., orthogonal codes applied to training fields including L-STF, L-LTF, HE-STF, HE-LTF) on the network which uses a spreading code.

Citation 52: Parameter channels in HE TB PPDU Format

The format of the HE TB PPDU is defined as in Figure 27-11 (HE TB PPDU format). This format is used for a transmission that is a response to a triggering frame from an AP.

The format of the HE TB PPDU is the same as the HE SU PPDU except that the duration of the HE-STF field in the HE TB PPDU is twice the duration of the HE-STF field in the HE SU PPDU.

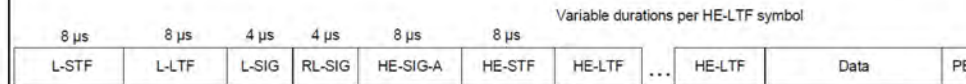


Figure 27-11—HE TB PPDU format

Fig 30

Source: <https://ieeexplore.ieee.org/document/9442429>, Page 512, last accessed March 15, 2024, Exhibit C

Citation 53: Channels occupied by HE TB PPDU

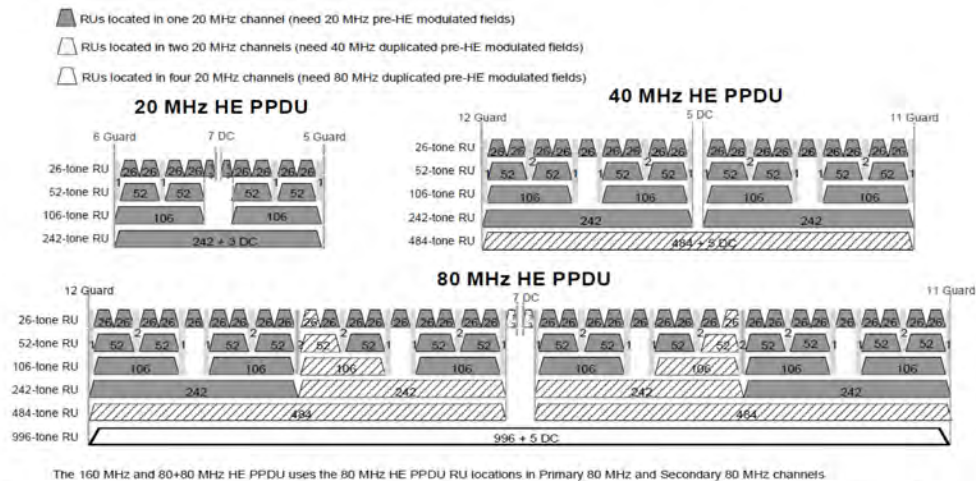


Figure 27-12—Number of 20 MHz channels occupied by the pre-HE modulated fields in an HE TB PPDU

'071 Claim 2	<u>Accused Products</u>
	Fig 31 Source: https://ieeexplore.ieee.org/document/9442429, Page 513, last accessed March 15, 2024, Exhibit C OFDMA is a key feature introduced in 802.11ax. It extends the concept of OFDM by dividing each channel into smaller resource units called Resource Units (RUs). These RUs can be allocated to different users or devices simultaneously, enabling more efficient use of the available spectrum. OFDMA allows the user equipment (UE) to schedule transmissions to multiple clients within a single channel simultaneously, improving the network's ability to handle multiple devices and diverse traffic demands. Citation 54: OFDMA in Channel-spreading orthogonal frequency division multiple access (OFDMA) high-efficiency (HE) physical layer (PHY) protocol data unit (PPDU) (OFDMA HE PPDU): A 20 MHz HE PPDU with resource units (RUs) smaller than 242-tone, or a 40 MHz HE PPDU with RUs smaller than 484-tone, or an 80 MHz HE PPDU with RUs smaller than 996-tone, or a 160 MHz or 80+80 MHz HE PPDU with RUs smaller than 2×996-tone. Fig 32 Source: https://ieeexplore.ieee.org/document/9442429, Page 44, last accessed March 15, 2024, Exhibit C

Citation 55: OFDMA in Channel-spreading**27.3.1.2 OFDMA**

OFDMA is an OFDM-based multiple access scheme where different subsets of subcarriers are allocated to different users, and this scheme allows simultaneous data transmission to or from one or more users. In OFDMA, users are allocated different subsets of subcarriers that can change from one PPDU to the next. The difference between OFDM and OFDMA is illustrated in Figure 27-4. Similar to OFDM, OFDMA employs multiple subcarriers, but the subcarriers are divided into several groups where each group is referred to as an RU. With OFDMA, different transmit powers may be applied to different RUs.

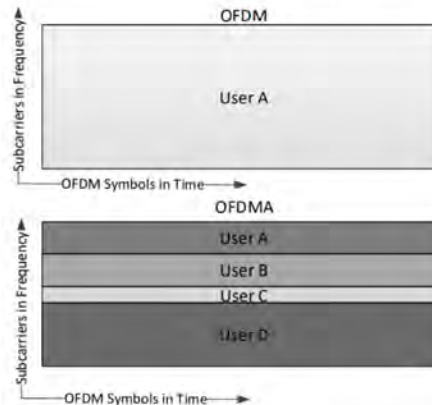
**Figure 27-4—Illustration of OFDM and OFDMA concepts**

Fig 33

Source: <https://ieeexplore.ieee.org/document/9442429>, Page 498, last accessed March 15, 2024, Exhibit C

If this element is not literally satisfied by the disclosures cited herein, it is satisfied under the doctrine of equivalents by the disclosures cited herein because the accused functionality would be insubstantially different from or function in the same way to provide the same result as the relevant claim element.

'071 Claim 3	<u>Accused Products</u>
The method of claim 2, wherein said channel spreading technology comprises at least one of FDMA, TDMA, CDMA, and SDMA.	<u>Cellular</u> The accused products include the method of claim 2, <i>see</i> Claim 2, wherein said channel spreading technology comprises at least one of FDMA, TDMA, CDMA, and SDMA. For example, in LTE and 5G multiple access technologies the sources in the time domain are divided into time slots and the different time slots are assigned to different UEs (“TDMA”); the resources in frequency domain are divided into a set of frequency resources (“FDMA”) and the resulting frequency resources are shared among different UEs. In spatial domain, beamforming at the eNB and gNB creates multiple beams, the different beam forming different UEs (“SDMA”). <u>LTE Book:</u> 6.2 Transmission Resource Structure The downlink transmission resources in LTE possess dimensions of time, frequency and space. The spatial dimension, measured in “layers”, is accessed by means of multiple “antenna ports” at the eNodeB; for each antenna port a Reference Signal (RS) is provided to enable the User Equipment (UE) to estimate the radio channel (see Section 8.2); the techniques for using multiple antenna ports to exploit multiple spatial layers are explained in Section 11.2. The time-frequency resources for each transmit antenna port are subdivided according to the following structure: the largest unit of time is the 10 ms radio frame, which is subdivided into ten 1 ms subframes, each of which is split into two 0.5 ms slots. Each slot comprises seven OFDM symbols in the case of the normal Cyclic Prefix (CP) length, or six if the extended CP is configured in the cell as explained in Section 5.4.1. In the frequency domain, resources are grouped in units of 12 subcarriers (thus occupying a total of 180 kHz with a subcarrier spacing of 15 kHz), such that one unit of 12 subcarriers for a duration of one slot is termed a Resource Block (RB).¹ The smallest unit of resource is the Resource Element (RE), which consists of one subcarrier for a duration of one OFDM symbol. An RB thus comprises 84 REs in the case of the normal cyclic prefix length, and 72 REs in the case of the extended cyclic prefix. The detailed resource structure is shown in Figure 6.1 for the normal cyclic prefix length.

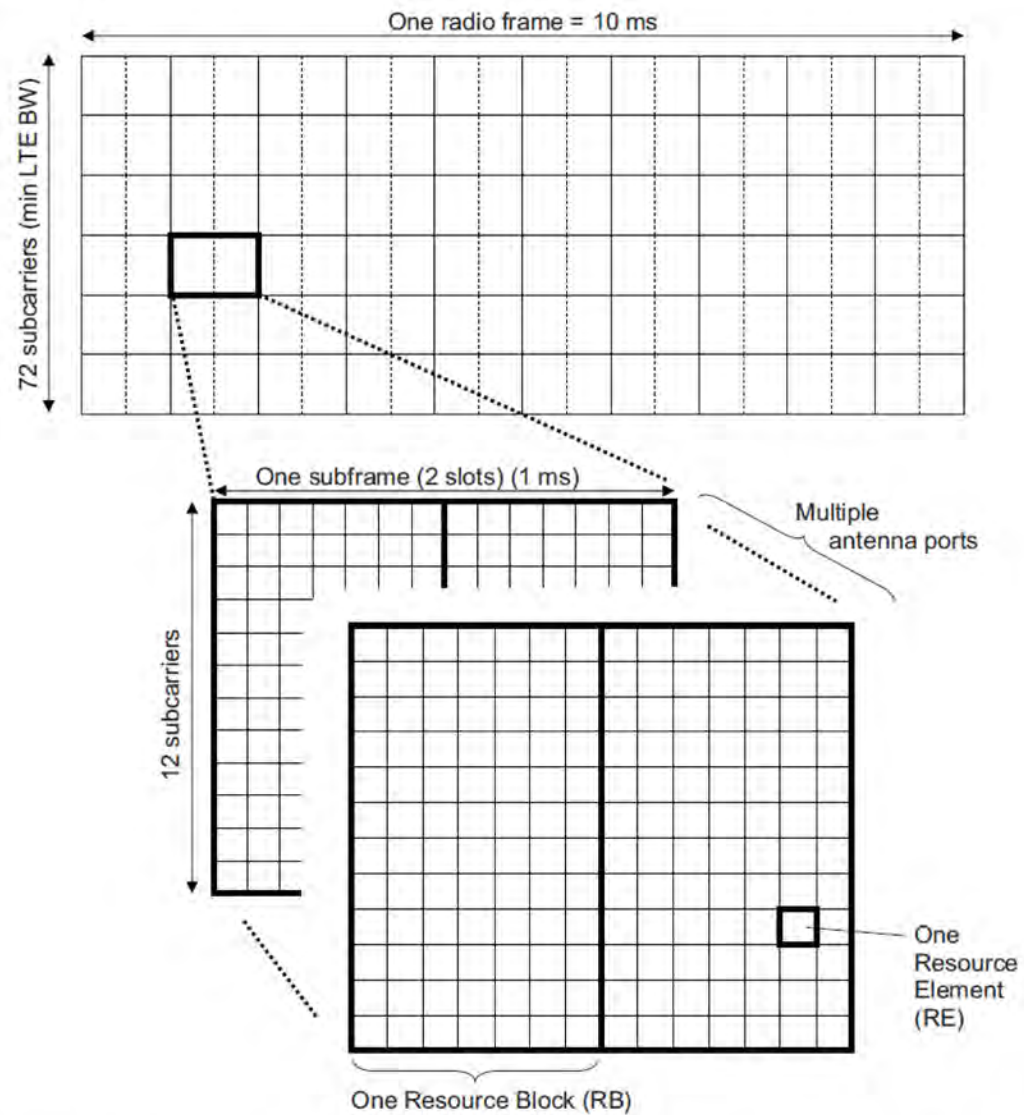
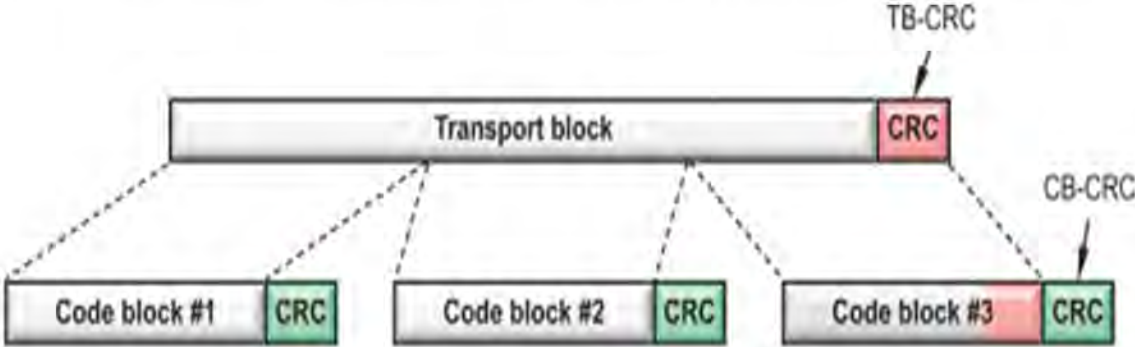


Figure 6.1: Basic time-frequency resource structure of LTE (normal cyclic prefix case).

5G NR

'071 Claim 3	Accused Products
	<u>Transport Block Size (TBS) Calculation (Techplayon Article)</u> August 16, 2020Author3GPP Specification, 5G MAC Layer, 5G NR, 5G Physical Layer Transport Block in 5G NR, is nothing but the payload, which is passed between the MAC and Phy Layers, specifically for the shared data channel such as PDSCH and PUSCH. A Transport Block undergoes Phy layer processing at the transmitter before being mapped onto the PDSCH for transmission over the air interface. A Transport block is added with CRC and segmented into code blocks as shown as below. The transport block consists of up to million bits and the code block consists of up to 8448 bits.  The diagram illustrates the structure of a Transport Block. At the top, a long horizontal bar represents the 'Transport block'. To its right, a red box labeled 'CRC' is connected to the main bar by a dashed line. An arrow labeled 'TB-CRC' points to this red box. Below the 'Transport block' bar, three dashed lines branch out to three separate blocks. Each block is labeled 'Code block #1', 'Code block #2', and 'Code block #3' respectively. To the right of each code block is a green box labeled 'CRC'. An arrow labeled 'CB-CRC' points to the green CRC box of 'Code block #3'. <u>Time-Frequency resource (GaussianWaves Article)</u> A <i>resource element</i> is the smallest time-frequency resource over one subcarrier of a single OFDM symbol. It is identified as $(k,l)_{p,\mu}$ where k is the index of the subcarrier in the frequency domain, l is the OFDM symbol position in time domain, p is the antenna port and μ is the subcarrier spacing configuration defined in Table 1 above. A <i>resource block</i> (a.k.a <i>physical resource block – PRB</i>) is a block of $N_{sc}^{RB} = 12$ subcarriers over which the transmissions are scheduled. 5G NR physical layer uses time-frequency resource (<i>physical resource block</i>) for transmission. A resource grid consists of $N_{grid,x}^{size,\mu}$ subcarriers and $N_{subframe,\mu}^{subframe,\mu}$ number of OFDM symbols (<i>Table 2 and 3</i>).

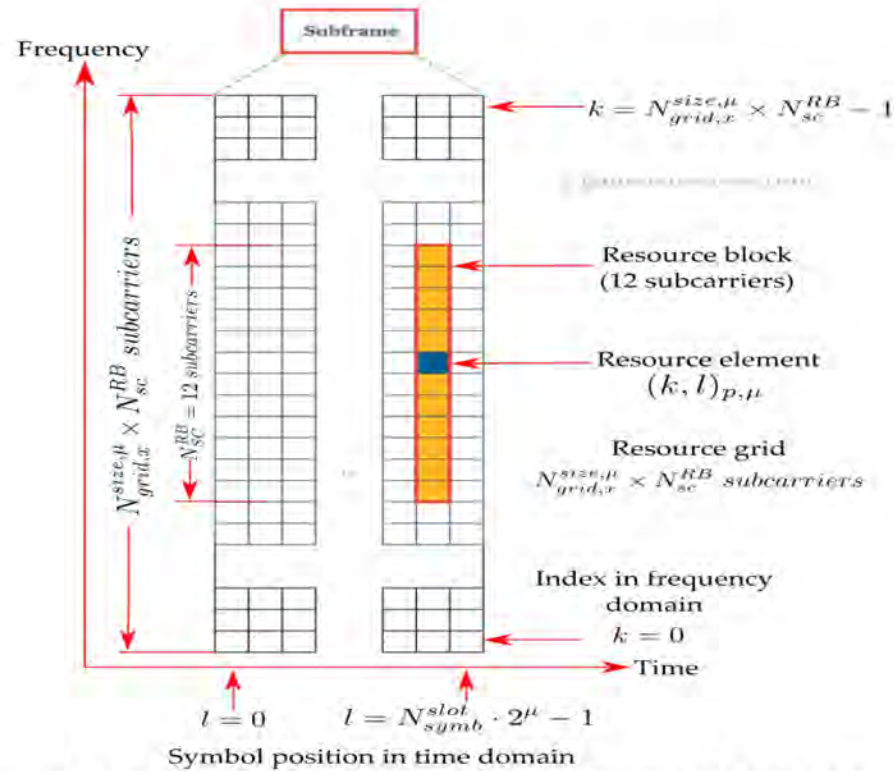


Figure 3: Resource element, Resource block, Resource grid in 5G NR

The Accused Instrumentalities (WiFi) practice a method wherein requiring each transmitting node to transmit a parameter-estimating signal includes requiring each transmitting node to transmit the parameter-estimating signal while simultaneously transmitting information on the shared communication channel.

'071 Claim 3	<u>Accused Products</u>
	<u>Wi-Fi Access Point</u> IEEE Standard 802.11ac (AP) The Accused Wi-Fi Router Instrumentalities require each transmitting node (e.g., WiFi STAs) to transmit a parameter-estimating signal (e.g., training field) while simultaneously transmitting information on the shared communication channel. The VHT LTF (long training fields) are used by the receiver to estimate the MIMO channel and equalize the received signal. The number of LTF symbols sent in a packet depends on the number of space-time streams: one LTF for one space-time stream, two LTFs for two space-time streams, four LTFs for three or four space-time streams, six LTFs for five or six space-time streams, eight LTFs for seven or eight space-time streams.

Citation 11: VHT-LTF

21.3.8.3.5 VHT-LTF definition

The VHT Long Training field (VHT-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. The transmitter provides training for $N_{STS, total}$ space-time streams (spatial mapper inputs) used for the transmission of the PSDU(s). For each tone, the MIMO channel that can be estimated is an $N_{RX} \times N_{STS, total}$ matrix. A VHT transmission has a preamble that contains VHT-LTF symbols, where the data tones of each VHT-LTF symbol are multiplied by entries belonging to a matrix $P_{VHT-LTF}$, to enable channel estimation at the receiver. The pilot tones of each VHT-LTF symbol are multiplied by the entries of a matrix $R_{VHT-LTF}$ defined in the following text. The multiplication of the pilot tones in the VHT-LTF symbol by the $R_{VHT-LTF}$ matrix instead of the $P_{VHT-LTF}$ matrix allows receivers to track phase and frequency offset during MIMO channel estimation using the VHT-LTF. The number of VHT-LTF symbols, $N_{VHT-LTF}$, is a function of the total number of space-time streams $N_{STS, total}$ as shown in Table 21-13. As a result the VHT-LTF field consists of one, two, four, six or eight symbols.

Table 21-13—Number of VHT-LTFs required for different numbers of space-time streams

$N_{STS, total}$	$N_{VHT-LTF}$
1	1
2	2
3	4
4	4
5	6
6	6
7	8
8	8

FIG. 11

Source: <https://ieeexplore.ieee.org/document/7786995>, Page 2549, last accessed Mar 07, 2024, Exhibit B

Citation 12: Stations support SU-MIMO

21.3.11 SU-MIMO and DL-MU-MIMO Beamforming

21.3.11.1 General

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. With DL-MU-MIMO beamforming, disjoint subsets of the space-time streams are intended for reception at different STAs.

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. The feedback report format is described in 9.4.1.49.

For DL-MU-MIMO beamforming, the receive signal vector in subcarrier k at beamformee u , $y_{k,u} = [y_{k,u}^T, y_{k,u}^T, \dots, y_{k,u}^T]^T$, is shown in Equation (21-101), where $x_k = [x_{k,0}^T, x_{k,1}^T, \dots, x_{k,N_{\text{MIMO}}-1}^T]^T$ denotes the transmit signal vector in subcarrier k for all N_{MIMO} beamformers, with $x_{k,u} = [x_{k,u}^T, x_{k,u}^T, \dots, x_{k,u}^T]^T$ being the transmit signal for beamformee u .

$$y_{k,u} = H_{k,u} \times [Q_{k,0}, Q_{k,1}, \dots, Q_{k,N_{\text{MIMO}}-1}] \times x_k + n \quad (21-101)$$

where

$H_{k,u}$ is the channel matrix from the beamformer to beamformee u in subcarrier k with dimensions $N_{\text{RX}_u} \times N_{\text{TX}}$

FIG. 12

Source: <https://ieeexplore.ieee.org/document/7786995>, Page 2579, last accessed Mar 07, 2024, Exhibit B

The primary channel-spreading technology used by devices supporting 802.11ac is Orthogonal Frequency Division Multiplexing (OFDM). OFDM is a modulation technique that divides the available frequency spectrum into multiple subchannels, each using a different orthogonal carrier frequency. This enables parallel transmission of data streams over these subchannels, improving spectral efficiency and providing resistance against frequency-selective fading and interference.

Citation 56: VHT PPDU frame with VHT-LTF Field

	17.3 OFDM PHY 17.3.1 Introduction Subclause 17.3 provides a convergence procedure in which PSDUs are converted to and from PPDU. During transmission, the PSDU shall be provided with a PHY preamble and header to create the PPDU. At the receiver, the PHY preamble and header are processed to aid in demodulation and delivery of the PSDU. 17.3.2 PPDU format 17.3.2.1 General Figure 17-1 shows the format for the PPDU including the OFDM PHY preamble, OFDM PHY header, PSDU, tail bits, and pad bits. The PHY header contains the following fields: LENGTH, RATE, a reserved bit, an even parity bit, and the SERVICE field. In terms of modulation, the LENGTH, RATE, reserved bit, and parity bit (with 6 zero tail bits appended) constitute a separate single OFDM symbol, denoted SIGNAL, which is transmitted with the most robust combination of BPSK modulation and a coding rate of $R = 1/2$. The SERVICE field of the PHY header and the PSDU (with 6 zero tail bits and pad bits appended), denoted as DATA, are transmitted at the data rate described in the RATE field and may constitute multiple OFDM symbols. The tail bits in the SIGNAL symbol enable decoding of the RATE and LENGTH fields immediately after the reception of the tail bits. The RATE and LENGTH fields are required for decoding the DATA part of the packet. In addition, the CCA mechanism is augmented by predicting the duration of the packet from the contents of the RATE and LENGTH fields, even if the data rate is not supported by the STA. Each of these fields is described in detail in 17.3.3, 17.3.4, and 17.3.5. FIG. 23 Source: https://ieeexplore.ieee.org/document/7786995, Page 2283, last accessed Mar 07, 2024, Exhibit B IEEE Standard 802.11ax (AP) The Wi-Fi standard 802.11ax provides the transmitting nodes (e.g., STAs) on a shared communication channel of a wireless digital network and each transmitting nodes (e.g., STAs) transmit parameter-estimating signals (e.g., training fields). Citation 57: HE-LTF
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27.3.11.10 HE-LTF

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 subcarrier 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. When single stream pilot is used in HE-LTF, the pilot subcarriers of each HE-LTF symbol are multiplied by the entries of a matrix R_{HE-LTF} defined below to allow receivers to track phase and/or frequency offset during MIMO channel estimation using the HE-LTF. Single stream pilots shall be used in the HE-LTF field for SU, DL and UL OFDMA, DL MU-MIMO and partial bandwidth UL MU-MIMO transmissions. Single stream pilots shall be used in the HE-LTF field for a full bandwidth UL MU-MIMO transmission if single stream pilot HE-LTF mode is selected.

Fig 34

Source: <https://ieeexplore.ieee.org/document/9442429>, Page 580, last accessed March 05, 2024, Exhibit C

Citation 58: HE TB PPDU format

The format of the HE TB PPDU is defined as in Figure 27-11 (HE TB PPDU format). This format is used for a transmission that is a response to a triggering frame from an AP.

The format of the HE TB PPDU is the same as the HE SU PPDU except that the duration of the HE-STF field in the HE TB PPDU is twice the duration of the HE-STF field in the HE SU PPDU.



Figure 27-11—HE TB PPDU format

Fig 35

Source: <https://ieeexplore.ieee.org/document/9442429>, Page 512, last accessed March 05, 2024, Exhibit C

Citation 59: Channels occupied by HE TB PPDU

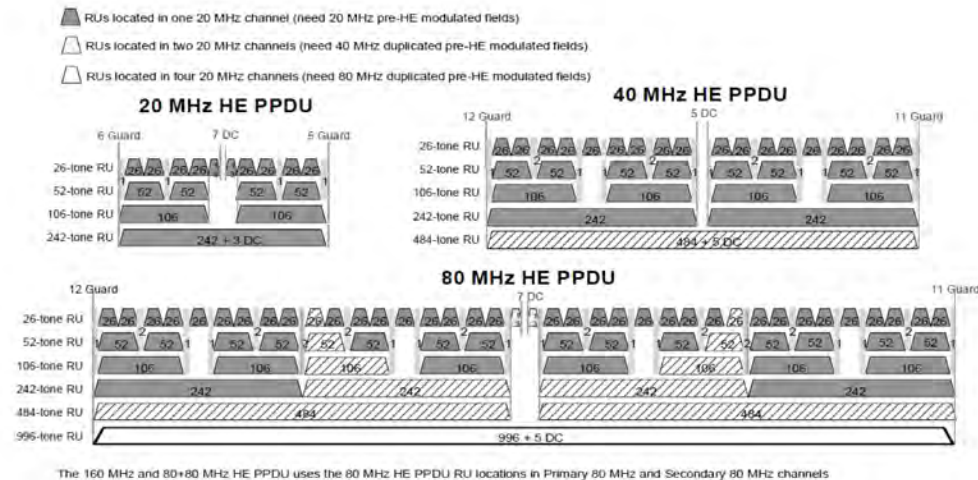


Figure 27-12—Number of 20 MHz channels occupied by the pre-HE modulated fields in an HE TB PPDU

Fig 36

Source: <https://ieeexplore.ieee.org/document/9442429>, Page 513, last accessed March 05, 2024, Exhibit C

OFDMA allows the access point (AP) to schedule transmissions to multiple clients within a single channel simultaneously, improving the network's ability to handle multiple devices and diverse traffic demands. STAs can use UL-OFDMA to send data to the AP simultaneously.

'071 Claim 3	<u>Accused Products</u>
	Citation 60: OFDMA in Channel-spreading orthogonal frequency division multiple access (OFDMA) high-efficiency (HE) physical layer (PHY) protocol data unit (PPDU) (OFDMA HE PPDU): A 20 MHz HE PPDU with resource units (RUs) smaller than 242-tone, or a 40 MHz HE PPDU with RUs smaller than 484-tone, or an 80 MHz HE PPDU with RUs smaller than 996-tone, or a 160 MHz or 80+80 MHz HE PPDU with RUs smaller than 2×996-tone. Fig 37 Source: https://ieeexplore.ieee.org/document/9442429, Page 44, last accessed March 05, 2024, Exhibit C

Citation 61: OFDMA in Channel-spreading

27.3.1.2 OFDMA

OFDMA is an OFDM-based multiple access scheme where different subsets of subcarriers are allocated to different users, and this scheme allows simultaneous data transmission to or from one or more users. In OFDMA, users are allocated different subsets of subcarriers that can change from one PPDU to the next. The difference between OFDM and OFDMA is illustrated in Figure 27-4. Similar to OFDM, OFDMA employs multiple subcarriers, but the subcarriers are divided into several groups where each group is referred to as an RU. With OFDMA, different transmit powers may be applied to different RUs.

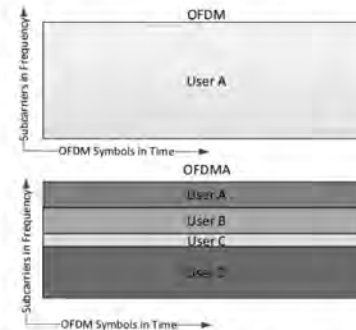


Figure 27-4—Illustration of OFDM and OFDMA concepts

Fig 38

Source: <https://ieeexplore.ieee.org/document/9442429>, Page 498, last accessed March 05, 2024, Exhibit C

Wi-Fi User Equipment

IEEE Standard 802.11ac (UE)

The user equipment (UE) requires each transmitting node (e.g., APs) to transmit a parameter-estimating signal (e.g., training field) while simultaneously transmitting information on the shared communication channel.

The VHT LTF (long training fields) are used by the receiver to estimate the MIMO channel and equalize the received signal. The number of LTF symbols sent in a packet depends on the number of space-time streams: one LTF for one space-time stream, two LTFs for two space-time streams, four LTFs for three or four space-time streams, six LTFs for five or six space-time streams, eight LTFs for seven or eight space-time streams.

Citation 11: VHT-LTF

21.3.8.3.5 VHT-LTF definition

The VHT Long Training field (VHT-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. The transmitter provides training for $N_{STS,total}$ space-time streams (spatial mapper inputs) used for the transmission of the PSDU(s). For each tone, the MIMO channel that can be estimated is an $N_{RX} \times N_{STS,total}$ matrix. A VHT transmission has a preamble that contains VHT-LTF symbols, where the data tones of each VHT-LTF symbol are multiplied by entries belonging to a matrix $P_{VHT-LTF}$, to enable channel estimation at the receiver. The pilot tones of each VHT-LTF symbol are multiplied by the entries of a matrix $R_{VHT-LTF}$ defined in the following text. The multiplication of the pilot tones in the VHT-LTF symbol by the $R_{VHT-LTF}$ matrix instead of the $P_{VHT-LTF}$ matrix allows receivers to track phase and frequency offset during MIMO channel estimation using the VHT-LTF. The number of VHT-LTF symbols, $N_{VHT-LTF}$, is a function of the total number of space-time streams $N_{STS,total}$ as shown in Table 21-13. As a result the VHT-LTF field consists of one, two, four, six or eight symbols.

Table 21-13—Number of VHT-LTFs required for different numbers of space-time streams

$N_{STS,total}$	$N_{VHT-LTF}$
1	1
2	2
3	4
4	4
5	6
6	6
7	8
8	8

FIG. 11

Source: <https://ieeexplore.ieee.org/document/7786995>, Page 2549, last accessed Mar 15, 2024, Exhibit B

Citation 12: Stations support DL-MU-MIMO

21.3.11 SU-MIMO and DL-MU-MIMO Beamforming

21.3.11.1 General

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. With DL-MU-MIMO beamforming, disjoint subsets of the space-time streams are intended for reception at different STAs.

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. The feedback report format is described in 9.4.1.49.

For DL-MU-MIMO beamforming, the receive signal vector in subcarrier k at beamformee u , $y_{k,u} = [y_{k,u}^0, y_{k,u}^1, \dots, y_{k,N_{RX,u}-1}]^T$, is shown in Equation (21-101), where $x_k = [x_{k,0}^T, x_{k,1}^T, \dots, x_{k,N_{MIMO}-1}^T]^T$ denotes the transmit signal vector in subcarrier k for all N_{MIMO} beamformers, with $x_{k,u} = [x_{k,u}^0, x_{k,u}^1, \dots, x_{k,N_{RX,u}-1}^T]^T$ being the transmit signal for beamformee u .

$$y_{k,u} = H_{k,u} \times [Q_{k,0}^T, Q_{k,1}^T, \dots, Q_{k,N_{MIMO}-1}^T] \times x_k + n \quad (21-101)$$

where

$H_{k,u}$ is the channel matrix from the beamformer to beamformee u in subcarrier k with dimensions $N_{RX,u} \times N_{TX}$

FIG. 12

Source: <https://ieeexplore.ieee.org/document/7786995>, Page 2579, last accessed Mar 15, 2024, Exhibit B

The primary channel-spreading technology used by user equipment (UE) supporting 802.11ac is Orthogonal Frequency Division Multiplexing (OFDM). OFDM is a modulation technique that divides the available frequency spectrum into multiple subchannels, each using a different orthogonal carrier frequency. This enables parallel transmission of data streams over these subchannels, improving spectral efficiency and providing resistance against frequency-selective fading and interference.

Citation 62: VHT PPDU frame with VHT-LTF Field

	17.3 OFDM PHY 17.3.1 Introduction Subclause 17.3 provides a convergence procedure in which PSDUs are converted to and from PPDU. During transmission, the PSDU shall be provided with a PHY preamble and header to create the PPDU. At the receiver, the PHY preamble and header are processed to aid in demodulation and delivery of the PSDU. 17.3.2 PPDU format 17.3.2.1 General Figure 17-1 shows the format for the PPDU including the OFDM PHY preamble, OFDM PHY header, PSDU, tail bits, and pad bits. The PHY header contains the following fields: LENGTH, RATE, a reserved bit, an even parity bit, and the SERVICE field. In terms of modulation, the LENGTH, RATE, reserved bit, and parity bit (with 6 zero tail bits appended) constitute a separate single OFDM symbol, denoted SIGNAL, which is transmitted with the most robust combination of BPSK modulation and a coding rate of $R = 1/2$. The SERVICE field of the PHY header and the PSDU (with 6 zero tail bits and pad bits appended), denoted as DATA, are transmitted at the data rate described in the RATE field and may constitute multiple OFDM symbols. The tail bits in the SIGNAL symbol enable decoding of the RATE and LENGTH fields immediately after the reception of the tail bits. The RATE and LENGTH fields are required for decoding the DATA part of the packet. In addition, the CCA mechanism is augmented by predicting the duration of the packet from the contents of the RATE and LENGTH fields, even if the data rate is not supported by the STA. Each of these fields is described in detail in 17.3.3, 17.3.4, and 17.3.5. FIG. 24 Source: https://ieeexplore.ieee.org/document/7786995, Page 2283, last accessed Mar 15, 2024, Exhibit B IEEE Standard 802.11ax (UE) The user equipment (UE) supporting Wi-Fi standard 802.11ax provides the transmitting nodes (e.g., STAs) on a shared communication channel of a wireless digital network and each transmitting nodes (e.g., STAs) transmit parameter-estimating signals (e.g., training fields). Citation 63: HE DL MU Operation
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26.5.1 HE DL MU operation

26.5.1.1 General

HE DL MU operation allows an AP to transmit simultaneously to one or more non-AP STAs in DL OFDMA, DL MU-MIMO, or both.

The PSDU on each RU in an HE MU PPDU shall be padded to end at the same time, indicated by the L-SIG field as described in 27.3.11.5.

Fig 39

Source: <https://ieeexplore.ieee.org/document/9442429>, Page 339, last accessed March 15, 2024, Exhibit C

Citation 64: HE-LTF

27.3.11.10 HE-LTF

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 subcarrier 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. When single stream pilot is used in HE-LTF, the pilot subcarriers of each HE-LTF symbol are multiplied by the entries of a matrix R_{HE-LTF} defined below to allow receivers to track phase and/or frequency offset during MIMO channel estimation using the HE-LTF. Single stream pilots shall be used in the HE-LTF field for SU, DL and UL OFDMA, DL MU-MIMO and partial bandwidth UL MU-MIMO transmissions. Single stream pilots shall be used in the HE-LTF field for a full bandwidth UL MU-MIMO transmission if single stream pilot HE-LTF mode is selected.

Fig 40

'071 Claim 3	Accused Products Source: https://ieeexplore.ieee.org/document/9442429, Page 580, last accessed March 15, 2024, Exhibit C Citation 65: HE TB PPDU format The format of the HE TB PPDU is defined as in Figure 27-11 (HE TB PPDU format). This format is used for a transmission that is a response to a triggering frame from an AP. The format of the HE TB PPDU is the same as the HE SU PPDU except that the duration of the HE-STF field in the HE TB PPDU is twice the duration of the HE-STF field in the HE SU PPDU. 8 μs8 μs4 μs4 μs8 μs8 μs Variable durations per HE-LTF symbol <table><tr><td>L-STF</td><td>L-LTF</td><td>L-SIG</td><td>RL-SIG</td><td>HE-SIG-A</td><td>HE-STF</td><td>HE-LTF</td><td>...</td><td>HE-LTF</td><td>Data</td><td>PE</td></tr></table> Figure 27-11—HE TB PPDU format Fig 41 Source: https://ieeexplore.ieee.org/document/9442429, Page 512, last accessed March 15, 2024, Exhibit C	L-STF	L-LTF	L-SIG	RL-SIG	HE-SIG-A	HE-STF	HE-LTF	...	HE-LTF	Data	PE
L-STF	L-LTF	L-SIG	RL-SIG	HE-SIG-A	HE-STF	HE-LTF	...	HE-LTF	Data	PE		

Citation 66: Channels occupied by HE TB PPDU

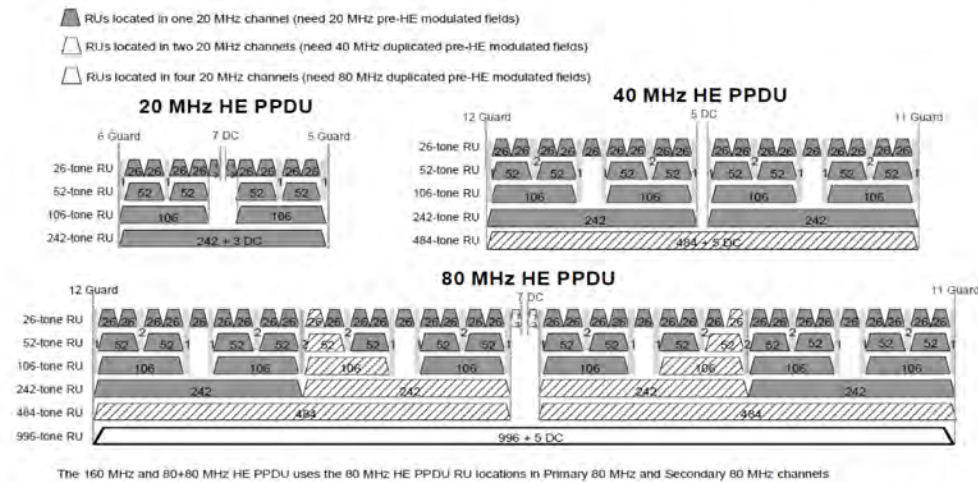


Figure 27-12—Number of 20 MHz channels occupied by the pre-HE modulated fields in an HE TB PPDU

Fig 42

Source: <https://ieeexplore.ieee.org/document/9442429>, Page 513, last accessed March 15, 2024, Exhibit C

OFDMA allows the user equipment (UE) to schedule transmissions to multiple clients within a single channel simultaneously, improving the network's ability to handle multiple devices and diverse traffic demands. STAs can use UL-OFDMA to send data to the AP simultaneously.

Citation 67: OFDMA in Channel-spreading

orthogonal frequency division multiple access (OFDMA) high-efficiency (HE) physical layer (PHY) protocol data unit (PPDU) (OFDMA HE PPDU): A 20 MHz HE PPDU with resource units (RUs) smaller than 242-tone, or a 40 MHz HE PPDU with RUs smaller than 484-tone, or an 80 MHz HE PPDU with RUs smaller than 996-tone, or a 160 MHz or 80+80 MHz HE PPDU with RUs smaller than 2×996-tone.

Fig 43

Source: <https://ieeexplore.ieee.org/document/9442429>, Page 44, last accessed March 15, 2024, Exhibit C

Citation 68: OFDMA in Channel-spreading

27.3.1.2 OFDMA

OFDMA is an OFDM-based multiple access scheme where different subsets of subcarriers are allocated to different users, and this scheme allows simultaneous data transmission to or from one or more users. In OFDMA, users are allocated different subsets of subcarriers that can change from one PPDU to the next. The difference between OFDM and OFDMA is illustrated in Figure 27-4. Similar to OFDM, OFDMA employs multiple subcarriers, but the subcarriers are divided into several groups where each group is referred to as an RU. With OFDMA, different transmit powers may be applied to different RUs.

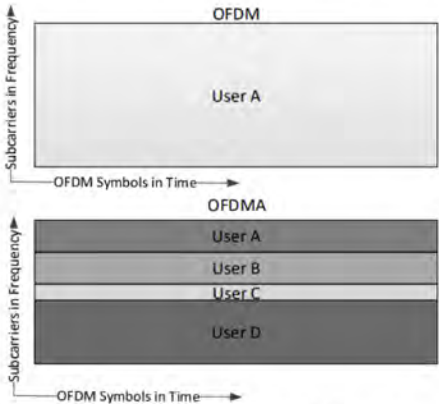


Figure 27-4—Illustration of OFDM and OFDMA concepts

Fig 44

'071 Claim 3	<u>Accused Products</u>
	Source: https://ieeexplore.ieee.org/document/9442429, Page 498, last accessed March 15, 2024, Exhibit C If this element is not literally satisfied by the disclosures cited herein, it is satisfied under the doctrine of equivalents by the disclosures cited herein because the accused functionality would be insubstantially different from or function in the same way to provide the same result as the relevant claim element.

'071 Claim 4	<u>Accused Products</u>
The method of claim 1, wherein <u>requiring each transmitting node to transmit a parameter - estimating signal includes requiring each transmitting node to transmit the parameter estimating signal while simultaneously transmitting information on the shared communication channel.</u>	<u>Cellular</u> The accused products include the method of claim 1, <i>see</i> Claim 1, wherein requiring each transmitting node to transmit a parameter - estimating signal includes requiring each transmitting node to transmit the parameter - estimating signal while simultaneously transmitting information on the shared communication channel. For example, in LTE and 5G air interfaces the eNB/gNB and UEs transmit DMRS reference symbols dedicated (“unshared”) to a UE on the downlink or uplink; the DMRS symbols are used by the UE or eNB/gNB receiver to demodulate the data that is simultaneously transmitted to the UE or eNB/gNB on the same (“shared”) frequency time resources where other data streams are transmitted by other nodes.

'071 Claim 4	<u>Accused Products</u>
	<u>TS 36.211 v11.5.0</u> 5.5.2 Demodulation reference signal 5.5.2.1 <u>Demodulation reference signal for PUSCH</u> 5.5.2.1.1 Reference signal sequence The PUSCH demodulation reference signal sequence $r_{\text{PUSCH}}^{(\lambda)}(\cdot)$ associated with layer $\lambda \in \{0,1,\dots,v-1\}$ is defined by $r_{\text{PUSCH}}^{(\lambda)}(m \cdot M_{\text{sc}}^{\text{RS}} + n) = w^{(\lambda)}(m) r_{u,v}^{(\alpha_\lambda)}(n)$ where $m = 0,1$ $n = 0,\dots,M_{\text{sc}}^{\text{RS}} - 1$ and $M_{\text{sc}}^{\text{RS}} = M_{\text{sc}}^{\text{PUSCH}}$ Subclause 5.5.1 defines the sequence $r_{u,v}^{(\alpha_\lambda)}(0),\dots,r_{u,v}^{(\alpha_\lambda)}(M_{\text{sc}}^{\text{RS}} - 1)$. The orthogonal sequence $w^{(\lambda)}(m)$ is given by $\begin{bmatrix} w^{(\lambda)}(0) & w^{(\lambda)}(1) \end{bmatrix} = \begin{bmatrix} 1 & 1 \end{bmatrix}$ for DCI format 0 if the higher-layer parameter <i>Activate-DMRS-with OCC</i> is not set or if the temporary C-RNTI was used to transmit the most recent uplink-related DCI for the transport block associated with the corresponding PUSCH transmission, otherwise it is given by Table 5.5.2.1.1-1 using the cyclic shift field in most recent uplink-related DCI 3GPP TS 36.212 [3] for the transport block associated with the corresponding PUSCH transmission. The cyclic shift α_λ in a slot n_s is given as $\alpha_\lambda = 2\pi n_{\text{cs},\lambda}/12$ with $n_{\text{cs},\lambda} = (n_{\text{DMRS}}^{(1)} + n_{\text{DMRS},\lambda}^{(2)} + n_{\text{PN}}(n_s)) \bmod 12$ where the values of $n_{\text{DMRS}}^{(1)}$ is given by Table 5.5.2.1.1-2 according to the parameter <i>cyclicShift</i> provided by higher layers, $n_{\text{DMRS},\lambda}^{(2)}$ is given by the cyclic shift for DMRS field in most recent uplink-related DCI 3GPP TS 36.212 [3] for the transport block associated with the corresponding PUSCH transmission where the value of $n_{\text{DMRS},\lambda}^{(2)}$ is given in Table 5.5.2.1.1-1.

TS 36.211 v11.5.0:5.3 Physical uplink shared channel

The baseband signal representing the physical uplink shared channel is defined in terms of the following steps:

- scrambling
- modulation of scrambled bits to generate complex-valued symbols
- mapping of the complex-valued modulation symbols onto one or several transmission layers
- transform precoding to generate complex-valued symbols
- precoding of the complex-valued symbols
- mapping of precoded complex-valued symbols to resource elements
- generation of complex-valued time-domain SC-FDMA signal for each antenna port

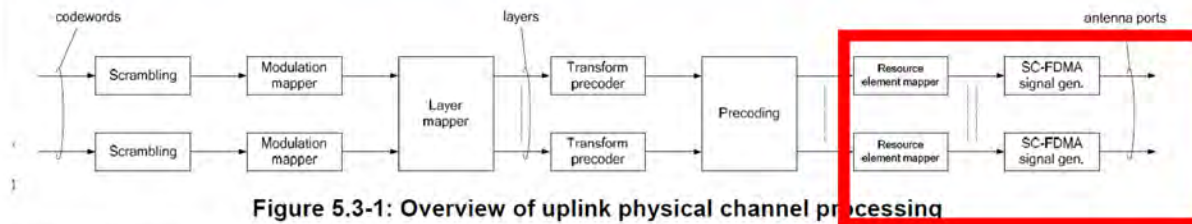


Figure 5.3-1: Overview of uplink physical channel processing

3GPP TS 36.213 [4].

'071 Claim 4	<u>Accused Products</u>
	<u>TS 36.211 v11.5.0:</u> 6.10.3 <u>UE-specific reference signals associated with PDSCH</u> UE-specific reference signals associated with PDSCH - are transmitted on antenna port(s) $p = 5$, $p = 7$, $p = 8$ or $p = 7, 8, \dots, v+6$, where v is the number of layers used for transmission of the PDSCH; - are present and are a valid reference for PDSCH demodulation only if the PDSCH transmission is associated with the corresponding antenna port according to clause 7.1 of 3GPP TS 36.213 [4]; - are transmitted only on the physical resource blocks upon which the corresponding PDSCH is mapped. A UE-specific reference signal associated with PDSCH is not transmitted in resource elements (k, l) in which one of the physical channels or physical signals other than the UE-specific reference signals defined in 6.1 are transmitted using resource elements with the same index pair (k, l) regardless of their antenna port p. 6.10.3.1 Sequence generation For antenna port 5, the UE-specific reference-signal sequence $r_{n_s}(m)$ is defined by $r_{n_s}(m) = \frac{1}{\sqrt{2}}(1 - 2 \cdot c(2m)) + j \frac{1}{\sqrt{2}}(1 - 2 \cdot c(2m+1)), \quad m = 0, 1, \dots, 12N_{\text{RB}}^{\text{PDSCH}} - 1$ where $N_{\text{RB}}^{\text{PDSCH}}$ denotes the bandwidth in resource blocks of the corresponding PDSCH transmission. The pseudo-random sequence $c(i)$ is defined in clause 7.2. The pseudo-random sequence generator shall be initialised with $c_{\text{init}} = (\lfloor n_s/2 \rfloor + 1) \cdot (2N_{\text{ID}}^{\text{cell}} + 1) \cdot 2^{16} + n_{\text{RNTI}}$ at the start of each subframe where n_{RNTI} is as described in clause 7.1 3GPP TS 36.213 [4]. <u>TS 36.211 v11.5.0:</u> 7.3.1.3 <u>Layer mapping</u> The UE shall assume that complex-valued modulation symbols for each of the codewords to be transmitted are mapped onto one or several layers according to Table 7.3.1.3-1. <u>Complex-valued modulation symbols $d^{(q)}(0), \dots, d^{(q)}(M_{\text{symb}}^{(q)} - 1)$ for codeword q shall be mapped onto the layers $x(i) = [x^{(0)}(i) \dots x^{(v-1)}(i)]^T, i = 0, 1, \dots, M_{\text{symb}}^{\text{layer}} - 1$ where v is the number of layers and $M_{\text{symb}}^{\text{layer}}$ is the number of modulation symbols per layer.</u>

Table 6.3.3.2-1: Codeword-to-layer mapping for spatial multiplexing

Number of layers	Number of codewords	Codeword-to-layer mapping $i = 0, 1, \dots, M_{\text{symb}}^{\text{layer}} - 1$
1	1	$x^{(0)}(i) = d^{(0)}(i)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)}$
2	1	$x^{(0)}(i) = d^{(0)}(2i)$ $x^{(1)}(i) = d^{(0)}(2i + 1)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 2$
2	2	$x^{(0)}(i) = d^{(0)}(i)$ $x^{(1)}(i) = d^{(1)}(i)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} = M_{\text{symb}}^{(1)}$
3	1	$x^{(0)}(i) = d^{(0)}(3i)$ $x^{(1)}(i) = d^{(0)}(3i + 1)$ $x^{(2)}(i) = d^{(0)}(3i + 2)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 3$
3	2	$x^{(0)}(i) = d^{(0)}(i)$ $x^{(1)}(i) = d^{(1)}(2i)$ $x^{(2)}(i) = d^{(1)}(2i + 1)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} = M_{\text{symb}}^{(1)} / 2$
4	1	$x^{(0)}(i) = d^{(0)}(4i)$ $x^{(1)}(i) = d^{(0)}(4i + 1)$ $x^{(2)}(i) = d^{(0)}(4i + 2)$ $x^{(3)}(i) = d^{(0)}(4i + 3)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 4$
4	2	$x^{(0)}(i) = d^{(0)}(2i)$ $x^{(1)}(i) = d^{(0)}(2i + 1)$ $x^{(2)}(i) = d^{(1)}(2i)$ $x^{(3)}(i) = d^{(1)}(2i + 1)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 2 = M_{\text{symb}}^{(1)} / 2$
5	2	$x^{(0)}(i) = d^{(0)}(2i)$ $x^{(1)}(i) = d^{(0)}(2i + 1)$ $x^{(2)}(i) = d^{(1)}(3i)$ $x^{(3)}(i) = d^{(1)}(3i + 1)$ $x^{(4)}(i) = d^{(1)}(3i + 2)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 2 = M_{\text{symb}}^{(1)} / 3$
6	2	$x^{(0)}(i) = d^{(0)}(3i)$ $x^{(1)}(i) = d^{(0)}(3i + 1)$ $x^{(2)}(i) = d^{(0)}(3i + 2)$ $x^{(3)}(i) = d^{(1)}(3i)$ $x^{(4)}(i) = d^{(1)}(3i + 1)$ $x^{(5)}(i) = d^{(1)}(3i + 2)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 3 = M_{\text{symb}}^{(1)} / 3$
7	2	$x^{(0)}(i) = d^{(0)}(3i)$ $x^{(1)}(i) = d^{(0)}(3i + 1)$ $x^{(2)}(i) = d^{(0)}(3i + 2)$ $x^{(3)}(i) = d^{(1)}(4i)$ $x^{(4)}(i) = d^{(1)}(4i + 1)$ $x^{(5)}(i) = d^{(1)}(4i + 2)$ $x^{(6)}(i) = d^{(1)}(4i + 3)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 3 = M_{\text{symb}}^{(1)} / 4$

'071 Claim 4	<u>Accused Products</u>
	<u>TS 38.211 v15.8.0:</u> 7.3 Physical channels 7.3.1 <u>Physical downlink shared channel</u> 7.3.1.1 Scrambling Up to two codewords $q \in \{0,1\}$ can be transmitted. In case of single-codeword transmission, $q = 0$. <u>For each codeword q, the UE shall assume the block of bits $b^{(q)}(0), \dots, b^{(q)}(M_{\text{bit}}^{(q)} - 1)$, where $M_{\text{bit}}^{(q)}$ is the number of bits in codeword q transmitted on the physical channel, are scrambled prior to modulation, resulting in a block of scrambled bits $\tilde{b}^{(q)}(0), \dots, \tilde{b}^{(q)}(M_{\text{bit}}^{(q)} - 1)$ according to</u> $\tilde{b}^{(q)}(i) = (b^{(q)}(i) + c^{(q)}(i)) \bmod 2$ where the scrambling sequence $c^{(q)}(i)$ is given by clause 5.2.1. The scrambling sequence generator shall be initialized with $c_{\text{init}} = n_{\text{RNTI}} \cdot 2^{15} + q \cdot 2^{14} + n_{\text{ID}}$ where - $n_{\text{ID}} \in \{0,1,\dots,1023\}$ equals the higher-layer parameter <i>dataScramblingIdentityPDSCH</i> if configured and the RNTI equals the C-RNTI, MCS-C-RNTI, or CS-RNTI, and the transmission is not scheduled using DCI format 1_0 in a common search space, - $n_{\text{ID}} = N_{\text{ID}}^{\text{cell}}$ otherwise and where n_{RNTI} corresponds to the RNTI associated with the PDSCH transmission as described in clause 5.1 of [6, TS 38.214]. 7.3.1.3 <u>Layer mapping</u> The UE shall assume that complex-valued modulation symbols for each of the codewords to be transmitted are mapped onto one or several layers according to Table 7.3.1.3-1. <u>Complex-valued modulation symbols $d^{(q)}(0), \dots, d^{(q)}(M_{\text{symb}}^{(q)} - 1)$ for codeword q shall be mapped onto the layers $x(i) = [x^{(0)}(i) \dots x^{(v-1)}(i)]^T$, $i = 0, 1, \dots, M_{\text{symb}}^{\text{layer}} - 1$ where v is the number of layers and $M_{\text{symb}}^{\text{layer}}$ is the number of modulation symbols per layer.</u>

'071 Claim 4

Accused Products

Table 6.3.3.2-1: Codeword-to-layer mapping for spatial multiplexing

Number of layers	Number of codewords	Codeword-to-layer mapping $i = 0, 1, \dots, M_{\text{symb}}^{\text{layer}} - 1$	
1	1	$x^{(0)}(i) = d^{(0)}(i)$	$M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)}$
2	1	$x^{(0)}(i) = d^{(0)}(2i)$ $x^{(1)}(i) = d^{(0)}(2i + 1)$	$M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 2$
2	2	$x^{(0)}(i) = d^{(0)}(i)$ $x^{(1)}(i) = d^{(1)}(i)$	$M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} = M_{\text{symb}}^{(1)}$
3	1	$x^{(0)}(i) = d^{(0)}(3i)$ $x^{(1)}(i) = d^{(0)}(3i + 1)$ $x^{(2)}(i) = d^{(0)}(3i + 2)$	$M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 3$
3	2	$x^{(0)}(i) = d^{(0)}(i)$ $x^{(1)}(i) = d^{(1)}(2i)$ $x^{(2)}(i) = d^{(1)}(2i + 1)$	$M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} = M_{\text{symb}}^{(1)} / 2$
4	1	$x^{(0)}(i) = d^{(0)}(4i)$ $x^{(1)}(i) = d^{(0)}(4i + 1)$ $x^{(2)}(i) = d^{(0)}(4i + 2)$ $x^{(3)}(i) = d^{(0)}(4i + 3)$	$M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 4$
4	2	$x^{(0)}(i) = d^{(0)}(2i)$ $x^{(1)}(i) = d^{(0)}(2i + 1)$ $x^{(2)}(i) = d^{(1)}(2i)$ $x^{(3)}(i) = d^{(1)}(2i + 1)$	$M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 2 = M_{\text{symb}}^{(1)} / 2$
5	2	$x^{(0)}(i) = d^{(0)}(2i)$ $x^{(1)}(i) = d^{(0)}(2i + 1)$ $x^{(2)}(i) = d^{(1)}(3i)$ $x^{(3)}(i) = d^{(1)}(3i + 1)$ $x^{(4)}(i) = d^{(1)}(3i + 2)$	$M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 2 = M_{\text{symb}}^{(1)} / 3$
6	2	$x^{(0)}(i) = d^{(0)}(3i)$ $x^{(1)}(i) = d^{(0)}(3i + 1)$ $x^{(2)}(i) = d^{(0)}(3i + 2)$ $x^{(3)}(i) = d^{(1)}(3i)$ $x^{(4)}(i) = d^{(1)}(3i + 1)$ $x^{(5)}(i) = d^{(1)}(3i + 2)$	$M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 3 = M_{\text{symb}}^{(1)} / 3$
7	2	$x^{(0)}(i) = d^{(0)}(3i)$ $x^{(1)}(i) = d^{(0)}(3i + 1)$ $x^{(2)}(i) = d^{(0)}(3i + 2)$ $x^{(3)}(i) = d^{(1)}(4i)$ $x^{(4)}(i) = d^{(1)}(4i + 1)$ $x^{(5)}(i) = d^{(1)}(4i + 2)$ $x^{(6)}(i) = d^{(1)}(4i + 3)$	$M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 3 = M_{\text{symb}}^{(1)} / 4$

'071 Claim 4	<u>Accused Products</u>
	<u>TS 38.211 v15.10.0:</u> 6.4.1.1 Demodulation reference signal for PUSCH 6.4.1.1.1 Sequence generation 6.4.1.1.1.1 Sequence generation when transform precoding is disabled If transform precoding for PUSCH is not enabled, the sequence $r(n)$ shall be generated according to $r(n) = \frac{1}{\sqrt{2}}(1 - 2 \cdot c(2n)) + j \frac{1}{\sqrt{2}}(1 - 2 \cdot c(2n+1)).$ where the pseudo-random sequence $c(i)$ is defined in clause 5.2.1. The pseudo-random sequence generator shall be initialized with $c_{\text{init}} = \left(2^{17} \left(N_{\text{symbol}}^{\text{slot}} n_{\text{s,f}}^{\mu} + l + 1 \right) \left(2N_{\text{ID}}^{n_{\text{SCID}}} + 1 \right) + 2N_{\text{ID}}^{n_{\text{SCID}}} + n_{\text{SCID}} \right) \bmod 2^{31}$ where l is the OFDM symbol number within the slot, $n_{\text{s,f}}^{\mu}$ is the slot number within a frame, and - $N_{\text{ID}}^0, N_{\text{ID}}^1 \in \{0, 1, \dots, 65535\}$ are given by the higher-layer parameters <i>scramblingID0</i> and <i>scramblingID1</i>, respectively, in the <i>DMRS-UplinkConfig</i> IE if provided and the PUSCH is scheduled by DCI format 0_1 or by a PUSCH transmission with a configured grant; - $N_{\text{ID}}^0 \in \{0, 1, \dots, 65535\}$ is given by the higher-layer parameter <i>scramblingID0</i> in the <i>DMRS-UplinkConfig</i> IE if provided and the PUSCH is scheduled by DCI format 0_0 with the CRC scrambled by C-RNTI, MCS-C-RNTI, or CS-RNTI; - $N_{\text{ID}}^{n_{\text{SCID}}} = N_{\text{ID}}^{\text{cell}}$ otherwise. The quantity $n_{\text{SCID}} \in \{0, 1\}$ is indicated by the DM-RS initialization field, if present, either in the DCI associated with the PUSCH transmission if DCI format 0_1 in [4, TS 38.212] is used or by the higher layer parameter <i>dmrs-SeqInitialization</i>, if present, for a Type 1 PUSCH transmission with a configured grant, otherwise $n_{\text{SCID}} = 0$.

'071 Claim 4	<u>Accused Products</u>
	If this element is not literally satisfied by the disclosures cited herein, it is satisfied under the doctrine of equivalents by the disclosures cited herein because the accused functionality would be insubstantially different from or function in the same way to provide the same result as the relevant claim element.

'071 Claim 5	<u>Accused Products</u>
The method of claim 1, wherein <u>the parameter estimating signal is a parameter estimating symbol pattern</u>.	The accused products include the method of claim 1, <i>see</i> Claim 1, wherein the parameter estimating signal is a parameter estimating symbol pattern. For example, the downlink and uplink demodulated reference symbols in 4G and 5G are spread using a specific pattern.

'071 Claim 5	<u>Accused Products</u>
	TS 36.211 v11.5.0 7.4.1.1 <u>Demodulation reference signals for PDSCH</u> 7.4.1.1.1 Sequence generation The UE shall assume the sequence $r(n)$ is defined by $r(n) = \frac{1}{\sqrt{2}}(1 - 2 \cdot c(2n)) + j \frac{1}{\sqrt{2}}(1 - 2 \cdot c(2n+1)) .$ where the pseudo-random sequence $c(i)$ is defined in clause 5.2.1. <u>The pseudo-random sequence generator shall be initialized with</u> $c_{\text{init}} = \left(2^{17} \left(N_{\text{symbol}}^{\text{slot}} n_{\text{s,f}}^{\mu} + l + 1 \right) \left(2N_{\text{ID}}^{\text{nscw}} + 1 \right) + 2N_{\text{ID}}^{\text{nscw}} + n_{\text{SCID}} \right) \bmod 2^{31}$ where l is the OFDM symbol number within the slot, $n_{\text{s,f}}^{\mu}$ is the slot number within a frame, and - $N_{\text{ID}}^0, N_{\text{ID}}^1 \in \{0, 1, \dots, 65535\}$ are given by the higher-layer parameters <i>scramblingID0</i> and <i>scramblingID1</i>, respectively, in the <i>DMRS-DownlinkConfig</i> IE if provided and the PDSCH is scheduled by PDCCH using DCI format 1_1 with the CRC scrambled by C-RNTI, MCS-C-RNTI, or CS-RNTI - $N_{\text{ID}}^0 \in \{0, 1, \dots, 65535\}$ is given by the higher-layer parameter <i>scramblingID0</i> in the <i>DMRS-DownlinkConfig</i> IE if provided and the PDSCH is scheduled by PDCCH using DCI format 1_0 with the CRC scrambled by C-RNTI, MCS-C-RNTI, or CS-RNTI; - $N_{\text{ID}}^{\text{nscw}} = N_{\text{ID}}^{\text{cell}}$ otherwise; The quantity $n_{\text{SCID}} \in \{0, 1\}$ is given by the DM-RS sequence initialization field, in the DCI associated with the PDSCH transmission if DCI format 1_1 in [4, TS 38.212] is used, otherwise $n_{\text{SCID}} = 0$.

'071 Claim 5	<u>Accused Products</u>
	<u>TS 36.211 v11.5.0:</u> 6.4.1 Reference signals 6.4.1.1 <u>Demodulation reference signal for PUSCH</u> 6.4.1.1.1 Sequence generation 6.4.1.1.1.1 Sequence generation when transform precoding is disabled If transform precoding for PUSCH is not enabled, the sequence $r(n)$ shall be generated according to $r(n) = \frac{1}{\sqrt{2}}(1 - 2 \cdot c(2n)) + j \frac{1}{\sqrt{2}}(1 - 2 \cdot c(2n+1)).$ where the pseudo-random sequence $c(i)$ is defined in clause 5.2.1. The pseudo-random sequence generator shall be initialized with $c_{\text{init}} = \left(2^{17} \left(N_{\text{slot}}^{\text{slot}} n_{s,f}^{\mu} + l + 1 \right) \left(2N_{\text{ID}}^{\text{scid}} + 1 \right) + 2N_{\text{ID}}^{\text{scid}} + n_{\text{scid}} \right) \bmod 2^{31}$ where l is the OFDM symbol number within the slot, $n_{s,f}^{\mu}$ is the slot number within a frame, and - $N_{\text{ID}}^0, N_{\text{ID}}^1 \in \{0, 1, \dots, 65535\}$ are given by the higher-layer parameters <i>scramblingID0</i> and <i>scramblingID1</i>, respectively, in the <i>DMRS-UplinkConfig</i> IE if provided and the PUSCH is scheduled by DCI format 0_1 or by a PUSCH transmission with a configured grant; - $N_{\text{ID}}^0 \in \{0, 1, \dots, 65535\}$ is given by the higher-layer parameter <i>scramblingID0</i> in the <i>DMRS-UplinkConfig</i> IE if provided and the PUSCH is scheduled by DCI format 0_0 with the CRC scrambled by C-RNTI, MCS-C-RNTI, or CS-RNTI; - $N_{\text{ID}}^{\text{scid}} = N_{\text{ID}}^{\text{cell}}$ otherwise. The quantity $n_{\text{scid}} \in \{0, 1\}$ is indicated by the DM-RS initialization field, if present, either in the DCI associated with the PUSCH transmission if DCI format 0_1 in [4, TS 38.212] is used or by the higher layer parameter <i>dmrs-SeqInitialization</i>, if present, for a Type 1 PUSCH transmission with a configured grant, otherwise $n_{\text{scid}} = 0$.

'071 Claim 5	<u>Accused Products</u>
	<u>5G Book:</u> The NR reference signals include: • <i>Demodulation reference signals</i> (DM-RS) for PDSCH are intended for channel estimation at the device as part of coherent demodulation. They are present only in the resource blocks used for PDSCH transmission. Similarly, the DM-RS for PUSCH allows the gNB to coherently demodulate the PUSCH. The DM-RS for PDSCH and PUSCH is the focus of this section; DM-RS for PDCCH and PBCH is described in Chapters 10 and 16, respectively. Demodulation reference signals are, as discussed in Section 9.11, transmitted in the scheduled resource blocks and it is from those reference signals that the device can estimate the channel, including any precoding W and spatial filtering F applied for PDSCH. In principle, knowledge about the correlation between reference signal transmissions, both in terms of correlation introduced by the radio channel itself and correlation in the use of precoder, is useful to know and can be exploited by the device to improve the channel estimation accuracy.

'071 Claim 5	<u>Accused Products</u>
	The Accused Instrumentalities (WiFi) wherein the parameter estimating signal is a parameter estimating symbol pattern. <u>Wi-Fi Access Point</u> IEEE Standard 802.11ac (AP) The accused product supporting Wi-Fi Standard 802.11ac requires each transmitting node to transmit a parameter-estimating signal (e.g., training field) on an unshared said parameter channel (e.g., orthogonal code applied to the training field). Very High Throughput Long Training Field (VHT-LTF) is a symbol used for channel estimation and synchronization. The VHT-LTF symbol is part of the preamble in the transmission and is employed to assist in the demodulation process at the receiver.

Citation 13: VHT-LTF

21.3.8.3.5 VHT-LTF definition

The VHT Long Training field (VHT-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. The transmitter provides training for $N_{STS, total}$ space-time streams (spatial mapper inputs) used for the transmission of the PSDU(s). For each tone, the MIMO channel that can be estimated is an $N_{RX} \times N_{STS, total}$ matrix. A VHT transmission has a preamble that contains VHT-LTF symbols, where the data tones of each VHT-LTF symbol are multiplied by entries belonging to a matrix $P_{VHT-LTF}$, to enable channel estimation at the receiver. The pilot tones of each VHT-LTF symbol are multiplied by the entries of a matrix $R_{VHT-LTF}$ defined in the following text. The multiplication of the pilot tones in the VHT-LTF symbol by the $R_{VHT-LTF}$ matrix instead of the $P_{VHT-LTF}$ matrix allows receivers to track phase and frequency offset during MIMO channel estimation using the VHT-LTF. The number of VHT-LTF symbols, $N_{VHT-LTF}$, is a function of the total number of space-time streams $N_{STS, total}$ as shown in Table 21-13. As a result the VHT-LTF field consists of one, two, four, six or eight symbols.

Table 21-13—Number of VHT-LTFs required for different numbers of space-time streams

$N_{STS, total}$	$N_{VHT-LTF}$
1	1
2	2
3	4
4	4
5	6
6	6
7	8
8	8

FIG. 13

Source: <https://ieeexplore.ieee.org/document/7786995>, Page 2549, last accessed Mar 07, 2024, Exhibit B

For e.g. in the spectral flatness test, the VHT PPDU's demodulation process includes the below (or equivalent) procedure. For each VHT-LTF symbol, the symbol is transformed into subcarrier received values, the phase from the pilot subcarriers is estimated, and subcarrier values according to the estimated phase are compensated. (See fig. below)

Citation 14: Spectral Flatness test

21.3.17.2 Spectral flatness

Spectral flatness measurements shall be conducted using BPSK modulated PPDU's. Demodulate the PPDU's according to the following (or equivalent) procedure:

- a) Start of PPDU shall be detected.
- b) Transition from L-STF to L-LTF shall be detected and fine timing shall be established.
- c) Coarse and fine frequency offsets shall be estimated.
- d) Symbols in a PPDU shall be derotated according to estimated frequency offset.
- e) For each VHT-LTF symbol, transform the symbol into subcarrier received values, estimate the phase from the pilot subcarriers, and derotate the subcarrier values according to the estimated phase.
- f) For each of the data OFDM symbols: transform the symbol into subcarrier received values.

FIG. 14

Source: <https://ieeexplore.ieee.org/document/7786995>, Page 2586, last accessed Mar 07, 2024, Exhibit B

IEEE Standard 802.11ax (AP)

The accused product supporting Wi-Fi Standard 802.11ax requires each transmitting node to transmit a parameter-estimating signal (e.g., training field) on an unshared said parameter channel (e.g., orthogonal code applied to training field). High-Efficiency Long Training Field (HE-LTF) is a symbol used for channel estimation and synchronization. The HE-LTF symbol is part of the preamble in the transmission and is employed to assist in the demodulation process at the receiver.

Citation 69: Using HE-LTF in an UL MU-MIMO transmission

27.3.11.10 HE-LTF field

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 subcarrier 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. When single stream pilot is used in HE-LTF, the pilot subcarriers of each HE-LTF symbol are multiplied by the entries of a matrix R_{HE-LTF} defined below to allow receivers to track phase and/or frequency offset during MIMO channel estimation using the HE-LTF. Single stream pilots shall be used in the HE-LTF field for SU, DL, and UL OFDMA, DL MU-MIMO, and partial-bandwidth UL MU-MIMO transmissions. Single stream pilots shall be used in the HE-LTF field for a full-bandwidth UL MU-MIMO transmission if single stream pilot HE-LTF mode is selected.

Fig 45

Source: <https://ieeexplore.ieee.org/document/9442429>, Page 580, last accessed March 05, 2024, Exhibit C

Citation 70: Using HE-LTF in a UL MU-MIMO transmission

In an UL MU-MIMO transmission using the HE masked HE-LTF sequence mode, the HE-LTF sequence per frequency segment is generated by masking the nonzero elements in the common HE-LTF sequence repeatedly with a distinct orthogonal code as defined by Equation (27-53).

$$HELTF_{k,u,m}^{\text{Mask}} = HELTF_k \cdot \left[P_{8 \times 8} \right]_{M_{r,u} + m, \left(\left(\left\lceil \frac{k}{N_{\text{HE-LTF-Type}}} \right\rceil - 1 \right) \bmod 8 \right) + 1} \quad (27-53)$$

where

$HELTF_k$ is the value of the common HE-LTF sequence on subcarrier k generated by one of the equations from Equation (27-41) to Equation (27-52) depending on the bandwidth and the HE-LTF type (excluding the 1x HE-LTF, which shall not be masked).

$\left[P_{8 \times 8} \right]$ is defined in Equation (21-46)

$M_{r,u} + m$ is the row index of the $\left[P_{8 \times 8} \right]$ corresponding to spatial time stream m of user u in the r -th RU

$$N_{\text{HE-LTF-Type}} = \begin{cases} 2, & \text{for 2x HE-LTF} \\ 1, & \text{for 4x HE-LTF} \end{cases}$$

Fig 46

Source: <https://ieeexplore.ieee.org/document/9442429>, Page 590, last accessed March 05, 2024, Exhibit C

For e.g. in the spectral flatness test, the HE PPDU's demodulation process includes the below (or equivalent) procedure. For each HE-LTF symbol, the symbol is transformed into subcarrier received values, the phase from the pilot subcarriers is estimated, and subcarrier values according to the estimated phase are compensated. (See fig. below)

Citation 71: Spectral Flatness test

27.3.19.2 Spectral flatness

Spectral flatness measurements shall be conducted using BPSK modulated HE PPDU. The HE PPDU shall be demodulated using the following (or equivalent) procedure:

- a) Start of PPDU shall be detected.
- b) Transition from L-STF to L-LTF shall be detected, and fine timing shall be established.
- c) Coarse and fine frequency offsets shall be estimated.
- d) Symbols in a PPDU shall be manipulated to account for both frequency error and sampling offset drift.
- e) For each HE-LTF symbol, transform the symbol into subcarrier received values, estimate the phase from the pilot subcarriers, and compensate the subcarrier values according to the estimated phase.
- f) For each of the data OFDM symbols, transform the symbol into subcarrier received values.

The spectral flatness test shall be performed over at least 20 HE PPDU. The PPDU under test shall be at least 16 data OFDM symbols long.

Fig 47

Source: <https://ieeexplore.ieee.org/document/9442429>, Page 590, last accessed March 05, 2024, Exhibit C

Wi-Fi User Equipment

IEEE Standard 802.11ac (UE)

The user equipment (UE) supporting Wi-Fi standard 802.11ac requires each transmitting node to transmit a parameter-estimating signal (e.g., training field) on an unshared said parameter channel (e.g., orthogonal code applied to the training field). Very High Throughput Long Training Field (VHT-LTF) is a symbol used for channel estimation and synchronization. The VHT-LTF symbol is part of the preamble in the transmission and is employed to assist in the demodulation process at the receiver.

Citation 13: VHT-LTF

21.3.8.3.5 VHT-LTF definition

The VHT Long Training field (VHT-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. The transmitter provides training for $N_{STS,total}$ space-time streams (spatial mapper inputs) used for the transmission of the PSDU(s). For each tone, the MIMO channel that can be estimated is an $N_{RX} \times N_{STS,total}$ matrix. A VHT transmission has a preamble that contains VHT-LTF symbols, where the data tones of each VHT-LTF symbol are multiplied by entries belonging to a matrix $P_{VHT-LTF}$, to enable channel estimation at the receiver. The pilot tones of each VHT-LTF symbol are multiplied by the entries of a matrix $R_{VHT-LTF}$ defined in the following text. The multiplication of the pilot tones in the VHT-LTF symbol by the $R_{VHT-LTF}$ matrix instead of the $P_{VHT-LTF}$ matrix allows receivers to track phase and frequency offset during MIMO channel estimation using the VHT-LTF. The number of VHT-LTF symbols, $N_{VHT-LTF}$, is a function of the total number of space-time streams $N_{STS,total}$ as shown in Table 21-13. As a result the VHT-LTF field consists of one, two, four, six or eight symbols.

Table 21-13—Number of VHT-LTFs required for different numbers of space-time streams

$N_{STS,total}$	$N_{VHT-LTF}$
1	1
2	2
3	4
4	4
5	6
6	6
7	8
8	8

FIG. 13

Source: <https://ieeexplore.ieee.org/document/7786995>, Page 2549, last accessed Mar 15, 2024, Exhibit B

For e.g. in the spectral flatness test, the VHT PPDU demodulation process includes the below (or equivalent) procedure. For each VHT-LTF symbol, the symbol is transformed into subcarrier received values, the phase from the pilot subcarriers is estimated, and subcarrier values according to the estimated phase are compensated. (See fig. below)

Citation 14: Spectral Flatness test

21.3.17.2 Spectral flatness

Spectral flatness measurements shall be conducted using BPSK modulated PPDU. Demodulate the PPDU according to the following (or equivalent) procedure:

- a) Start of PPDU shall be detected.
- b) Transition from L-STF to L-LTF shall be detected and fine timing shall be established.
- c) Coarse and fine frequency offsets shall be estimated.
- d) Symbols in a PPDU shall be derotated according to estimated frequency offset.
- e) For each VHT-LTF symbol, transform the symbol into subcarrier received values, estimate the phase from the pilot subcarriers, and derotate the subcarrier values according to the estimated phase.
- f) For each of the data OFDM symbols: transform the symbol into subcarrier received values.

FIG. 14

Source: <https://ieeexplore.ieee.org/document/7786995>, Page 2586, last accessed Mar 15, 2024, Exhibit B

IEEE Standard 802.11ax (UE)

The accused product supporting Wi-Fi Standard 802.11ax requires each transmitting node to transmit a parameter-estimating signal (e.g., training field) on an unshared said parameter channel (e.g., orthogonal code applied to training field). High-Efficiency Long Training Field (HE-LTF) is a symbol used for channel estimation and synchronization. The HE-LTF symbol is part of the preamble in the transmission and is employed to assist in the demodulation process at the receiver.

Citation 72: Using HE-LTF in DL MU-MIMO transmission

27.3.11.10 HE-LTF field

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 subcarrier 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. When single stream pilot is used in HE-LTF, the pilot subcarriers of each HE-LTF symbol are multiplied by the entries of a matrix R_{HE-LTF} defined below to allow receivers to track phase and/or frequency offset during MIMO channel estimation using the HE-LTF. Single stream pilots shall be used in the HE-LTF field for SU, DL, and UL OFDMA, DL MU-MIMO, and partial-bandwidth UL MU-MIMO transmissions. Single stream pilots shall be used in the HE-LTF field for a full-bandwidth UL MU-MIMO transmission if single stream pilot HE-LTF mode is selected.

Fig 48

Source: <https://ieeexplore.ieee.org/document/9442429>, Page 580, last accessed March 15, 2024, Exhibit C

Citation 73: Using HE-LTF symbols in the DL HE MU PPDU

HE-LTF symbols in the DL HE MU PPDU are used to measure the channel for the space-time streams intended for the STA and can also be used to measure the channel for the interfering space-time streams. To successfully demodulate the space-time streams intended for the STA, it is recommended that the STA use the channel knowledge for all space-time streams to reduce the effect of space-time streams allocated to other users.

Fig 49

Source: <https://ieeexplore.ieee.org/document/9442429>, Page 507, last accessed March 15, 2024, Exhibit C

'071 Claim 5	<u>Accused Products</u>
	For e.g. in the spectral flatness test, the HE PPDU's demodulation process includes the below (or equivalent) procedure. For each HE-LTF symbol, the symbol is transformed into subcarrier received values, the phase from the pilot subcarriers is estimated, and subcarrier values according to the estimated phase are compensated. (See fig. below) Citation 74: Spectral Flatness test 27.3.19.2 Spectral flatness Spectral flatness measurements shall be conducted using BPSK modulated HE PPDU's. The HE PPDU's shall be demodulated using the following (or equivalent) procedure: a) Start of PPDU shall be detected. b) Transition from L-STF to L-LTF shall be detected, and fine timing shall be established. c) Coarse and fine frequency offsets shall be estimated. d) Symbols in a PPDU shall be manipulated to account for both frequency error and sampling offset drift. e) For each HE-LTF symbol, transform the symbol into subcarrier received values, estimate the phase from the pilot subcarriers, and compensate the subcarrier values according to the estimated phase. f) For each of the data OFDM symbols, transform the symbol into subcarrier received values. The spectral flatness test shall be performed over at least 20 HE PPDU's. The PPDU's under test shall be at least 16 data OFDM symbols long. Fig 50 Source: https://ieeexplore.ieee.org/document/9442429, Page 590, last accessed March 15, 2024, Exhibit C

'071 Claim 5	<u>Accused Products</u>
	If this element is not literally satisfied by the disclosures cited herein, it is satisfied under the doctrine of equivalents by the disclosures cited herein because the accused functionality would be insubstantially different from or function in the same way to provide the same result as the relevant claim element.

'071 Claim 6	<u>Accused Products</u>
The method of claim 1, wherein <u>the at least one unique signal parameter comprises signal amplitude</u>.	<u>Cellular</u> The accused products include the method of claim 1, <i>see</i> Claim 1, wherein at least one unique signal parameter comprises signal amplitude. For example, LTE and 5G use an OFDM multiple access where the frequency channel comprises of a plurality of Resource Elements (REs), also known as frequency tone or subcarrier, and the propagation channel effect manifests itself in changing the gain (amplitude) and phase of the symbol on each RE, requiring estimating <u>amplitude</u> and phase of the channel effect from the reference REs. The UE and base station receivers apply FFT to the received signal, generating the symbols values on each resource element which is a complex number that is the transmitting complex symbols times the propagation channel complex number.

'071 Claim 6	<u>Accused Products</u>
	<u>LTE Book:</u> 6.2 Transmission Resource Structure The downlink transmission resources in LTE possess dimensions of time, frequency and space. The spatial dimension, measured in 'layers', is accessed by means of multiple 'antenna ports' at the eNodeB; for each antenna port a Reference Signal (RS) is provided to enable the User Equipment (UE) to estimate the radio channel (see Section 8.2); the techniques for using multiple antenna ports to exploit multiple spatial layers are explained in Section 11.2. The time-frequency resources for each transmit antenna port are subdivided according to the following structure: the largest unit of time is the 10 ms radio frame, which is subdivided into ten 1 ms subframes, each of which is split into two 0.5 ms slots. Each slot comprises seven OFDM symbols in the case of the normal Cyclic Prefix (CP) length, or six if the extended CP is configured in the cell as explained in Section 5.4.1. In the frequency domain, resources are grouped in units of 12 subcarriers (thus occupying a total of 180 kHz with a subcarrier spacing of 15 kHz), such that one unit of 12 subcarriers for a duration of one slot is termed a Resource Block (RB).¹ The smallest unit of resource is the Resource Element (RE), which consists of one subcarrier for a duration of one OFDM symbol. An RB thus comprises 84 REs in the case of the normal cyclic prefix length, and 72 REs in the case of the extended cyclic prefix. The detailed resource structure is shown in Figure 6.1 for the normal cyclic prefix length.

LTE Receiver Paper:*C. LTE Uplink Receiver Baseband Processing*

The front-end of the LTE base station receiver includes several components: the radio receiver, receive filter, cyclic prefix removal, and fast Fourier transform (FFT), as shown in Fig. 2. Once the FFT is computed, the PRBs of one subframe for one user can be processed as a chain of signal processing kernels that can be modeled as shown in Fig. 3.

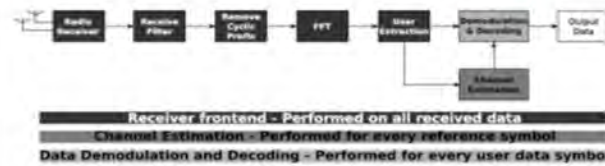


Fig. 2. Illustration of a typical model of an LTE receiver.

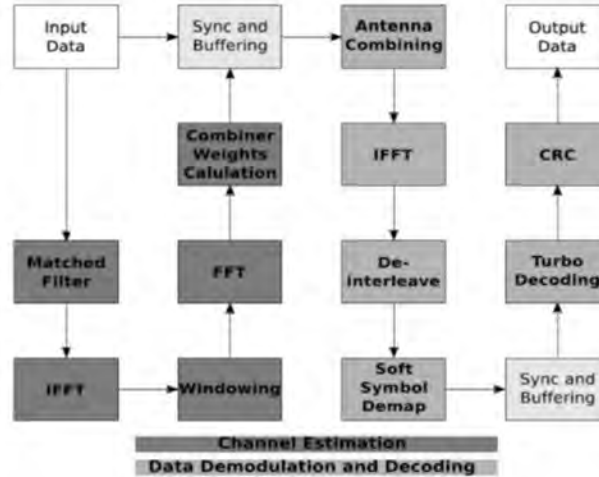


Fig. 3. Illustration of a typical model for processing a user.

'071 Claim 6	<u>Accused Products</u>
	Channel estimation is typically performed for a slot before the data are demodulated and decoded for the user. This requires that the first three symbols be buffered until the reference symbol is received and processed. Channel estimation first applies a matched filter that multiplies the received reference symbol (which has been distorted by the channel) with the defined reference symbol. An inverse FFT (IFFT) follows the matched filter, transforming the data back to the time domain, where a window is used to extract part of the time domain samples. An FFT then transforms these samples back to the frequency domain. For a MIMO system, channel estimation must be performed for each receive antenna and layer, the results of which are used to calculate combiner weights to be used in demodulation. <u>5G Book:</u> Demodulation reference signals are, as discussed in Section 9.11, transmitted in the scheduled resource blocks and it is from those reference signals that the device can estimate the channel, including any precoding W and spatial filtering F applied for PDSCH. In principle, knowledge about the correlation between reference signal transmissions, both in terms of correlation introduced by the radio channel itself and correlation in the use of precoder, is useful to know and can be exploited by the device to improve the channel estimation accuracy.

'071 Claim 6	<u>Accused Products</u>
	The NR reference signals include: • <i>Demodulation reference signals</i> (DM-RS) for PDSCH are intended for channel estimation at the device as part of coherent demodulation. They are present only in the resource blocks used for PDSCH transmission. Similarly, the DM-RS for PUSCH allows the gNB to coherently demodulate the PUSCH. The DM-RS for PDSCH and PUSCH is the focus of this section; DM-RS for PDCCH and PBCH is described in Chapters 10 and 16, respectively. The Accused Instrumentalities (WiFi) have at least one unique signal parameter comprises signal amplitude. A POSITA (Person of Ordinary Skill in the Art) would agree that each electrical signal comprises a signal parameter, which is signal amplitude. <u>Wi-Fi Access Point</u> IEEE Standard 802.11ac (AP) The accused product supporting Wi-Fi Standard 802.11ac requires each transmitting node to transmit a parameter-estimating signal (e.g., training field) on an unshared said parameter channel (e.g., orthogonal code applied to the training field). Very High Throughput Long Training Field (VHT-LTF) is a symbol used for channel estimation and synchronization. The VHT-LTF symbol is part of the preamble in the transmission and is employed to assist in the demodulation process at the receiver.

'071 Claim 6**Accused Products**

The Very High Throughput Long Training Field (VHT-LTF) in 802.11ac (Wi-Fi 5) is designed to assist in channel estimation and synchronization. The VHT-LTF contains information that allows the device to detect the signal, perform frequency/phase offset estimation, etc.

Citation 15: VHT-LTF**21.3.8.3.5 VHT-LTF definition**

The VHT Long Training field (VHT-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. The transmitter provides training for $N_{STS,total}$ space-time streams (spatial mapper inputs) used for the transmission of the PSDU(s). For each tone, the MIMO channel that can be estimated is an $N_{RX} \times N_{STS,total}$ matrix. A VHT transmission has a preamble that contains VHT-LTF symbols, where the data tones of each VHT-LTF symbol are multiplied by entries belonging to a matrix $P_{VHT-LTF}$, to enable channel estimation at the receiver. The pilot tones of each VHT-LTF symbol are multiplied by the entries of a matrix $R_{VHT-LTF}$ defined in the following text. The multiplication of the pilot tones in the VHT-LTF symbol by the $R_{VHT-LTF}$ matrix instead of the $P_{VHT-LTF}$ matrix allows receivers to track phase and frequency offset during MIMO channel estimation using the VHT-LTF. The number of VHT-LTF symbols, $N_{VHT-LTF}$, is a function of the total number of space-time streams $N_{STS,total}$ as shown in Table 21-13. As a result the VHT-LTF field consists of one, two, four, six or eight symbols.

Table 21-13—Number of VHT-LTFs required for different numbers of space-time streams

$N_{STS,total}$	$N_{VHT-LTF}$
1	1
2	2
3	4
4	4
5	6
6	6
7	8
8	8

FIG. 15

Source: <https://ieeexplore.ieee.org/document/7786995>, Page 2549, last accessed Mar 07, 2024, Exhibit B

'071 Claim 6	<u>Accused Products</u>
	IEEE Standard 802.11ax (AP) The accused product supporting Wi-Fi Standard 802.11ax requires each transmitting node to transmit a parameter-estimating signal (e.g., training field) on an unshared said parameter channel (e.g., orthogonal code applied to training field). High-Efficiency Long Training Field (HE-LTF) is a symbol used for channel estimation and synchronization. The HE-LTF symbol is part of the preamble in the transmission and is employed to assist in the demodulation process at the receiver. The High-Efficiency Long Training Field (HE-LTF) in 802.11ax (Wi-Fi 6) is designed to assist in channel estimation and synchronization. The HE-LTF contain information that allows the device to detect the signal, perform frequency/phase offset estimation, timing synchronization, etc.

Citation 75: Using HE-LTF in an UL MU-MIMO transmission

27.3.11.10 HE-LTF field

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 subcarrier 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. When single stream pilot is used in HE-LTF, the pilot subcarriers of each HE-LTF symbol are multiplied by the entries of a matrix R_{HE-LTF} defined below to allow receivers to track phase and/or frequency offset during MIMO channel estimation using the HE-LTF. Single stream pilots shall be used in the HE-LTF field for SU, DL, and UL OFDMA, DL MU-MIMO, and partial-bandwidth UL MU-MIMO transmissions. Single stream pilots shall be used in the HE-LTF field for a full-bandwidth UL MU-MIMO transmission if single stream pilot HE-LTF mode is selected.

Fig 51

Source: <https://ieeexplore.ieee.org/document/9442429>, Page 580, last accessed March 05, 2024, Exhibit C

Citation 76: Using HE-LTF in an UL MU-MIMO transmission

In an UL MU-MIMO transmission using the HE masked HE-LTF sequence mode, the HE-LTF sequence per frequency segment is generated by masking the nonzero elements in the common HE-LTF sequence repeatedly with a distinct orthogonal code as defined by Equation (27-53).

$$HELTf_{k,u,m}^{\text{Mask}} = HELTF_k \cdot \left[P_{8 \times 8} \right]_{M_{r,u} + m, \left(\left(\left\lceil \frac{k}{N_{\text{HE-LTF-Type}}} \right\rceil - 1 \right) \bmod 8 \right) + 1} \quad (27-53)$$

where

$HELTf_k$ is the value of the common HE-LTF sequence on subcarrier k generated by one of the equations from Equation (27-41) to Equation (27-52) depending on the bandwidth and the HE-LTF type (excluding the 1x HE-LTF, which shall not be masked).

$\left[P_{8 \times 8} \right]$ is defined in Equation (21-46)

$M_{r,u} + m$ is the row index of the $\left[P_{8 \times 8} \right]$ corresponding to spatial time stream m of user u in the r -th RU

$$N_{\text{HE-LTF-Type}} = \begin{cases} 2, & \text{for 2x HE-LTF} \\ 1, & \text{for 4x HE-LTF} \end{cases}$$

Fig 52

Source: <https://ieeexplore.ieee.org/document/9442429>, Page 590, last accessed March 05, 2024, Exhibit C

Wi-Fi User Equipment

IEEE Standard 802.11ac (UE)

The user equipment (UE) supporting Wi-Fi Standard 802.11ac requires each transmitting node to transmit a parameter-estimating signal (e.g., training field) on an unshared said parameter channel (e.g., orthogonal code applied to the training field). Very High Throughput Long Training Field (VHT-LTF) is a symbol used for channel

'071 Claim 6	<u>Accused Products</u>
	estimation and synchronization. The VHT-LTF symbol is part of the preamble in the transmission and is employed to assist in the demodulation process at the receiver. The Very High Throughput Long Training Field (VHT-LTF) in 802.11ac (Wi-Fi 5) is designed to assist in channel estimation and synchronization. The VHT-LTF contains information that allows the device to detect the signal, perform frequency/phase offset estimation, etc.

Citation 15: VHT-LTF

21.3.8.3.5 VHT-LTF definition

The VHT Long Training field (VHT-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. The transmitter provides training for $N_{STS,total}$ space-time streams (spatial mapper inputs) used for the transmission of the PSDU(s). For each tone, the MIMO channel that can be estimated is an $N_{RX} \times N_{STS,total}$ matrix. A VHT transmission has a preamble that contains VHT-LTF symbols, where the data tones of each VHT-LTF symbol are multiplied by entries belonging to a matrix $P_{VHT-LTF}$, to enable channel estimation at the receiver. The pilot tones of each VHT-LTF symbol are multiplied by the entries of a matrix $R_{VHT-LTF}$ defined in the following text. The multiplication of the pilot tones in the VHT-LTF symbol by the $R_{VHT-LTF}$ matrix instead of the $P_{VHT-LTF}$ matrix allows receivers to track phase and frequency offset during MIMO channel estimation using the VHT-LTF. The number of VHT-LTF symbols, $N_{VHT-LTF}$, is a function of the total number of space-time streams $N_{STS,total}$ as shown in Table 21-13. As a result the VHT-LTF field consists of one, two, four, six or eight symbols.

Table 21-13—Number of VHT-LTFs required for different numbers of space-time streams

$N_{STS,total}$	$N_{VHT-LTF}$
1	1
2	2
3	4
4	4
5	6
6	6
7	8
8	8

FIG. 15

Source: <https://ieeexplore.ieee.org/document/7786995>, Page 2549, last accessed Mar 15, 2024, Exhibit B

IEEE Standard 802.11ax (UE)

The user equipment (UE) supporting Wi-Fi Standard 802.11ax requires each transmitting node to transmit a parameter-estimating signal (e.g., training field) on an unshared said parameter channel (e.g., orthogonal code applied to training field). High-Efficiency Long Training Field (HE-LTF) is a symbol used for channel estimation

'071 Claim 6	<u>Accused Products</u>
	and synchronization. The HE-LTF symbol is part of the preamble in the transmission and is employed to assist in the demodulation process at the receiver. The High-Efficiency Long Training Field (HE-LTF) in 802.11ax (Wi-Fi 6) is designed to assist in channel estimation and synchronization. The HE-LTF contain information that allows the device to detect the signal, perform frequency/phase offset estimation, timing synchronization, etc. Citation 77: Using HE-LTF in DL MU-MIMO transmission 27.3.11.10 HE-LTF field 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 subcarrier 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. When single stream pilot is used in HE-LTF, the pilot subcarriers of each HE-LTF symbol are multiplied by the entries of a matrix R_{HE-LTF} defined below to allow receivers to track phase and/or frequency offset during MIMO channel estimation using the HE-LTF. Single stream pilots shall be used in the HE-LTF field for SU, DL, and UL OFDMA, DL MU-MIMO, and partial-bandwidth UL MU-MIMO transmissions. Single stream pilots shall be used in the HE-LTF field for a full-bandwidth UL MU-MIMO transmission if single stream pilot HE-LTF mode is selected. Fig 53

'071 Claim 6	<u>Accused Products</u>
	Source: https://ieeexplore.ieee.org/document/9442429, Page 580, last accessed March 15, 2024, Exhibit C Citation 78: Using HE-LTF symbols in the DL HE MU PPDU HE-LTF symbols in the DL HE MU PPDU are used to measure the channel for the space-time streams intended for the STA and can also be used to measure the channel for the interfering space-time streams. To successfully demodulate the space-time streams intended for the STA, it is recommended that the STA use the channel knowledge for all space-time streams to reduce the effect of space-time streams allocated to other users. Fig 54 Source: https://ieeexplore.ieee.org/document/9442429, Page 590, last accessed March 15, 2024, Exhibit C If this element is not literally satisfied by the disclosures cited herein, it is satisfied under the doctrine of equivalents by the disclosures cited herein because the accused functionality would be insubstantially different from or function in the same way to provide the same result as the relevant claim element.

'071 Claim 7	<u>Accused Products</u>
The method of claim 1 , wherein <u>the at least one unique signal parameter includes a signal phase.</u>	<u>Cellular</u> The accused products include the method of claim 1, <i>see</i> claim 1, wherein the at least one unique signal parameter includes a signal phase. For example, LTE and 5G use an OFDM multiple access where the frequency channel comprises of a plurality of Resource Elements (REs), also known as frequency tone or subcarrier, and the propagation channel effect manifests itself in changing the gain (amplitude) and phase of the symbol on each RE, requiring estimating amplitude and <u>phase</u> of the channel effect from the reference REs. <u>LTE Book:</u> 6.2 Transmission Resource Structure The downlink transmission resources in LTE possess dimensions of time, frequency and space. The spatial dimension, measured in 'layers', is accessed by means of multiple 'antenna ports' at the eNodeB; for each antenna port a Reference Signal (RS) is provided to enable the User Equipment (UE) to estimate the radio channel (see Section 8.2); the techniques for using multiple antenna ports to exploit multiple spatial layers are explained in Section 11.2. <u>The time-frequency resources for each transmit antenna port are subdivided according to the following structure: the largest unit of time is the 10 ms radio frame, which is subdivided into ten 1 ms subframes, each of which is split into two 0.5 ms slots. Each slot comprises seven OFDM symbols in the case of the normal Cyclic Prefix (CP) length, or six if the extended CP is configured in the cell as explained in Section 5.4.1. In the frequency domain, resources are grouped in units of 12 subcarriers (thus occupying a total of 180 kHz with a subcarrier spacing of 15 kHz), such that one unit of 12 subcarriers for a duration of one slot is termed a Resource Block (RB).¹</u> <u>The smallest unit of resource is the Resource Element (RE), which consists of one subcarrier for a duration of one OFDM symbol. An RB thus comprises 84 REs in the case of the normal cyclic prefix length, and 72 REs in the case of the extended cyclic prefix.</u> The detailed resource structure is shown in Figure 6.1 for the normal cyclic prefix length.

LTE Receiver Paper:

C. LTE Uplink Receiver Baseband Processing

The front-end of the LTE base station receiver includes several components: the radio receiver, receive filter, cyclic prefix removal, and fast Fourier transform (FFT), as shown in Fig. 2. Once the FFT is computed, the PRBs of one subframe for one user can be processed as a chain of signal processing kernels that can be modeled as shown in Fig. 3.

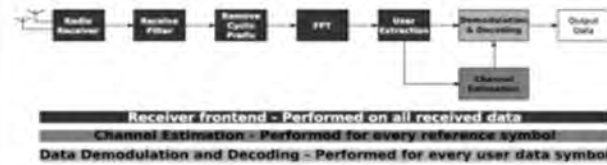


Fig. 2. Illustration of a typical model of an LTE receiver.

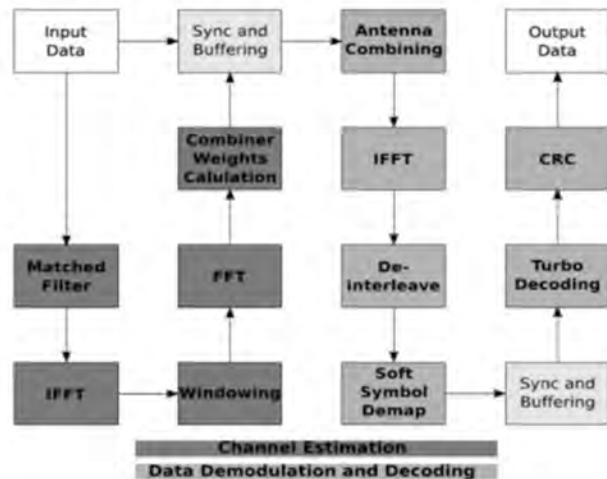


Fig. 3. Illustration of a typical model for processing a user.

'071 Claim 7	<u>Accused Products</u>
	Channel estimation is typically performed for a slot before the data are demodulated and decoded for the user. This requires that the first three symbols be buffered until the reference symbol is received and processed. Channel estimation first applies a matched filter that multiplies the received reference symbol (which has been distorted by the channel) with the defined reference symbol. An inverse FFT (IFFT) follows the matched filter, transforming the data back to the time domain, where a window is used to extract part of the time domain samples. An FFT then transforms these samples back to the frequency domain. For a MIMO system, channel estimation must be performed for each receive antenna and layer, the results of which are used to calculate combiner weights to be used in demodulation. <u>5G Book:</u> The NR reference signals include: • <i>Demodulation reference signals</i> (DM-RS) for PDSCH are intended for channel estimation at the device as part of coherent demodulation. They are present only in the resource blocks used for PDSCH transmission. Similarly, the DM-RS for PUSCH allows the gNB to coherently demodulate the PUSCH. The DM-RS for PDSCH and PUSCH is the focus of this section; DM-RS for PDCCH and PBCH is described in Chapters 10 and 16, respectively.

'071 Claim 7	<u>Accused Products</u>
	Demodulation reference signals are, as discussed in Section 9.11, transmitted in the scheduled resource blocks and it is from those reference signals that the device can estimate the channel, including any precoding W and spatial filtering F applied for PDSCH. In principle, knowledge about the correlation between reference signal transmissions, both in terms of correlation introduced by the radio channel itself and correlation in the use of precoder, is useful to know and can be exploited by the device to improve the channel estimation accuracy. The Accused Instrumentalities (WiFi) have at least one unique signal parameter including a signal phase. <u>Wi-Fi Access Point</u> The Accused Wi-Fi Router Instrumentalities provides a plurality of parameter channels on the network that have OFDM symbols. The phase information is shared by the Pilot subcarriers of the OFDM symbol, requiring estimating <u>phase</u> of the channel. IEEE Standard 802.11ac (AP) The accused product supporting Wi-Fi Standard 802.11ac requires each transmitting node to transmit a parameter-estimating signal (e.g., training field) on an unshared said parameter channel (e.g., orthogonal code applied to the training field). Very High Throughput Long Training Field (VHT-LTF) is a symbol used for channel estimation and synchronization. The VHT-LTF symbol is part of the preamble in the transmission and is employed to assist in the demodulation process at the receiver.

'071 Claim 7	<u>Accused Products</u>
	The Very High Throughput Long Training Field (VHT-LTF) in 802.11ac (Wi-Fi 5) is designed to assist in channel estimation and synchronization. The VHT-LTF contains information that allows the device to detect the signal, perform frequency/phase offset estimation, timing synchronization, etc. The Accused Wi-Fi Router Instrumentalities detect the parameter-estimating signals on the unshared parameter channels and estimate therefrom at least one unique signal parameter for each of the transmitting nodes wherein the unique signal parameter includes a signal phase.

Citation 16: VHT-LTF

21.3.8.3.5 VHT-LTF definition

The VHT Long Training field (VHT-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. The transmitter provides training for $N_{STS,total}$ space-time streams (spatial mapper inputs) used for the transmission of the PSDU(s). For each tone, the MIMO channel that can be estimated is an $N_{RX} \times N_{STS,total}$ matrix. A VHT transmission has a preamble that contains VHT-LTF symbols, where the data tones of each VHT-LTF symbol are multiplied by entries belonging to a matrix $P_{VHT-LTF}$, to enable channel estimation at the receiver. The pilot tones of each VHT-LTF symbol are multiplied by the entries of a matrix $R_{VHT-LTF}$ defined in the following text. The multiplication of the pilot tones in the VHT-LTF symbol by the $R_{VHT-LTF}$ matrix instead of the $P_{VHT-LTF}$ matrix allows receivers to track phase and frequency offset during MIMO channel estimation using the VHT-LTF. The number of VHT-LTF symbols, $N_{VHT-LTF}$, is a function of the total number of space-time streams $N_{STS,total}$ as shown in Table 21-13. As a result the VHT-LTF field consists of one, two, four, six or eight symbols.

Table 21-13—Number of VHT-LTFs required for different numbers of space-time streams

$N_{STS,total}$	$N_{VHT-LTF}$
1	1
2	2
3	4
4	4
5	6
6	6
7	8
8	8

FIG. 16

Source: <https://ieeexplore.ieee.org/document/7786995>, Page 2549, last accessed Mar 07, 2024, Exhibit B

Citation 17: Phase Information by Pilot subcarrier

'071 Claim 7	<u>Accused Products</u>
	21.3.17.2 Spectral flatness Spectral flatness measurements shall be conducted using BPSK modulated PPDU's. Demodulate the PPDU's according to the following (or equivalent) procedure: a) Start of PPDU shall be detected. b) Transition from L-STF to L-LTF shall be detected and fine timing shall be established. c) Coarse and fine frequency offsets shall be estimated. d) Symbols in a PPDU shall be derotated according to estimated frequency offset. e) For each VHT-LTF symbol, transform the symbol into subcarrier received values, estimate the phase from the pilot subcarriers, and derotate the subcarrier values according to the estimated phase. f) For each of the data OFDM symbols: transform the symbol into subcarrier received values. FIG. 17 Source: https://ieeexplore.ieee.org/document/7786995, Page 2587, last accessed Mar 07, 2024, Exhibit B IEEE Standard 802.11ax (AP) The Wi-Fi Standard 802.11ax provides a plurality of parameter channels on the network which have OFDMA where different subsets of subcarriers are allocated to different users, and this scheme allows simultaneous data transmission to or from one or more users. The subcarriers are divided into groups called Resource Unit (RU). The phase information is shared by the Pilot subcarriers of the OFDMA symbol, requiring estimating amplitude and <u>phase</u> of the channel from the RUs.

Citation 79: OFDMA

27.3.1.2 OFDMA

OFDMA is an OFDM-based multiple access scheme where different subsets of subcarriers are allocated to different users, and this scheme allows simultaneous data transmission to or from one or more users. In OFDMA, users are allocated different subsets of subcarriers that can change from one PPDU to the next. The difference between OFDM and OFDMA is illustrated in Figure 27-4. Similar to OFDM, OFDMA employs multiple subcarriers, but the subcarriers are divided into several groups where each group is referred to as an RU. With OFDMA, different transmit powers may be applied to different RUs.

Fig 55

Source: <https://ieeexplore.ieee.org/document/9442429>, Pages 498, last accessed March 05, 2024, Exhibit C

Citation 80: Phase Information by Pilot subcarrier

27.3.2 Subcarrier and resource allocation

27.3.2.1 General

An OFDM symbol is constructed of subcarriers, the number of which is a function of the PPDU bandwidth. There are several subcarrier types:

- a) Data subcarriers, which are used for data transmission (see 27.3.2.2).
- b) Pilot subcarriers, which are used for phase information and parameter tracking (see 27.3.2.4).

Fig 56

Source: <https://ieeexplore.ieee.org/document/9442429>, Pages 499, last accessed March 05, 2024, Exhibit C

The accused product supporting Wi-Fi Standard 802.11ax requires each transmitting node to transmit a parameter-estimating signal (e.g., training field) on an unshared said parameter channel (e.g., orthogonal code applied to

'071 Claim 7	<u>Accused Products</u>
	training field). High-Efficiency Long Training Field (HE-LTF) is a symbol used for channel estimation and synchronization. The HE-LTF symbol is part of the preamble in the transmission and is employed to assist in the demodulation process at the receiver. The High-Efficiency Long Training Field (HE-LTF) in 802.11ax (Wi-Fi 6) is designed to assist in channel estimation and synchronization. The HE-LTF contains information that allows the device to detect the signal, perform frequency/phase offset estimation, etc. Citation 81: Using HE-LTF in an UL MU-MIMO transmission 27.3.11.10 HE-LTF field 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 subcarrier 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. When single stream pilot is used in HE-LTF, the pilot subcarriers of each HE-LTF symbol are multiplied by the entries of a matrix R_{HE-LTF} defined below to allow receivers to track phase and/or frequency offset during MIMO channel estimation using the HE-LTF. Single stream pilots shall be used in the HE-LTF field for SU, DL, and UL OFDMA, DL MU-MIMO, and partial-bandwidth UL MU-MIMO transmissions. Single stream pilots shall be used in the HE-LTF field for a full-bandwidth UL MU-MIMO transmission if single stream pilot HE-LTF mode is selected. Fig 57 Source: https://ieeexplore.ieee.org/document/9442429, Page 580, last accessed March 05, 2024, Exhibit C

Citation 82: Using HE-LTF in an UL MU-MIMO transmission

In an UL MU-MIMO transmission using the HE masked HE-LTF sequence mode, the HE-LTF sequence per frequency segment is generated by masking the nonzero elements in the common HE-LTF sequence repeatedly with a distinct orthogonal code as defined by Equation (27-53).

$$HELT_{k,u,m}^{\text{Mask}} = HELT_k \cdot \left[P_{8 \times 8} \right]_{M_{r,u} + m, \left(\left(\left\lfloor \frac{k}{N_{\text{HE-LTF-Type}}} \right\rfloor - 1 \right) \bmod 8 \right) + 1} \quad (27-53)$$

where

$HELT_k$ is the value of the common HE-LTF sequence on subcarrier k generated by one of the equations from Equation (27-41) to Equation (27-52) depending on the bandwidth and the HE-LTF type (excluding the 1x HE-LTF, which shall not be masked).

$\left[P_{8 \times 8} \right]$ is defined in Equation (21-46)

$M_{r,u} + m$ is the row index of the $\left[P_{8 \times 8} \right]$ corresponding to spatial time stream m of user u in the r -th RU

$$N_{\text{HE-LTF-Type}} = \begin{cases} 2, & \text{for 2x HE-LTF} \\ 1, & \text{for 4x HE-LTF} \end{cases}$$

Fig 58

Source: <https://ieeexplore.ieee.org/document/9442429>, Page 590, last accessed March 05, 2024, Exhibit C

Wi-Fi User Equipment

IEEE Standard 802.11ac (UE)

The accused product supporting Wi-Fi Standard 802.11ac requires each transmitting node to transmit a parameter-estimating signal (e.g., training field) on an unshared said parameter channel (e.g., orthogonal code applied to the training field). Very High Throughput Long Training Field (VHT-LTF) is a symbol used for channel estimation

'071 Claim 7	<u>Accused Products</u>
	and synchronization. The VHT-LTF symbol is part of the preamble in the transmission and is employed to assist in the demodulation process at the receiver. The Very High Throughput Long Training Field (VHT-LTF) in 802.11ac (Wi-Fi 5) is designed to assist in channel estimation and synchronization. The VHT-LTF contains information that allows the device to detect the signal, perform frequency/phase offset estimation, etc. The user equipment (UE) supporting Wi-Fi standard 8-2.11ac detects the parameter-estimating signals on the unshared parameter channels and estimates therefrom at least one unique signal parameter for each of the transmitting nodes wherein the unique signal parameter includes a signal phase.

Citation 16: VHT-LTF

21.3.8.3.5 VHT-LTF definition

The VHT Long Training field (VHT-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. The transmitter provides training for $N_{STS, total}$ space-time streams (spatial mapper inputs) used for the transmission of the PSDU(s). For each tone, the MIMO channel that can be estimated is an $N_{RV} \times N_{STS, total}$ matrix. A VHT transmission has a preamble that contains VHT-LTF symbols, where the data tones of each VHT-LTF symbol are multiplied by entries belonging to a matrix $P_{VHT-LTF}$, to enable channel estimation at the receiver. The pilot tones of each VHT-LTF symbol are multiplied by the entries of a matrix $R_{VHT-LTF}$ defined in the following text. The multiplication of the pilot tones in the VHT-LTF symbol by the $R_{VHT-LTF}$ matrix instead of the $P_{VHT-LTF}$ matrix allows receivers to track phase and frequency offset during MIMO channel estimation using the VHT-LTF. The number of VHT-LTF symbols, $N_{VHT-LTF}$, is a function of the total number of space-time streams $N_{STS, total}$ as shown in Table 21-13. As a result the VHT-LTF field consists of one, two, four, six or eight symbols.

Table 21-13—Number of VHT-LTFs required for different numbers of space-time streams

$N_{STS, total}$	$N_{VHT-LTF}$
1	1
2	2
3	4
4	4
5	6
6	6
7	8
8	8

FIG. 16

Source: <https://ieeexplore.ieee.org/document/7786995>, Page 2549, last accessed Mar 15, 2024, Exhibit B

For e.g. in the spectral flatness test, the VHT PPDU's demodulation process includes the below (or equivalent) procedure. For each VHT-LTF symbol, the symbol is transformed into subcarrier received values, the phase from the pilot subcarriers is estimated, and subcarrier values according to the estimated phase are compensated. (See fig. below)

'071 Claim 7	<u>Accused Products</u>
	Citation 17: Phase Information by Pilot subcarrier 21.3.17.2 Spectral flatness Spectral flatness measurements shall be conducted using BPSK modulated PPDU's. Demodulate the PPDU's according to the following (or equivalent) procedure: a) Start of PPDU shall be detected. b) Transition from L-STF to L-LTF shall be detected and fine timing shall be established. c) Coarse and fine frequency offsets shall be estimated. d) Symbols in a PPDU shall be derotated according to estimated frequency offset. e) For each VHT-LTF symbol, transform the symbol into subcarrier received values, estimate the phase from the pilot subcarriers, and derotate the subcarrier values according to the estimated phase. f) For each of the data OFDM symbols: transform the symbol into subcarrier received values. FIG. 17 Source: https://ieeexplore.ieee.org/document/7786995, Page 2587, last accessed Mar 15, 2024, Exhibit B IEEE Standard 802.11ax (UE) The user equipment (UE) supporting Wi-Fi Standard 802.11ax provides a plurality of parameter channels on the network which have OFDMA where different subsets of subcarriers are allocated to different users, and this scheme allows simultaneous data transmission to or from one or more users. The subcarriers are divided into groups called Resource Unit (RU). The phase information is shared by the Pilot subcarriers of the OFDMA symbol, requiring estimating amplitude and <u>phase</u> of the channel from the RUs.

Citation 83: OFDMA

27.3.1.2 OFDMA

OFDMA is an OFDM-based multiple access scheme where different subsets of subcarriers are allocated to different users, and this scheme allows simultaneous data transmission to or from one or more users. In OFDMA, users are allocated different subsets of subcarriers that can change from one PPDU to the next. The difference between OFDM and OFDMA is illustrated in Figure 27-4. Similar to OFDM, OFDMA employs multiple subcarriers, but the subcarriers are divided into several groups where each group is referred to as an RU. With OFDMA, different transmit powers may be applied to different RUs.

Fig 59

Source: <https://ieeexplore.ieee.org/document/9442429>, Pages 498, last accessed March 15, 2024, Exhibit C

Citation 84: Phase Information by Pilot subcarrier

27.3.2 Subcarrier and resource allocation

27.3.2.1 General

An OFDM symbol is constructed of subcarriers, the number of which is a function of the PPDU bandwidth. There are several subcarrier types:

- a) Data subcarriers, which are used for data transmission (see 27.3.2.2).
- b) Pilot subcarriers, which are used for phase information and parameter tracking (see 27.3.2.4).

Fig 60

Source: <https://ieeexplore.ieee.org/document/9442429>, Pages 499, last accessed March 15, 2024, Exhibit C

The user equipment (UE) supporting Wi-Fi Standard 802.11ax requires each transmitting node to transmit a parameter-estimating signal (e.g., training field) on an unshared said parameter channel (e.g., orthogonal code

'071 Claim 7	<u>Accused Products</u>
	applied to training field). High-Efficiency Long Training Field (HE-LTF) is a symbol used for channel estimation and synchronization. The HE-LTF symbol is part of the preamble in the transmission and is employed to assist in the demodulation process at the receiver. The High-Efficiency Long Training Field (HE-LTF) in 802.11ax (Wi-Fi 6) is designed to assist in channel estimation and synchronization. The HE-LTF contains information that allows the device to detect the signal, perform frequency/phase offset estimation, etc.

Citation 85: Using HE-LTF in DL MU-MIMO transmission

27.3.11.10 HE-LTF field

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 subcarrier 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. When single stream pilot is used in HE-LTF, the pilot subcarriers of each HE-LTF symbol are multiplied by the entries of a matrix R_{HE-LTF} defined below to allow receivers to track phase and/or frequency offset during MIMO channel estimation using the HE-LTF. Single stream pilots shall be used in the HE-LTF field for SU, DL, and UL OFDMA, DL MU-MIMO, and partial-bandwidth UL MU-MIMO transmissions. Single stream pilots shall be used in the HE-LTF field for a full-bandwidth UL MU-MIMO transmission if single stream pilot HE-LTF mode is selected.

Fig 61

Source: <https://ieeexplore.ieee.org/document/9442429>, Page 580, last accessed March 15, 2024, Exhibit C

Citation 86: Using HE-LTF symbols in DL MU-MIMO transmission

HE-LTF symbols in the DL HE MU PPDU are used to measure the channel for the space-time streams intended for the STA and can also be used to measure the channel for the interfering space-time streams. To successfully demodulate the space-time streams intended for the STA, it is recommended that the STA use the channel knowledge for all space-time streams to reduce the effect of space-time streams allocated to other users.

'071 Claim 7	<u>Accused Products</u>
	Fig 62 Source: https://ieeexplore.ieee.org/document/9442429, Page 507, last accessed March 15, 2024, Exhibit C If this element is not literally satisfied by the disclosures cited herein, it is satisfied under the doctrine of equivalents by the disclosures cited herein because the accused functionality would be insubstantially different from or function in the same way to provide the same result as the relevant claim element.

'071 Claim 8	<u>Accused Products</u>
The method of claim 1, wherein <u>the at least one unique signal parameter includes a signal carrier frequency offset</u>.	<u>Cellular</u> The accused products include the method of claim 1, <i>see</i> Claim 1, wherein the at least one unique signal parameter includes a signal carrier frequency offset. For example, the frequency reference of the base station and the UE may have an offset which if not corrected will result in the loss of orthogonality of the OFDM REs and create cross-RE interference and result in the loss of the data rate. The frequency offset must be estimated and corrected.

LTE Book:**5.2.3 Sensitivity to Carrier Frequency Offset and Time-Varying Channels**

The orthogonality of OFDM relies on the condition that transmitter and receiver operate with exactly the same frequency reference. If this is not the case, the perfect orthogonality of the subcarriers is lost, causing subcarrier leakage, also known as Inter-Carrier Interference (ICI), as can be seen in Figure 5.7.

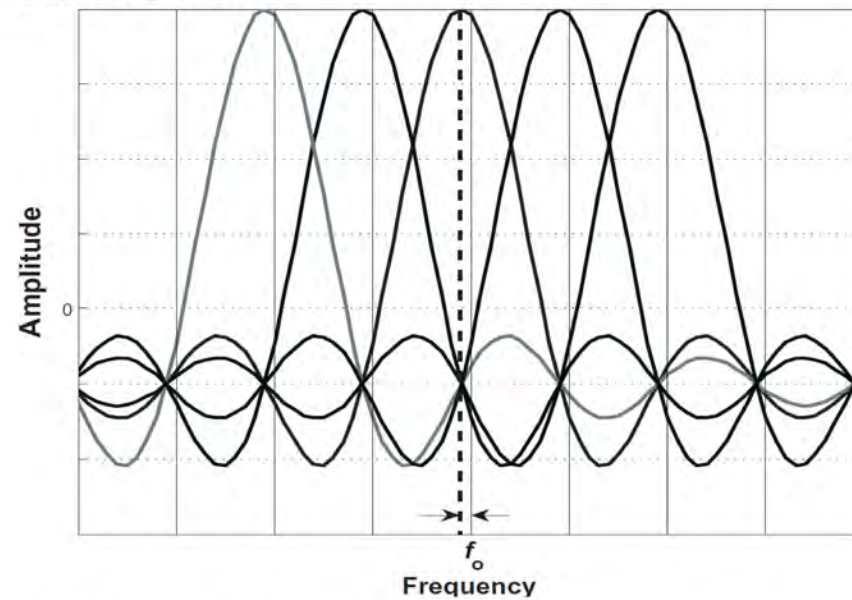


Figure 5.7: Loss of orthogonality between OFDM subcarriers due to frequency offset.

'071 Claim 8	<u>Accused Products</u>
	<u>Frequency errors typically arise from a mismatch between the reference frequencies of the transmitter and the receiver local oscillators.</u> On the receiver side in particular, due to the importance of using low-cost components in the mobile handset, local oscillator frequency drifts are usually greater than in the eNodeB and are typically a function of parameters such as temperature changes and voltage variations. This difference between the reference frequencies is widely referred to as Carrier Frequency Offset (CFO). Phase noise in the UE receiver may also result in frequency errors. <u>ScienceDirect Frequency Offset:</u> 5.1.3 Channel estimation and synchronization Carrier frequency offset between transmitter and receiver is an important source for degradation in an OFDM based transmission system. Because of the dense spacing between subcarriers in OFDM, even low frequency offsets lead to a significant degradation which depends on the carrier frequency offset normalized to the frequency spacing between subcarriers. Due to the frequency offset, the <u>received symbols</u> are multiplied with a subcarrier-independent complex gain factor U. The frequency offset furthermore creates <u>Inter Carrier Interference</u> (ICI) between subcarriers at the receiver. In [OV18] this ICI is reviewed and it is proposed to reduce the ICI by a <u>precoding</u> method. In order to carry out the precoding at the transmitter, it is assumed that the frequency offset is known at the transmitter. The precoding method consists of two steps: First, the complex transmit symbols of a <u>Quadrature Amplitude Modulation</u> (QAM) alphabet are multiplied with the inverse gain factor $1/U$ in order to adjust the amplitude and phase of the received signal. Second, ICI is compensated by simply subtracting it. The second step can be formulated by multiplication of the transmit symbol vector by a <u>precoding matrix</u>. Numerical analysis shows that the direct neighbor subcarriers create the largest contribution of ICI. Therefore, it is sufficient to take for the precoding matrix only neighbor subcarriers into account. For a normalized carrier

The Accused Wi-Fi Router Instrumentalities detect the parameter-estimating signals on the unshared parameter channels and estimate therefrom at least one unique signal parameter for each of the transmitting nodes wherein the unique signal parameter includes a signal carrier frequency offset.

Citation 18: VHT-LTF

21.3.8.3.5 VHT-LTF definition

The VHT Long Training field (VHT-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. The transmitter provides training for $N_{STS,total}$ space-time streams (spatial mapper inputs) used for the transmission of the PSDU(s). For each tone, the MIMO channel that can be estimated is an $N_{RX} \times N_{STS,total}$ matrix. A VHT transmission has a preamble that contains VHT-LTF symbols, where the data tones of each VHT-LTF symbol are multiplied by entries belonging to a matrix $P_{VHT-LTF}$, to enable channel estimation at the receiver. The pilot tones of each VHT-LTF symbol are multiplied by the entries of a matrix $R_{VHT-LTF}$ defined in the following text. The multiplication of the pilot tones in the VHT-LTF symbol by the $R_{VHT-LTF}$ matrix instead of the $P_{VHT-LTF}$ matrix allows receivers to track phase and frequency offset during MIMO channel estimation using the VHT-LTF. The number of VHT-LTF symbols, $N_{VHT-LTF}$, is a function of the total number of space-time streams $N_{STS,total}$ as shown in Table 21-13. As a result the VHT-LTF field consists of one, two, four, six or eight symbols.

Table 21-13—Number of VHT-LTFs required for different numbers of space-time streams

$N_{STS,total}$	$N_{VHT-LTF}$
1	1
2	2
3	4
4	4
5	6
6	6
7	8
8	8

FIG. 18

Source: <https://ieeexplore.ieee.org/document/7786995>, Page 2549, last accessed Mar 07, 2024, Exhibit B

IEEE Standard 802.11ax (AP)

'071 Claim 8	<u>Accused Products</u>
	The accused product supporting Wi-Fi Standard 802.11ax requires each transmitting node to transmit a parameter-estimating signal (e.g., training field) on an unshared said parameter channel (e.g., orthogonal code applied to training field). High-Efficiency Long Training Field (HE-LTF) is a symbol used for channel estimation and synchronization. The HE-LTF symbol is part of the preamble in the transmission and is employed to assist in the demodulation process at the receiver. The High-Efficiency Long Training Field (HE-LTF) in 802.11ax (Wi-Fi 6) is designed to assist in channel estimation and synchronization. The HE-LTF contains information that allows the device to detect the signal, perform frequency/phase offset estimation, timing synchronization, etc.

Citation 87: Using HE-LTF in an UL MU-MIMO transmission

27.3.11.10 HE-LTF field

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 subcarrier 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. When single stream pilot is used in HE-LTF, the pilot subcarriers of each HE-LTF symbol are multiplied by the entries of a matrix R_{HE-LTF} defined below to allow receivers to track phase and/or frequency offset during MIMO channel estimation using the HE-LTF. Single stream pilots shall be used in the HE-LTF field for SU, DL, and UL OFDMA, DL MU-MIMO, and partial-bandwidth UL MU-MIMO transmissions. Single stream pilots shall be used in the HE-LTF field for a full-bandwidth UL MU-MIMO transmission if single stream pilot HE-LTF mode is selected.

Fig 63

Source: <https://ieeexplore.ieee.org/document/9442429>, Page 580, last accessed March 05, 2024, Exhibit C

Citation 88: Using HE-LTF in an UL MU-MIMO transmission

In an UL MU-MIMO transmission using the HE masked HE-LTF sequence mode, the HE-LTF sequence per frequency segment is generated by masking the nonzero elements in the common HE-LTF sequence repeatedly with a distinct orthogonal code as defined by Equation (27-53).

$$HELTf_{k,u,m}^{\text{Mask}} = HELTF_k \cdot \left[P_{8 \times 8} \right]_{M_{r,u} + m, \left(\left(\left\lceil \frac{k}{N_{\text{HE-LTF-Type}}} \right\rceil - 1 \right) \bmod 8 \right) + 1} \quad (27-53)$$

where

$HELTf_k$ is the value of the common HE-LTF sequence on subcarrier k generated by one of the equations from Equation (27-41) to Equation (27-52) depending on the bandwidth and the HE-LTF type (excluding the 1x HE-LTF, which shall not be masked).

$\left[P_{8 \times 8} \right]$ is defined in Equation (21-46)

$M_{r,u} + m$ is the row index of the $\left[P_{8 \times 8} \right]$ corresponding to spatial time stream m of user u in the r -th RU

$$N_{\text{HE-LTF-Type}} = \begin{cases} 2, & \text{for 2x HE-LTF} \\ 1, & \text{for 4x HE-LTF} \end{cases}$$

Fig 64

Source: <https://ieeexplore.ieee.org/document/9442429>, Page 590, last accessed March 05, 2024, Exhibit C

Wi-Fi User Equipment

IEEE Standard 802.11ac (UE)

The accused product supporting Wi-Fi Standard 802.11ac requires each transmitting node to transmit a parameter-estimating signal (e.g., training field) on an unshared said parameter channel (e.g., orthogonal code applied to the training field). Very High Throughput Long Training Field (VHT-LTF) is a symbol used for channel estimation and

'071 Claim 8	<u>Accused Products</u>
	synchronization. The VHT-LTF symbol is part of the preamble in the transmission and is employed to assist in the demodulation process at the receiver. The Very High Throughput Long Training Field (VHT-LTF) in 802.11ac (Wi-Fi 5) is designed to assist in channel estimation and synchronization. The VHT-LTF contains information that allows the device to detect the signal, perform frequency/phase offset estimation, timing synchronization, etc. The user equipment (UE) detect the parameter-estimating signals on the unshared parameter channels and estimate therefrom at least one unique signal parameter for each of the transmitting nodes wherein the unique signal parameter includes a signal carrier frequency offset.

Citation 18: VHT-LTF

21.3.8.3.5 VHT-LTF definition

The VHT Long Training field (VHT-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. The transmitter provides training for $N_{STS,total}$ space-time streams (spatial mapper inputs) used for the transmission of the PSDUs(s). For each tone, the MIMO channel that can be estimated is an $N_{RX} \times N_{STS,total}$ matrix. A VHT transmission has a preamble that contains VHT-LTF symbols, where the data tones of each VHT-LTF symbol are multiplied by entries belonging to a matrix $P_{VHT-LTF}$, to enable channel estimation at the receiver. The pilot tones of each VHT-LTF symbol are multiplied by the entries of a matrix $R_{VHT-LTF}$ defined in the following text. The multiplication of the pilot tones in the VHT-LTF symbol by the $R_{VHT-LTF}$ matrix instead of the $P_{VHT-LTF}$ matrix allows receivers to track phase and frequency offset during MIMO channel estimation using the VHT-LTF. The number of VHT-LTF symbols, $N_{VHT-LTF}$, is a function of the total number of space-time streams $N_{STS,total}$ as shown in Table 21-13. As a result the VHT-LTF field consists of one, two, four, six or eight symbols.

Table 21-13—Number of VHT-LTFs required for different numbers of space-time streams

$N_{STS,total}$	$N_{VHT-LTF}$
1	1
2	2
3	4
4	4
5	6
6	6
7	8
8	8

FIG. 18

Source: <https://ieeexplore.ieee.org/document/7786995>, Page 2549, last accessed Mar 15, 2024, Exhibit B

IEEE Standard 802.11ax (UE)

The user equipment (UE) supporting Wi-Fi Standard 802.11ax requires each transmitting node to transmit a parameter-estimating signal (e.g., training field) on an unshared said parameter channel (e.g., orthogonal code applied to training field). High-Efficiency Long Training Field (HE-LTF) is a symbol used for channel estimation

'071 Claim 8	<u>Accused Products</u>
	and synchronization. The HE-LTF symbol is part of the preamble in the transmission and is employed to assist in the demodulation process at the receiver. The High-Efficiency Long Training Field (HE-LTF) in 802.11ax (Wi-Fi 6) is designed to assist in channel estimation and synchronization. The HE-LTF contains information that allows the device to detect the signal, perform frequency/phase offset estimation, etc. Citation 89: Using HE-LTF in DL MU-MIMO transmission. 27.3.11.10 HE-LTF field 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 subcarrier 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. When single stream pilot is used in HE-LTF, the pilot subcarriers of each HE-LTF symbol are multiplied by the entries of a matrix R_{HE-LTF} defined below to allow receivers to track phase and/or frequency offset during MIMO channel estimation using the HE-LTF. Single stream pilots shall be used in the HE-LTF field for SU, DL, and UL OFDMA, DL MU-MIMO, and partial-bandwidth UL MU-MIMO transmissions. Single stream pilots shall be used in the HE-LTF field for a full-bandwidth UL MU-MIMO transmission if single stream pilot HE-LTF mode is selected. Fig 65 Source: https://ieeexplore.ieee.org/document/9442429, Page 580, last accessed March 15, 2024, Exhibit C

'071 Claim 8	<u>Accused Products</u>
	Citation 90: Using HE-LTF symbols in the DL HE MU PPDU HE-LTF symbols in the DL HE MU PPDU are used to measure the channel for the space-time streams intended for the STA and can also be used to measure the channel for the interfering space-time streams. To successfully demodulate the space-time streams intended for the STA, it is recommended that the STA use the channel knowledge for all space-time streams to reduce the effect of space-time streams allocated to other users. Fig 66 Source: https://ieeexplore.ieee.org/document/9442429, Page 507, last accessed March 15, 2024, Exhibit C If this element is not literally satisfied by the disclosures cited herein, it is satisfied under the doctrine of equivalents by the disclosures cited herein because the accused functionality would be insubstantially different from or function in the same way to provide the same result as the relevant claim element.

'071 Claim 9	<u>Accused Products</u>
The method of claim 1, wherein <u>the at least one unique signal parameter includes a signal relative time delay.</u>	<u>Cellular</u> The accused products include the method of claim 1, <i>see</i> Claim 1, wherein the at least one unique signal parameter includes a signal relative time delay. For example, the signals transmitted by different UEs arrive at the eNB/gNB with relative delays due different delays of the different transmit/receive paths, clock offsets between the eNB/gNB and UE as well as the different propagation delays. Similarly, the signals from different cell site transmitters arrive at the UE with relative delays due to different transmitter delay offsets as well as different propagation delays. <u>LTE Book:</u> <u>5.2.4 Timing Offset and Cyclic Prefix Dimensioning</u> In the case of a memoryless channel (i.e. no delay spread), OFDM is insensitive to timing synchronization errors provided that the misalignment remains within the CP duration. In other words, if $T_o < T_{CP}$ (with T_o being the timing error), then orthogonality is maintained thanks to the cyclic nature of the CP. <u>Any symbol timing delay only introduces a constant phase shift from one subcarrier to another. The received signal at the m-th subcarrier is given by</u> $R[k] = X[k] \exp(j2\pi d m) \quad (5.19)$ <u>where d is the timing offset in samples corresponding to a duration equal to T_o. This phase shift can be recovered as part of the channel estimation operation.</u> <i>ScienceDirect Timing Offset:</i>

'071 Claim 9	<u>Accused Products</u>
	9.2.4 Synchronization As mentioned before, the multipath channel and the filters will cause delay (timing offset) of the received signal. The timing offset has to be estimated before further processing of the received signal. The CFO represents the frequency difference between the carrier frequencies at the transmitter and at the receiver. If left uncompensated, it will cause a phase rotation of the received signal and the phase increases linearly with time. The synchronization module performs timing and frequency synchronization. By assuming common preamble, the timing offset, and CFO are estimated using the methods in [24] and [23], respectively. One can also choose perfect timing and frequency synchronization. In the former case, the true value of the timing offset is used for timing synchronization. In the latter case, the CFO is set to zero and the frequency synchronization module is disabled (since perfect frequency synchronization results in a CFO-free signal). The Accused Instrumentalities (WiFi) practice a method wherein the at least one unique signal parameter includes a signal relative time delay. A POSITA (Person of Ordinary Skill in the Art) would agree that signals transmitted from different antennas may take different paths to reach the receiver due to variations in distance or reflections. This can result in differences in the arrival times of the signals, causing a time delay between them. Based on information and belief the unique signal parameter may includes a signal relative time delay. <u>Wi-Fi Access Point</u> IEEE Standard 802.11ac (AP) The accused product supporting Wi-Fi Standard 802.11ac requires each transmitting node to transmit a parameter-estimating signal (e.g., training field) on an unshared said parameter channel (e.g., orthogonal code applied to the

'071 Claim 9	<u>Accused Products</u>
	training field). Very High Throughput Long Training Field (VHT-LTF) is a symbol used for channel estimation and synchronization. The VHT-LTF symbol is part of the preamble in the transmission and is employed to assist in the demodulation process at the receiver. The Very High Throughput Long Training Field (VHT-LTF) in 802.11ac (Wi-Fi 5) is designed to assist in channel estimation and synchronization. The VHT-LTF contains information that allows the device to detect the signal, perform frequency/phase offset estimation, etc.

Citation 19: VHT-LTF

21.3.8.3.5 VHT-LTF definition

The VHT Long Training field (VHT-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. The transmitter provides training for $N_{STS,total}$ space-time streams (spatial mapper inputs) used for the transmission of the PSDU(s). For each tone, the MIMO channel that can be estimated is an $N_{RX} \times N_{STS,total}$ matrix. A VHT transmission has a preamble that contains VHT-LTF symbols, where the data tones of each VHT-LTF symbol are multiplied by entries belonging to a matrix $P_{VHT-LTF}$, to enable channel estimation at the receiver. The pilot tones of each VHT-LTF symbol are multiplied by the entries of a matrix $R_{VHT-LTF}$ defined in the following text. The multiplication of the pilot tones in the VHT-LTF symbol by the $R_{VHT-LTF}$ matrix instead of the $P_{VHT-LTF}$ matrix allows receivers to track phase and frequency offset during MIMO channel estimation using the VHT-LTF. The number of VHT-LTF symbols, $N_{VHT-LTF}$, is a function of the total number of space-time streams $N_{STS,total}$ as shown in Table 21-13. As a result the VHT-LTF field consists of one, two, four, six or eight symbols.

Table 21-13—Number of VHT-LTFs required for different numbers of space-time streams

$N_{STS,total}$	$N_{VHT-LTF}$
1	1
2	2
3	4
4	4
5	6
6	6
7	8
8	8

FIG. 19

Source: <https://ieeexplore.ieee.org/document/7786995>, Page 2549, last accessed Mar 07, 2024, Exhibit B

IEEE Standard 802.11ax (AP)

The accused product supporting Wi-Fi Standard 802.11ax requires each transmitting node to transmit a parameter-estimating signal (e.g., training field) on an unshared said parameter channel (e.g., orthogonal code applied to training field). High-Efficiency Long Training Field (HE-LTF) is a symbol used for channel estimation and

'071 Claim 9	<u>Accused Products</u>
	synchronization. The HE-LTF symbol is part of the preamble in the transmission and is employed to assist in the demodulation process at the receiver. The High-Efficiency Long Training Field (HE-LTF) in 802.11ax (Wi-Fi 6) is designed to assist in channel estimation and synchronization. The HE-LTF contains information that allows the device to detect the signal, perform frequency/phase offset estimation, etc. Citation 91: Using HE-LTF in an UL MU-MIMO transmission 27.3.11.10 HE-LTF field 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 subcarrier 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. When single stream pilot is used in HE-LTF, the pilot subcarriers of each HE-LTF symbol are multiplied by the entries of a matrix R_{HE-LTF} defined below to allow receivers to track phase and/or frequency offset during MIMO channel estimation using the HE-LTF. Single stream pilots shall be used in the HE-LTF field for SU, DL, and UL OFDMA, DL MU-MIMO, and partial-bandwidth UL MU-MIMO transmissions. Single stream pilots shall be used in the HE-LTF field for a full-bandwidth UL MU-MIMO transmission if single stream pilot HE-LTF mode is selected. Fig 67 Source: https://ieeexplore.ieee.org/document/9442429, Page 580, last accessed March 05, 2024, Exhibit C

'071 Claim 9	<u>Accused Products</u>
	Citation 92: Using HE-LTF in an UL MU-MIMO transmission In an UL MU-MIMO transmission using the HE masked HE-LTF sequence mode, the HE-LTF sequence per frequency segment is generated by masking the nonzero elements in the common HE-LTF sequence repeatedly with a distinct orthogonal code as defined by Equation (27-53). $HELTf_{k,u,m}^{Mask} = HELTF_k \cdot \left[P_{8 \times 8} \right]_{M_{r,u} + m, \left(\left(\left\lfloor \frac{k}{N_{HE-LTF-Type}} \right\rfloor - 1 \right) \bmod 8 \right) + 1} \quad (27-53)$ where $HELTf_k$ is the value of the common HE-LTF sequence on subcarrier k generated by one of the equations from Equation (27-41) to Equation (27-52) depending on the bandwidth and the HE-LTF type (excluding the 1x HE-LTF, which shall not be masked). $\left[P_{8 \times 8} \right]$ is defined in Equation (21-46) $M_{r,u} + m$ is the row index of the $\left[P_{8 \times 8} \right]$ corresponding to spatial time stream m of user u in the r-th RU $N_{HE-LTF-Type} = \begin{cases} 2, & \text{for 2x HE-LTF} \\ 1, & \text{for 4x HE-LTF} \end{cases}$ Fig 68 Source: https://ieeexplore.ieee.org/document/9442429, Page 590, last accessed March 05, 2024, Exhibit C <u>Wi-Fi User Equipment</u> IEEE Standard 802.11ac (UE)

'071 Claim 9	<u>Accused Products</u>
	The user equipment (UE) supporting Wi-Fi Standard 802.11ac requires each transmitting node to transmit a parameter-estimating signal (e.g., training field) on an unshared said parameter channel (e.g., orthogonal code applied to the training field). Very High Throughput Long Training Field (VHT-LTF) is a symbol used for channel estimation and synchronization. The VHT-LTF symbol is part of the preamble in the transmission and is employed to assist in the demodulation process at the receiver. The Very High Throughput Long Training Field (VHT-LTF) in 802.11ac (Wi-Fi 5) is designed to assist in channel estimation and synchronization. The VHT-LTF contains information that allows the device to detect the signal, perform frequency/phase offset estimation, etc.

Citation 19: VHT-LTF

21.3.8.3.5 VHT-LTF definition

The VHT Long Training field (VHT-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. The transmitter provides training for $N_{STS,total}$ space-time streams (spatial mapper inputs) used for the transmission of the PSDU(s). For each tone, the MIMO channel that can be estimated is an $N_{RX} \times N_{STS,total}$ matrix. A VHT transmission has a preamble that contains VHT-LTF symbols, where the data tones of each VHT-LTF symbol are multiplied by entries belonging to a matrix $P_{VHT-LTF}$, to enable channel estimation at the receiver. The pilot tones of each VHT-LTF symbol are multiplied by the entries of a matrix $R_{VHT-LTF}$ defined in the following text. The multiplication of the pilot tones in the VHT-LTF symbol by the $R_{VHT-LTF}$ matrix instead of the $P_{VHT-LTF}$ matrix allows receivers to track phase and frequency offset during MIMO channel estimation using the VHT-LTF. The number of VHT-LTF symbols, $N_{VHT-LTF}$, is a function of the total number of space-time streams $N_{STS,total}$ as shown in Table 21-13. As a result the VHT-LTF field consists of one, two, four, six or eight symbols.

Table 21-13—Number of VHT-LTFs required for different numbers of space-time streams

$N_{STS,total}$	$N_{VHT-LTF}$
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6	6
7	8
8	8

FIG. 19

Source: <https://ieeexplore.ieee.org/document/7786995>, Page 2549, last accessed Mar 15, 2024, Exhibit B

IEEE Standard 802.11ax (UE)

The user equipment (UE) supporting Wi-Fi Standard 802.11ax requires each transmitting node to transmit a parameter-estimating signal (e.g., training field) on an unshared said parameter channel (e.g., orthogonal code applied to training field). High-Efficiency Long Training Field (HE-LTF) is a symbol used for channel estimation

'071 Claim 9	<u>Accused Products</u>
	and synchronization. The HE-LTF symbol is part of the preamble in the transmission and is employed to assist in the demodulation process at the receiver. The High-Efficiency Long Training Field (HE-LTF) in 802.11ax (Wi-Fi 6) is designed to assist in channel estimation and synchronization. The HE-LTF contains information that allows the device to detect the signal, perform frequency/phase offset estimation, etc. Citation 93: Using HE-LTF in DL MU-MIMO transmission 27.3.11.10 HE-LTF field 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 subcarrier 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. When single stream pilot is used in HE-LTF, the pilot subcarriers of each HE-LTF symbol are multiplied by the entries of a matrix R_{HE-LTF} defined below to allow receivers to track phase and/or frequency offset during MIMO channel estimation using the HE-LTF. Single stream pilots shall be used in the HE-LTF field for SU, DL, and UL OFDMA, DL MU-MIMO, and partial-bandwidth UL MU-MIMO transmissions. Single stream pilots shall be used in the HE-LTF field for a full-bandwidth UL MU-MIMO transmission if single stream pilot HE-LTF mode is selected. Fig 69 Source: https://ieeexplore.ieee.org/document/9442429, Page 580, last accessed March 15, 2024, Exhibit C

'071 Claim 9	<u>Accused Products</u>
	Citation 94: Using HE-LTF using in the DL HE MU PPDU HE-LTF symbols in the DL HE MU PPDU are used to measure the channel for the space-time streams intended for the STA and can also be used to measure the channel for the interfering space-time streams. To successfully demodulate the space-time streams intended for the STA, it is recommended that the STA use the channel knowledge for all space-time streams to reduce the effect of space-time streams allocated to other users. Fig 70 Source: https://ieeexplore.ieee.org/document/9442429, Page 590, last accessed March 15, 2024, Exhibit C If this element is not literally satisfied by the disclosures cited herein, it is satisfied under the doctrine of equivalents by the disclosures cited herein because the accused functionality would be insubstantially different from or function in the same way to provide the same result as the relevant claim element.

'071 Claim 11	<u>Accused Products</u>
The method of claim 1, further comprising <u>requiring each transmitting node to transmit spreading code type information on the unshared parameter channel.</u>	<u>Cellular</u> The accused products include the method of claim 1, <i>see</i> Claim 1, further comprising requiring each transmitting node to transmit spreading code type information on the unshared parameter channel. For example, in LTE and 5G the reference symbols on the uplink and on the downlink are scrambled using a spreading code and then spread over multiple Resource Elements (REs), i.e., frequency tones.

'071 Claim 11	<u>Accused Products</u>
	<u>TS 38.211 v15.8.0:</u> 7.4.1 Reference signals 7.4.1.1 Demodulation reference signals for PDSCH 7.4.1.1.1 Sequence generation The UE shall assume the sequence $r(n)$ is defined by $r(n) = \frac{1}{\sqrt{2}}(1 - 2 \cdot c(2n)) + j \frac{1}{\sqrt{2}}(1 - 2 \cdot c(2n+1)) .$ where the pseudo-random sequence $c(i)$ is defined in clause 5.2.1. The pseudo-random sequence generator shall be initialized with $c_{\text{init}} = \left(2^{17} \left(N_{\text{symbol}}^{\text{slot}} n_{\text{s,f}}^{\mu} + l + 1 \right) \left(2N_{\text{ID}}^{n_{\text{SCID}}} + 1 \right) + 2N_{\text{ID}}^{n_{\text{SCID}}} + n_{\text{SCID}} \right) \bmod 2^{31}$ where l is the OFDM symbol number within the slot, $n_{\text{s,f}}^{\mu}$ is the slot number within a frame, and - $N_{\text{ID}}^0, N_{\text{ID}}^1 \in \{0, 1, \dots, 65535\}$ are given by the higher-layer parameters <i>scramblingID0</i> and <i>scramblingID1</i>, respectively, in the <i>DMRS-DownlinkConfig</i> IE if provided and the PDSCH is scheduled by PDCCH using DCI format 1_1 with the CRC scrambled by C-RNTI, MCS-C-RNTI, or CS-RNTI - $N_{\text{ID}}^0 \in \{0, 1, \dots, 65535\}$ is given by the higher-layer parameter <i>scramblingID0</i> in the <i>DMRS-DownlinkConfig</i> IE if provided and the PDSCH is scheduled by PDCCH using DCI format 1_0 with the CRC scrambled by C-RNTI, MCS-C-RNTI, or CS-RNTI; - $N_{\text{ID}}^{n_{\text{SCID}}} = N_{\text{ID}}^{\text{cell}}$ otherwise; The quantity $n_{\text{SCID}} \in \{0, 1\}$ is given by the DM-RS sequence initialization field, in the DCI associated with the PDSCH transmission if DCI format 1_1 in [4, TS 38.212] is used, otherwise $n_{\text{SCID}} = 0$.

'071 Claim 11	<u>Accused Products</u>
	<u>TS 38.211 v15.8.0:</u> 6.4.1 Reference signals 6.4.1.1 <u>Demodulation reference signal for PUSCH</u> 6.4.1.1.1 Sequence generation 6.4.1.1.1.1 Sequence generation when transform precoding is disabled If transform precoding for PUSCH is not enabled, the sequence $r(n)$ shall be generated according to $r(n) = \frac{1}{\sqrt{2}}(1 - 2 \cdot c(2n)) + j \frac{1}{\sqrt{2}}(1 - 2 \cdot c(2n+1)).$ where the pseudo-random sequence $c(i)$ is defined in clause 5.2.1. <u>The pseudo-random sequence generator shall be initialized with</u> $c_{\text{init}} = \left(2^{17} \left(N_{\text{slot}}^{\text{slot}} n_{s,f}^{\mu} + l + 1 \right) \left(2N_{\text{ID}}^{\text{scid}} + 1 \right) + 2N_{\text{ID}}^{\text{scid}} + n_{\text{scid}} \right) \bmod 2^{31}$ where l is the OFDM symbol number within the slot, $n_{s,f}^{\mu}$ is the slot number within a frame, and - $N_{\text{ID}}^0, N_{\text{ID}}^1 \in \{0, 1, \dots, 65535\}$ are given by the higher-layer parameters <i>scramblingID0</i> and <i>scramblingID1</i>, respectively, in the <i>DMRS-UplinkConfig</i> IE if provided and the PUSCH is scheduled by DCI format 0_1 or by a PUSCH transmission with a configured grant; - $N_{\text{ID}}^0 \in \{0, 1, \dots, 65535\}$ is given by the higher-layer parameter <i>scramblingID0</i> in the <i>DMRS-UplinkConfig</i> IE if provided and the PUSCH is scheduled by DCI format 0_0 with the CRC scrambled by C-RNTI, MCS-C-RNTI, or CS-RNTI; - $N_{\text{ID}}^{\text{scid}} = N_{\text{ID}}^{\text{cell}}$ otherwise. The quantity $n_{\text{scid}} \in \{0, 1\}$ is indicated by the DM-RS initialization field, if present, either in the DCI associated with the PUSCH transmission if DCI format 0_1 in [4, TS 38.212] is used or by the higher layer parameter <i>dmrs-SeqInitialization</i>, if present, for a Type 1 PUSCH transmission with a configured grant, otherwise $n_{\text{scid}} = 0$.

'071 Claim 11	<u>Accused Products</u>
	where the pseudo-random sequence $c(i)$ is defined in clause 5.2.1. <u>The pseudo-random sequence generator shall be initialized with</u> $c_{\text{init}} = \left(2^{17} \left(N_{\text{symbol}}^{\text{slot}} n_{s,f}^{\mu} + l + 1 \right) \left(2N_{\text{ID}}^{\text{scid}} + 1 \right) + 2N_{\text{ID}}^{\text{scid}} + n_{\text{SCID}} \right) \bmod 2^{31}$ where l is the OFDM symbol number within the slot, $n_{s,f}^{\mu}$ is the slot number within a frame, and - $N_{\text{ID}}^0, N_{\text{ID}}^1 \in \{0, 1, \dots, 65535\}$ are given by the higher-layer parameters <i>scramblingID0</i> and <i>scramblingID1</i>, respectively, in the <i>DMRS-DownlinkConfig</i> IE if provided and the PDSCH is scheduled by PDCCH using DCI format 1_1 with the CRC scrambled by C-RNTI, MCS-C-RNTI, or CS-RNTI - $N_{\text{ID}}^0 \in \{0, 1, \dots, 65535\}$ is given by the higher-layer parameter <i>scramblingID0</i> in the <i>DMRS-DownlinkConfig</i> IE if provided and the PDSCH is scheduled by PDCCH using DCI format 1_0 with the CRC scrambled by C-RNTI, MCS-C-RNTI, or CS-RNTI; - $N_{\text{ID}}^{\text{scid}} = N_{\text{ID}}^{\text{cell}}$ otherwise; The quantity $n_{\text{SCID}} \in \{0, 1\}$ is given by the DM-RS sequence initialization field, in the DCI associated with the PDSCH transmission if DCI format 1_1 in [4, TS 38.212] is used, otherwise $n_{\text{SCID}} = 0$.

TS 36.211 v11.5.0

5.5.2 Demodulation reference signal

5.5.2.1 Demodulation reference signal for PUSCH

5.5.2.1.1 Reference signal sequence

The PUSCH demodulation reference signal sequence $r_{\text{PUSCH}}^{(\lambda)}(\cdot)$ associated with layer $\lambda \in \{0, 1, \dots, v-1\}$ is defined by

$$r_{\text{PUSCH}}^{(\lambda)}(m \cdot M_{\text{sc}}^{\text{RS}} + n) = w^{(\lambda)}(m) r_{u,n}^{(\alpha_\lambda)}(n)$$

where

$$\begin{aligned} m &= 0, 1 \\ n &= 0, \dots, M_{\text{sc}}^{\text{RS}} - 1 \end{aligned}$$

and

$$M_{\text{sc}}^{\text{RS}} = M_{\text{sc}}^{\text{PUSCH}}$$

Subclause 5.5.1 defines the sequence $r_{u,n}^{(\alpha_\lambda)}(0), \dots, r_{u,n}^{(\alpha_\lambda)}(M_{\text{sc}}^{\text{RS}} - 1)$. The orthogonal sequence $w^{(\lambda)}(m)$ is given by $[w^{(\lambda)}(0) \ w^{(\lambda)}(1)] = [1 \ 1]$ for DCI format 0 if the higher-layer parameter *Activate-DMRS-with OCC* is not set or if the temporary C-RNTI was used to transmit the most recent uplink-related DCI for the transport block associated with the corresponding PUSCH transmission, otherwise it is given by Table 5.5.2.1.1-1 using the cyclic shift field in most recent uplink-related DCI 3GPP TS 36.212 [3] for the transport block associated with the corresponding PUSCH transmission.

The cyclic shift α_λ in a slot n_s is given as $\alpha_\lambda = 2\pi n_{\text{cs},\lambda}/12$ with

$$n_{\text{cs},\lambda} = (n_{\text{DMRS}}^{(1)} + n_{\text{DMRS},\lambda}^{(2)} + n_{\text{PN}}(n_s)) \bmod 12$$

where the values of $n_{\text{DMRS}}^{(1)}$ is given by Table 5.5.2.1.1-2 according to the parameter *cyclicShift* provided by higher layers, $n_{\text{DMRS},\lambda}^{(2)}$ is given by the cyclic shift for DMRS field in most recent uplink-related DCI 3GPP TS 36.212 [3] for the transport block associated with the corresponding PUSCH transmission where the value of $n_{\text{DMRS},\lambda}^{(2)}$ is given in Table 5.5.2.1.1-1.

The first row of Table 5.5.2.1.1-1 shall be used to obtain $n_{\text{DMRS},0}^{(2)}$ and $w^{(\lambda)}(m)$ if there is no uplink-related DCI for the same transport block associated with the corresponding PUSCH transmission, and

- if the initial PUSCH for the same transport block is semi-persistently scheduled, or
- if the initial PUSCH for the same transport block is scheduled by the random access response grant.

The quantity $n_{\text{PN}}(n_s)$ is given by

$$n_{\text{PN}}(n_s) = \sum_{i=0}^7 c(8N_{\text{sym}}^{\text{UL}} \cdot n_s + i) \cdot 2^i$$

where the pseudo-random sequence $c(i)$ is defined by clause 7.2. The application of $c(i)$ is cell-specific. The pseudo-random sequence generator shall be initialized with c_{init} at the beginning of each radio frame. The quantity c_{init} is

given by $c_{\text{init}} = \left\lfloor \frac{N_{\text{ID}}^{\text{cell}}}{30} \right\rfloor \cdot 2^5 + ((N_{\text{ID}}^{\text{cell}} + \Delta_{\text{ss}}) \bmod 30)$ if no value for $N_{\text{ID}}^{\text{cell_DMRS}}$ is configured by higher layers or the

PUSCH transmission corresponds to a Random Access Response Grant or a retransmission of the same transport block

'071 Claim 11	<u>Accused Products</u>
	<u>TS 36.211 v11.5.0</u> 6.10.3 UE-specific reference signals associated with PDSCH UE-specific reference signals associated with PDSCH - are transmitted on antenna port(s) $p = 5$, $p = 7$, $p = 8$ or $p = 7, 8, \dots, v+6$, where v is the number of layers used for transmission of the PDSCH; - are present and are a valid reference for PDSCH demodulation only if the PDSCH transmission is associated with the corresponding antenna port according to clause 7.1 of 3GPP TS 36.213 [4]; - are transmitted only on the physical resource blocks upon which the corresponding PDSCH is mapped. A UE-specific reference signal associated with PDSCH is not transmitted in resource elements (k, l) in which one of the physical channels or physical signals other than the UE-specific reference signals defined in 6.1 are transmitted using resource elements with the same index pair (k, l) regardless of their antenna port p. 6.10.3.1 Sequence generation For antenna port 5, the UE-specific reference-signal sequence $r_{n_s}(m)$ is defined by $r_{n_s}(m) = \frac{1}{\sqrt{2}}(1 - 2 \cdot c(2m)) + j \frac{1}{\sqrt{2}}(1 - 2 \cdot c(2m+1)), \quad m = 0, 1, \dots, 12N_{RB}^{PDSCH} - 1$ where N_{RB}^{PDSCH} denotes the bandwidth in resource blocks of the corresponding PDSCH transmission. The pseudo-random sequence $c(i)$ is defined in clause 7.2. The pseudo-random sequence generator shall be initialised with $c_{init} = (\lfloor n_s/2 \rfloor + 1) \cdot (2N_{ID}^{cell} + 1) \cdot 2^{16} + n_{RNTI}$ at the start of each subframe where n_{RNTI} is as described in clause 7.1 3GPP TS 36.213 [4]. For any of the antenna ports $p \in \{7, 8, \dots, v+6\}$, the reference-signal sequence $r(m)$ is defined by $r(m) = \frac{1}{\sqrt{2}}(1 - 2 \cdot c(2m)) + j \frac{1}{\sqrt{2}}(1 - 2 \cdot c(2m+1)), \quad m = \begin{cases} 0, 1, \dots, 12N_{RB}^{max, DL} - 1 & \text{normal cyclic prefix} \\ 0, 1, \dots, 16N_{RB}^{max, DL} - 1 & \text{extended cyclic prefix} \end{cases}$ The pseudo-random sequence $c(i)$ is defined in clause 7.2. The pseudo-random sequence generator shall be initialised with $c_{init} = (\lfloor n_s/2 \rfloor + 1) \cdot (2n_{ID}^{(n_{SCID})} + 1) \cdot 2^{16} + n_{SCID}$ at the start of each subframe.

'071 Claim 11	<u>Accused Products</u>
	The Accused Instrumentalities (WiFi) practice a method step of comprising requiring each transmitting node (e.g., STAs) to transmit spreading code type information on the unshared parameter channel. <u>Wi-Fi Access Point</u> IEEE Standard 802.11ac (AP) The Accused Wi-Fi Router Instrumentalities require each transmitting node to transmit spreading code type information on an unshared said parameter channel (e.g., orthogonal code applied to the training field). Citation 20: VHT-PHY 21. Very high throughput (VHT) PHY specification 21.1 Introduction 21.1.1 Introduction to the VHT PHY The VHT PHY is based on the HT PHY defined in Clause 19, which in turn is based on the OFDM PHY defined in Clause 17. The VHT PHY extends the maximum number of space-time streams supported to eight and provides support for downlink multi-user (MU) transmissions. A downlink MU transmission supports up to four users with up to four space-time streams per user with the total number of space-time streams not exceeding eight. FIG. 20 Source: https://ieeexplore.ieee.org/document/7786995, Page 2498, last accessed Mar 07, 2024, Exhibit B

The Wi-Fi Standard 802.11ac provides a plurality of parameter channels (e.g., orthogonal codes applied to training fields including L-STF, L-LTF, HE-STF, HE-LTF) on the network which uses a spreading code.

Citation 21: VHT PPDU frame with VHT-LTF Field

21.3.2 VHT PPDU format

A single PPDU format is defined for this PHY: the VHT PPDU format. Figure 21-4 shows the VHT PPDU format.

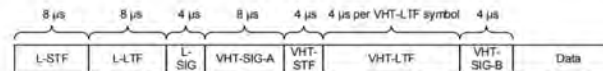


Figure 21-4—VHT PPDU format

The fields of the VHT PPDU format are summarized in Table 21-4.

Table 21-4—Fields of the VHT PPDU

Field	Description
L-STF	Non-HT Short Training field
L-LTF	Non-HT Long Training field
L-SIG	Non-HT SIGNAL field
VHT-SIG-A	VHT Signal A field
VHT-STF	VHT Short Training field
VHT-LTF	VHT Long Training field
VHT-SIG-B	VHT Signal B field
Data	The Data field carrying the PSDU(s)

FIG. 21

Source: <https://ieeexplore.ieee.org/document/7786995>, Page 2514, last accessed Mar 07, 2024, Exhibit B

The primary channel-spreading technology used by devices supporting 802.11ac is Orthogonal Frequency Division Multiplexing (OFDM). OFDM is a modulation technique that divides the available frequency spectrum into multiple subchannels, each using a different orthogonal carrier frequency. This enables parallel transmission of data streams

'071 Claim 11	<u>Accused Products</u>
	over these subchannels, improving spectral efficiency and providing resistance against frequency-selective fading and interference. Citation 22: VHT PPDU frame with VHT-LTF Field 17.3 OFDM PHY 17.3.1 Introduction Subclause 17.3 provides a convergence procedure in which PSDUs are converted to and from PPDU. During transmission, the PSDU shall be provided with a PHY preamble and header to create the PPDU. At the receiver, the PHY preamble and header are processed to aid in demodulation and delivery of the PSDU. 17.3.2 PPDU format 17.3.2.1 General Figure 17-1 shows the format for the PPDU including the OFDM PHY preamble, OFDM PHY header, PSDU, tail bits, and pad bits. The PHY header contains the following fields: LENGTH, RATE, a reserved bit, an even parity bit, and the SERVICE field. In terms of modulation, the LENGTH, RATE, reserved bit, and parity bit (with 6 zero tail bits appended) constitute a separate single OFDM symbol, denoted SIGNAL, which is transmitted with the most robust combination of BPSK modulation and a coding rate of $R = 1/2$. The SERVICE field of the PHY header and the PSDU (with 6 zero tail bits and pad bits appended), denoted as DATA, are transmitted at the data rate described in the RATE field and may constitute multiple OFDM symbols. The tail bits in the SIGNAL symbol enable decoding of the RATE and LENGTH fields immediately after the reception of the tail bits. The RATE and LENGTH fields are required for decoding the DATA part of the packet. In addition, the CCA mechanism is augmented by predicting the duration of the packet from the contents of the RATE and LENGTH fields, even if the data rate is not supported by the STA. Each of these fields is described in detail in 17.3.3, 17.3.4, and 17.3.5. FIG. 22 Source: https://ieeexplore.ieee.org/document/7786995, Page 2283, last accessed Mar 07, 2024, Exhibit B IEEE Standard 802.11ax (AP) The Wi-Fi standard 802.11ax further requires each transmitting node (e.g., STAs) to transmit spreading code type information on the unshared parameter channel (e.g., orthogonal code applied to the training field).

Citation 95: High Efficiency (HE) PHY

27. High Efficiency (HE) PHY specification

27.1 Introduction

27.1.1 Introduction to the HE PHY

The HE PHY extends the maximum number of users supported for DL MU-MIMO transmissions to 8 users per resource unit (RU) and provides support for DL and UL orthogonal frequency division multiple access (OFDMA) as well as for UL MU-MIMO. Both DL and UL MU-MIMO transmissions are supported on portions of the PPDU bandwidth (on resource units greater than or equal to 106 tones). In an MU-MIMO resource unit, there is support for up to 8 users with up to 4 space-time streams per user with the total across all users not exceeding 8 space-time streams.

Fig 71

Source: <https://ieeexplore.ieee.org/document/9442429>, Page 446, last accessed March 05, 2024, Exhibit C

The Wi-Fi Standard 802.11ax provides a plurality of parameter channels (e.g., orthogonal codes applied to training fields including L-STF, L-LTF, HE-STF, HE-LTF) on the network which uses a spreading code.

Citation 96: Parameter channels in HB TB PPDU Format

The format of the HE TB PPDU is defined as in Figure 27-11 (HE TB PPDU format). This format is used for a transmission that is a response to a triggering frame from an AP.

The format of the HE TB PPDU is the same as the HE SU PPDU except that the duration of the HE-STF field in the HE TB PPDU is twice the duration of the HE-STF field in the HE SU PPDU.

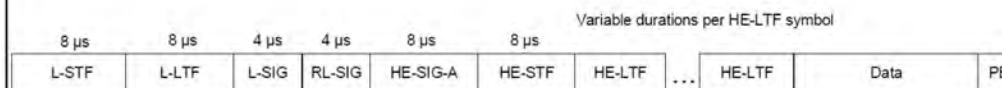


Figure 27-11—HE TB PPDU format

Fig 72

Source: <https://ieeexplore.ieee.org/document/9442429>, Page 512, last accessed March 05, 2024, Exhibit C

Citation 97: Channels occupied by HE TB PPDU

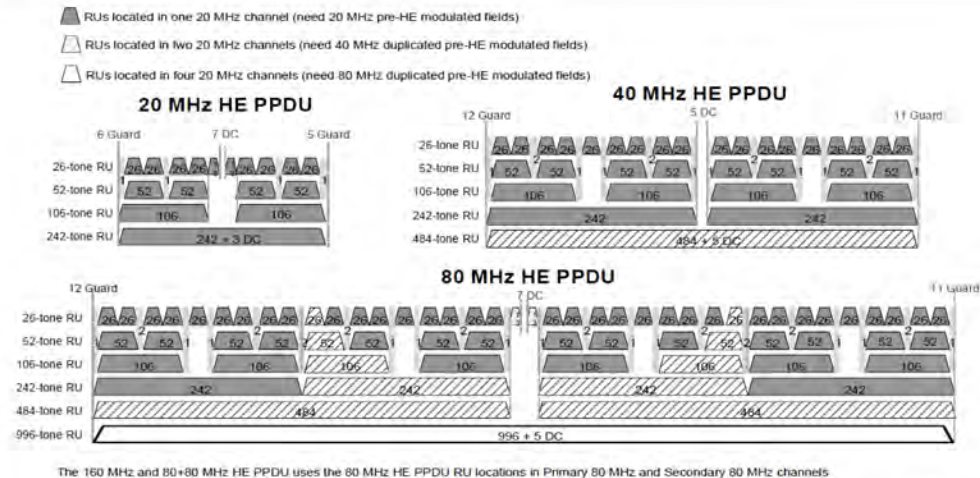


Figure 27-12—Number of 20 MHz channels occupied by the pre-HE modulated fields in an HE TB PPDU

Fig 73

Source: <https://ieeexplore.ieee.org/document/9442429>, Page 513, last accessed March 05, 2024, Exhibit C

OFDMA is a key feature introduced in 802.11ax. It extends the concept of OFDM by dividing each channel into smaller resource units called Resource Units (RUs). These RUs can be allocated to different users or devices simultaneously, enabling more efficient use of the available spectrum. OFDMA allows the access point (AP) to schedule transmissions to multiple clients within a single channel simultaneously, improving the network's ability to handle multiple devices and diverse traffic demands.

Citation 98: OFDMA in Channel-spreading

orthogonal frequency division multiple access (OFDMA) high-efficiency (HE) physical layer (PHY) protocol data unit (PPDU) (OFDMA HE PPDU): A 20 MHz HE PPDU with resource units (RUs) smaller than 242-tone, or a 40 MHz HE PPDU with RUs smaller than 484-tone, or an 80 MHz HE PPDU with RUs smaller than 996-tone, or a 160 MHz or 80+80 MHz HE PPDU with RUs smaller than 2×996-tone.

Fig 74

Source: <https://ieeexplore.ieee.org/document/9442429>, Page 44, last accessed March 05, 2024, Exhibit C

Citation 99: OFDMA in Channel-spreading

27.3.1.2 OFDMA

OFDMA is an OFDM-based multiple access scheme where different subsets of subcarriers are allocated to different users, and this scheme allows simultaneous data transmission to or from one or more users. In OFDMA, users are allocated different subsets of subcarriers that can change from one PPDU to the next. The difference between OFDM and OFDMA is illustrated in Figure 27-4. Similar to OFDM, OFDMA employs multiple subcarriers, but the subcarriers are divided into several groups where each group is referred to as an RU. With OFDMA, different transmit powers may be applied to different RUs.

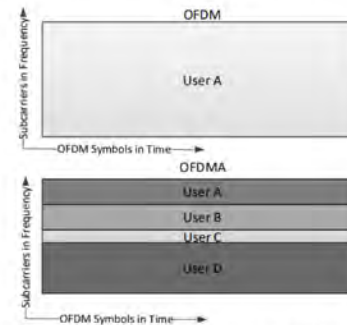


Figure 27-4—Illustration of OFDM and OFDMA concepts

Fig 75

Source: <https://ieeexplore.ieee.org/document/9442429>, Page 44, last accessed March 05, 2024, Exhibit C

User Equipment

'071 Claim 11	<u>Accused Products</u>
	IEEE Standard 802.11ac (UE) The user equipment (UE) require each transmitting node to transmit spreading code type information on an unshared said parameter channel (e.g., orthogonal code applied to the training field). Citation 20: VHT-PHY 21. Very high throughput (VHT) PHY specification 21.1 Introduction 21.1.1 Introduction to the VHT PHY The VHT PHY is based on the HT PHY defined in Clause 19, which in turn is based on the OFDM PHY defined in Clause 17. The VHT PHY extends the maximum number of space-time streams supported to eight and provides support for downlink multi-user (MU) transmissions. A downlink MU transmission supports up to four users with up to four space-time streams per user with the total number of space-time streams not exceeding eight. FIG. 20 Source: https://ieeexplore.ieee.org/document/7786995, Page 2498, last accessed Mar 15, 2024, Exhibit B The user equipment (UE) supporting Wi-Fi Standard 802.11ac provides a plurality of parameter channels (e.g., orthogonal codes applied to training fields including L-STF, L-LTF, HE-STF, HE-LTF) on the network which uses a spreading code.

Citation 21: VHT PPDU frame with VHT-LTF Field

21.3.2 VHT PPDU format

A single PPDU format is defined for this PHY: the VHT PPDU format. Figure 21-4 shows the VHT PPDU format.



Figure 21-4—VHT PPDU format

The fields of the VHT PPDU format are summarized in Table 21-4.

Table 21-4—Fields of the VHT PPDU

Field	Description
L-STF	Non-HT Short Training field
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L-SIG	Non-HT SIGNAL field
VHT-SIG-A	VHT Signal A field
VHT-STF	VHT Short Training field
VHT-LTF	VHT Long Training field
VHT-SIG-B	VHT Signal B field
Data	The Data field carrying the PSDU(s)

FIG. 21

Source: <https://ieeexplore.ieee.org/document/7786995>, Page 2514, last accessed Mar 15, 2024, Exhibit B

The primary channel-spreading technology used by user equipment supporting 802.11ac is Orthogonal Frequency Division Multiplexing (OFDM). OFDM is a modulation technique that divides the available frequency spectrum into multiple subchannels, each using a different orthogonal carrier frequency. This enables parallel transmission of data streams over these subchannels, improving spectral efficiency and providing resistance against frequency-selective fading and interference.

Citation 22: VHT PPDU frame with VHT-LTF Field

17.3 OFDM PHY

17.3.1 Introduction

Subclause 17.3 provides a convergence procedure in which PSDUs are converted to and from PPDU. During transmission, the PSDU shall be provided with a PHY preamble and header to create the PPDU. At the receiver, the PHY preamble and header are processed to aid in demodulation and delivery of the PSDU.

17.3.2 PPDU format

17.3.2.1 General

Figure 17-1 shows the format for the PPDU including the OFDM PHY preamble, OFDM PHY header, PSDU, tail bits, and pad bits. The PHY header contains the following fields: LENGTH, RATE, a reserved bit, an even parity bit, and the SERVICE field. In terms of modulation, the LENGTH, RATE, reserved bit, and parity bit (with 6 zero tail bits appended) constitute a separate single OFDM symbol, denoted SIGNAL, which is transmitted with the most robust combination of BPSK modulation and a coding rate of $R = 1/2$. The SERVICE field of the PHY header and the PSDU (with 6 zero tail bits and pad bits appended), denoted as DATA, are transmitted at the data rate described in the RATE field and may constitute multiple OFDM symbols. The tail bits in the SIGNAL symbol enable decoding of the RATE and LENGTH fields immediately after the reception of the tail bits. The RATE and LENGTH fields are required for decoding the DATA part of the packet. In addition, the CCA mechanism is augmented by predicting the duration of the packet from the contents of the RATE and LENGTH fields, even if the data rate is not supported by the STA. Each of these fields is described in detail in 17.3.3, 17.3.4, and 17.3.5.

FIG. 22

Source: <https://ieeexplore.ieee.org/document/7786995>, Page 2283, last accessed Mar 15, 2024, Exhibit B

IEEE Standard 802.11ax (UE)

The user equipment (UE) supporting Wi-Fi standard 802.11ax further requires each transmitting node (e.g., STAs) to transmit spreading code type information on the unshared parameter channel (e.g., orthogonal code applied to the training field).

Citation 100: High Efficiency (HE) PHY

'071 Claim 11	<u>Accused Products</u>
	27. High Efficiency (HE) PHY specification 27.1 Introduction 27.1.1 Introduction to the HE PHY The HE PHY extends the maximum number of users supported for DL MU-MIMO transmissions to 8 users per resource unit (RU) and provides support for DL and UL orthogonal frequency division multiple access (OFDMA) as well as for UL MU-MIMO. Both DL and UL MU-MIMO transmissions are supported on portions of the PPDU bandwidth (on resource units greater than or equal to 106 tones). In an MU-MIMO resource unit, there is support for up to 8 users with up to 4 space-time streams per user with the total across all users not exceeding 8 space-time streams. Fig 76 Source: https://ieeexplore.ieee.org/document/9442429, Page 446, last accessed March 15, 2024, Exhibit C The user equipment (UE) supporting Wi-Fi Standard 802.11ax provides a plurality of parameter channels (e.g., orthogonal codes applied to training fields including L-STF, L-LTF, HE-STF, HE-LTF) on the network which uses a spreading code.

Citation 101: Parameter channels in HB TB PPDU Format

The format of the HE TB PPDU is defined as in Figure 27-11 (HE TB PPDU format). This format is used for a transmission that is a response to a triggering frame from an AP.

The format of the HE TB PPDU is the same as the HE SU PPDU except that the duration of the HE-STF field in the HE TB PPDU is twice the duration of the HE-STF field in the HE SU PPDU.

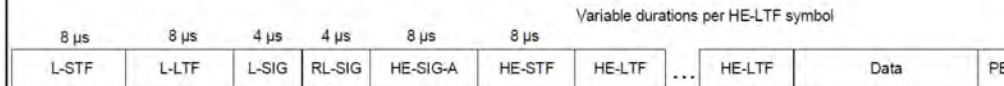


Figure 27-11—HE TB PPDU format

Fig 77

Source: <https://ieeexplore.ieee.org/document/9442429>, Page 512, last accessed March 15, 2024, Exhibit C

Citation 102: Channels occupied by HE TB PPDU

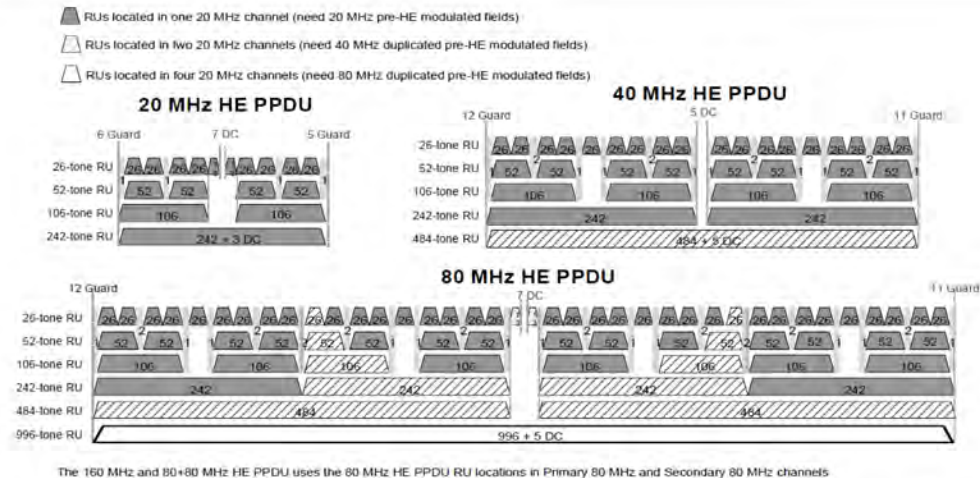


Figure 27-12—Number of 20 MHz channels occupied by the pre-HE modulated fields in an HE TB PPDU

Fig 78

Source: <https://ieeexplore.ieee.org/document/9442429>, Page 513, last accessed March 15, 2024, Exhibit C

OFDMA is a key feature introduced in 802.11ax. It extends the concept of OFDM by dividing each channel into smaller resource units called Resource Units (RUs). These RUs can be allocated to different users or devices simultaneously, enabling more efficient use of the available spectrum. OFDMA allows the access point (AP) to schedule transmissions to multiple clients within a single channel simultaneously, improving the network's ability to handle multiple devices and diverse traffic demands.

Citation 103: OFDMA in Channel-spreading

orthogonal frequency division multiple access (OFDMA) high-efficiency (HE) physical layer (PHY) protocol data unit (PPDU) (OFDMA HE PPDU): A 20 MHz HE PPDU with resource units (RUs) smaller than 242-tone, or a 40 MHz HE PPDU with RUs smaller than 484-tone, or an 80 MHz HE PPDU with RUs smaller than 996-tone, or a 160 MHz or 80+80 MHz HE PPDU with RUs smaller than 2×996-tone.

Fig 79

Source: <https://ieeexplore.ieee.org/document/9442429>, Page 44, last accessed March 15, 2024, Exhibit C

Citation 104: OFDMA in Channel-spreading

27.3.1.2 OFDMA

OFDMA is an OFDM-based multiple access scheme where different subsets of subcarriers are allocated to different users, and this scheme allows simultaneous data transmission to or from one or more users. In OFDMA, users are allocated different subsets of subcarriers that can change from one PPDU to the next. The difference between OFDM and OFDMA is illustrated in Figure 27-4. Similar to OFDM, OFDMA employs multiple subcarriers, but the subcarriers are divided into several groups where each group is referred to as an RU. With OFDMA, different transmit powers may be applied to different RUs.

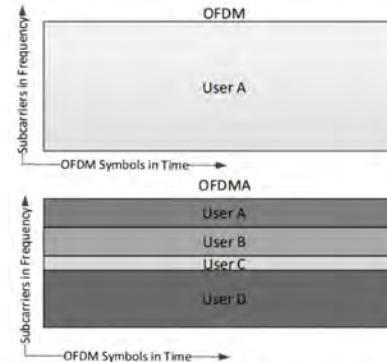


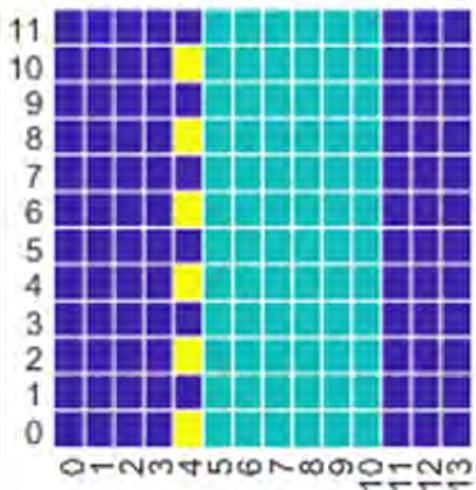
Figure 27-4—Illustration of OFDM and OFDMA concepts

Fig 80

Source: <https://ieeexplore.ieee.org/document/9442429>, Page 44, last accessed March 15, 2024, Exhibit C

'071 Claim 11	<u>Accused Products</u>
	If this element is not literally satisfied by the disclosures cited herein, it is satisfied under the doctrine of equivalents by the disclosures cited herein because the accused functionality would be insubstantially different from or function in the same way to provide the same result as the relevant claim element.

'071 Claim 16	<u>Accused Products</u>
The method of claim 1, wherein <u>the parameter channels are low in communication rate compared to the shared communication channel</u> .	<u>Cellular</u> The accused products include the method of claim 1, <i>see</i> Claim 1, wherein the parameter channels are low in communication rate compared to the shared communication channel. The parameter channels of accused products are low in communication rate compared to the shared communication channel. For example, the fraction of resource Elements (REs) assigned to DMRS reference symbols on the downlink and uplink are a fraction of the resources assigned to the shared PDSCH channel. <u>Sharetechnote DMRS Diagram:</u> NOTE : Following is the color coding for the RE (Resource Elements) in the examples in this note

'071 Claim 16	Accused Products
	 PDSCH DMRS RE PDSCH RE EMPTY RE (No Signal) <u>Mathworks DMRS Diagram:</u> <u>Symbol allocation of PUSCH indicates the OFDM symbol locations allocated for the PUSCH transmission in a slot.</u> The mapping type indicates the first DM-RS OFDM symbol location and the duration of OFDM symbols (l_d). For mapping type A, l_d is the duration between the first OFDM symbol of the slot and the last OFDM symbol of the allocated PUSCH resources. For mapping type B, l_d is the duration of the allocated PUSCH resources. When intra-slot frequency hopping is enabled, l_d is the duration per hop. The DM-RS symbols are present in each hop when intra-slot frequency hopping is enabled. When intra-slot frequency hopping is enabled, DM-RS is single-symbol with the maximum number of additional positions either 0 or 1. The DM-RS symbol locations is given by TS 38.211 Tables 6.4.1.1.3-3, 6.4.1.1.3-4, and 6.4.1.1.3-6. Figure 1 shows the DM-RS symbol locations for PUSCH occupying 14 symbols with PUSCH mapping type A, intra-slot frequency hopping enabled, and number of DM-RS additional positions as 1. The figure shows DM-RS is present in each hop. The locations of DM-RS symbols in each hop depends on the number of OFDM symbols allocated for PUSCH in each hop.

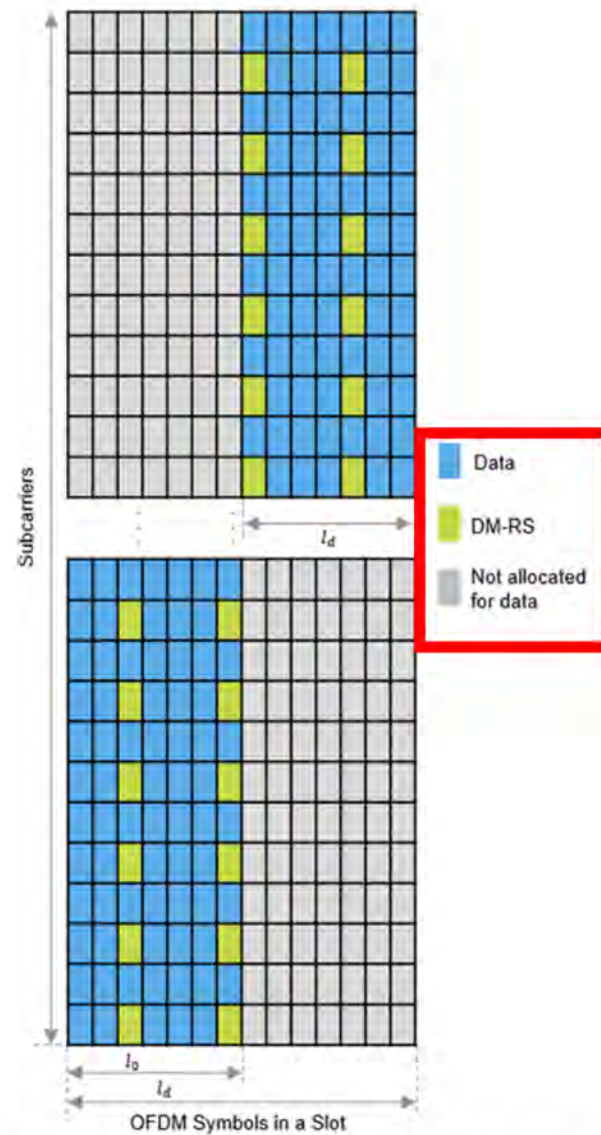


Figure 1: DM-RS Symbol Locations Based on Intra-Slot Frequency Hopping

'071 Claim 16	<u>Accused Products</u>
	If this element is not literally satisfied by the disclosures cited herein, it is satisfied under the doctrine of equivalents by the disclosures cited herein because the accused functionality would be insubstantially different from or function in the same way to provide the same result as the relevant claim element.

U.S. Pat. No. 9,814,071	<u>Accused Products</u>
21. A method for enabling a receiving node to distinguish information concurrently received from a plurality of transmitting nodes on a shared communication channel of a wireless digital network , the method comprising:	<u>Cellular</u> To the extent the preamble is construed as a limitation, the Accused LTE/5G Base Stations include a method for enabling a receiving node to distinguish information simultaneously received from a plurality of transmitting nodes (e.g., UEs) on a shared communication channel of a wireless digital network. See e.g., 3GPP TS 36.300 V10.12.0 (2014-12): 4 Overall architecture The E-UTRAN consists of eNBs, providing the E-UTRA user plane (PDCP/RLC/MAC/PHY) and control plane (RRC) protocol terminations towards the UE. The eNBs are interconnected with each other by means of the X2 interface. The eNBs are also connected by means of the S1 interface to the EPC (Evolved Packet Core), more specifically to the MME (Mobility Management Entity) by means of the S1-MME interface and to the Serving Gateway (S-GW) by means of the S1-U interface. The S1 interface supports a many-to-many relation between MMEs / Serving Gateways and eNBs. The E-UTRAN architecture is illustrated in Figure 4 below.

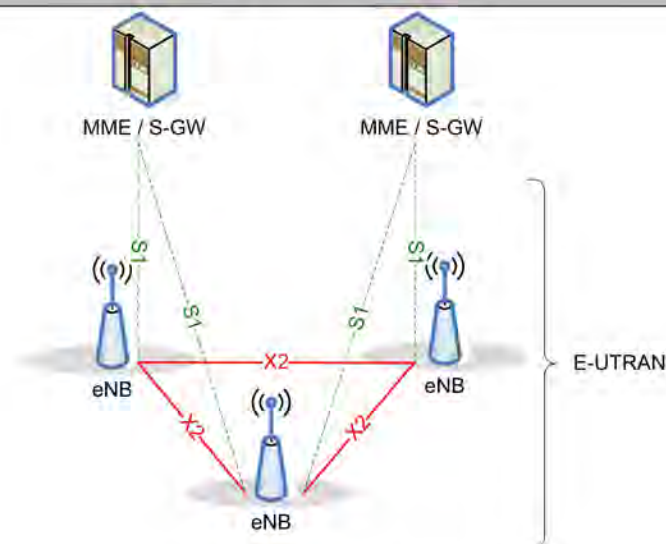


Figure 4-1: Overall Architecture

4.1 Functional Split

The eNB hosts the following functions:

- Functions for Radio Resource Management: Radio Bearer Control, Radio Admission Control, Connection Mobility Control, Dynamic allocation of resources to UEs in both uplink and downlink (scheduling);

[...]

5.2.6 Uplink multi-antenna transmission

The antenna configuration for uplink supports both SU-MIMO and MU-MIMO.

U.S. Pat. No. 9,814,071	<u>Accused Products</u>
	[3] 5.1.1 Physical channels An uplink physical channel corresponds to a set of resource elements carrying information originating from higher layers and is the interface defined between 36.212 and 36.211. The following uplink physical channels are defined: - Physical Uplink Shared Channel, PUSCH - Physical Uplink Control Channel, PUCCH - Physical Random Access Channel, PRACH 5.1.2 Physical signals An uplink physical signal is used by the physical layer but does not carry information originating from higher layers. The following uplink physical signals are defined: - Reference signal See e.g., 3GPP TS 36.300 V10.12.0 (2014-12): 4.1 Overall Architecture An NG-RAN node is either: - a gNB, providing NR user plane and control plane protocol terminations towards the UE; or - an ng-eNB, providing E-UTRA user plane and control plane protocol terminations towards the UE. The gNBs and ng-eNBs are interconnected with each other by means of the Xn interface. The gNBs and ng-eNBs are also connected by means of the NG interfaces to the 5GC, more specifically to the AMF (Access and Mobility Management

Function) by means of the NG-C interface and to the UPF (User Plane Function) by means of the NG-U interface (see TS 23.501 [3]).

NOTE: The architecture and the F1 interface for a functional split are defined in TS 38.401 [4].

The NG-RAN architecture is illustrated in Figure 4.1-1 below.

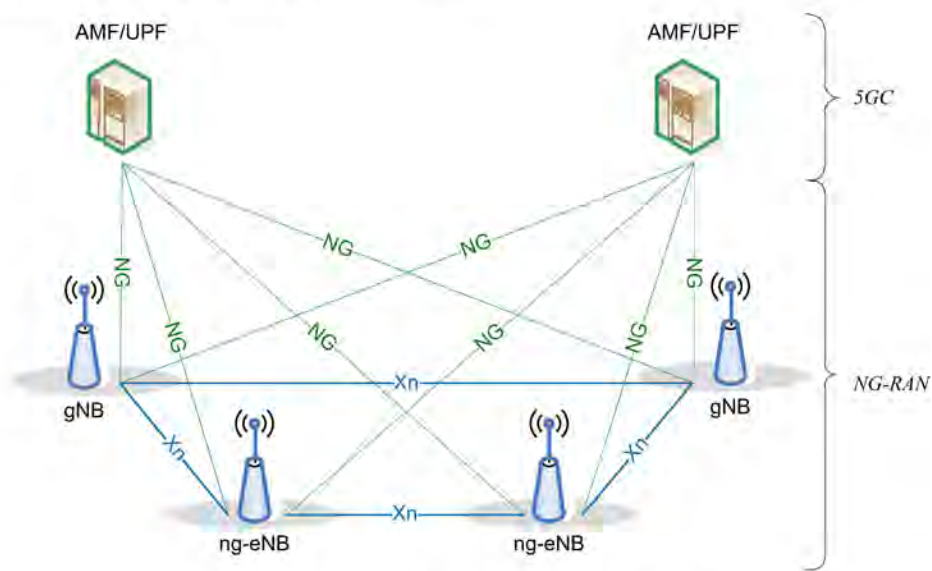


Figure 4.1-1: Overall Architecture

4.2 Functional Split

The **gNB** and ng-eNB host the following functions:

- Functions for Radio Resource Management: Radio Bearer Control, Radio Admission Control, Connection Mobility Control, Dynamic allocation of resources to UEs in both uplink and downlink (scheduling);

U.S. Pat. No. 9,814,071	<u>Accused Products</u>
	To the extent the preamble is construed as a limitation, the Accused LTE/5G UEs use a method for enabling a receiving node to distinguish information simultaneously received from a plurality of transmitting nodes (e.g., UEs) on a shared communication channel of a wireless digital network.

U.S. Pat. No. 9,814,071	<u>Accused Products</u>
	<u>TS 36.211 v12.5.0:</u> <u>6.4 Physical downlink shared channel</u> The physical downlink shared channel shall be processed and mapped to resource elements as described in clause 6.3 with the following additions and exceptions: - In resource blocks in which UE-specific reference signals are not transmitted, the PDSCH shall be transmitted on the same set of antenna ports as the PBCH, which is one of $\{0\}$, $\{0,1\}$, or $\{0,1,2,3\}$. - <u>In resource blocks in which UE-specific reference signals are transmitted, the PDSCH shall be transmitted on antenna port(s) $\{5\}$, $\{7\}$, $\{8\}$, or $p \in \{7,8,\dots,v+6\}$, where v is the number of layers used for transmission of the PDSCH.</u> - If PDSCH is transmitted in MBSFN subframes as defined in 3GPP TS 36.213 [4], the PDSCH shall be transmitted on one or several of antenna port(s) $p \in \{7,8,\dots,v+6\}$, where v is the number of layers used for transmission of the PDSCH. - PDSCH is not mapped to resource elements used for UE-specific reference signals associated with PDSCH - In mapping to resource elements, the positions of the cell-specific reference signals are given by clause 6.10.1.2 with the number of antenna ports and the frequency shift of the cell-specific reference signals derived as described in clause 6.10.1.2, unless other values for these parameters are provided by clause 7.1.9 in 3GPP TS 36.213 [4], in which case these values are used in the resource blocks indicated by the relevant DCI. - If the DCI associated with the PDSCH uses the C-RNTI or semi-persistent C-RNTI, the PDSCH is not mapped to resource elements assumed by the UE to be used for transmission of: - zero-power CSI reference signals, where the positions of the CSI reference signals are given by clause 6.10.5.2. The configuration for zero power CSI reference signals is - obtained as described in clause 6.10.5.2, unless other values for these parameters are provided by clause 7.1.9 in 3GPP TS 36.213 [4], in which case these values are used in the resource blocks indicated by the relevant DCI, and - obtained by higher-layer configuration of up to five reserved CSI-RS resources as part of the discovery signal configuration following the procedure for zero-power CSI-RS in clause 6.10.5.2. - non-zero-power CSI reference signals for CSI reporting, where the positions of the non-zero-power CSI reference signals for CSI reporting are given by clause 6.10.5.2. The configuration for non-zero power CSI reference signals is obtained as described in clause 6.10.5.2.

U.S. Pat. No. 9,814,071	<u>Accused Products</u>
	7.3 Physical channels 7.3.1 <u>Physical downlink shared channel</u> 7.3.1.1 Scrambling Up to two codewords $q \in \{0,1\}$ can be transmitted. In case of single-codeword transmission, $q = 0$. For each codeword q, the UE shall assume the block of bits $b^{(q)}(0), \dots, b^{(q)}(M_{\text{bit}}^{(q)} - 1)$, where $M_{\text{bit}}^{(q)}$ is the number of bits in codeword q transmitted on the physical channel, are scrambled prior to modulation, resulting in a block of scrambled bits $\bar{b}^{(q)}(0), \dots, \bar{b}^{(q)}(M_{\text{bit}}^{(q)} - 1)$ according to $\bar{b}^{(q)}(i) = (b^{(q)}(i) + c^{(q)}(i)) \bmod 2$ where the scrambling sequence $c^{(q)}(i)$ is given by clause 5.2.1. The scrambling sequence generator shall be initialized with $c_{\text{init}} = n_{\text{RNTI}} \cdot 2^{15} + q \cdot 2^{14} + n_{\text{ID}}$ where - $n_{\text{ID}} \in \{0,1,\dots,1023\}$ equals the higher-layer parameter <i>dataScramblingIdentityPDSCH</i> if configured and the RNTI equals the C-RNTI, MCS-C-RNTI, or CS-RNTI, and the transmission is not scheduled using DCI format 1_0 in a common search space, - $n_{\text{ID}} = N_{\text{ID}}^{\text{cell}}$ otherwise and where n_{RNTI} corresponds to the RNTI associated with the PDSCH transmission as described in clause 5.1 of [6, TS 38.214].

U.S. Pat. No. 9,814,071	<u>Accused Products</u>
	7.3.1.3 <u>Layer mapping</u> The UE shall assume that complex-valued modulation symbols for each of the codewords to be transmitted are mapped onto one or several layers according to Table 7.3.1.3-1. <u>Complex-valued modulation symbols $d^{(q)}(0), \dots, d^{(q)}(M_{\text{symb}}^{(q)} - 1)$ for codeword q shall be mapped onto the layers $x(i) = [x^{(0)}(i) \dots x^{(v-1)}(i)]^T, i = 0, 1, \dots, M_{\text{symb}}^{\text{layer}} - 1$ where v is the number of layers and $M_{\text{symb}}^{\text{layer}}$ is the number of modulation symbols per layer.</u>

Table 6.3.3.2-1: Codeword-to-layer mapping for spatial multiplexing

Number of layers	Number of codewords	Codeword-to-layer mapping $i = 0, 1, \dots, M_{\text{symb}}^{\text{layer}} - 1$
1	1	$x^{(0)}(i) = d^{(0)}(i)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)}$
2	1	$x^{(0)}(i) = d^{(0)}(2i)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 2$ $x^{(1)}(i) = d^{(0)}(2i + 1)$
2	2	$x^{(0)}(i) = d^{(0)}(i)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} = M_{\text{symb}}^{(1)}$ $x^{(1)}(i) = d^{(1)}(i)$
3	1	$x^{(0)}(i) = d^{(0)}(3i)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 3$ $x^{(1)}(i) = d^{(0)}(3i + 1)$ $x^{(2)}(i) = d^{(0)}(3i + 2)$
3	2	$x^{(0)}(i) = d^{(0)}(i)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} = M_{\text{symb}}^{(1)} / 2$ $x^{(1)}(i) = d^{(1)}(2i)$ $x^{(2)}(i) = d^{(1)}(2i + 1)$
4	1	$x^{(0)}(i) = d^{(0)}(4i)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 4$ $x^{(1)}(i) = d^{(0)}(4i + 1)$ $x^{(2)}(i) = d^{(0)}(4i + 2)$ $x^{(3)}(i) = d^{(0)}(4i + 3)$
4	2	$x^{(0)}(i) = d^{(0)}(2i)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 2 = M_{\text{symb}}^{(1)} / 2$ $x^{(1)}(i) = d^{(0)}(2i + 1)$ $x^{(2)}(i) = d^{(1)}(2i)$ $x^{(3)}(i) = d^{(1)}(2i + 1)$
5	2	$x^{(0)}(i) = d^{(0)}(2i)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 2 = M_{\text{symb}}^{(1)} / 3$ $x^{(1)}(i) = d^{(0)}(2i + 1)$ $x^{(2)}(i) = d^{(1)}(3i)$ $x^{(3)}(i) = d^{(1)}(3i + 1)$ $x^{(4)}(i) = d^{(1)}(3i + 2)$
6	2	$x^{(0)}(i) = d^{(0)}(3i)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 3 = M_{\text{symb}}^{(1)} / 3$ $x^{(1)}(i) = d^{(0)}(3i + 1)$ $x^{(2)}(i) = d^{(0)}(3i + 2)$ $x^{(3)}(i) = d^{(1)}(3i)$ $x^{(4)}(i) = d^{(1)}(3i + 1)$ $x^{(5)}(i) = d^{(1)}(3i + 2)$
7	2	$x^{(0)}(i) = d^{(0)}(3i)$ $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 3 = M_{\text{symb}}^{(1)} / 4$ $x^{(1)}(i) = d^{(0)}(3i + 1)$ $x^{(2)}(i) = d^{(0)}(3i + 2)$ $x^{(3)}(i) = d^{(1)}(4i)$ $x^{(4)}(i) = d^{(1)}(4i + 1)$ $x^{(5)}(i) = d^{(1)}(4i + 2)$ $x^{(6)}(i) = d^{(1)}(4i + 3)$

U.S. Pat. No. 9,814,071	<u>Accused Products</u>
	The Accused Instrumentalities (WiFi) include a method for enabling a receiving node to distinguish information concurrently received from a plurality of transmitting nodes on a shared communication channel of a wireless digital network. <u>Wi-Fi Access Point</u> IEEE Standard 802.11ac (AP) The accused AP devices are equipped with IEEE 802.11ac support as well as multiple-input multiple-output (MIMO) capabilities. The Accused Wi-Fi Router Instrumentalities detect and distinguish the information concurrently received from a plurality of transmitting nodes on a shared communication channel of a wireless digital network. Citation 23: VHT-PHY 21. Very high throughput (VHT) PHY specification 21.1 Introduction 21.1.1 Introduction to the VHT PHY The VHT PHY is based on the HT PHY defined in Clause 19, which in turn is based on the OFDM PHY defined in Clause 17. The VHT PHY extends the maximum number of space-time streams supported to eight and provides support for downlink multi-user (MU) transmissions. A downlink MU transmission supports up to four users with up to four space-time streams per user with the total number of space-time streams not exceeding eight.

U.S. Pat. No. 9,814,071	Accused Products
	FIG. 23 Source: https://ieeexplore.ieee.org/document/7786995, Page 2498, last accessed Mar 07, 2024, Exhibit B Citation 24: Stations support SU-MIMO 21.3.11 SU-MIMO and DL-MU-MIMO Beamforming 21.3.11.1 General 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. With DL-MU-MIMO beamforming, disjoint subsets of the space-time streams are intended for reception at different STAs. 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. The feedback report format is described in 9.4.1.49. For DL-MU-MIMO beamforming, the receive signal vector in subcarrier k at beamformee u, $y_{k,u} = [y_{k,u,1}, \dots, y_{k,u,N_{RX,u}}]^T$, is shown in Equation (21-101), where $x_k = [x_{k,0}, x_{k,1}, \dots, x_{k,N_{TX}-1}]^T$ denotes the transmit signal vector in subcarrier k for all N_{BSER} beamformers, with $x_{k,u} = [x_{k,u,1}, \dots, x_{k,u,N_{TX,u}-1}]^T$ being the transmit signal for beamformee u. $y_{k,u} = H_{k,u} \times [Q_{k,0}, Q_{k,1}, \dots, Q_{k,N_{BSER}-1}] \times x_k + n \quad (21-101)$ where $H_{k,u}$ is the channel matrix from the beamformer to beamformee u in subcarrier k with dimensions $N_{RX,u} \times N_{TX}$ FIG. 24 Source: https://ieeexplore.ieee.org/document/7786995, Page 2579, last accessed Mar 07, 2024, Exhibit B IEEE Standard 802.11ax (AP) The accused AP devices are equipped with IEEE 802.11ax support as well as multiple-input multiple-output (MIMO) capabilities.

U.S. Pat. No. 9,814,071	<u>Accused Products</u>
	The Wi-Fi Standard 802.11ax uses a method for enabling a receiving node to distinguish information simultaneously/concurrently received from a plurality of transmitting nodes (e.g., STAs) on a shared communication channel of a wireless digital network. Citation 105: UL MU Operation 26.5.2 UL MU operation 26.5.2.1 General 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 frames in an HE TB PPDU unless the Trigger frame is an MU-RTS Trigger frame, in which case the response is a CTS frame sent in a non-HT PPDU (see 26.2.6 (MU-RTS Trigger/CTS frame exchange procedure)). Fig 81 Source: https://ieeexplore.ieee.org/document/9442429, Page 342, last accessed March 05, 2024, Exhibit C Citation 106: High Efficiency (HE) PHY specification

U.S. Pat. No. 9,814,071	<u>Accused Products</u>
	IEEE P802.11ax/D6.0, November 2019 27. High Efficiency (HE) PHY specification 27.1 Introduction 27.1.1 Introduction to the HE PHY Clause 27 (High Efficiency (HE) PHY specification) specifies the PHY entity for a high efficiency (HE) orthogonal frequency division multiplexing (OFDM) system. In addition to the requirements in Clause 27 (High Efficiency (HE) PHY specification), an HE STA shall be capable of transmitting and receiving PPDU's that are compliant with the mandatory requirements of the following PHY specifications: Fig 82 Source: <a href="https://ieeexplore.ieee.org/document/9442429">https://ieeexplore.ieee.org/document/9442429, Page 466, last accessed March 05, 2024, Exhibit C Citation 107: Features supported by High Efficiency (HE) AP An HE AP may support the following features:

U.S. Pat. No. 9,814,071	<u>Accused Products</u>
	— MU-MIMO transmission on an RU in an HE MU PPDU where the RU does not span the entire PPDU bandwidth (DL MU-MIMO within OFDMA). — MU-MIMO reception on an RU in an HE TB PPDU where the RU spans the entire PPDU bandwidth (UL MU-MIMO). — MU-MIMO reception on an RU in an HE TB PPDU where the RU does not span the entire PPDU bandwidth (UL MU-MIMO within OFDMA). — Reception of the payload on an RU in an HE MU PPDU where RU spans the entire PPDU bandwidth or a 106-tone RU within 20 MHz PPDU bandwidth. — 40 MHz channel width in the 2.4 GHz band (transmit and receive). If it is supported then all RU sizes and locations applicable to 40 MHz channel width are supported in 2.4 GHz band (transmit and receive). Fig 83 Source: https://ieeexplore.ieee.org/document/9442429, Page 468, last accessed March 05, 2024, Exhibit C Citation 108: UL MU-MIMO 27.3.3.2 UL MU-MIMO 27.3.3.2.1 Introduction UL MU-MIMO is a technique to allow multiple STAs to transmit simultaneously over the same frequency resource to the receiver. The concept is very similar to SU-MIMO where multiple space-time streams are transmitted simultaneously over the same frequency resource utilizing spatial multiplexing through multiple antennas at the transmitter and receiver. The key difference from SU-MIMO is that in UL MU-MIMO, the transmitted streams originate from multiple STAs. Fig 84 Source: https://ieeexplore.ieee.org/document/9442429, Page 510, last accessed March 05, 2024, Exhibit C

U.S. Pat. No. 9,814,071	<u>Accused Products</u>
	<u>Wi-Fi User Equipment</u> IEEE Standard 802.11ac (UE) The accused UE devices (User equipment i.e., UE) are equipped with IEEE 802.11ac support as well as multiple-input multiple-output (MIMO) capabilities. Each accused instrumentality includes multiple Wi-Fi antennas such that the device may receive at least two spatial streams simultaneously. This occurs during SU-MIMO for user devices. For example, a user device may receive a single digital data stream from a user device that comprises two or more spatial streams. The user equipment ((UE) detects and distinguishes the information concurrently received from a plurality of transmitting nodes (i.e., APs) on a shared communication channel of a wireless digital network. Citation 109: Stations support DL-MU-MIMO 21.3.11 SU-MIMO and DL-MU-MIMO Beamforming 21.3.11.1 General 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. With DL-MU-MIMO beamforming, disjoint subsets of the space-time streams are intended for reception at different STAs. For SU-MIMO beamforming, the steering matrix Q_k can be determined from the beamforming feedback matrix F_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. The feedback report format is described in 9.4.1.49. For DL-MU-MIMO beamforming, the receive signal vector in subcarrier k at beamformee u, $y_{k,u} = [y_{k,u,1}, y_{k,u,2}, \dots, y_{k,u,N_{RX,u}}]^\top$, is shown in Equation (21-101), where $x_k = [x_{k,0}, x_{k,1}, \dots, x_{k,N_{user}-1}]^\top$ denotes the transmit signal vector in subcarrier k for all N_{user} beamformers, with $x_{k,u} = [x_{k,u,0}, x_{k,u,1}, \dots, x_{k,u,N_{RX,u}}]^\top$ being the transmit signal for beamformee u. $y_{k,u} = H_{k,u} \times [Q_{k,0}, Q_{k,1}, \dots, Q_{k,N_{user}-1}] \times x_k + n \quad (21-101)$ where $H_{k,u}$ is the channel matrix from the beamformer to beamformee u in subcarrier k with dimensions $N_{RX,u} \times N_{TX}$

U.S. Pat. No. 9,814,071	Accused Products
	N_{RX_u} is the number of receive antennas at beamformer u $Q_{k,u}$ is a steering matrix for beamformer u in subcarrier k with dimensions $N_{FS} \times N_{STB_u}$ N_{user} is the number of VHT MU PPDUs recipients (see Table 21-6) n is a vector of additive noise and may include interference The DL-MU-MIMO steering matrix $Q_k = [Q_{k,0}, Q_{k,1}, \dots, Q_{k,N_{user}-1}]$ can be determined by the beamformer using the beamforming feedback matrices for subcarrier k from beamformer u, $V_{k,u}$ and SNR information for subcarrier k from beamformer 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 beamformers might replace the existing steering matrix Q_k for the next DL-MU-MIMO data transmission. The beamformer group for the MU transmission is signaled using the Group ID field in VHT-SIG-A (see 21.3.8.3.3 and 21.3.11.4). FIG. 25 Source: https://ieeexplore.ieee.org/document/7786995, Pages 2579 & 2580, last accessed Mar 15, 2024, Exhibit B The accused product exchanges its capabilities (e.g., VHT capabilities) with mobile devices to initiate the connection in Probe request/response frames. The user equipment informs the mobile terminal about its capabilities through the Probe response frame. These capabilities include information about if the user equipment supports DL-MU-MIMO and SU-MIMO. The mobile terminal sends the VHT NDP announcement frame to an access point. An access point responds with the action frame containing the Beamforming feedback matrix. The Beamforming feedback matrix field comprises a Compressed beamforming feedback matrix and the mobile device processes the received beams. Citation 110: STA information subfield

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	Table 9-25—STA Info subfields <table><tr><th>Field</th><th>Description</th></tr><tr><td>AID12</td><td>Contains the 12 least significant bits of the AID of a STA expected to process the following VHT NDP and prepare the sounding feedback. Equal to 0 if the STA is an AP, mesh STA, or STA that is a member of an IBSS.</td></tr><tr><td>Feedback Type</td><td>Indicates the type of feedback requested. Set to 0 for SU. Set to 1 for MU.</td></tr><tr><td>Nc Index</td><td>If the Feedback Type field indicates MU, then Nc Index indicates the number of columns, N_c, in the Compressed Beamforming Feedback Matrix subfield minus 1: Set to 0 to request $N_c = 1$ Set to 1 to request $N_c = 2$... Set to 7 to request $N_c = 8$ Reserved if the Feedback Type field indicates SU.</td></tr></table> FIG. 26 Source: https://ieeexplore.ieee.org/document/7786995, Page 687, last accessed Mar 15, 2024, Exhibit B Citation 111: Beamforming Feedback Matrix and its use to compute Steering matrix.	Field	Description	AID12	Contains the 12 least significant bits of the AID of a STA expected to process the following VHT NDP and prepare the sounding feedback. Equal to 0 if the STA is an AP, mesh STA, or STA that is a member of an IBSS.	Feedback Type	Indicates the type of feedback requested. Set to 0 for SU. Set to 1 for MU.	Nc Index	If the Feedback Type field indicates MU, then Nc Index indicates the number of columns, N_c , in the Compressed Beamforming Feedback Matrix subfield minus 1: Set to 0 to request $N_c = 1$ Set to 1 to request $N_c = 2$... Set to 7 to request $N_c = 8$ Reserved if the Feedback Type field indicates SU.
Field	Description								
AID12	Contains the 12 least significant bits of the AID of a STA expected to process the following VHT NDP and prepare the sounding feedback. Equal to 0 if the STA is an AP, mesh STA, or STA that is a member of an IBSS.								
Feedback Type	Indicates the type of feedback requested. Set to 0 for SU. Set to 1 for MU.								
Nc Index	If the Feedback Type field indicates MU, then Nc Index indicates the number of columns, N_c , in the Compressed Beamforming Feedback Matrix subfield minus 1: Set to 0 to request $N_c = 1$ Set to 1 to request $N_c = 2$... Set to 7 to request $N_c = 8$ Reserved if the Feedback Type field indicates SU.								

U.S. Pat. No. 9,814,071	Accused Products
	22.3.11.2 Beamforming Feedback Matrix V 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. The beamformee shall generate the beamforming feedback matrices with the number of rows (N_r) equal to the N_{STS} of the NDP. After receiving the angle information, $\phi(k,u)$ 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. FIG. 27 Source: https://ieeexplore.ieee.org/document/7786995, Page 2580, last accessed Mar 15, 2024, Exhibit B IEEE Standard 802.11ax (UE) The accused UE devices are equipped with IEEE 802.11ax support as well as multiple-input multiple-output (MIMO) capabilities. The user equipment (UE) supporting Wi-Fi Standard 802.11ax uses a method for enabling a receiving node to distinguish information simultaneously/concurrently received from a plurality of transmitting nodes (e.g., APs) on a shared communication channel of a wireless digital network. Citation 112: DL MU Transmission

U.S. Pat. No. 9,814,071	<u>Accused Products</u>
	27.3.1.1 MU transmission The MU transmissions include DL MU transmissions and UL MU transmissions. 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 or 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 triggering frame from the AP. The non-AP STAs transmit using the HE TB PPDU format and employ either UL OFDMA or UL MU-MIMO, or a mixture of both. The HE PHY supports OFDMA transmissions, in both the DL and the UL where different users can occupy different RUs in a PPDU (see 27.3.10). The transmission within an RU in a PPDU may be a single stream to one user (SISO), multiple streams spatially multiplexed to one user (SU-MIMO), or multiple streams spatially multiplexed to multiple users (MU-MIMO). NOTE—The VHT PHY supports only full-bandwidth DL MU-MIMO as described in 21.3.11. The HE PHY supports DL MU-MIMO and UL MU-MIMO, for both the full-bandwidth case and the partial-bandwidth case where MU-MIMO is used only on certain RUs in the PPDU. The combination of non-MU-MIMO allocations for some RUs and MU-MIMO allocations on different RUs in one PPDU is also supported. Fig 85 Source: https://ieeexplore.ieee.org/document/9442429, Page 498, last accessed March 15, 2024, Exhibit C Citation 113: High Efficiency (HE) PHY specification

U.S. Pat. No. 9,814,071	<u>Accused Products</u>
	IEEE P802.11ax/D6.0, November 2019 27. High Efficiency (HE) PHY specification 27.1 Introduction 27.1.1 Introduction to the HE PHY Clause 27 (High Efficiency (HE) PHY specification) specifies the PHY entity for a high efficiency (HE) orthogonal frequency division multiplexing (OFDM) system. In addition to the requirements in Clause 27 (High Efficiency (HE) PHY specification), an HE STA shall be capable of transmitting and receiving PPDU's that are compliant with the mandatory requirements of the following PHY specifications: Fig 86 Source: <a href="https://ieeexplore.ieee.org/document/9442429">https://ieeexplore.ieee.org/document/9442429, Page 466, last accessed March 15, 2024, Exhibit C Citation 114: Features supported by non-AP High Efficiency (HE) STA

U.S. Pat. No. 9,814,071	<u>Accused Products</u>
	A non-AP HE STA shall support the following features: — Reception of an HE MU PPDU where the RU allocated to the non-AP STA is not utilizing MU-MIMO (DL OFDMA). — Transmission of an HE TB PPDU where the RU allocated to the non-AP STA is not utilizing MU-MIMO (UL OFDMA). — Reception of an HE MU PPDU consisting of a single RU spanning the entire PPDU bandwidth and utilizing MU-MIMO (DL MU-MIMO). The maximum number of spatial streams per user the non-AP STA can receive in the DL MU-MIMO transmission shall be equal to the minimum of 4 and the maximum number of spatial streams supported for reception of HE SU PPDU's. The non-AP STA shall be able to receive its intended spatial streams in a DL MU-MIMO transmission with a total number of spatial streams across all users of at least 4. — Reception of an HE MU PPDU with up to 4 HE-LTF OFDM symbols, where the RU allocated to the non-AP STA does not span the entire PPDU bandwidth. — Responding with the requested beamforming feedback in an HE sounding procedure with the maximum number of space-time streams in the HE sounding NDP that the non-AP STA can respond to being at least 4. — Reception of the HE-SIG-B field in an HE MU PPDU at HE-MCSs 0 to 5. — Single spatial stream HE-MCSs 0 to 7 in all supported channel widths and RU sizes for HE MU PPDU's (receive) or HE TB PPDU's (transmit). — 40 MHz and 80 MHz channel widths and all RU sizes and locations applicable to the 40 MHz and 80 MHz channel widths in the 5 GHz band (transmit and receive), except for a 20 MHz-only non-AP HE STA in which case the 40 MHz and 80 MHz channel widths, 996-tone RU, and 484-tone RU sizes in the 5 GHz and 6 GHz bands are not applicable. — Reception of an HE MU PPDU with a 2x HE-LTF and 0.8 μs GI duration on the HE-LTF and Data field OFDM symbols. — Reception of an HE MU PPDU with a 2x HE-LTF and 1.6 μs GI duration on the HE-LTF and Data field OFDM symbols. — Transmission of an HE TB PPDU with a 2x HE-LTF and 1.6 μs GI duration on the HE-LTF and Data field OFDM symbols. — Reception of an HE MU PPDU with a 4x HE-LTF and 3.2 μs GI duration on the HE-LTF and Data field OFDM symbols. — Transmission of an HE TB PPDU with a 4x HE-LTF and 3.2 μs GI duration on the HE-LTF and Data field OFDM symbols. — Reception of an HE MU PPDU with a 4x HE-LTF and 0.8 μs GI duration on the HE-LTF and the Data field OFDM symbols if the non-AP HE STA supports HE ER SU PPDU's with the same HE-LTF and GI combinations. — 26-, 52-, and 106-tone RU sizes on locations allowed in 27.3.2.8 in the primary 20 MHz channel within 40 MHz channel width if the non-AP HE STA is a 20 MHz operating non-AP HE STA and

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	that is capable of supporting 40 MHz channel width (B0 of the Supported Channel Width Set subfield in the HE PHY Capabilities Information field in the HE Capabilities element is 1) (transmit and receive). — 26-, 52-, and 106-tone RU sizes on locations allowed in 27.3.2.8 in the primary 20 MHz channel within 80 MHz channel width if the non-AP HE STA is a 20 MHz operating non-AP HE STA and is operating in the 5 GHz or 6 GHz bands (transmit and receive). Fig 87 Source: https://ieeexplore.ieee.org/document/9442429, Pages 469 & 470, last accessed March 15, 2024, Exhibit C Citation 115: DL MU-MIMO 27.3.3.1 DL MU-MIMO 27.3.3.1.1 Supported RU sizes in DL MU-MIMO A STA that sets the Partial Bandwidth DL MU-MIMO subfield of the HE PHY Capabilities Information field in the HE Capabilities element that it transmits to 1 shall support receiving an RU in an HE MU PPDU where MU-MIMO is employed in the RU, the RU size is greater than or equal to 106 tones, and the RU does not span the entire PPDU bandwidth. Fig 88 Source: https://ieeexplore.ieee.org/document/9442429, Page 509, last accessed March 15, 2024, Exhibit C
receiving a plurality of parameter - estimating	<u>Cellular</u>

U.S. Pat. No. 9,814,071	<u>Accused Products</u>
signals each on an unshared parameter channel from a corresponding transmitting node;	The Accused LTE/5G Base Stations include receiving a plurality of parameter-estimating signals each on an unshared parameter channel from a corresponding transmitting node. The Accused LTE/5G Base Stations receive a plurality of parameter channels on the network in addition to the shared communication channel (e.g., data portion of a frame). See e.g., 3GPP TS 36.211 V10.7.0 (2013-02): 5.5.2 Demodulation reference signal 5.5.2.1 Demodulation reference signal for PUSCH 5.5.2.1.1 Reference signal sequence The PUSCH demodulation reference signal sequence $r_{\text{PUSCH}}^{(\lambda)}(\cdot)$ associated with layer $\lambda \in \{0,1,\dots,\nu-1\}$ is defined by $r_{\text{PUSCH}}^{(\lambda)}(m \cdot M_{\text{sc}}^{\text{RS}} + n) = w^{(\lambda)}(m) r_{u,v}^{(\alpha_\lambda)}(n)$ where $m = 0,1$ $n = 0,\dots,M_{\text{sc}}^{\text{RS}} - 1$ and $M_{\text{sc}}^{\text{RS}} = M_{\text{sc}}^{\text{PUSCH}}$ Section 5.5.1 defines the sequence $r_{u,v}^{(\alpha_\lambda)}(0),\dots,r_{u,v}^{(\alpha_\lambda)}(M_{\text{sc}}^{\text{RS}} - 1)$. The orthogonal sequence $w^{(\lambda)}(m)$ is given by $\begin{bmatrix} w^{(\lambda)}(0) & w^{(\lambda)}(1) \end{bmatrix} = \begin{bmatrix} 1 & 1 \end{bmatrix}$ for DCI format 0 if the higher-layer parameter <i>Activate-DMRS-with OCC</i> is not set or if the temporary C-RNTI was used to transmit the most recent uplink-related DCI for the transport block associated with the corresponding PUSCH transmission, otherwise it is given by Table 5.5.2.1.1-1 using the cyclic shift field in most recent uplink-related DCI [3] for the transport block associated with the corresponding PUSCH transmission.

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	The cyclic shift α_λ in a slot n_s is given as $\alpha_\lambda = 2\pi m_{cs,\lambda}/12$ with $n_{cs,\lambda} = (n_{DMRS}^{(1)} + n_{DMRS,\lambda}^{(2)} + n_{PN}(n_s)) \bmod 12$ where the values of $n_{DMRS}^{(1)}$ is given by Table 5.5.2.1.1-2 according to the parameter <i>cyclicShift</i> provided by higher layers, $n_{DMRS,\lambda}^{(2)}$ is given by the cyclic shift for DMRS field in most recent uplink-related DCI [3] for the transport block associated with the corresponding PUSCH transmission where the value of $n_{DMRS,\lambda}^{(2)}$ is given in Table 5.5.2.1.1-1. The Accused LTE/5G UEs also include receiving a plurality of parameter-estimating signals each on an unshared parameter channel from a corresponding transmitting node. The Accused LTE/5G UEs receive a plurality of parameter channels on the network in addition to the shared communication channel (e.g., data portion of a frame).

U.S. Pat. No. 9,814,071	<u>Accused Products</u>
	<u>TS 36.211 v12.5.0:</u> 6.10.3 <u>UE-specific reference signals associated with PDSCH</u> UE-specific reference signals associated with PDSCH - are transmitted on antenna port(s) $p = 5, p = 7, p = 8$ or $p = 7, 8, \dots, v+6$, where v is the number of layers used for transmission of the PDSCH; - are present and are a valid reference for PDSCH demodulation only if the PDSCH transmission is associated with the corresponding antenna port according to clause 7.1 of 3GPP TS 36.213 [4]; - are transmitted only on the physical resource blocks upon which the corresponding PDSCH is mapped. A UE-specific reference signal associated with PDSCH is not transmitted in resource elements (k, l) in which one of the physical channels or physical signals other than the UE-specific reference signals defined in 6.1 are transmitted using resource elements with the same index pair (k, l) regardless of their antenna port p. 6.10.3.1 Sequence generation For antenna port 5, the UE-specific reference-signal sequence $r_{n_s}(m)$ is defined by $r_{n_s}(m) = \frac{1}{\sqrt{2}}(1 - 2 \cdot c(2m)) + j \frac{1}{\sqrt{2}}(1 - 2 \cdot c(2m+1)), \quad m = 0, 1, \dots, 12N_{\text{RB}}^{\text{PDSCH}} - 1$ where $N_{\text{RB}}^{\text{PDSCH}}$ denotes the assigned bandwidth in resource blocks of the corresponding PDSCH transmission. The pseudo-random sequence $c(i)$ is defined in clause 7.2. The pseudo-random sequence generator shall be initialised with $c_{\text{init}} = (\lfloor n_s/2 \rfloor + 1) \cdot (2N_{\text{ID}}^{\text{cell}} + 1) \cdot 2^{16} + n_{\text{RNTI}}$ at the start of each subframe where n_{RNTI} is as described in clause 7.1 3GPP TS 36.213 [4]. For any of the antenna ports $p \in \{7, 8, \dots, v+6\}$, the reference-signal sequence $r(m)$ is defined by $r(m) = \frac{1}{\sqrt{2}}(1 - 2 \cdot c(2m)) + j \frac{1}{\sqrt{2}}(1 - 2 \cdot c(2m+1)), \quad m = \begin{cases} 0, 1, \dots, 12N_{\text{RB}}^{\text{max,DL}} - 1 & \text{normal cyclic prefix} \\ 0, 1, \dots, 16N_{\text{RB}}^{\text{max,DL}} - 1 & \text{extended cyclic prefix} \end{cases}$ <u>TS 38.211 v15.8.0:</u>

U.S. Pat. No. 9,814,071	<u>Accused Products</u>
	7.4.1.1 <u>Demodulation reference signals for PDSCH</u> 7.4.1.1.1 Sequence generation The UE shall assume the sequence $r(n)$ is defined by $r(n) = \frac{1}{\sqrt{2}}(1 - 2 \cdot c(2n)) + j \frac{1}{\sqrt{2}}(1 - 2 \cdot c(2n+1))$ where the pseudo-random sequence $c(i)$ is defined in clause 5.2.1. The pseudo-random sequence generator shall be initialized with $c_{\text{init}} = \left(2^{17} \left(N_{\text{symbol}}^{\text{slot}} n_{\text{s,f}}^{\mu} + l + 1 \right) \left(2N_{\text{ID}}^{\text{SCID}} + 1 \right) + 2N_{\text{ID}}^{\text{SCID}} + n_{\text{SCID}} \right) \bmod 2^{31}$ where l is the OFDM symbol number within the slot, $n_{\text{s,f}}^{\mu}$ is the slot number within a frame, and - $N_{\text{ID}}^0, N_{\text{ID}}^1 \in \{0, 1, \dots, 65535\}$ are given by the higher-layer parameters <i>scramblingID0</i> and <i>scramblingID1</i>, respectively, in the <i>DMRS-DownlinkConfig</i> IE if provided and the PDSCH is scheduled by PDCCH using DCI format 1_1 with the CRC scrambled by C-RNTI, MCS-C-RNTI, or CS-RNTI - $N_{\text{ID}}^0 \in \{0, 1, \dots, 65535\}$ is given by the higher-layer parameter <i>scramblingID0</i> in the <i>DMRS-DownlinkConfig</i> IE if provided and the PDSCH is scheduled by PDCCH using DCI format 1_0 with the CRC scrambled by C-RNTI, MCS-C-RNTI, or CS-RNTI; - $N_{\text{ID}}^{\text{SCID}} = N_{\text{ID}}^{\text{cell}}$ otherwise; The quantity $n_{\text{SCID}} \in \{0, 1\}$ is given by the DM-RS sequence initialization field, in the DCI associated with the PDSCH transmission if DCI format 1_1 in [4, TS 38.212] is used, otherwise $n_{\text{SCID}} = 0$. 7.4.1.1.2 Mapping to physical resources The UE shall assume the PDSCH DM-RS being mapped to physical resources according to configuration type 1 or configuration type 2 as given by the higher-layer parameter <i>dmrs-Type</i>.

U.S. Pat. No. 9,814,071	<u>Accused Products</u>
	The Accused Instrumentalities (WiFi) practice a method of receiving a plurality of parameter-estimating signals each on an unshared parameter channel from a corresponding transmitting node. <u>Wi-Fi Access Point</u> IEEE Standard 802.11ac (AP) The Accused Wi-Fi Router Instrumentalities require each transmitting node to transmit a parameter-estimating signal (e.g., training field) on an unshared said parameter channel (e.g., orthogonal code applied to training field). The VHT LTF (long training fields) are used by the receiver to estimate the MIMO channel and equalize the received signal. The number of LTF symbols sent in a packet depends on the number of space-time streams: one LTF for one space-time stream, two LTFs for two space-time streams, four LTFs for three or four space-time streams, six LTFs for five or six space-time streams, eight LTFs for seven or eight space-time streams. Citation 25: VHT-LTF

21.3.8.3.5 VHT-LTF definition

The VHT Long Training field (VHT-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. The transmitter provides training for $N_{STS, total}$ space-time streams (spatial mapper inputs) used for the transmission of the PSDU(s). For each tone, the MIMO channel that can be estimated is an $N_{RX} \times N_{STS, total}$ matrix. A VHT transmission has a preamble that contains VHT-LTF symbols, where the data tones of each VHT-LTF symbol are multiplied by entries belonging to a matrix $P_{VHT-LTF}$, to enable channel estimation at the receiver. The pilot tones of each VHT-LTF symbol are multiplied by the entries of a matrix $R_{VHT-LTF}$ defined in the following text. The multiplication of the pilot tones in the VHT-LTF symbol by the $R_{VHT-LTF}$ matrix instead of the $P_{VHT-LTF}$ matrix allows receivers to track phase and frequency offset during MIMO channel estimation using the VHT-LTF. The number of VHT-LTF symbols, $N_{VHT-LTF}$, is a function of the total number of space-time streams $N_{STS, total}$ as shown in Table 21-13. As a result the VHT-LTF field consists of one, two, four, six or eight symbols.

Table 21-13—Number of VHT-LTFs required for different numbers of space-time streams

$N_{STS, total}$	$N_{VHT-LTF}$
1	1
2	2
3	4
4	4
5	6
6	6
7	8
8	8

FIG. 25

Source: <https://ieeexplore.ieee.org/document/7786995>, Page 2549, last accessed Mar 07, 2024, Exhibit B

IEEE Standard 802.11ax (AP)

The accused product supporting Wi-Fi Standard 802.11ax receives a parameter-estimating signal (e.g., training field) on an unshared said parameter channel (e.g., orthogonal code applied to training field).

Citation 116: Using HE-LTF in an UL MU-MIMO transmission

U.S. Pat. No. 9,814,071	Accused Products
	In an UL MU-MIMO transmission using the HE masked HE-LTF sequence mode, the HE-LTF sequence per frequency segment is generated by masking the nonzero elements in the common HE-LTF sequence repeatedly with a distinct orthogonal code as defined by Equation (27-53). $ \text{HELT}F_{k,u,m}^{\text{Mask}} = \text{HELT}F_k \cdot \left[P_{8 \times 8} \right]_{M_{r,u} + m, \left(\left(\left\lceil \frac{k}{N_{\text{HE-LTF-Type}}} \right\rceil - 1 \right) \bmod 8 \right) + 1} \quad (27-53) $ where $\text{HELT}F_k$ is the value of the common HE-LTF sequence on subcarrier k generated by one of the equations from Equation (27-41) to Equation (27-52) depending on the bandwidth and the HE-LTF type (excluding the 1x HE-LTF, which shall not be masked). $\left[P_{8 \times 8} \right]$ is defined in Equation (21-46) $M_{r,u} + m$ is the row index of the $\left[P_{8 \times 8} \right]$ corresponding to spatial time stream m of user u in the r-th RU $ N_{\text{HE-LTF-Type}} = \begin{cases} 2, & \text{for 2x HE-LTF} \\ 1, & \text{for 4x HE-LTF} \end{cases} $ Fig 89 Source: https://ieeexplore.ieee.org/document/9442429, Page 590, last accessed March 05, 2024, Exhibit C <u>Wi-Fi User Equipment</u> IEEE Standard 802.11ac (UE) The user equipment (UE) require each transmitting node to transmit a parameter-estimating signal (e.g., training field) on an unshared said parameter channel (e.g., orthogonal code applied to training field).

The VHT LTF (long training fields) are used by the receiver to estimate the MIMO channel and equalize the received signal. The number of LTF symbols sent in a packet depends on the number of space-time streams: one LTF for one space-time stream, two LTFs for two space-time streams, four LTFs for three or four space-time streams, six LTFs for five or six space-time streams, eight LTFs for seven or eight space-time streams.

Citation 25: VHT-LTF

21.3.8.3.5 VHT-LTF definition

The VHT Long Training field (VHT-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. The transmitter provides training for $N_{STS, total}$ space-time streams (spatial mapper inputs) used for the transmission of the PSDU(s). For each tone, the MIMO channel that can be estimated is an $N_{RX} \times N_{STS, total}$ matrix. A VHT transmission has a preamble that contains VHT-LTF symbols, where the data tones of each VHT-LTF symbol are multiplied by entries belonging to a matrix $P_{VHT-LTF}$, to enable channel estimation at the receiver. The pilot tones of each VHT-LTF symbol are multiplied by the entries of a matrix $R_{VHT-LTF}$ defined in the following text. The multiplication of the pilot tones in the VHT-LTF symbol by the $R_{VHT-LTF}$ matrix instead of the $P_{VHT-LTF}$ matrix allows receivers to track phase and frequency offset during MIMO channel estimation using the VHT-LTF. The number of VHT-LTF symbols, $N_{VHT-LTF}$, is a function of the total number of space-time streams $N_{STS, total}$ as shown in Table 21-13. As a result the VHT-LTF field consists of one, two, four, six or eight symbols.

Table 21-13—Number of VHT-LTFs required for different numbers of space-time streams

$N_{STS, total}$	$N_{VHT-LTF}$
1	1
2	2
3	4
4	4
5	6
6	6
7	8
8	8

FIG. 25

Source: <https://ieeexplore.ieee.org/document/7786995>, Page 2549, last accessed Mar 15, 2024, Exhibit B

IEEE Standard 802.11ax (UE)

The user equipment (UE) supporting Wi-Fi Standard 802.11ax receives a parameter-estimating signal (e.g., training field) on an unshared said parameter channel (e.g., orthogonal code applied to training field).

U.S. Pat. No. 9,814,071	<u>Accused Products</u>
	Citation 117: Using HE-LTF symbols in the DL MU PPDU HE-LTF symbols in the DL HE MU PPDU are used to measure the channel for the space-time streams intended for the STA and can also be used to measure the channel for the interfering space-time streams. To successfully demodulate the space-time streams intended for the STA, it is recommended that the STA use the channel knowledge for all space-time streams to reduce the effect of space-time streams allocated to other users. Fig 90 Source: https://ieeexplore.ieee.org/document/9442429, Page 507, last accessed March 15, 2024, Exhibit C Citation 118: HE-LTF 27.3.11.10 HE-LTF 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 subcarrier 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. When single stream pilot is used in HE-LTF, the pilot subcarriers of each HE-LTF symbol are multiplied by the entries of a matrix R_{HE-LTF} defined below to allow receivers to track phase and/or frequency offset during MIMO channel estimation using the HE-LTF. Single stream pilots shall be used in the HE-LTF field for SU, DL and UL OFDMA, DL MU-MIMO and partial bandwidth UL MU-MIMO transmissions. Single stream pilots shall be used in the HE-LTF field for a full bandwidth UL MU-MIMO transmission if single stream pilot HE-LTF mode is selected.

U.S. Pat. No. 9,814,071	<u>Accused Products</u>
	Fig 91 Source: https://ieeexplore.ieee.org/document/9442429, Page 580, last accessed March 15, 2024, Exhibit C If this element is not literally satisfied by the disclosures cited herein, it is satisfied under the doctrine of equivalents by the disclosures cited herein because the accused functionality would be insubstantially different from or function in the same way to provide the same result as the relevant claim element.
estimating at least one unique signal parameter for each of the received plurality of parameter - estimating signals; and	<u>Cellular</u> The Accused LTE/5G Base Stations include estimating at least one unique signal parameter for each of the received plurality of parameter - estimating signals. See 3GPP R1-122385: The BSI and CSH pattern should be configured in a UE-specific manner in order to provide interference randomization among Receiving Points (RPs), in particular for supporting CoMP scenario 4. Uplink MU-MIMO requires orthogonal PUSCH DMRS sequences among the paired UEs. R1-164144: The uplink MU-MIMO has been discussed since Rel-8. The Zadoff-Chu sequence is used for DMRS sequence generation. Different UEs with fully overlapping bandwidth allocation can use the same sequence with different cyclic shifts. However, if the UEs are allocated with partial overlapping bandwidth, different DMRS sequences may be applied so that their DMRS are not orthogonal with different cyclic shifts. In Rel-10, the UL DMRS has been enhanced by applying time domain OCC to support 2 orthogonal DMRS for MU-MIMO with partially overlapping bandwidth allocation. The two scheduled UEs with partially overlapping bandwidth can still have orthogonal DMRS by using different OCC codes.

U.S. Pat. No. 9,814,071	<u>Accused Products</u>
	See On Channel Estimation for Multi-User MIMO in LTE-A Uplink: Abstract: In 3GPP Long Term Evolution-Advanced (LTE-A), uplink multi-input-multi-output(MIMO) transmission have been introduced as a key technology to improve the spectrum efficiency. Both single-user MIMO (SU-MIMO) and multi-user MIMO (MU-MIMO) modes are supported. With UL-MIMO, multiple layers of data are mapped on the same set of resources and transmitted simultaneously. Accordingly, the demodulation reference signal (DMRS) in LTE-A applies both frequency domain code division multiplexing and time domain code division multiplexing to support channel estimation for each multiplexed layer. Discrete Fourier transform (DFT)-based channel estimation schemes and the applications for LTE UL-MIMO have been widely studied. However, the orthogonality among DMRS of different layers could be reduced due to the channel conditions. The effect is significant when the arrival times of the paired user equipment (UE) at the receiver are not strictly aligned if MU-MIMO is applied. Consequently, the performance of DFT-based channel estimation schemes is affected. In this paper, we demonstrate a novel DFT based channel estimation scheme that can restore the inter-layer orthogonality. Simulation results show that the proposed method provides significant improvement over conventional DFT-based channel estimation methods. The performance of UL-MIMO depends heavily on the accuracy of channel estimation, which is based on DMRS. For each layer, a DMRS sequence is transmitted. When SFM is used, multiple DMRS sequences are transmitted over the same set of single carrier-frequency division multiple access (SC-FDMA) symbols. Different sequence adopts a unique orthogonal cover code so that the receiver can de-multiplex these sequences and estimate the channel corresponding to each layer respectively. The degree of orthogonality preserved at the receiver depends on the channel condition and affects the accuracy of channel estimation.

U.S. Pat. No. 9,814,071	<u>Accused Products</u>
	Here $r_m^{(\lambda,u)}(n)$ is the DMRS sequence for layer λ of UE u in slot m, where $m \in \{0, 1\}$ and $\lambda \in \{0, 1, 2, 3\}$. $\bar{r}(n)$ is the base sequence. $e^{\frac{j2\pi n_{cs,\lambda,u}}{12}}$ can be viewed as the frequency domain orthogonal cover code applied. It is named as cyclic shift (CS) within LTE-A vocabulary, as the application is equivalent to applying a cyclic shift to the transmitted signal in the time domain. $n_{cs,\lambda,u} \in \{0, 1, 2, \dots, 11\}$ is the cyclic shift used for layer λ of UE u. $w^{(\lambda,u)}(m)$ is the time domain orthogonal cover code, it is referred to as orthogonal cover code (OCC) in LTE-A. $w^{(\lambda,u)}(m)$ can be selected from either $[+1, +1]$ or $[+1, -1]$. OCC is frequently used to ensure the orthogonality between DMRS transmissions from the different UEs involved in the MU-MIMO transmission. Compare to CS, OCC does not require the bandwidths allocated for paired UEs to be the same, and hence allows more flexibility in MU-MIMO scheduling. See 5G NR: The Next Generation Wireless Access Technology, p. 186

U.S. Pat. No. 9,814,071	<u>Accused Products</u>
	these regions, the PDSCH mapping is slightly different than the PDSCH mapping. Multiple orthogonal reference signals can be created in each DM-RS occasion. The different reference signals are separated in the frequency and code domains, and, in the case of a double-symbol DM-RS, additionally in the time domain. Two different types of demodulation reference signals can be configured, type 1 and type 2, differing in the mapping in the frequency domain and the maximum number of orthogonal reference signals. Type 1 can provide up to four orthogonal signals using a single-symbol DM-RS and up to eight orthogonal reference signals using a double-symbol DM-RS. The corresponding numbers for type 2 are six and twelve. The reference signal types (1 or 2) should not be confused with the mapping types (A or B); different mapping types can be combined with different reference signal types. The Accused LTE/5G UEs include estimating at least one unique signal parameter for each of the received plurality of parameter - estimating signals. <u>5Ghub Tutorial:</u>

U.S. Pat. No. 9,814,071	<u>Accused Products</u>
	5G NR Downlink Physical channels • • • Demodulation Reference Signals (DMRS) <u>Demodulation Reference Signals (DMRS) are used for downlink data demodulation (channel adaptation) and time-frequency synchronization.</u> <u>PDSCH/PUSCH DM-RS signals are used for decoding the Physical Downlink Shared Channel (PDSCH), which contains the downlink user data. These signals can be divided into Front Loaded (FL) DMRS which occupies 1 to 2 symbols and Additional (Add) DRMS, which occupies 1 to 3 symbols, and is used in high-speed scenarios at the latter part of a slot.</u> Different DMRS types allow a different maximum number of ports: Type 1: Single-symbol: 4, dual-symbol: up to 8 orthogonal ports, used for SU-MIMO. Type 2: Single-symbol: 6, dual-symbol: up to 12 orthogonal ports, used for MU-MIMO. DMRS time-frequency mapping position is divided into two different types, as well. Type A, starting from the 3rd of 4th symbol in the slot, and Type B, starting from 1st symbol on scheduled PDSCH and is practical only for cases there is no CORESET on the 1st OFDM symbol. <u>5G New Radio Paper:</u>

U.S. Pat. No. 9,814,071	<u>Accused Products</u>
	A. Downlink and Uplink Demodulation Reference Signals (DMRS) <u>DMRS is used by the receiver to produce channel estimates for demodulation of the associated physical channel.</u> The design of DMRS is specific for each physical channel – PBCH, PDCCH, PDSCH, PUSCH, and PUCCH. In all cases, DMRS is UE specific, transmitted on demand, and normally does not extend outside of the scheduled physical resource of the channel it supports. In the sequel, we focus on the DMRS for PDSCH and PUSCH when CP-OFDM is used. The PDSCH/PUSCH DMRS structure supports a wide range of scenarios, UE capabilities, and use cases. The number of DMRS symbols in a PDSCH/PUSCH duration can be configured; this enables support for very high UE mobility, but also, low DMRS overhead when the scenario allows so. Similarly, the density of DMRS in the frequency domain is configurable to allow for an optimized overhead. The first DMRS instance comes early in the PDSCH/PUSCH transmission; this enables channel estimation to start early in the receiver, thereby reducing the processing latency. DMRS can be on a regular comb structure, and RB bundling is configurable. This is beneficial for efficient, high performance channel estimation. NR DMRS supports massive multi-user MIMO; it can be beamformed and supports up to 12 orthogonal layers. DMRS sequence for CP-OFDM is QPSK based on Gold sequences. For PUSCH with DFT-S-OFDM there is also a low PAPR Zadoff-Chu mode.

U.S. Pat. No. 9,814,071	<u>Accused Products</u>
	If this element is not literally satisfied by the disclosures cited herein, it is satisfied under the doctrine of equivalents by the disclosures cited herein because the accused functionality would be insubstantially different from or function in the same way to provide the same result as the relevant claim element.
distinguishing information concurrently received from the transmitting nodes according to their corresponding estimated unique signal parameter.	<u>Cellular</u> The Accused LTE/5G Base Stations include distinguishing information concurrently received from the transmitting nodes according to their corresponding estimated unique signal parameter. See Samsung Delivers the Promises of Massive MIMO:

U.S. Pat. No. 9,814,071	<u>Accused Products</u>
	Samsung's Massive MIMO Solution Benefits Samsung Massive MIMO Unit (MMU): The key product in the solution is the Samsung Massive MIMO Unit (MMU), which is operating in the 2.5 GHz and CBRS (3.5 GHz) spectrum bands. This product also supports the following RAN technologies: • 4G LTE • 5G NR • Co-deploy 4G LTE and 5G NR. A key differentiator of Samsung's MMU is its ability to support LTE and 5G NR simultaneously. The "split mode" configuration allocates 32 of the 64 transmit-receiver pairs to each of the RAN technologies. This unique capability reduces the CAPEX spend by MNOs for co-deployment of LTE and 5G in those sites, as the existing equipment supports both technologies in the existing footprint. High-Density Antenna System with Integrated Radio Control: The high-density antenna 64T64R option allows MNOs to reduce CAPEX as they now need fewer products to cover the same area. When operating in 2.5 GHz markets, the MMU leverages five 10 Gbps CPRI links, while the solution for CBRS markets uses four 10 Gbps CPRI links. Carrier Aggregation: This MMU supports carrier aggregation and offers different options based on the deployment. For 2.5GHz, Carrier Aggregation supports up to three 20 MHz carriers, creating up to 60MHz of downlink bandwidth, while deployments in CBRS spectrum supports up to five 20MHz channels, offering up to 100 MHz of downlink bandwidth. MIMO and MU-MIMO: In addition to supports 2x2 and 4x4 single-user MIMO, the MMU supports multi-user MIMO with by allowing up to 16 layers, or independent streams, of downlink transmission for up to 16 users. For 2.5 GHz deployments, the MMU supports up to 2 layers for uplink MU-MIMO transmissions for multi-user MIMO, while the CBRS solution in the 3.5 GHz spectrum allows up to 8 layers for uplink transmissions.

U.S. Pat. No. 9,814,071	<u>Accused Products</u>
	1503.02192.pdf (arxiv.org) Uplink Performance Evaluation of Massive MU-MIMO Systems • • • where the pseudo-random sequence $c(i)$ is defined in clause 5.2.1. The pseudo-random sequence generator shall be initialized with $c_{init} = \left\lfloor 2^{17} \left(N_{cell}^{\text{DL}} \cdot n_{sf}^{\text{DL}} + 1 \right) \left(2N_{ID}^{\text{DM}} + 1 \right) + 2N_{ID}^{\text{DM}} + n_{\text{DM}} \right\rfloor \bmod 2^{31}$ where l is the OFDM symbol number within the slot, n_{sf}^{DL} is the slot number within a frame, and • $N_{ID}^{\text{DL}}, N_{ID}^{\text{UL}} \in \{0, 1, \dots, 85535\}$ are given by the higher-layer parameters <i> scramblingID0 </i> and <i> scramblingID1 </i>, respectively, in the <i> DMRS-DownlinkConfig </i> IE if provided and the PDSCH is scheduled by PDCCH using DCI format 1_1 with the CRC scrambled by C-RNTI, MCS-C-RNTI, or CS-RNTI • $N_{ID}^{\text{UL}} \in \{0, 1, \dots, 85535\}$ is given by the higher-layer parameter <i> scramblingID0 </i> in the <i> DMRS-DownlinkConfig </i> IE if provided and the PDSCH is scheduled by PDCCH using DCI format 1_0 with the CRC scrambled by C-RNTI, MCS-C-RNTI, or CS-RNTI. = $N_{ID}^{\text{UL}} = N_{ID}^{\text{UL}}$ otherwise; The quantity $n_{\text{DM}} \in \{0, 1\}$ is given by the DM-RS sequence initialization field, in the DCI associated with the PDSCH transmission if DCI format 1_1 in [4, TS 38.212] is used, otherwise $n_{\text{DM}} = 0$. • • •

U.S. Pat. No. 9,814,071	<u>Accused Products</u>
	III. UPLINK DETECTION Detection techniques must be employed in order to separate each of the data streams transmitted by the various users in a massive MU-MIMO system. Despite being the optimum detector, the maximum likelihood (ML) detector is highly complex. It has a complexity cost that grows exponentially with the number of transmit antennas, K, and modulation order used, which makes it very complex to be implemented in systems with hundreds of antennas as is the case with massive MIMO systems. Thus, when ML detection is impractical, we must resort to sub-optimal alternatives with reduced complexity [8]. Linear sub-optimal detectors with low complexity, such as MRC (also known as MF), ZF and MMSE detectors, are feasible candidates for the role in massive MIMO systems. In the case where M is much larger than K, i.e., $1 \ll K \ll M$, it is known that those linear detectors (MRC, ZF and MMSE) perform fairly well. They asymptotically achieve capacity as M grows [7] and therefore we will only consider those detectors in this paper. We consider here the case where the BS has perfect CSI, i.e., it knows $\mathbf{H}$. Let $\mathbf{A}$ be an $M \times K$ linear detector matrix which depends on the channel $\mathbf{H}$. By using a linear detector, the received signal is separated into different data streams by multiplying it with $\mathbf{A}^H$ as follows $\mathbf{r} = \mathbf{A}^H \mathbf{y}, \quad (8)$ where $\mathbf{r}$ is a $K \times 1$ signal vector containing the data streams of the K single-antenna devices. As stated before, we consider three conventional linear detectors MRC, ZF and MMSE, i.e., $\mathbf{A} = \begin{cases} \mathbf{H} & \text{for MRC} \\ \mathbf{H}(\mathbf{H}^H \mathbf{H})^{-1} & \text{for ZF} \\ \mathbf{H}(\mathbf{H}^H \mathbf{H} + \frac{\sigma_n^2}{\sigma_s^2} \mathbf{I})^{-1} & \text{for MMSE} \end{cases} \quad (9)$ where σ_s^2 and σ_n^2 are the signal and noise variances, i.e., power, respectively. See 5G NR: The Next Generation Wireless Access Technology, p. 184

U.S. Pat. No. 9,814,071	<u>Accused Products</u>
	• <i>Demodulation reference signals</i> (DM-RS) for PDSCH are intended for channel estimation at the device as part of coherent demodulation. They are present only in the resource blocks used for PDSCH transmission. Similarly, the DM-RS for PUSCH allows the gNB to coherently demodulate the PUSCH. The DM-RS for PDSCH and PUSCH is the focus of this section; DM-RS for PDCCH and PBCH is described in Chapters 10 and 16, respectively. The Accused LTE/5G UEs include distinguishing information concurrently received from the transmitting nodes according to their corresponding estimated unique signal parameter. <i>See e.g.:</i>

U.S. Pat. No. 9,814,071	<u>Accused Products</u>
	<u>5G New Radio Paper:</u> A. Downlink and Uplink Demodulation Reference Signals (DMRS) <u>DMRS is used by the receiver to produce channel estimates for demodulation of the associated physical channel.</u> The design of DMRS is specific for each physical channel – PBCH, PDCCH, PDSCH, PUSCH, and PUCCH. In all cases, DMRS is UE specific, transmitted on demand, and normally does not extend outside of the scheduled physical resource of the channel it supports. In the sequel, we focus on the DMRS for PDSCH and PUSCH when CP-OFDM is used. The PDSCH/PUSCH DMRS structure supports a wide range of scenarios, UE capabilities, and use cases. The number of DMRS symbols in a PDSCH/PUSCH duration can be configured; this enables support for very high UE mobility, but also, low DMRS overhead when the scenario allows so. Similarly, the density of DMRS in the frequency domain is configurable to allow for an optimized overhead. The first DMRS instance comes early in the PDSCH/PUSCH transmission; this enables channel estimation to start early in the receiver, thereby reducing the processing latency. DMRS can be on a regular comb structure, and RB bundling is configurable. This is beneficial for efficient, high performance channel estimation. NR DMRS supports massive multi-user MIMO; it can be beamformed and supports up to 12 orthogonal layers. DMRS sequence for CP-OFDM is QPSK based on Gold sequences. For PUSCH with DFT-S-OFDM there is also a low PAPR Zadoff-Chu mode.

U.S. Pat. No. 9,814,071	<u>Accused Products</u>
	<u>5Ghub Tutorial:</u> 5G NR Downlink Physical channels • • • Demodulation Reference Signals (DMRS) <u>Demodulation Reference Signals (DMRS) are used for downlink data demodulation (channel adaptation) and time-frequency synchronization.</u> <u>PDSCH/PUSCH DM-RS signals are used for decoding the Physical Downlink Shared Channel (PDSCH), which contains the downlink user data.</u> These signals can be divided into Front Loaded (FL) DMRS which occupies 1 to 2 symbols and Additional (Add) DRMS, which occupies 1 to 3 symbols, and is used in high-speed scenarios at the latter part of a slot. Different DMRS types allow a different maximum number of ports: Type 1: Single-symbol: 4, dual-symbol: up to 8 orthogonal ports, used for SU-MIMO. Type 2: Single-symbol: 6, dual-symbol: up to 12 orthogonal ports, used for MU-MIMO. DMRS time-frequency mapping position is divided into two different types, as well. Type A, starting from the 3rd of 4th symbol in the slot, and Type B, starting from 1st symbol on scheduled PDSCH and is practical only for cases there is no CORESET on the 1st OFDM symbol.

U.S. Pat. No. 9,814,071	<u>Accused Products</u>
	<u>TR 36.866 v12.0.1 (2014-03):</u> 7.2 <u>Interference Suppression (IS) receivers</u> IS receivers refer to receivers that apply linear filtering to the received signal to suppress the interference, as opposed to explicitly cancel the interference. Three types of IS receivers are identified: - LMMSE-IRC; - It is baseline for Rel-11 MMSE-IRC study (refer to TR36.829). - No knowledge of interferer parameter(s) is required. - Enhanced LMMSE-IRC (E-LMMSE-IRC): - MMSE-IRC that explicitly considers interferer channel estimates and other interferer knowledge. - Interference parameters that can enable interferer channel estimation are needed, including, for example, its DMRS or CRS with PMI/RI. - Widely linear MMSE-IRC (WLMMSE-IRC): - WLMMSE-IRC exploits the additional degrees of freedom from the real and imaginary part of the received signal to enhance suppression of interference - Real-valued modulation may be used to increase performance of the WLMMSE-IRC receiver 7.3 <u>Maximum Likelihood (ML) receivers</u> ML-type of receivers are non-linear in nature. Three types of ML receivers are also identified: - ML;

U.S. Pat. No. 9,814,071	<u>Accused Products</u>
	- Full-blown joint detection of useful and interference signals in accordance to the ML criterion - Interference parameters that can enable interferer channel estimation and interferer detection at symbol level (e.g. modulation) are needed. - Reduced complexity ML (<u>R-ML</u>): - Reduced complexity joint detection of useful and interference modulation symbols in accordance to the ML criterion (e.g. sphere decoding, QR-MLD, MLM, etc.) - Same interference knowledge as for ML - Iterative ML and Iterative R-ML: - Iterative MAP detection and decoding of useful and interference signals. Both successive and parallel processing implementations may be applied. - In addition to the interference knowledge needed for ML, interference knowledge that can enable code word demodulation and decoding is needed. - Additionally, assumptions on network coordination may be necessary. 7.4 <u>Interference Cancellation (IC) receivers</u> IC-type of receivers are also non-linear in nature. Four types of IC receivers are identified - Linear Code word level SIC (<u>L-CWIC</u>): - receiver utilizing successive application of <u>linear detection</u> (e.g.: LMMSE-IRC), decoding, re-encoding, and cancellation - May have iteration (e.g. Turbo L-CWIC) - May utilize CRC check (e.g. hard L-CWIC)

U.S. Pat. No. 9,814,071	<u>Accused Products</u>
	- Same interference knowledge as Iterative ML and Iterative R-ML. Additionally, interferer RNTI knowledge may be needed. - Additionally, assumptions on network coordination may be necessary. - ML-CWIC: - receiver utilizing successive application of <u>ML or reduced complexity ML detection</u>, decoding, re-encoding, and cancellation - May have iteration (e.g. Turbo ML-CWIC) - May utilize CRC check (e.g. hard ML-CWIC) - Same interference knowledge as L-CWIC - Additionally, assumptions on network coordination may be necessary. - Symbol level IC (<u>SLIC</u>): - successive cancellation receiver utilizing successive application of linear detection, reconstruction, and cancellation - May have iteration - Same interference knowledge as ML/R-ML. - Parallel interference cancellation (<u>PIC</u>): - Parallel IC as opposed to successive IC, otherwise similar to SIC - PIC receivers can be categorized into L-CW-PIC, ML-CW-PIC or SL-PIC similar to SIC The method practiced by the accused product comprises, distinguishing information concurrently received from the transmitting nodes according to their corresponding estimated unique signal parameter.

U.S. Pat. No. 9,814,071	<u>Accused Products</u>
	<u>Wi-Fi Access Point</u> IEEE Standard 802.11ac (AP) The accused AP devices are equipped with IEEE 802.11ac support as well as multiple-input multiple-output (MIMO) capabilities. The Wi-Fi Standard 802.11ac detects and distinguishes the information simultaneously/concurrently received from each of the transmitting nodes (e.g., Wi-Fi STAs) according to their respective said unique estimated signal parameters. The 802.11ac frame format is shown in Figure 4 and begins as expected with a preamble. The first 3 fields are L-STF (Short Training Field), L-LTF (Long Training Field), and L-SIG (Signal). The L-STF and L-LTF contain information that allows the device to detect the signal, perform frequency offset estimation, timing synchronization, etc. Citation 27: VHT-PHY 21. Very high throughput (VHT) PHY specification 21.1 Introduction 21.1.1 Introduction to the VHT PHY The VHT PHY is based on the HT PHY defined in Clause 19, which in turn is based on the OFDM PHY defined in Clause 17. The VHT PHY extends the maximum number of space-time streams supported to eight and provides support for downlink multi-user (MU) transmissions. A downlink MU transmission supports up to four users with up to four space-time streams per user with the total number of space-time streams not exceeding eight. FIG. 27

U.S. Pat. No. 9,814,071	Accused Products
	Source: https://ieeexplore.ieee.org/document/7786995, Page 2498, last accessed Mar 07, 2024, Exhibit B Citation 28: Stations support SU-MIMO 21.3.11 SU-MIMO and DL-MU-MIMO Beamforming 21.3.11.1 General 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. With DL-MU-MIMO beamforming, disjoint subsets of the space-time streams are intended for reception at different STAs. 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. The feedback report format is described in 9.4.1.49. For DL-MU-MIMO beamforming, the receive signal vector in subcarrier k at beamformee u, $y_{k,u} = [y_{k,u}^1, y_{k,u}^2, \dots, y_{k,u}^{N_{RX,u}}]^T$, is shown in Equation (21-101), where $x_k = [x_{k,0}^T, x_{k,1}^T, \dots, x_{k,N_{user}-1}^T]^T$ denotes the transmit signal vector in subcarrier k for all N_{user} beamformers, with $x_{k,u} = [x_{k,u}^1, x_{k,u}^2, \dots, x_{k,u}^{N_{RX,u}}]^T$ being the transmit signal for beamformee u. $y_{k,u} = H_{k,u} \times [Q_{k,0}, Q_{k,1}, \dots, Q_{k,N_{user}-1}] \times x_k + n \quad (21-101)$ where $H_{k,u}$ is the channel matrix from the beamformer to beamformee u in subcarrier k with dimensions $N_{RX,u} \times N_{TX}$ FIG. 28 Source: https://ieeexplore.ieee.org/document/7786995, Page 2579, last accessed Mar 07, 2024, Exhibit B IEEE Standard 802.11ax (AP) The Wi-Fi Standard 802.11ax detects and distinguishes the information simultaneously/concurrently received from each of the transmitting nodes (e.g., Wi-Fi STAs) according to their respective said unique estimated signal parameters.

U.S. Pat. No. 9,814,071	<u>Accused Products</u>
	Citation 119: High Efficiency (HE) PHY specification 27. High Efficiency (HE) PHY specification 27.1 Introduction 27.1.1 Introduction to the HE PHY The HE PHY extends the maximum number of users supported for DL MU-MIMO transmissions to 8 users per resource unit (RU) and provides support for DL and UL orthogonal frequency division multiple access (OFDMA) as well as for UL MU-MIMO. Both DL and UL MU-MIMO transmissions are supported on portions of the PPDU bandwidth (on resource units greater than or equal to 106 tones). In an MU-MIMO resource unit, there is support for up to 8 users with up to 4 space-time streams per user with the total across all users not exceeding 8 space-time streams. Fig 92 Source: https://ieeexplore.ieee.org/document/9442429, Page 466, last accessed March 05, 2024, Exhibit C Citation 120: Features supported by High Efficiency (HE) AP An HE AP may support the following features: — MU-MIMO reception on an RU in an HE TB PPDU where the RU spans the entire PPDU bandwidth (UL MU-MIMO). — MU-MIMO reception on an RU in an HE TB PPDU where the RU does not span the entire PPDU bandwidth (UL MU-MIMO within OFDMA). — Reception of the payload on an RU in an HE MU PPDU where RU spans the entire PPDU bandwidth or a 106-tone RU within 20 MHz PPDU bandwidth. Fig 93

U.S. Pat. No. 9,814,071	<u>Accused Products</u>
	Source: https://ieeexplore.ieee.org/document/9442429, Page 468, last accessed March 05, 2024, Exhibit C Citation 121: RU support in UL MU-MIMO 27.3.3.2 UL MU-MIMO 27.3.3.2.1 Introduction UL MU-MIMO is a technique to allow multiple STAs to transmit simultaneously over the same frequency resource to the receiver. The concept is very similar to SU-MIMO where multiple space-time streams are transmitted simultaneously over the same frequency resource utilizing spatial multiplexing through multiple antennas at the transmitter and receiver. The key difference from SU-MIMO is that in UL MU-MIMO, the transmitted streams originate from multiple STAs. 27.3.3.2.2 Supported RU sizes in UL MU-MIMO An AP that sets the Partial Bandwidth UL MU-MIMO subfield of the HE PHY Capabilities Information field in the HE Capabilities element that it transmits to 1 shall support receiving an RU in an HE TB PPDU where MU-MIMO is employed in the RU, the RU size is greater than or equal to 106 tones, and the RU does not span the entire PPDU bandwidth. A non-AP STA that sets the Partial Bandwidth UL MU-MIMO subfield of the HE PHY Capabilities Information field in the HE Capabilities element that it transmits to 1 shall support transmitting an RU in an HE TB PPDU where UL MU-MIMO is employed in the RU, the RU size is greater than or equal to 106 tones, and the RU does not span the entire PPDU bandwidth. A STA that sets the Partial Bandwidth UL MU-MIMO subfield to 1 shall set the Full Bandwidth UL MU-MIMO subfield in the HE PHY Capabilities Information field to 1. Fig 94 Source: https://ieeexplore.ieee.org/document/9442429, Page 510, last accessed March 05, 2024, Exhibit C <u>Wi-Fi User Equipment</u>

U.S. Pat. No. 9,814,071	<u>Accused Products</u>
	IEEE Standard 802.11ac (UE) The accused UE devices are equipped with IEEE 802.11ac support as well as multiple-input multiple-output (MIMO) capabilities. The user equipment (UE) detects and distinguishes the information simultaneously received from each of the transmitting nodes (e.g., APs) according to their respective said unique estimated signal parameters. The user equipment (UE) receives a digital data stream comprising multiple spatial streams, it includes a VHT Long Training Field (VHT-LTF). The VHT LTF (long training fields) are used by the receiver to estimate the MIMO channel and equalize the received signal. VHT-LTF allows the receiver to track Phase or Frequency offset during the MIMO channel estimation. Citation 122: Stations support DL-MU-MIMO

U.S. Pat. No. 9,814,071	Accused Products
	21.3.11 SU-MIMO and DL-MU-MIMO Beamforming 21.3.11.1 General 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. With DL-MU-MIMO beamforming, disjoint subsets of the space-time streams are intended for reception at different STAs. 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. The feedback report format is described in 9.4.1.49. For DL-MU-MIMO beamforming, the receive signal vector in subcarrier k at beamformee u, $y_{k,u} = [y_{k,0}, y_{k,1}, \dots, y_{k,N_{\text{ant}}-1}]^T$, is shown in Equation (21-101), where $x_k = [x_{k,0}^T, x_{k,1}^T, \dots, x_{k,N_{\text{user}}-1}^T]^T$ denotes the transmit signal vector in subcarrier k for all N_{user} beamformers, with $x_{k,u} = [x_{k,0}, x_{k,1}, \dots, x_{k,N_{\text{ant}}-1}]^T$ being the transmit signal for beamformee u. $y_{k,u} = H_{k,u} \times [Q_{k,0}, Q_{k,1}, \dots, Q_{k,N_{\text{user}}-1}] \times x_k + n \quad (21-101)$ where $H_{k,u}$ is the channel matrix from the beamformer to beamformee u in subcarrier k with dimensions $N_{\text{RX}} \times N_{\text{TX}}$ FIG. 28 Source: https://ieeexplore.ieee.org/document/7786995, Page 2579, last accessed Mar 15, 2024, Exhibit A Citation 123: VHT-LTF

21.3.8.3.5 VHT-LTF definition

The VHT Long Training field (VHT-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. The transmitter provides training for $N_{STS,total}$ space-time streams (spatial mapper inputs) used for the transmission of the PSDU(s). For each tone, the MIMO channel that can be estimated is an $N_{RX} \times N_{STS,total}$ matrix. A VHT transmission has a preamble that contains VHT-LTF symbols, where the data tones of each VHT-LTF symbol are multiplied by entries belonging to a matrix $P_{VHT-LTF}$, to enable channel estimation at the receiver. The pilot tones of each VHT-LTF symbol are multiplied by the entries of a matrix $R_{VHT-LTF}$ defined in the following text. The multiplication of the pilot tones in the VHT-LTF symbol by the $R_{VHT-LTF}$ matrix instead of the $P_{VHT-LTF}$ matrix allows receivers to track phase and frequency offset during MIMO channel estimation using the VHT-LTF. The number of VHT-LTF symbols, $N_{VHT-LTF}$, is a function of the total number of space-time streams $N_{STS,total}$ as shown in Table 21-13. As a result the VHT-LTF field consists of one, two, four, six or eight symbols.

Table 21-13—Number of VHT-LTFs required for different numbers of space-time streams

$N_{STS,total}$	$N_{VHT-LTF}$
1	1
2	2
3	4
4	4
5	6
6	6
7	8
8	8

FIG. 29

Source: <https://ieeexplore.ieee.org/document/7786995>, Page 2549, last accessed Mar 15, 2024, Exhibit B

IEEE Standard 802.11ax (UE)

The user equipment (UE) supporting Wi-Fi Standard 802.11ax detects and distinguishes the information simultaneously/concurrently received from each of the transmitting nodes (e.g., Wi-Fi STAs) according to their respective said unique estimated signal parameters (such as Phase and/or Frequency offset).

U.S. Pat. No. 9,814,071	<u>Accused Products</u>
	Citation 124: High Efficiency (HE) PHY specification 27. High Efficiency (HE) PHY specification 27.1 Introduction 27.1.1 Introduction to the HE PHY The HE PHY extends the maximum number of users supported for DL MU-MIMO transmissions to 8 users per resource unit (RU) and provides support for DL and UL orthogonal frequency division multiple access (OFDMA) as well as for UL MU-MIMO. Both DL and UL MU-MIMO transmissions are supported on portions of the PPDU bandwidth (on resource units greater than or equal to 106 tones). In an MU-MIMO resource unit, there is support for up to 8 users with up to 4 space-time streams per user with the total across all users not exceeding 8 space-time streams. Fig 95 Source: https://ieeexplore.ieee.org/document/9442429, Page 466, last accessed March 15, 2024, Exhibit C Citation 125: Features supported by non-AP High Efficiency (HE) STA

U.S. Pat. No. 9,814,071	<u>Accused Products</u>
	A non-AP HE STA shall support the following features: — Reception of an HE MU PPDU where the RU allocated to the non-AP STA is not utilizing MU-MIMO (DL OFDMA). — Transmission of an HE TB PPDU where the RU allocated to the non-AP STA is not utilizing MU-MIMO (UL OFDMA). — Reception of an HE MU PPDU consisting of a single RU spanning the entire PPDU bandwidth and utilizing MU-MIMO (DL MU-MIMO). The maximum number of spatial streams per user the non-AP STA can receive in the DL MU-MIMO transmission shall be equal to the minimum of 4 and the maximum number of spatial streams supported for reception of HE SU PPDU. The non-AP STA shall be able to receive its intended spatial streams in a DL MU-MIMO transmission with a total number of spatial streams across all users of at least 4. — Reception of an HE MU PPDU with up to 4 HE-LTF OFDM symbols, where the RU allocated to the non-AP STA does not span the entire PPDU bandwidth. — Responding with the requested beamforming feedback in an HE sounding procedure with the maximum number of space-time streams in the HE sounding NDP that the non-AP STA can respond to being at least 4. — Reception of the HE-SIG-B field in an HE MU PPDU at HE-MCSs 0 to 5. — Single spatial stream HE-MCSs 0 to 7 in all supported channel widths and RU sizes for HE MU PPDU (receive) or HE TB PPDU (transmit). — 40 MHz and 80 MHz channel widths and all RU sizes and locations applicable to the 40 MHz and 80 MHz channel widths in the 5 GHz band (transmit and receive), except for a 20 MHz-only non-AP HE STA in which case the 40 MHz and 80 MHz channel widths, 996-tone RU, and 484-tone RU sizes in the 5 GHz and 6 GHz bands are not applicable. — Reception of an HE MU PPDU with a 2x HE-LTF and 0.8 μs GI duration on the HE-LTF and Data field OFDM symbols. — Reception of an HE MU PPDU with a 2x HE-LTF and 1.6 μs GI duration on the HE-LTF and Data field OFDM symbols. — Transmission of an HE TB PPDU with a 2x HE-LTF and 1.6 μs GI duration on the HE-LTF and Data field OFDM symbols. — Reception of an HE MU PPDU with a 4x HE-LTF and 3.2 μs GI duration on the HE-LTF and Data field OFDM symbols. — Transmission of an HE TB PPDU with a 4x HE-LTF and 3.2 μs GI duration on the HE-LTF and Data field OFDM symbols. — Reception of an HE MU PPDU with a 4x HE-LTF and 0.8 μs GI duration on the HE-LTF and the Data field OFDM symbols if the non-AP HE STA supports HE ER SU PPDU with the same HE-LTF and GI combinations. — 26-, 52-, and 106-tone RU sizes on locations allowed in 27.3.2.8 in the primary 20 MHz channel within 40 MHz channel width if the non-AP HE STA is a 20 MHz operating non-AP HE STA and

U.S. Pat. No. 9,814,071	<u>Accused Products</u>
	that is capable of supporting 40 MHz channel width (B0 of the Supported Channel Width Set subfield in the HE PHY Capabilities Information field in the HE Capabilities element is 1) (transmit and receive). — 26-, 52-, and 106-tone RU sizes on locations allowed in 27.3.2.8 in the primary 20 MHz channel within 80 MHz channel width if the non-AP HE STA is a 20 MHz operating non-AP HE STA and is operating in the 5 GHz or 6 GHz bands (transmit and receive). Fig 96 Source: https://ieeexplore.ieee.org/document/9442429, Pages 469 & 470, last accessed March 15, 2024, Exhibit C Citation 126: RU support in DL MU-MIMO 27.3.3.1.1 Supported RU sizes in DL MU-MIMO A STA that sets the Partial Bandwidth DL MU-MIMO subfield of the HE PHY Capabilities Information field in the HE Capabilities element that it transmits to 1 shall support receiving an RU in an HE MU PPDU where MU-MIMO is employed in the RU, the RU size is greater than or equal to 106 tones, and the RU does not span the entire PPDU bandwidth. Fig 97 Source: https://ieeexplore.ieee.org/document/9442429, Page 509, last accessed March 15, 2024, Exhibit C Citation 127: HE-LTF

U.S. Pat. No. 9,814,071	Accused Products
	27.3.11.10 HE-LTF 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 subcarrier 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. When single stream pilot is used in HE-LTF, the pilot subcarriers of each HE-LTF symbol are multiplied by the entries of a matrix R_{HE-LTF} defined below to allow receivers to track phase and/or frequency offset during MIMO channel estimation using the HE-LTF. Single stream pilots shall be used in the HE-LTF field for SU, DL and UL OFDMA, DL MU-MIMO and partial bandwidth UL MU-MIMO transmissions. Single stream pilots shall be used in the HE-LTF field for a full bandwidth UL MU-MIMO transmission if single stream pilot HE-LTF mode is selected. Fig 98 Source: https://ieeexplore.ieee.org/document/9442429, Page 580, last accessed March 15, 2024, Exhibit C If this element is not literally satisfied by the disclosures cited herein, it is satisfied under the doctrine of equivalents by the disclosures cited herein because the accused functionality would be insubstantially different from or function in the same way to provide the same result as the relevant claim element.

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Control (MAC) and Physical Layer (PHY) Specifications; Amendment 1: Enhancements for High Efficiency WLAN
("802.11ax") <https://ieeexplore.ieee.org/document/9442429>