IN THE UNITED STATES DISTRICT COURT
FOR THE EASTERN DISTRICT OF TEXAS
SHERMAN DIVISION

FREEDOM PATENTS LLC, Plaintiff, v. ALTICE USA, INC., CSC HOLDINGS, LLC D/B/A OPTIMUM-CABLEVISION, and CEQUEL COMMUNICATIONS, LLC D/B/A SUDDENLINK COMMUNICATIONS, Defendants.	CIVIL ACTION NO. 4:23-cv-300 ORIGINAL COMPLAINT FOR PATENT INFRINGEMENT **JURY TRIAL DEMANDED**

ORIGINAL COMPLAINT FOR PATENT INFRINGEMENT

Plaintiff Freedom Patents LLC ("Freedom Patents" or "Plaintiff") files this original complaint against Defendants Altice USA, Inc., CSC Holdings, LLC d/b/a Optimum-Cablevision, and Cequel Communications, LLC d/b/a Suddenlink Communications (collectively, "Altice" or "Defendants"), alleging, based on its own knowledge as to itself and its own actions and based on information and belief as to all other matters, as follows:

PARTIES

1. Freedom Patents is a limited liability company formed under the laws of the State of Texas, with its principal place of business at 2325 Oak Alley, Tyler, Texas, 75703.

2. Defendant Altice USA, Inc. ("Altice USA") is a corporation duly organized and existing under the laws of Delaware. Altice USA may be served through its registered agent Corporation Service Company, at 251 Little Falls Drive, Wilmington, DE 19808.

3. Altice USA—together with its subsidiaries—describes itself as "one of the largest broadband communications and video services providers in the United States."[1] It serves "nearly 5 million residential and business customers across 21 states" with a portfolio of "connectivity services, including Optimum Fiber Internet, Optimum TV and Optimum Mobile."[2]

4. Defendant CSC Holdings, LLC d/b/a Optimum-Cablevision ("CSC Holdings") is a corporation duly organized and existing under the laws of Delaware. CSC Holdings may be served through its registered agent Corporation Service Company, at 251 Little Falls Drive, Wilmington, DE 19808.

5. CSC Holdings is a wholly-owned subsidiary of Altice USA. CSC Holdings, along with its subsidiaries, provides video-on-demand services under the Optimum brand.

6. Defendant Cequel Communications, LLC d/b/a Suddenlink Communications ("Cequel") is a corporation duly organized and existing under the laws of Delaware. Cequel may be served through its registered agent Corporation Service Company, at 251 Little Falls Drive, Wilmington, DE 19808.

7. Cequel is a wholly-owned subsidiary of Altice USA. Cequel provides broadband communications and video services through itself and its affiliates.

8. The Defendants identified in paragraphs 2-7 above (collectively, "Altice") are an interrelated group of companies which together comprise one of the world's largest providers of wireless devices in the United States, including under the Altice, Optimum, and Suddenlink brands.

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[1] *See* www.alticeusa.com/about#OurStory.

[2] *Id.*

9. The Altice defendants named above and their affiliates are part of the same corporate structure and distribution chain for the making, importing, offering to sell, selling, and using of the accused devices in the United States, including in the State of Texas generally and this judicial district in particular.

10. The Altice defendants named above and their affiliates share the same management, common ownership, advertising platforms, facilities, distribution chains and platforms, and accused product lines and products involving related technologies.

11. The Altice defendants regularly contract with customers regarding equipment or services that will be provided by their affiliates on their behalf.

12. Thus, the Altice defendants named above and their affiliates operate as a unitary business venture and are jointly and severally liable for the acts of patent infringement alleged herein.

13. The parties to this action are properly joined under 35 U.S.C. § 299 because the right to relief asserted against Defendants jointly and severally arises out of the same series of transactions or occurrences relating to the making and using of the same products or processes, including wireless routers and related processes bearing the Altice brands or that are otherwise made for use with services provided by Altice (under its Optimum and/or Suddenlink brands). Additionally, questions of fact common to all defendants will arise in this action.

JURISDICTION AND VENUE

14. This is an action for infringement of United States patents arising under 35 U.S.C. §§ 271, 281, and 284–85, among others. This Court has subject matter jurisdiction of the action under 28 U.S.C. § 1331 and § 1338(a).

15. This Court has personal jurisdiction over Altice pursuant to due process and/or the Texas Long Arm Statute because, *inter alia*, (i) Altice has done and continues to do business in

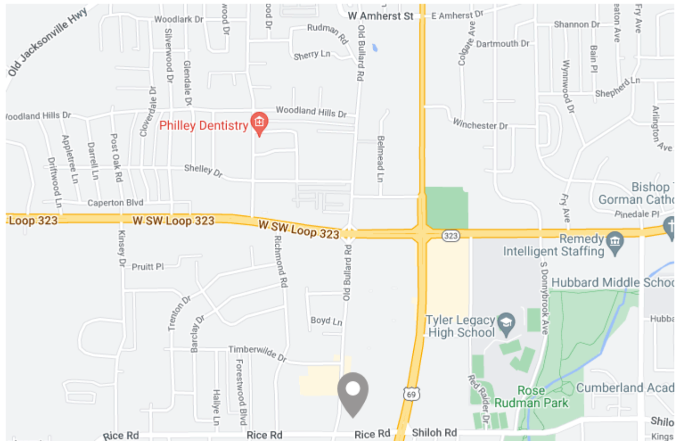
Texas, (ii) Altice has committed and continues to commit acts of patent infringement in the State of Texas, including making, using, offering to sell, and/or selling accused products in Texas, and/or importing accused products into Texas, including by Internet sales and/or sales via retail and wholesale stores, inducing others to commit acts of patent infringement in Texas, and/or committing a least a portion of any other infringements alleged herein in Texas, and (iii) Altice regularly places its products or services within the stream of commerce—directly, through subsidiaries, or through third parties—with the expectation and knowledge that such products or services will be sold or used in Texas and elsewhere in the United States.

16. Venue is proper in this district as to Altice pursuant to 28 U.S.C. § 1400(b). Venue is further proper because Altice has committed and continues to commit acts of patent infringement in this district, including making, using, offering to sell, and/or selling accused products in this district, and/or importing accused products into this district, including by Internet sales and sales via retail and wholesale stores, inducing others to commit acts of patent infringement in Texas, and/or committing at least a portion of any other infringements alleged herein in this district. Altice has regular and established places of business in this district, including at least at 4949 S. Broadway, Tyler, Texas, 75703; 25 19th St SE, Paris, Texas, 75460; 1921 N. Preston Road, Ste. 40, Prosper, TX 75078; 2500 Dallas Pkwy, Plano Texas 75093.

Tyler Optimum Store

4949 South Broadway
Tyler, TX 75703
(844) 874-7558

Get Directions »



Hours of Operation

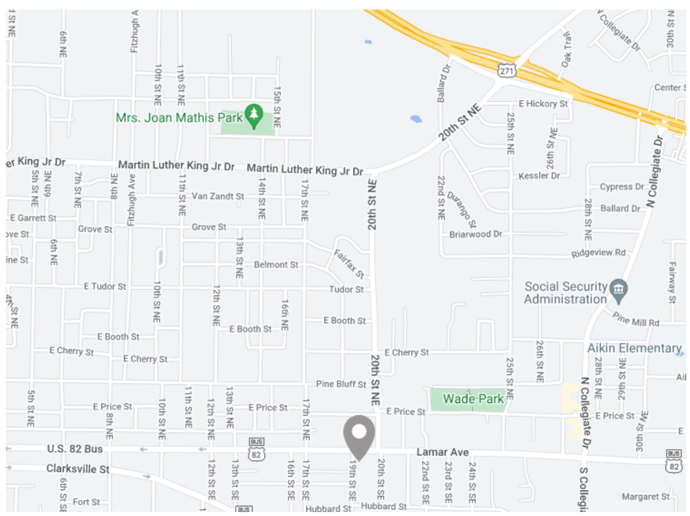
Monday	9:00 AM - 6:00 PM
Tuesday	9:00 AM - 6:00 PM
Wednesday	9:00 AM - 6:00 PM
Thursday	**Open until 6:00 PM**
Friday	9:00 AM - 6:00 PM
Saturday	9:00 AM - 6:00 PM
Sunday	Closed

Source: https://www.optimum.com/stores/tx/tyler/4949-south-broadway.html

Paris Optimum Store

25 19th St SE
Paris, TX 75460
(866) 950-3278

Get Directions »



Hours of Operation

We apologize for the inconvenience, but we will be closed from `12:30pm until 1:30pm for lunch on Wednesday February 22, 2023

Monday	9:00 AM - 6:00 PM
Tuesday	9:00 AM - 6:00 PM
Wednesday	9:00 AM - 6:00 PM
Thursday	**Open until 6:00 PM**
Friday	9:00 AM - 6:00 PM
Saturday	9:00 AM - 6:00 PM
Sunday	Closed

Source: https://www.optimum.com/stores/tx/paris/25-19th-st-se.html

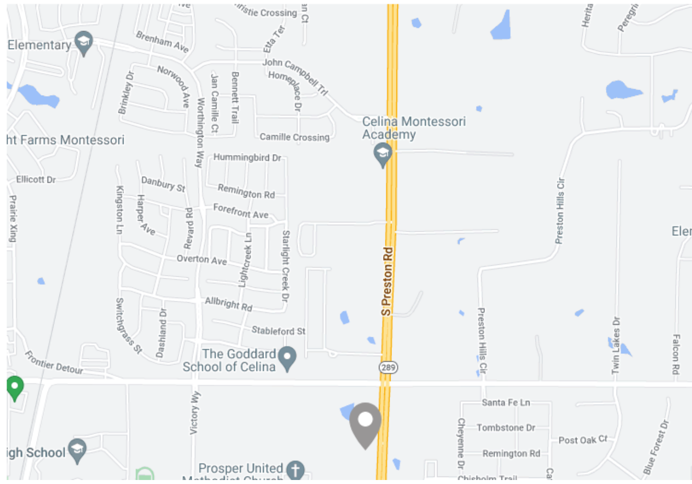
Prosper Optimum Store

1921 N. Preston Road
Ste 40
Prosper, TX 75078
(866) 950-3278

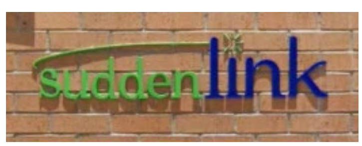
Get Directions »

Hours of Operation

Monday	9:00 AM - 6:00 PM
Tuesday	9:00 AM - 6:00 PM
Wednesday	9:00 AM - 6:00 PM
Thursday	**Open until 6:00 PM**
Friday	9:00 AM - 6:00 PM
Saturday	9:00 AM - 6:00 PM
Sunday	Closed



Source: https://www.optimum.com/stores/tx/prosper/1921-n--preston-road.html



Source: https://goo.gl/maps/xG83fhFz7sWPhPfq7

BACKGROUND

17. The patents-in-suit generally relate to improvements in wireless communication technology that allow users to communicate over a wireless network. In particular, the patents are directed to methods and systems for selecting antennas in multiple-input, multiple-output (MIMO) wireless networks.

18. The technology of the patents-in-suit was developed by engineers at the Mitsubishi Electric Research Laboratories (MERL), which is the North American arm of Mitsubishi Electric. MERL was founded in 1991 in Cambridge, Massachusetts, and has been known for its focus on innovation and long-range research.[3] From its beginning, MERL was focused on pioneering new technologies in various industries, including computer graphics, digital communication, medical imaging, transportation etc.[4] In the early 2000s, for example, "MERL focused on standardization and developments of new emerging technologies," such as "antenna selection, channel equalization, efficient channel state estimation, and Orthogonal Frequency Division Multiplexing (OFDM)."[5]

19. The inventions disclosed in the patents-in-suit have been cited during patent prosecution multiple times by electronics companies, including Apple, Broadcom, Cisco, Ericsson, Fujitsu, Hewlett Packard, Hitachi, Huawei, Intel, Kyocera, LG Electronics, Marvell, MediaTek, Motorola Mobility, Nokia, NTT Docomo, Panasonic, Philips, Qualcomm, Siemens, Samsung, Sharp, Sony, Toshiba, and ZTE.

COUNT I

DIRECT INFRINGEMENT OF U.S. PATENT NO. 8,284,686

20. On October 9, 2012, United States Patent No. 8,284,686 ("the '686 Patent") was duly and legally issued by the United States Patent and Trademark Office for an invention entitled "Antenna/Beam Selection Training in MIMO Wireless LANS with Different Sounding Frames."

[3] *See* https://www.merl.com/company/history.

[4] *See* https://www.merl.com/public/MERL-30Years.pdf.

[5] *Id*. at 22.

21. Freedom Patents is the owner of the ’686 Patent, with all substantive rights in and to that patent, including the sole and exclusive right to prosecute this action and enforce the ’686 Patent against infringers, and to collect damages for all relevant times.

22. Altice made, had made, used, imported, provided, supplied, distributed, sold, and/or offered for sale products and/or systems including, for example, its Altice Fiber Gateway Wi-Fi 6 (with 4x4 MIMO) family of products and other products[6] that implement MIMO Wi-Fi capabilities (“accused products”):

Source: https://www.alticelabs.com/wp-content/uploads/2022/10/FL_GPON_FGW-Wi-Fi6_EN.pdf

[6] *See, e.g.*, Fiber Gateway 4×4 (GR240BG), Fiber Gateway Wi-Fi 5, Smart Mesh Wi-Fi AP extenders, Optimum Amplify, Altice One router, Altice One Mini router, Fast 3965CV, F@st 5260CV, etc.

Model	Ports									
	FXS	Ethernet	RF	Wi-Fi 6 Dual Concurrent		USB	PON			
		1GE	Band: (47 ... 870MHz)	Antennas	Power* (dBm EIRP)	Type C	Type	Class	Bit rate (Gbps)	Wavelength (nm)
GR141DG	1x	4x	1x	2.4GHz: 4x4 Mimo 5GHz 4x4 MIMO	2.4Ghz: up to +20 (ETSI) or up to +34 (FCC) 5GHz : up to +30 (ETSI) or up to +34 (FCC)	1x	GPON	B+, C+,D	DS: 2.488 US: 1.244	DS:1480-1500 US:1260-1360
GR140DG	1x	4x	-	2.4GHz: 4x4 Mimo 5GHz :4x4 MIMO	2.4Ghz: up to +20 (ETSI) or up to +34 (FCC) 5GHz : up to +30 (ETSI) or up to +34 (FCC)	1x				

Source: https://www.alticelabs.com/wp-content/uploads/2022/10/FL_GPON_FGW-Wi-Fi6_EN.pdf (page 2)

2.4.1.5.1 Interfaces and features

- Concurrent mode 2.4GHz + 5GHz via 4 dual-band internal antennas

- 2.4GHz: Compatible with IEEE 802.11b 1x1 SISO and 802.11g/n/ax 4x4 MIMO

- 5GHz: Compatible with IEEE 802.11 a/n/ac/ax 4x4 MIMO

- Channel bandwidth: 20, 40, 80 MHz

- Multi User MIMO for best performance per user

2.4.1.5.3 Antennas

- 4x4 MIMO antennas
- Internal antennas with 4~5dBi antenna gain

Source: https://fccid.io/2ACJF-FGW-GR140DG/User-Manual/User-Manual-5082170.pdf (page 24)

23. By doing so, Altice has directly infringed (literally and/or under the doctrine of equivalents) at least Claims 1 and 21 of the ’686 Patent. Altice’s infringement in this regard is ongoing.

24. The Altice Fiber Gateway Wi-Fi 6 is an exemplary accused product.

25. Altice has infringed the ’686 Patent by using the accused products and thereby practicing a method for selecting antennas in a multiple-input, multiple-output (MIMO) wireless

local area network (WLAN) including a plurality of stations, each station including a set of antennas.

26. For example, the Altice Fiber Gateway Wi-Fi 6 communicates with other stations using the IEEE 802.11 protocol and includes a set of antennas that are used for both transmitting and receiving data to and from the other stations over a WLAN. The transmission and reception of data using multiple antennas simultaneously is known as MIMO ("multiple-input, multiple-output"). The stations communicating using MIMO implement the antenna selection process before establishing communication with each other.

Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications

1. Overview

1.1 Scope

The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area.

Source: IEEE 802.11-2016 Standard (Page 122)

An HT STA has PHY features consisting of the modulation and coding scheme (MCS) set described in 19.3.5 and physical layer (PHY) protocol data unit (PPDU) formats described in 19.1.4. Some PHY features that distinguish an HT STA from a non-HT STA are referred to as *multiple input, multiple output (MIMO)* operation; spatial multiplexing (SM); spatial mapping (including transmit beamforming); space-time block coding (STBC); low-density parity check (LDPC) encoding; and antenna selection (ASEL). The allowed PPDU formats are non-HT format, HT-mixed format, and HT-greenfield format (see 19.1.4). The PPDUs can be transmitted with 20 MHz bandwidth and might be transmitted with 40 MHz bandwidth.

Source: IEEE 802.11-2016 Standard (Page 197)

multiple input, multiple output (MIMO): A physical layer (PHY) configuration in which both transmitter and receiver use multiple antennas.

Source: IEEE 802.11-2016 Standard (Page 136)

multi-user multiple input, multiple output (MU-MIMO): A technique by which multiple stations (STAs), each with one or more antennas, either simultaneously transmit to a single STA or simultaneously receive from a single STA independent data streams over the same radio frequencies.

NOTE—IEEE Std 802.11 supports only downlink (DL) MU-MIMO. *See* **downlink multi-user multiple input, multiple output (DL-MU-MIMO)** (in 3.2).

Source: IEEE 802.11-2016 Standard (Page 136)

10.31 Link adaptation

10.31.1 Introduction

To fully exploit MIMO channel variations and transmit beamforming on a MIMO link, a STA can request that another STA provide MIMO channel sounding and MFB.

Source: IEEE 802.11-2016 Standard (Page 1463)

10.30 Sounding PPDUs

The behavior described in this subclause is specific to the use of the HT variant HT Control field.

A sounding PPDU is a PPDU for which the SOUNDING parameter of the corresponding RXVECTOR or TXVECTOR has the value SOUNDING. Sounding PPDUs are transmitted by STAs to enable the receiving STAs to estimate the channel between the transmitting STA and the receiving STA.

A STA transmits sounding PPDUs when it operates in the following roles:

- MFB requester (see 10.31.2)
- HT beamformee responding to a training request, calibration initiator, or responder involved in implicit transmit beamforming (see 10.32.2.2, 10.32.2.3, and 10.32.2.4)
- HT beamformer involved in explicit transmit beamforming (see 10.32.3)
- ASEL transmitter and ASEL sounding-capable transmitter involved in ASEL (see 10.33.2)

A STA receives sounding PPDUs when it operates in the following roles:

- MFB responder (see 10.31.2)
- HT beamformer sending a training request, calibration initiator, or responder involved in implicit transmit beamforming (see 10.32.2.2, 10.32.2.3, and 10.32.2.4)
- HT beamformee involved in explicit transmit beamforming (see 10.32.3)
- Transmit ASEL responder and ASEL receiver involved in ASEL (see 10.33.2)

Source: IEEE 802.11-2016 Standard (Pages 1462-63)

10.33 Antenna selection (ASEL)

10.33.1 Introduction

The procedures in this subclause apply only to HT and non-HT PPDUs for which the HT Control field, if present, is the HT variant HT Control field.

ASEL is a time-variant mapping of the signals at the RF chains onto a set of antenna elements when the number of RF chains is smaller than the number of antenna elements. The mapping might be chosen based on instantaneous or averaged CSI. ASEL requires the training of the full size channel associated with all antenna elements, which is obtained by transmitting or receiving sounding PPDUs over all antennas. These sounding PPDUs should be sent within a single TXOP. To avoid channel distortions, these sounding PPDUs shall be transmitted consecutively. The training information is exchanged using the HT Control field. When both transmitter and receiver have ASEL capabilities, training of transmit and receive antennas might be done one after another. ASEL supports up to eight antennas and up to four RF chains.

Source: IEEE 802.11-2016 Standard (Page 1481)

27. The method practiced using the accused products includes the step of receiving, via a channel, at a station in the WLAN plural consecutive packets including plural sounding packets, each sounding packet corresponding to a different subset of the set of antennas, and at least one of the plural consecutive packets including (i) a high throughput (HT) control field including a signal to initiate antenna selection and (ii) a number N indicative of a number of sounding packets which follow the at least one packet including the HT control field and which are to be used for antenna selection.

28. For example, during the antenna selection process, the stations receive multiple consecutive sounding PPDUs ("plural sounding packets"). Each sounding PPDU corresponds to a different set of antennas from the available antennas. The first PPDU frame received is a +HTC frame followed by consecutive NDP (Null Data Packet) frames.

10.30 Sounding PPDUs

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A sounding PPDU is a PPDU for which the SOUNDING parameter of the corresponding RXVECTOR or TXVECTOR has the value SOUNDING. Sounding PPDUs are transmitted by STAs to enable the receiving STAs to estimate the channel between the transmitting STA and the receiving STA.

A STA transmits sounding PPDUs when it operates in the following roles:

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— HT beamformer involved in explicit transmit beamforming (see 10.32.3)

— ASEL transmitter and ASEL sounding-capable transmitter involved in ASEL (see 10.33.2)

A STA receives sounding PPDUs when it operates in the following roles:

— MFB responder (see 10.31.2)

— HT beamformer sending a training request, calibration initiator, or responder involved in implicit transmit beamforming (see 10.32.2.2, 10.32.2.3, and 10.32.2.4)

— HT beamformee involved in explicit transmit beamforming (see 10.32.3)

— Transmit ASEL responder and ASEL receiver involved in ASEL (see 10.33.2)

Source: IEEE 802.11-2016 Standard (Pages 1462-63)

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Source: IEEE 802.11-2016 Standard (Page 1481)

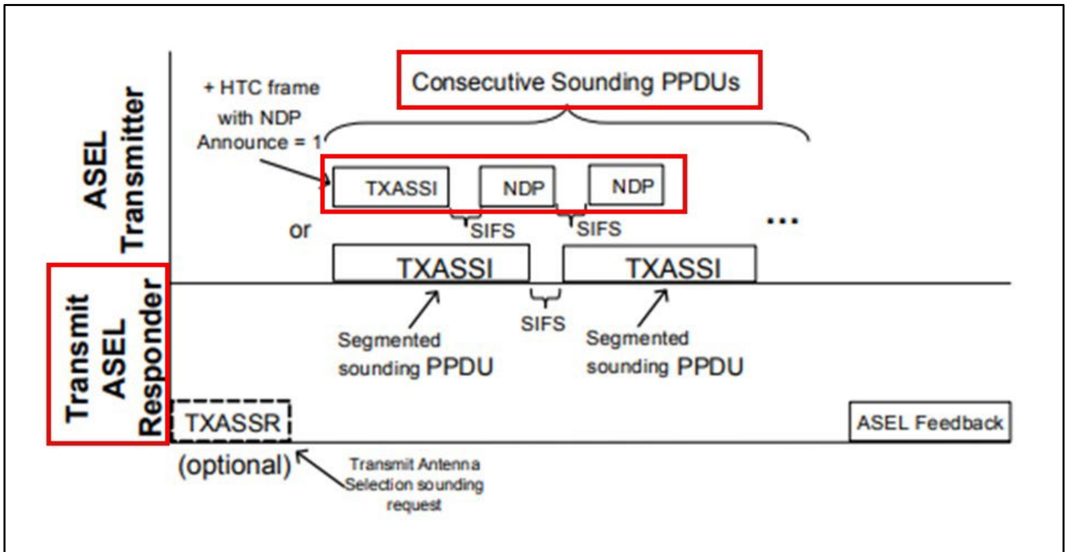

Figure 10-50—Transmit ASEL

Source: IEEE 802.11-2016 Standard (Page 1483)

29. The sounding PPDUs are Media Access Control (MAC) frames that comprise a set of fields, which can include a High Throughput (HT) control field. A frame that contains the HT Control field is referred to as "+HTC Frame." The HT Control field of a MAC frame can be of two types: High Throughput (HT) or Very High Throughput (VHT). The antenna selection procedure is only applicable to HT PPDUs (e.g., PPDUs that have an HT variant HT control field).

9.2.3 General frame format

The MAC frame format comprises a set of fields that occur in a fixed order in all frames. Figure 9-1 depicts the general MAC frame format. The first three fields (Frame Control, Duration/ID, and Address 1) and the last field (FCS) in Figure 9-1 constitute the minimal frame format and are present in all frames, including reserved types and subtypes. The fields Address 2, Address 3, Sequence Control, Address 4, QoS Control, HT Control, and Frame Body are present only in certain frame types and subtypes. Each field is defined in 9.2.4. The format of each of the individual subtypes of each frame type is defined in 9.3. The components of management frame bodies are defined in 9.4. The formats of Action frames are defined in 9.6.

Octets: 2	2	6	0 or 6	0 or 6	0 or 2	0 or 6	0 or 2	0 or 4	variable	4
Frame Control	Duration /ID	Address 1	Address 2	Address 3	Sequence Control	Address 4	QoS Control	HT Control	Frame Body	FCS

MAC header

Figure 9-1—MAC frame format

Source: IEEE 802.11-2016 Standard (Pages 637-38)

A frame that contains the HT Control field is referred to as a *+HTC frame*. A Control Wrapper frame is a +HTC frame.

Source: IEEE 802.11-2016 Standard (Page 637)

9.2.4.6 HT Control field

9.2.4.6.1 General

The HT Control field is always present in a Control Wrapper frame and is present in QoS Data and Management frames as determined by the +HTC/Order subfield of the Frame Control field as defined in 9.2.4.1.10.

NOTE—The only control frame subtype for which HT Control field is present is the Control Wrapper frame. A Control frame that is described as +HTC (e.g., an RTS+HTC, CTS+HTC, BlockAck+HTC or BlockAckReq+HTC frame) implies the use of the Control Wrapper frame to carry that Control frame.

The format of the 4-octet HT Control field is shown in Figure 9-8.

	B0	B1 B29	B30	B31
	VHT	HT Control Middle	AC Constraint	RDG/More PPDU
Bits	1	29	1	1

Figure 9-8—HT Control field

The HT Control field has two forms, the HT variant and the VHT variant. The two forms differ in the format of the HT Control Middle subfield, described in 9.2.4.6.2 for the HT variant and in 9.2.4.6.3 for the VHT variant and in the value of the VHT subfield.

The VHT subfield of the HT Control field indicates whether the HT Control Middle subfield is the VHT Variant or the HT Variant. The VHT subfield is set to 1 to indicate that the HT Control Middle subfield is the VHT Variant and is set to 0 to indicate that the HT Control Middle subfield is the HT Variant.

Source: IEEE 802.11-2016 Standard (Page 654)

10.33 Antenna selection (ASEL)

10.33.1 Introduction

The procedures in this subclause apply only to HT and non-HT PPDUs for which the HT Control field, if present, is the HT variant HT Control field.

ASEL is a time-variant mapping of the signals at the RF chains onto a set of antenna elements when the number of RF chains is smaller than the number of antenna elements. The mapping might be chosen based on instantaneous or averaged CSI. ASEL requires the training of the full size channel associated with all antenna elements, which is obtained by transmitting or receiving sounding PPDUs over all antennas. These sounding PPDUs should be sent within a single TXOP. To avoid channel distortions, these sounding PPDUs shall be transmitted consecutively. The training information is exchanged using the HT Control field. When both transmitter and receiver have ASEL capabilities, training of transmit and receive antennas might be done one after another. ASEL supports up to eight antennas and up to four RF chains.

Source: IEEE 802.11-2016 Standard (Page 1481)

30. The +HTC frames ("at least one of the plural consecutive packets") contain the HT variant HT Control field. The HT Control field also contains an HT control middle subfield,

which further contains an LAC subfield. The LAC subfield allows the station to perform antenna selection. The LAC frame format includes the MAI subfield (MCS request or ASEL Indication) and the MFB/ASELC subfield (MCS Feedback/Antenna Selection Command). If the MAI subfield is set to "14," the MFB/ASELC subfield acts as the Antenna Selection Command. The frame format of the ASELC subfield contains ASEL Command and ASEL Data subfields.

31. As one example, if the ASEL Command of the LAC frame is set to "0," it is interpreted as TXASSI ("Transmit Antenna Selection Sounding Indication"), a signal to initiate antenna selection. And the ASEL Data field contains the remaining number of sounding PPDUs to be transmitted ("a number N indicative of a number of sounding packets").

9.2.4.6.2 HT variant

The format of the HT Control Middle subfield of the HT variant HT Control field is shown in Figure 9-9.

	B1 B15	B16 B17	B18 B19	B20 B21	B22 B23	B24	B25 B28	B29
	Link Adaptation Control	Calibration Position	Calibration Sequence	Reserved	CSI/ Steering	HT NDP Announce ment	Reserved	DEI
Bits:	15	2	2	2	2	1	4	1

Figure 9-9—HT Control Middle subfield of the HT variant HT Control field

The format of the Link Adaptation Control subfield of the HT variant HT Control field is defined in Figure 9-10.

	B1	B2 B5	B6 B8	B9 B15
	TRQ	MAI	MFSI	MFB/ASELC
Bits:	1	4	3	7

Figure 9-10—Link Adaptation Control subfield

Source: IEEE 802.11-2016 Standard (Page 655)

Table 9-12—Subfields of Link Adaptation Control subfield

Subfield	Meaning	Definition
TRQ	Training request	Set to 1 to request the responder to transmit a sounding PPDU. Set to 0 to indicate that the responder is not requested to transmit a sounding PPDU. See 10.32.2 and 10.34.2.
MAI	MCS request (MRQ) or ASEL indication	Set to 14 (indicating ASELI) to indicate that the MFB/ASELC subfield is interpreted as ASELC. Otherwise, the MAI subfield is interpreted as shown in Figure 9-11, and the MFB/ASELC subfield is interpreted as MCS feedback (MFB).
MFSI	MCS feedback sequence identifier	Set to the received value of MSI contained in the frame to which the MFB information refers. Set to 7 for unsolicited MFB.
MFB/ASELC	MCS feedback and antenna selection command/data	When the MAI subfield is equal to the value ASELI, this subfield is interpreted as defined in Figure 9-12 and Table 9-14. Otherwise, this subfield contains recommended MFB. A value of 127 indicates that no feedback is present.

The structure of the MAI subfield of the Link Adaptation Control subfield is defined in Figure 9-11. The subfields of the MAI subfield are defined in Table 9-13.

Figure 9-11—MAI subfield

Source: IEEE 802.11-2016 Standard (Page 656)

The ASELC subfield of the Link Adaptation Control subfield contains the ASEL Command and ASEL Data subfields, as shown in Figure 9-12. The encoding of these subfields is shown in Table 9-14.

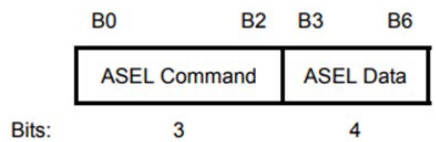

Figure 9-12—ASELC subfield

Source: IEEE 802.11-2016 Standard (Page 657)

Table 9-14—ASEL Command and ASEL Data subfields

ASEL Command	Interpretation of ASEL Command	ASEL Data
0	Transmit Antenna Selection Sounding Indication (TXASSI)	Number of remaining sounding PPDUs to be transmitted 0 to 15 See NOTE
1	Transmit Antenna Selection Sounding Request (TXASSR) or Transmit ASEL Sounding Resumption	0 when the command is Transmit ASEL Sounding Request A number in the range 1 to 15, the number being the number of the first sounding PPDU to be transmitted when the command is Transmit ASEL Sounding Resumption, where 0 corresponds to the first sounding PPDU in the original ASEL training sequence
2	Receive Antenna Selection Sounding Indication (RXASSI)	Number of remaining sounding PPDUs to be received 0 to 15 See NOTE
3	Receive Antenna Selection Sounding Request (RXASSR)	Number of sounding PPDUs required 0 to 15
4	Sounding Label	Sequence number of the sounding PPDU corresponding to a channel state information (CSI) frame in ASEL feedback 0 to 15
5	No Feedback Due to ASEL Training Failure or Stale Feedback	A number in the range 0 to 15, the number being the number of the first sounding PPDU that was not received properly, where 0 corresponds to the first sounding PPDU in the ASEL training sequence, or 0 if no sounding PPDUs were received properly, or 0 if this is a request for a full retraining sequence
6	Transmit Antenna Selection Sounding Indication requesting feedback of explicit CSI (TXASSI-CSI)	Number of remaining sounding PPDUs to be transmitted 0 to 15 See NOTE
7	Reserved	Reserved

NOTE—If the HT variant HT Control field is carried in a sounding PPDU, then the value of the ASEL Data field contains the remaining number of sounding frames following the current one. If null data packet (NDP) sounding frame is used, then the value in the ASEL Data field contains the number of NDPs following a non-NDP+HTC. The HT NDP Announcement subfield in the HT Control field is set to 1 to indicate NDP sounding.

Source: IEEE 802.11-2016 Standard (Page 657)

32. The method practiced using the accused products includes the step of estimating a channel matrix based on a characteristic of the channel as indicated by the received N sounding packets.

33. For example, the transmit ASEL responder station receives the sounding PPDUs ("N sounding packets"). The transmit ASEL responder station then estimates the channel state information ("a characteristic of the channel") based on the measurements from the received sounding PPDUs, each of which corresponds to a different set of antennas. After the estimate is complete, a Channel State Information report (CSI report) is generated and sent to the ASEL transmitter station. The CSI report is embedded in a CSI frame. The CSI Report field contains a

Channel Matrix subfield, which contains the channel matrices estimated for the different channels.

19.3.13.3 Sounding PPDU for calibration

In the case of a bidirectional calibration exchange, two STAs exchange sounding PPDUs, the exchange of which enables the receiving STA to compute an estimate of the MIMO channel matrix H_k for each subcarrier k. In general, in an exchange of calibration messages, the number of spatial streams is less than the number of transmit antennas. In such cases, HT-ELTFs are used. In the case of sounding PPDUs for calibration, the antenna mapping matrix shall be as shown in Equation (19-86).

$$Q_k = C_{CSD}(k)P_{CAL} \quad (19\text{-}86)$$

Source: IEEE 802.11-2016 Standard (Page 2401)

10.30 Sounding PPDUs

The behavior described in this subclause is specific to the use of the HT variant HT Control field.

A sounding PPDU is a PPDU for which the SOUNDING parameter of the corresponding RXVECTOR or TXVECTOR has the value SOUNDING. Sounding PPDUs are transmitted by STAs to enable the receiving STAs to estimate the channel between the transmitting STA and the receiving STA.

A STA transmits sounding PPDUs when it operates in the following roles:

— MFB requester (see 10.31.2)
— HT beamformee responding to a training request, calibration initiator, or responder involved in implicit transmit beamforming (see 10.32.2.2, 10.32.2.3, and 10.32.2.4)
— HT beamformer involved in explicit transmit beamforming (see 10.32.3)
— ASEL transmitter and ASEL sounding-capable transmitter involved in ASEL (see 10.33.2)

A STA receives sounding PPDUs when it operates in the following roles:

— MFB responder (see 10.31.2)
— HT beamformer sending a training request, calibration initiator, or responder involved in implicit transmit beamforming (see 10.32.2.2, 10.32.2.3, and 10.32.2.4)
— HT beamformee involved in explicit transmit beamforming (see 10.32.3)
— Transmit ASEL responder and ASEL receiver involved in ASEL (see 10.33.2)

Source: IEEE 802.11-2016 Standard (Pages 1462-63)

> The frame exchange sequence for transmit ASEL is shown in Figure 10-50, where the term *ASEL transmitter* identifies the STA that is conducting transmit ASEL, and the term *transmit ASEL responder* identifies the STA that provides ASEL feedback. The frame exchange comprises the following steps:
>
> a) (Optional) A transmit ASEL responder may initiate the transmit ASEL training by sending a +HTC frame with the ASEL Command subfield set to Transmit Antenna Selection Sounding Request (TXASSR).
>
> b) The ASEL transmitter sends out consecutive sounding PPDUs separated by SIFS in a TXOP of which it is the TXOP holder with no acknowledgment over different antenna sets, each PPDU containing a +HTC frame with the ASEL Command subfield set to Transmit Antenna Selection Sounding Indication (TXASSI or TXASSI-CSI). Each sounding PPDU is transmitted over one antenna set.

Source: IEEE 802.11-2016 Standard (Page 1482)

> c) The transmit ASEL responder estimates the subchannel corresponding to each sounding PPDU.
>
> d) If the ASEL Command subfield in the sounding frames is equal to TXASSI-CSI, after receiving all of the sounding PPDUs, the transmit ASEL responder shall respond with the full size CSI in a subsequent TXOP. If the ASEL Command subfield in the sounding frames is equal to TXASSI, after receiving all of the sounding PPDUs, the transmit ASEL responder may either respond with the full size CSI in a subsequent TXOP, or conduct ASEL computation and provide the selected antenna indices in a subsequent TXOP.
>
> 1) CSI is transported using the MIMO CSI Matrices frame defined in 9.6.12.6 contained within either an Action No Ack or Action frame. Multiple CSI frames may be required to provide the complete feedback, in which case the value of the Sounding Timestamp field within each of

Source: IEEE 802.11-2016 Standard (Page 1482)

> When the MIMO channel measurements become available at STA B, STA B shall send one or more CSI frames that contain the CSI report (Step 2 in Figure 10-47). This CSI report shall have full precision, i.e, *Ng*=1 (no grouping) and *Nb*=3 (8 bits). In these CSI frames, the Calibration Sequence subfields in HT Control fields shall be set to the same value that is indicated in the Calibration Sounding Complete frame. These CSI frames shall have a frame type of Management Action +HTC.

Source: IEEE 802.11-2016 Standard (Page 1477)

9.6.12.6 CSI frame format

The CSI frame is an Action or an Action No Ack frame of category HT. The format of its Action field is defined in Table 9-338.

Table 9-338—CSI frame Action field format

Order	Information
1	Category
2	HT Action
3	MIMO Control (see 9.4.1.27)
4	CSI Report (see 9.4.1.28)

Source: IEEE 802.11-2016 Standard (Page 1214)

9.4.1.28 CSI Report field

The CSI Report field is used by the CSI frame (see 9.6.12.6) to carry explicit channel state information to a transmit HT beamformer, as described in 10.32.3.

The CSI Matrix subfields in the CSI Report field shown in Table 9-52 and Table 9-53 are matrices whose elements are taken from the CHAN_MAT parameter of RXVECTOR (see Table 19-1).

Table 9-52—CSI Report field (20 MHz)

Field	Size (bits)	Meaning
SNR in receive chain 1	8	Signal-to-noise ratio in the first receive chain of the STA sending the report.
…		
SNR in receive chain Nr	8	Signal-to-noise ratio in the Nr'th receive chain of the STA sending the report.
CSI Matrix for carrier –28	$3+2\times Nb\times Nc\times Nr$	CSI matrix (see Figure 9-95)
…		

Source: IEEE 802.11-2016 Standard (Page 746)

Table 19-1—TXVECTOR and RXVECTOR parameters

Parameter	Condition	Value	TXVECTOR (See NOTE 1)	RXVECTOR (See NOTE 1)
CHAN_MAT	CHAN_MAT_TYPE is COMPRESSED_SV	Contains a set of compressed beamforming feedback matrices as defined in 19.3.12.3.6 based on the channel measured during the training symbols of the received PPDU. The number of elements depends on the number of spatial streams and the number of transmit chains.	N	Y
	CHAN_MAT_TYPE is NON_COMPRESSED_SV	Contains a set of noncompressed beamforming feedback matrices as defined in 19.3.12.3.5 based on the channel measured during the training symbols of the received PPDU. The number of complex elements is $N_{ST} \times N_r \times N_c$ where N_{ST} is the total number of subcarriers, N_c is the number of columns, and N_r is the number of rows in each matrix.	N	Y
	CHAN_MAT_TYPE is CSI_MATRICES	Contains a set of CSI matrices as defined in 19.3.12.3.2 based on the channel measured during the training symbols of the received PPDU. The number of complex elements is $N_{ST} \times N_r \times N_c$ where N_{ST} is the total number of subcarriers, N_c is the number of columns, and N_r is the number of rows in each matrix.	N	Y
	Otherwise	Not present	N	N
CHAN_MAT_TYPE	FORMAT is HT_MF or HT_GF	Enumerated type: COMPRESSED_SV indicates that CHAN_MAT is a set of compressed beamforming vector matrices. NON_COMPRESSED_SV indicates that CHAN_MAT is a set of noncompressed beamforming vector matrices. CSI_MATRICES indicates that CHAN_MAT is a set of channel state matrices.	N	Y
	Otherwise	Not present	N	N

Source: IEEE 802.11-2016 Standard (Pages 2340-41)

34. The method practiced using the accused products includes the step of selecting a subset of antennas according to the channel matrix, wherein the receiving further comprises receiving a non-ZLF+HTC packet immediately followed by plural consecutive zero length frame (ZLF) sounding packets, the non-ZLF+HTC packet having an antenna selection control (ASC) field including a transmit antenna selection sounding indication (TXASSI) signal to initiate antenna selection and a number N of the plural consecutive ZLF sounding packets.

35. For example, the transmit ASEL responder station, after receiving the consecutive sounding packets, estimates the Channel State Information (CSI) and generates a Channel State Information report (CSI report), which includes channel matrices. Based on the channel

matrices, the set of antennas to be used for MIMO communication is selected ("selecting a subset of antennas").

36. During the antenna selection process, the ASEL transmitter station transmits consecutive sounding PPDUs in which at least one of the PPDUs contains a +HTC frame ("non-ZLF+HTC packet") with the ASEL Command subfield set to TXASSI ("Transmit Antenna Selection Sounding Indication"). After receiving all the sounding PPDUs, e.g., sounding NDPs ("plural consecutive zero length frame (ZLF) sounding packets"), channel state information for all channels is measured, and the channel matrix is estimated. Based on the estimated channel matrix, the transmit ASEL performs antenna selection and subsequently provides the selected antenna indices.

> **Antenna Selection.** There are M columns and N rows in the CSI matrix **H**; each corresponds to one transmit or receive antenna. To compute the Effective CSI that would be used under a particular antenna selection, we simply pick the subset of rows and columns that correspond to the desired antennas. Note that this includes both transmit antenna selection (e.g., when S < M, pick the best S of the M transmit antennas to send with) and receive antenna selection (e.g., when N > S, turn off the least useful of the excess antennas in order to reduce power consumption).

Source: https://arxiv.org/ftp/arxiv/papers/1301/1301.6644.pdf (Page 76)

10.33 Antenna selection (ASEL)

10.33.1 Introduction

The procedures in this subclause apply only to HT and non-HT PPDUs for which the HT Control field, if present, is the HT variant HT Control field.

ASEL is a time-variant mapping of the signals at the RF chains onto a set of antenna elements when the number of RF chains is smaller than the number of antenna elements. The mapping might be chosen based on instantaneous or averaged CSI. ASEL requires the training of the full size channel associated with all antenna elements, which is obtained by transmitting or receiving sounding PPDUs over all antennas. These sounding PPDUs should be sent within a single TXOP. To avoid channel distortions, these sounding PPDUs shall be transmitted consecutively. The training information is exchanged using the HT Control field. When both transmitter and receiver have ASEL capabilities, training of transmit and receive antennas might be done one after another. ASEL supports up to eight antennas and up to four RF chains.

Source: IEEE 802.11-2016 Standard (Page 1481)

The frame exchange sequence for transmit ASEL is shown in Figure 10-50, where the term *ASEL transmitter* identifies the STA that is conducting transmit ASEL, and the term *transmit ASEL responder* identifies the STA that provides ASEL feedback. The frame exchange comprises the following steps:

a) (Optional) A transmit ASEL responder may initiate the transmit ASEL training by sending a +HTC frame with the ASEL Command subfield set to Transmit Antenna Selection Sounding Request (TXASSR).

b) The ASEL transmitter sends out consecutive sounding PPDUs separated by SIFS in a TXOP of which it is the TXOP holder with no acknowledgment over different antenna sets, each PPDU containing a +HTC frame with the ASEL Command subfield set to Transmit Antenna Selection Sounding Indication (TXASSI or TXASSI-CSI). Each sounding PPDU is transmitted over one antenna set.

Source: IEEE 802.11-2016 Standard (Page 1482)

c) The transmit ASEL responder estimates the subchannel corresponding to each sounding PPDU.

d) If the ASEL Command subfield in the sounding frames is equal to TXASSI-CSI, after receiving all of the sounding PPDUs, the transmit ASEL responder shall respond with the full size CSI in a subsequent TXOP. If the ASEL Command subfield in the sounding frames is equal to TXASSI, after receiving all of the sounding PPDUs, the transmit ASEL responder may either respond with the full size CSI in a subsequent TXOP, or conduct ASEL computation and provide the selected antenna indices in a subsequent TXOP.

   1) CSI is transported using the MIMO CSI Matrices frame defined in 9.6.12.6 contained within either an Action No Ack or Action frame. Multiple CSI frames may be required to provide the complete feedback, in which case the value of the Sounding Timestamp field within each of

Source: IEEE 802.11-2016 Standard (Page 1482)

When the MIMO channel measurements become available at STA B, STA B shall send one or more CSI frames that contain the CSI report (Step 2 in Figure 10-47). This CSI report shall have full precision, i.e, *Ng*=1 (no grouping) and *Nb*=3 (8 bits). In these CSI frames, the Calibration Sequence subfields in HT Control fields shall be set to the same value that is indicated in the Calibration Sounding Complete frame. These CSI frames shall have a frame type of Management Action +HTC.

Source: IEEE 802.11-2016 Standard (Page 1477)

9.6.12.6 CSI frame format

The CSI frame is an Action or an Action No Ack frame of category HT. The format of its Action field is defined in Table 9-338.

Table 9-338—CSI frame Action field format

Order	Information
1	Category
2	HT Action
3	MIMO Control (see 9.4.1.27)
4	CSI Report (see 9.4.1.28)

Source: IEEE 802.11-2016 Standard (Page 1214)

9.4.1.28 CSI Report field

The CSI Report field is used by the CSI frame (see 9.6.12.6) to carry explicit channel state information to a transmit HT beamformer, as described in 10.32.3.

The CSI Matrix subfields in the CSI Report field shown in Table 9-52 and Table 9-53 are matrices whose elements are taken from the CHAN_MAT parameter of RXVECTOR (see Table 19-1).

Table 9-52—CSI Report field (20 MHz)

Field	Size (bits)	Meaning
SNR in receive chain 1	8	Signal-to-noise ratio in the first receive chain of the STA sending the report.
...		
SNR in receive chain *Nr*	8	Signal-to-noise ratio in the *Nr*'th receive chain of the STA sending the report.
CSI Matrix for carrier –28	$3+2\times Nb\times Nc\times Nr$	CSI matrix (see Figure 9-95)
...		

Source: IEEE 802.11-2016 Standard (Page 746)

Table 19-1—TXVECTOR and RXVECTOR parameters

Parameter	Condition	Value	TXVECTOR	RXVECTOR
			See NOTE 1	
CHAN_MAT	CHAN_MAT_TYPE is COMPRESSED_SV	Contains a set of compressed beamforming feedback matrices as defined in 19.3.12.3.6 based on the channel measured during the training symbols of the received PPDU. The number of elements depends on the number of spatial streams and the number of transmit chains.	N	Y
	CHAN_MAT_TYPE is NON_COMPRESSED_SV	Contains a set of noncompressed beamforming feedback matrices as defined in 19.3.12.3.5 based on the channel measured during the training symbols of the received PPDU. The number of complex elements is $N_{ST} \times N_r \times N_c$ where N_{ST} is the total number of subcarriers, N_c is the number of columns, and N_r is the number of rows in each matrix.	N	Y
	CHAN_MAT_TYPE is CSI_MATRICES	Contains a set of CSI matrices as defined in 19.3.12.3.2 based on the channel measured during the training symbols of the received PPDU. The number of complex elements is $N_{ST} \times N_r \times N_c$ where N_{ST} is the total number of subcarriers, N_c is the number of columns, and N_r is the number of rows in each matrix.	N	Y
	Otherwise	Not present	N	N
CHAN_MAT_TYPE	FORMAT is HT_MF or HT_GF	Enumerated type: COMPRESSED_SV indicates that CHAN_MAT is a set of compressed beamforming vector matrices. NON_COMPRESSED_SV indicates that CHAN_MAT is a set of noncompressed beamforming vector matrices. CSI_MATRICES indicates that CHAN_MAT is a set of channel state matrices.	N	Y
	Otherwise	Not present	N	N

Source: IEEE 802.11-2016 Standard (Pages 2340-41)

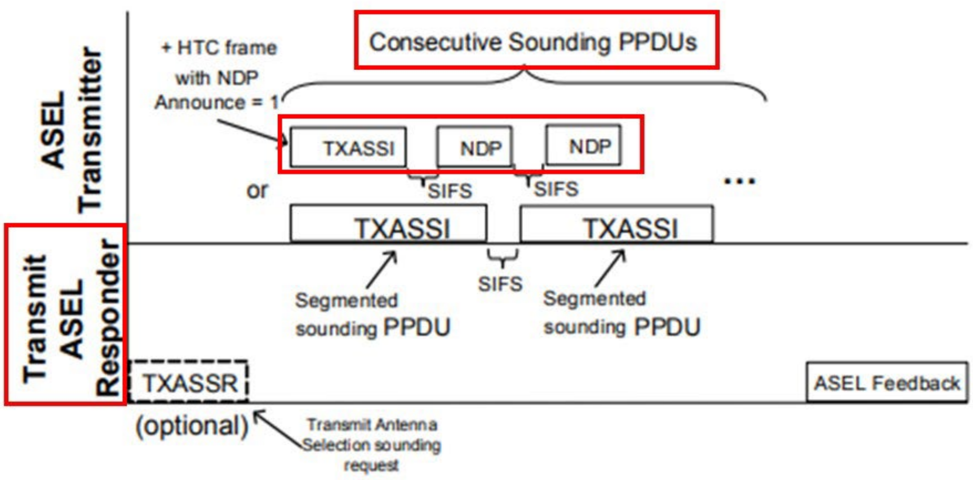

Figure 10-50—Transmit ASEL

Source: IEEE 802.11-2016 Standard (Page 1483)

37. PPDUs are MAC frames that include a set of fields. The High Throughput (HT) control field is in the MAC frame format and present only in certain frame types and subtypes. A frame that contains the HT Control Field is referred to as a "+HTC Frame" ("non-ZLF+HTC packet").

> A frame that contains the HT Control field is referred to as a *+HTC frame*. A Control Wrapper frame is a +HTC frame.

Source: IEEE 802.11-2016 Standard (Page 637)

9.2.3 General frame format

The MAC frame format comprises a set of fields that occur in a fixed order in all frames. Figure 9-1 depicts the general MAC frame format. The first three fields (Frame Control, Duration/ID, and Address 1) and the last field (FCS) in Figure 9-1 constitute the minimal frame format and are present in all frames, including reserved types and subtypes. The fields Address 2, Address 3, Sequence Control, Address 4, QoS Control, HT Control, and Frame Body are present only in certain frame types and subtypes. Each field is defined in 9.2.4. The format of each of the individual subtypes of each frame type is defined in 9.3. The components of management frame bodies are defined in 9.4. The formats of Action frames are defined in 9.6.

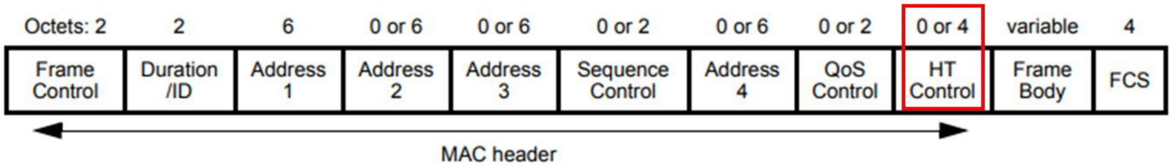

Figure 9-1—MAC frame format

Source: IEEE 802.11-2016 Standard (Pages 637-38)

38. The +HTC frame includes an LAC subfield, which allows the station to perform antenna selection. The LAC frame format includes the MAI subfield (MCS request or ASEL Indication). When MAI is set to "14," the MFB/ASELC subfield (MCS Feedback/Antenna Selection Command) is used as the Antenna Selection Command. Also, the frame format of ASELC subfield contains ASEL Command and ASEL Data subfields.

39. As an example, when ASEL Command is "0," it is interpreted as TXASSI signal ("including a transmit antenna selection sounding indication (TXASSI) signal"), and the ASEL Data field contains the number of remaining sounding PPDUs to be transmitted ("a number N of the plural consecutive ZLF sounding packets"). NDP sounding can be indicated by the HT NDP announcement subfield (when set to 1) in the HT Control field.

null data packet (NDP): A physical layer (PHY) protocol data unit (PPDU) that carries no Data field.

Source: IEEE 802.11-2016 Standard (Page 157)

9.2.4.6.2 HT variant

The format of the HT Control Middle subfield of the HT variant HT Control field is shown in Figure 9-9.

	B1 B15	B16 B17	B18 B19	B20 B21	B22 B23	B24	B25 B28	B29
	Link Adaptation Control	Calibration Position	Calibration Sequence	Reserved	CSI/ Steering	HT NDP Announcement	Reserved	DEI
Bits:	15	2	2	2	2	1	4	1

Figure 9-9—HT Control Middle subfield of the HT variant HT Control field

The format of the Link Adaptation Control subfield of the HT variant HT Control field is defined in Figure 9-10.

	B1	B2 B5	B6 B8	B9 B15
	TRQ	MAI	MFSI	MFB/ASELC
Bits:	1	4	3	7

Figure 9-10—Link Adaptation Control subfield

Source: IEEE 802.11-2016 Standard (Page 655)

Table 9-12—Subfields of Link Adaptation Control subfield

Subfield	Meaning	Definition
TRQ	Training request	Set to 1 to request the responder to transmit a sounding PPDU. Set to 0 to indicate that the responder is not requested to transmit a sounding PPDU. See 10.32.2 and 10.34.2.
MAI	MCS request (MRQ) or ASEL indication	Set to 14 (indicating ASELI) to indicate that the MFB/ASELC subfield is interpreted as ASELC. Otherwise, the MAI subfield is interpreted as shown in Figure 9-11, and the MFB/ASELC subfield is interpreted as MCS feedback (MFB).
MFSI	MCS feedback sequence identifier	Set to the received value of MSI contained in the frame to which the MFB information refers. Set to 7 for unsolicited MFB.
MFB/ASELC	MCS feedback and antenna selection command/data	When the MAI subfield is equal to the value ASELI, this subfield is interpreted as defined in Figure 9-12 and Table 9-14. Otherwise, this subfield contains recommended MFB. A value of 127 indicates that no feedback is present.

The structure of the MAI subfield of the Link Adaptation Control subfield is defined in Figure 9-11. The subfields of the MAI subfield are defined in Table 9-13.

	B0	B1 B3
	MRQ	MSI
Bits:	1	3

Figure 9-11—MAI subfield

Source: IEEE 802.11-2016 Standard (Page 656)

> The ASELC subfield of the Link Adaptation Control subfield contains the ASEL Command and ASEL Data subfields, as shown in Figure 9-12. The encoding of these subfields is shown in Table 9-14.
>
> | | B0 B2 | B3 B6 |
> |---|---|---|
> | | ASEL Command | ASEL Data |
> | Bits: | 3 | 4 |
>
> **Figure 9-12—ASELC subfield**

Source: IEEE 802.11-2016 Standard (Page 657)

> NOTE—If the HT variant HT Control field is carried in a sounding PPDU, then the value of the ASEL Data field contains the remaining number of sounding frames following the current one. If null data packet (NDP) sounding frame is used, then the value in the ASEL Data field contains the number of NDPs following a non-NDP+HTC. The HT NDP Announcement subfield in the HT Control field is set to 1 to indicate NDP sounding.

Source: IEEE 802.11-2016 Standard (Page 657)

Table 9-14—ASEL Command and ASEL Data subfields

ASEL Command	Interpretation of ASEL Command	ASEL Data
0	Transmit Antenna Selection Sounding Indication (TXASSI)	Number of remaining sounding PPDUs to be transmitted 0 to 15
		See NOTE
1	Transmit Antenna Selection Sounding Request (TXASSR) or Transmit ASEL Sounding Resumption	0 when the command is Transmit ASEL Sounding Request A number in the range 1 to 15, the number being the number of the first sounding PPDU to be transmitted when the command is Transmit ASEL Sounding Resumption, where 0 corresponds to the first sounding PPDU in the original ASEL training sequence
2	Receive Antenna Selection Sounding Indication (RXASSI)	Number of remaining sounding PPDUs to be received 0 to 15 See NOTE
3	Receive Antenna Selection Sounding Request (RXASSR)	Number of sounding PPDUs required 0 to 15
4	Sounding Label	Sequence number of the sounding PPDU corresponding to a channel state information (CSI) frame in ASEL feedback 0 to 15
5	No Feedback Due to ASEL Training Failure or Stale Feedback	A number in the range 0 to 15, the number being the number of the first sounding PPDU that was not received properly, where 0 corresponds to the first sounding PPDU in the ASEL training sequence, or 0 if no sounding PPDUs were received properly, or 0 if this is a request for a full retraining sequence
6	Transmit Antenna Selection Sounding Indication requesting feedback of explicit CSI (TXASSI-CSI)	Number of remaining sounding PPDUs to be transmitted 0 to 15 See NOTE
7	Reserved	Reserved

Source: IEEE 802.11-2016 Standard (Page 657)

> The frame exchange sequence for transmit ASEL is shown in Figure 10-50, where the term *ASEL transmitter* identifies the STA that is conducting transmit ASEL, and the term *transmit ASEL responder* identifies the STA that provides ASEL feedback. The frame exchange comprises the following steps:
>
> a) (Optional) A transmit ASEL responder may initiate the transmit ASEL training by sending a +HTC frame with the ASEL Command subfield set to Transmit Antenna Selection Sounding Request (TXASSR).
>
> b) The ASEL transmitter sends out consecutive sounding PPDUs separated by SIFS in a TXOP of which it is the TXOP holder with no acknowledgment over different antenna sets, each PPDU containing a +HTC frame with the ASEL Command subfield set to Transmit Antenna Selection Sounding Indication (TXASSI or TXASSI-CSI). Each sounding PPDU is transmitted over one antenna set.

Source: IEEE 802.11-2016 Standard (Page 1482)

> c) The transmit ASEL responder estimates the subchannel corresponding to each sounding PPDU.
>
> d) If the ASEL Command subfield in the sounding frames is equal to TXASSI-CSI, after receiving all of the sounding PPDUs, the transmit ASEL responder shall respond with the full size CSI in a subsequent TXOP. If the ASEL Command subfield in the sounding frames is equal to TXASSI, after receiving all of the sounding PPDUs, the transmit ASEL responder may either respond with the full size CSI in a subsequent TXOP, or conduct ASEL computation and provide the selected antenna indices in a subsequent TXOP.
>
> 1) CSI is transported using the MIMO CSI Matrices frame defined in 9.6.12.6 contained within either an Action No Ack or Action frame. Multiple CSI frames may be required to provide the complete feedback, in which case the value of the Sounding Timestamp field within each of

Source: IEEE 802.11-2016 Standard (Page 1482)

> An NDP sequence contains at least one HT NDP and at least one PPDU that is not an NDP. Only one PPDU in the NDP sequence may contain an HT NDP announcement. An NDP sequence begins with an HT NDP announcement. The NDP sequence ends at the end of the transmission of the last HT NDP that is announced by the HT NDP announcement. A STA that transmits the first PPDU of an NDP sequence is the NDP sequence owner. In the NDP sequence, only PPDUs carrying HT NDP and PPDUs carrying single MPDU Control frames may follow the NDP sequence's starting PPDU.

Source: IEEE 802.11-2016 Standard (Pages 1485 & 1486)

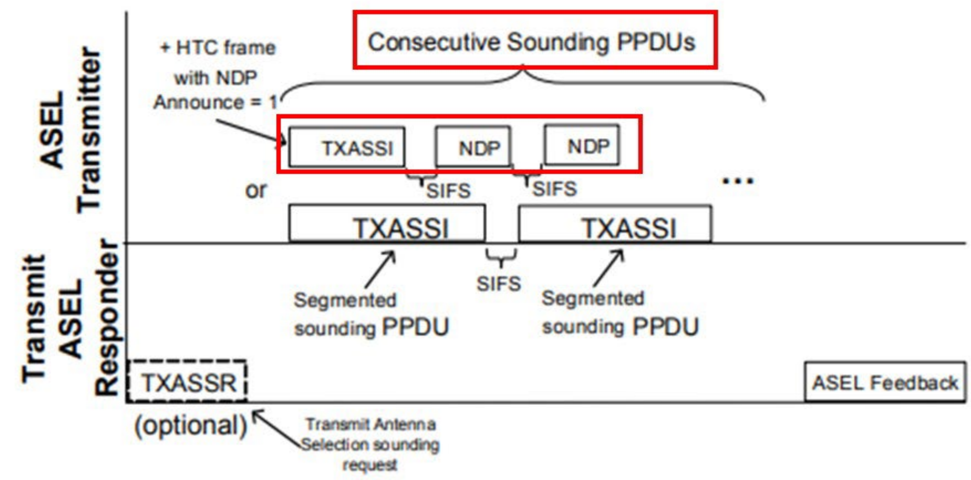

Figure 10-50—Transmit ASEL

Source: IEEE 802.11-2016 Standard (Page 1483)

40. The accused products include a station in a multiple-input, multiple-output (MIMO) wireless local area network (WLAN) including a plurality of stations, each station including a set of antennas.

41. For example, the Altice Fiber Gateway Wi-Fi 6 communicates with other stations using the IEEE 802.11 protocol and includes a set of antennas that are used for both transmitting and receiving data to and from the other stations over a WLAN. The transmission and reception of data using multiple antennas simultaneously is known as MIMO ("multiple-input, multiple-output"). The stations communicating using MIMO implement the antenna selection process before establishing communication with each other.

Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications

1. Overview

1.1 Scope

The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area.

Source: IEEE 802.11-2016 Standard (Page 122)

An HT STA has PHY features consisting of the modulation and coding scheme (MCS) set described in 19.3.5 and physical layer (PHY) protocol data unit (PPDU) formats described in 19.1.4. Some PHY features that distinguish an HT STA from a non-HT STA are referred to as *multiple input, multiple output (MIMO) operation*; spatial multiplexing (SM); spatial mapping (including transmit beamforming); space-time block coding (STBC); low-density parity check (LDPC) encoding; and antenna selection (ASEL). The allowed PPDU formats are non-HT format, HT-mixed format, and HT-greenfield format (see 19.1.4). The PPDUs can be transmitted with 20 MHz bandwidth and might be transmitted with 40 MHz bandwidth.

Source: IEEE 802.11-2016 Standard (Page 197)

multiple input, multiple output (MIMO): A physical layer (PHY) configuration in which both transmitter and receiver use multiple antennas.

Source: IEEE 802.11-2016 Standard (Page 136)

multi-user multiple input, multiple output (MU-MIMO): A technique by which multiple stations (STAs), each with one or more antennas, either simultaneously transmit to a single STA or simultaneously receive from a single STA independent data streams over the same radio frequencies.

NOTE—IEEE Std 802.11 supports only downlink (DL) MU-MIMO. *See* **downlink multi-user multiple input, multiple output (DL-MU-MIMO)** (in 3.2).

Source: IEEE 802.11-2016 Standard (Page 136)

10.31 Link adaptation

10.31.1 Introduction

To fully exploit MIMO channel variations and transmit beamforming on a MIMO link, a STA can request that another STA provide MIMO channel sounding and MFB.

Source: IEEE 802.11-2016 Standard (Page 1463)

10.30 Sounding PPDUs

The behavior described in this subclause is specific to the use of the HT variant HT Control field.

A sounding PPDU is a PPDU for which the SOUNDING parameter of the corresponding RXVECTOR or TXVECTOR has the value SOUNDING. Sounding PPDUs are transmitted by STAs to enable the receiving STAs to estimate the channel between the transmitting STA and the receiving STA.

A STA transmits sounding PPDUs when it operates in the following roles:

— MFB requester (see 10.31.2)

— HT beamformee responding to a training request, calibration initiator, or responder involved in implicit transmit beamforming (see 10.32.2.2, 10.32.2.3, and 10.32.2.4)

— HT beamformer involved in explicit transmit beamforming (see 10.32.3)

— ASEL transmitter and ASEL sounding-capable transmitter involved in ASEL (see 10.33.2)

A STA receives sounding PPDUs when it operates in the following roles:

— MFB responder (see 10.31.2)

— HT beamformer sending a training request, calibration initiator, or responder involved in implicit transmit beamforming (see 10.32.2.2, 10.32.2.3, and 10.32.2.4)

— HT beamformee involved in explicit transmit beamforming (see 10.32.3)

— Transmit ASEL responder and ASEL receiver involved in ASEL (see 10.33.2)

Source: IEEE 802.11-2016 Standard (Pages 1462-63)

10.33 Antenna selection (ASEL)

10.33.1 Introduction

The procedures in this subclause apply only to HT and non-HT PPDUs for which the HT Control field, if present, is the HT variant HT Control field.

ASEL is a time-variant mapping of the signals at the RF chains onto a set of antenna elements when the number of RF chains is smaller than the number of antenna elements. The mapping might be chosen based on instantaneous or averaged CSI. ASEL requires the training of the full size channel associated with all antenna elements, which is obtained by transmitting or receiving sounding PPDUs over all antennas. These sounding PPDUs should be sent within a single TXOP. To avoid channel distortions, these sounding PPDUs shall be transmitted consecutively. The training information is exchanged using the HT Control field. When both transmitter and receiver have ASEL capabilities, training of transmit and receive antennas might be done one after another. ASEL supports up to eight antennas and up to four RF chains.

Source: IEEE 802.11-2016 Standard (Page 1481)

42. The accused products include a receiver configured to receive, via a channel, plural consecutive packets including plural sounding packets, each sounding packet corresponding to a different subset of the set of antennas, and at least one of the plural

consecutive packets including (i) a high throughput (HT) control field including a signal to initiate antenna selection and (ii) a number N indicative of a number of sounding packets which follow the at least one packet including the HT control field and which are to be used for antenna selection.

43. For example, during the antenna selection process, the stations receive multiple consecutive sounding PPDUs ("plural sounding packets"). Each sounding PPDU corresponds to a different set of antennas from the available antennas. The first PPDU frame received is a +HTC frame followed by consecutive NDP (Null Data Packet) frames.

10.30 Sounding PPDUs

The behavior described in this subclause is specific to the use of the HT variant HT Control field.

A sounding PPDU is a PPDU for which the SOUNDING parameter of the corresponding RXVECTOR or TXVECTOR has the value SOUNDING. Sounding PPDUs are transmitted by STAs to enable the receiving STAs to estimate the channel between the transmitting STA and the receiving STA.

A STA transmits sounding PPDUs when it operates in the following roles:

— MFB requester (see 10.31.2)
— HT beamformee responding to a training request, calibration initiator, or responder involved in implicit transmit beamforming (see 10.32.2.2, 10.32.2.3, and 10.32.2.4)
— HT beamformer involved in explicit transmit beamforming (see 10.32.3)
— ASEL transmitter and ASEL sounding-capable transmitter involved in ASEL (see 10.33.2)

A STA receives sounding PPDUs when it operates in the following roles:

— MFB responder (see 10.31.2)
— HT beamformer sending a training request, calibration initiator, or responder involved in implicit transmit beamforming (see 10.32.2.2, 10.32.2.3, and 10.32.2.4)
— HT beamformee involved in explicit transmit beamforming (see 10.32.3)
— Transmit ASEL responder and ASEL receiver involved in ASEL (see 10.33.2)

Source: IEEE 802.11-2016 Standard (Pages 1462-63)

10.33 Antenna selection (ASEL)

10.33.1 Introduction

The procedures in this subclause apply only to HT and non-HT PPDUs for which the HT Control field, if present, is the HT variant HT Control field.

ASEL is a time-variant mapping of the signals at the RF chains onto a set of antenna elements when the number of RF chains is smaller than the number of antenna elements. The mapping might be chosen based on instantaneous or averaged CSI. ASEL requires the training of the full size channel associated with all antenna elements, which is obtained by transmitting or receiving sounding PPDUs over all antennas. These sounding PPDUs should be sent within a single TXOP. To avoid channel distortions, these sounding PPDUs shall be transmitted consecutively. The training information is exchanged using the HT Control field. When both transmitter and receiver have ASEL capabilities, training of transmit and receive antennas might be done one after another. ASEL supports up to eight antennas and up to four RF chains.

Source: IEEE 802.11-2016 Standard (Page 1481)

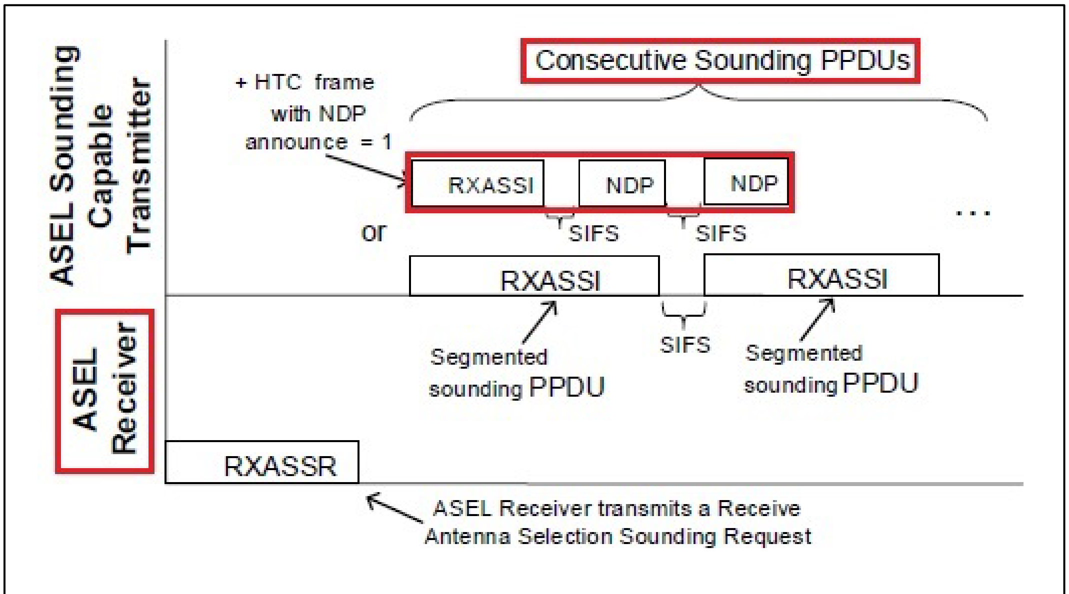

Figure 10-51—Receive ASEL

Source: IEEE 802.11-2016 Standard (Page 1484)

44. These sounding PPDUs are Media Access Control (MAC) frames that comprise a set of fields, which can include a High Throughput (HT) control field. A frame that contains the HT Control field is referred to as "+HTC Frame." The HT Control field of a MAC frame can be of two types: High Throughput (HT) or Very High Throughput (VHT). The antenna selection

procedure is only applicable to HT PPDUs (e.g., PPDUs that have a HT variant HT control field).

9.2.3 General frame format

The MAC frame format comprises a set of fields that occur in a fixed order in all frames. Figure 9-1 depicts the general MAC frame format. The first three fields (Frame Control, Duration/ID, and Address 1) and the last field (FCS) in Figure 9-1 constitute the minimal frame format and are present in all frames, including reserved types and subtypes. The fields Address 2, Address 3, Sequence Control, Address 4, QoS Control, HT Control, and Frame Body are present only in certain frame types and subtypes. Each field is defined in 9.2.4. The format of each of the individual subtypes of each frame type is defined in 9.3. The components of management frame bodies are defined in 9.4. The formats of Action frames are defined in 9.6.

Octets: 2	2	6	0 or 6	0 or 6	0 or 2	0 or 6	0 or 2	0 or 4	variable	4
Frame Control	Duration /ID	Address 1	Address 2	Address 3	Sequence Control	Address 4	QoS Control	HT Control	Frame Body	FCS

MAC header

Figure 9-1—MAC frame format

Source: IEEE 802.11-2016 Standard (Pages 637-38)

A frame that contains the HT Control field is referred to as a *+HTC frame*. A Control Wrapper frame is a +HTC frame.

Source: IEEE 802.11-2016 Standard (Page 637)

9.2.4.6 HT Control field

9.2.4.6.1 General

The HT Control field is always present in a Control Wrapper frame and is present in QoS Data and Management frames as determined by the +HTC/Order subfield of the Frame Control field as defined in 9.2.4.1.10.

NOTE—The only control frame subtype for which HT Control field is present is the Control Wrapper frame. A Control frame that is described as +HTC (e.g., an RTS+HTC, CTS+HTC, BlockAck+HTC or BlockAckReq+HTC frame) implies the use of the Control Wrapper frame to carry that Control frame.

The format of the 4-octet HT Control field is shown in Figure 9-8.

	B0	B1 B29	B30	B31
	VHT	HT Control Middle	AC Constraint	RDG/More PPDU
Bits	1	29	1	1

Figure 9-8—HT Control field

The HT Control field has two forms, the HT variant and the VHT variant. The two forms differ in the format of the HT Control Middle subfield, described in 9.2.4.6.2 for the HT variant and in 9.2.4.6.3 for the VHT variant and in the value of the VHT subfield.

The VHT subfield of the HT Control field indicates whether the HT Control Middle subfield is the VHT Variant or the HT Variant. The VHT subfield is set to 1 to indicate that the HT Control Middle subfield is the VHT Variant and is set to 0 to indicate that the HT Control Middle subfield is the HT Variant.

Source: IEEE 802.11-2016 Standard (Page 654)

10.33 Antenna selection (ASEL)

10.33.1 Introduction

The procedures in this subclause apply only to HT and non-HT PPDUs for which the HT Control field, if present, is the HT variant HT Control field.

ASEL is a time-variant mapping of the signals at the RF chains onto a set of antenna elements when the number of RF chains is smaller than the number of antenna elements. The mapping might be chosen based on instantaneous or averaged CSI. ASEL requires the training of the full size channel associated with all antenna elements, which is obtained by transmitting or receiving sounding PPDUs over all antennas. These sounding PPDUs should be sent within a single TXOP. To avoid channel distortions, these sounding PPDUs shall be transmitted consecutively. The training information is exchanged using the HT Control field. When both transmitter and receiver have ASEL capabilities, training of transmit and receive antennas might be done one after another. ASEL supports up to eight antennas and up to four RF chains.

Source: IEEE 802.11-2016 Standard (Page 1481)

45. The +HTC frames ("at least one of the plural consecutive packets") contain the HT variant HT Control field. The HT Control field also contains a HT control middle subfield,

which further contains an LAC subfield. The LAC subfield allows the station to perform Antenna Selection. The LAC frame format includes the MAI (MCS request or ASEL Indication) subfield and the MFB/ASELC (MCS Feedback/Antenna Selection Command) subfield. If the MAI subfield is set to "14," the MFB/ASELC subfield acts as the Antenna Selection Command, and the frame format of ASELC subfield contains ASEL Command and ASEL Data subfields.

46. As one example, if the ASEL Command of the LAC frame is set to "2," it is interpreted as RXASSI ("Receive Antenna Selection Sounding Indication"), a signal to initiate antenna selection. And the ASEL Data field contains the remaining number of sounding PPDUs to be received ("a number N indicative of a number of sounding packets").

9.2.4.6.2 HT variant

The format of the HT Control Middle subfield of the HT variant HT Control field is shown in Figure 9-9.

	B1 B15	B16 B17	B18 B19	B20 B21	B22 B23	B24	B25 B28	B29
	Link Adaptation Control	Calibration Position	Calibration Sequence	Reserved	CSI/ Steering	HT NDP Announce ment	Reserved	DEI
Bits:	15	2	2	2	2	1	4	1

Figure 9-9—HT Control Middle subfield of the HT variant HT Control field

The format of the Link Adaptation Control subfield of the HT variant HT Control field is defined in Figure 9-10.

	B1	B2 B5	B6 B8	B9 B15
	TRQ	MAI	MFSI	MFB/ASELC
Bits:	1	4	3	7

Figure 9-10—Link Adaptation Control subfield

Source: IEEE 802.11-2016 Standard (Page 655)

Table 9-12—Subfields of Link Adaptation Control subfield

Subfield	Meaning	Definition
TRQ	Training request	Set to 1 to request the responder to transmit a sounding PPDU. Set to 0 to indicate that the responder is not requested to transmit a sounding PPDU. See 10.32.2 and 10.34.2.
MAI	MCS request (MRQ) or ASEL indication	Set to 14 (indicating ASELI) to indicate that the MFB/ASELC subfield is interpreted as ASELC. Otherwise, the MAI subfield is interpreted as shown in Figure 9-11, and the MFB/ASELC subfield is interpreted as MCS feedback (MFB).
MFSI	MCS feedback sequence identifier	Set to the received value of MSI contained in the frame to which the MFB information refers. Set to 7 for unsolicited MFB.
MFB/ASELC	MCS feedback and antenna selection command/data	When the MAI subfield is equal to the value ASELI, this subfield is interpreted as defined in Figure 9-12 and Table 9-14. Otherwise, this subfield contains recommended MFB. A value of 127 indicates that no feedback is present.

The structure of the MAI subfield of the Link Adaptation Control subfield is defined in Figure 9-11. The subfields of the MAI subfield are defined in Table 9-13.

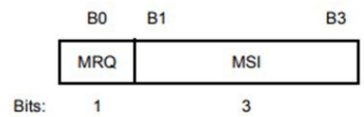

Figure 9-11—MAI subfield

Source: IEEE 802.11-2016 Standard (Page 656)

The ASELC subfield of the Link Adaptation Control subfield contains the ASEL Command and ASEL Data subfields, as shown in Figure 9-12. The encoding of these subfields is shown in Table 9-14.

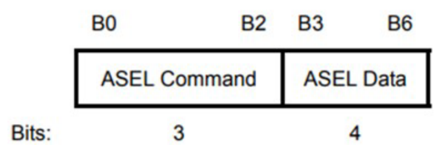

Figure 9-12—ASELC subfield

Source: IEEE 802.11-2016 Standard (Page 657)

Table 9-14—ASEL Command and ASEL Data subfields

ASEL Command	Interpretation of ASEL Command	ASEL Data
0	Transmit Antenna Selection Sounding Indication (TXASSI)	Number of remaining sounding PPDUs to be transmitted 0 to 15 See NOTE
1	Transmit Antenna Selection Sounding Request (TXASSR) or Transmit ASEL Sounding Resumption	0 when the command is Transmit ASEL Sounding Request A number in the range 1 to 15, the number being the number of the first sounding PPDU to be transmitted when the command is Transmit ASEL Sounding Resumption, where 0 corresponds to the first sounding PPDU in the original ASEL training sequence
2	Receive Antenna Selection Sounding Indication (RXASSI)	Number of remaining sounding PPDUs to be received 0 to 15 See NOTE
3	Receive Antenna Selection Sounding Request (RXASSR)	Number of sounding PPDUs required 0 to 15
4	Sounding Label	Sequence number of the sounding PPDU corresponding to a channel state information (CSI) frame in ASEL feedback 0 to 15
5	No Feedback Due to ASEL Training Failure or Stale Feedback	A number in the range 0 to 15, the number being the number of the first sounding PPDU that was not received properly, where 0 corresponds to the first sounding PPDU in the ASEL training sequence, or 0 if no sounding PPDUs were received properly, or 0 if this is a request for a full retraining sequence
6	Transmit Antenna Selection Sounding Indication requesting feedback of explicit CSI (TXASSI-CSI)	Number of remaining sounding PPDUs to be transmitted 0 to 15 See NOTE
7	Reserved	Reserved

NOTE—If the HT variant HT Control field is carried in a sounding PPDU, then the value of the ASEL Data field contains the remaining number of sounding frames following the current one. If null data packet (NDP) sounding frame is used, then the value in the ASEL Data field contains the number of NDPs following a non-NDP+HTC. The HT NDP Announcement subfield in the HT Control field is set to 1 to indicate NDP sounding.

Source: IEEE 802.11-2016 Standard (Page 657)

Table 9-14—ASEL Command and ASEL Data subfields

ASEL Command	Interpretation of ASEL Command	ASEL Data
0	Transmit Antenna Selection Sounding Indication (TXASSI)	Number of remaining sounding PPDUs to be transmitted 0 to 15 See NOTE
1	Transmit Antenna Selection Sounding Request (TXASSR) or Transmit ASEL Sounding Resumption	0 when the command is Transmit ASEL Sounding Request A number in the range 1 to 15, the number being the number of the first sounding PPDU to be transmitted when the command is Transmit ASEL Sounding Resumption, where 0 corresponds to the first sounding PPDU in the original ASEL training sequence
2	Receive Antenna Selection Sounding Indication (RXASSI)	Number of remaining sounding PPDUs to be received 0 to 15 See NOTE
3	Receive Antenna Selection Sounding Request (RXASSR)	Number of sounding PPDUs required 0 to 15
4	Sounding Label	Sequence number of the sounding PPDU corresponding to a channel state information (CSI) frame in ASEL feedback 0 to 15
5	No Feedback Due to ASEL Training Failure or Stale Feedback	A number in the range 0 to 15, the number being the number of the first sounding PPDU that was not received properly, where 0 corresponds to the first sounding PPDU in the ASEL training sequence, or 0 if no sounding PPDUs were received properly, or 0 if this is a request for a full retraining sequence
6	Transmit Antenna Selection Sounding Indication requesting feedback of explicit CSI (TXASSI-CSI)	Number of remaining sounding PPDUs to be transmitted 0 to 15 See NOTE
7	Reserved	Reserved

NOTE—If the HT variant HT Control field is carried in a sounding PPDU, then the value of the ASEL Data field contains the remaining number of sounding frames following the current one. If null data packet (NDP) sounding frame is used, then the value in the ASEL Data field contains the number of NDPs following a non-NDP+HTC. The HT NDP Announcement subfield in the HT Control field is set to 1 to indicate NDP sounding.

Source: IEEE 802.11-2016 Standard (Page 657)

47. The accused products include an estimating unit configured to estimate a channel matrix based on a characteristic of the channel as indicated by the received N sounding packets.

48. For example, the ASEL receiver station receives the sounding PPDUs ("N sounding packets"). The ASEL receiver station then estimates the channel state information ("a characteristic of the channel") based on the measurements from the received sounding PPDUs, each of which corresponds to a different set of antennas. After the estimate is complete, a Channel State Information report (CSI report) is generated. The CSI report is part of the CSI frame format, and is present as a CSI Report field. The CSI Report field contains a Channel Matrix subfield, which contains the channel matrices estimated for the different channels.

19.3.13.3 Sounding PPDU for calibration

In the case of a bidirectional calibration exchange, two STAs exchange sounding PPDUs, the exchange of which enables the receiving STA to compute an estimate of the MIMO channel matrix H_k for each subcarrier k. In general, in an exchange of calibration messages, the number of spatial streams is less than the number of transmit antennas. In such cases, HT-ELTFs are used. In the case of sounding PPDUs for calibration, the antenna mapping matrix shall be as shown in Equation (19-86).

$$Q_k = C_{CSD}(k)P_{CAL} \quad (19\text{-}86)$$

Source: IEEE 802.11-2016 Standard (Page 2401)

10.30 Sounding PPDUs

The behavior described in this subclause is specific to the use of the HT variant HT Control field.

A sounding PPDU is a PPDU for which the SOUNDING parameter of the corresponding RXVECTOR or TXVECTOR has the value SOUNDING. Sounding PPDUs are transmitted by STAs to enable the receiving STAs to estimate the channel between the transmitting STA and the receiving STA.

A STA transmits sounding PPDUs when it operates in the following roles:

— MFB requester (see 10.31.2)

— HT beamformee responding to a training request, calibration initiator, or responder involved in implicit transmit beamforming (see 10.32.2.2, 10.32.2.3, and 10.32.2.4)

— HT beamformer involved in explicit transmit beamforming (see 10.32.3)

— ASEL transmitter and ASEL sounding-capable transmitter involved in ASEL (see 10.33.2)

A STA receives sounding PPDUs when it operates in the following roles:

— MFB responder (see 10.31.2)

— HT beamformer sending a training request, calibration initiator, or responder involved in implicit transmit beamforming (see 10.32.2.2, 10.32.2.3, and 10.32.2.4)

— HT beamformee involved in explicit transmit beamforming (see 10.32.3)

— Transmit ASEL responder and ASEL receiver involved in ASEL (see 10.33.2)

Source: IEEE 802.11-2016 Standard (Pages 1462-63)

The frame exchange sequence for receive ASEL is shown in Figure 10-51, where the term *ASEL receiver* identifies the STA that is conducting receive ASEL, and the term *ASEL sounding-capable transmitter* identifies the STA sending the consecutive sounding PPDUs used for receive ASEL calculations. The frame exchange comprises the following steps:

— The ASEL receiver transmits a +HTC frame with the MAI subfield set to ASELI, the ASEL Command subfield set to Receive Antenna Selection Sounding Request (RXASSR), and the ASEL Data subfield set to the number of sounding PPDUs required.

NOTE— For example, in the case of sounding over all disjointed antenna sets, the number of total consecutive sounding PPDUs or NDPs equals the smallest integer that is greater than or equal to the number of antennas divided by the number of RF chains.

— The ASEL sounding-capable transmitter responds with the corresponding number of sounding PPDUs in its subsequent TXOP. These PPDUs are separated by SIFS. When using non-NDP sounding, each PPDU contains a +HTC frame in which the MAI subfield is set to ASELI, the ASEL Command subfield is set to Receive Antenna Selection Sounding Indication (RXASSI), and the ASEL Data subfield is set to the remaining number of sounding PPDUs to be transmitted. When using NDP sounding, the PPDU that precedes the first NDP contains a +HTC frame in which the NDP Announce field is set to 1, the MAI subfield is set to ASELI, the ASEL Command subfield is set to RXASSI, and the ASEL Data subfield is set to the remaining number of sounding PPDUs to be transmitted.

Source: IEEE 802.11-2016 Standard (Page 1484)

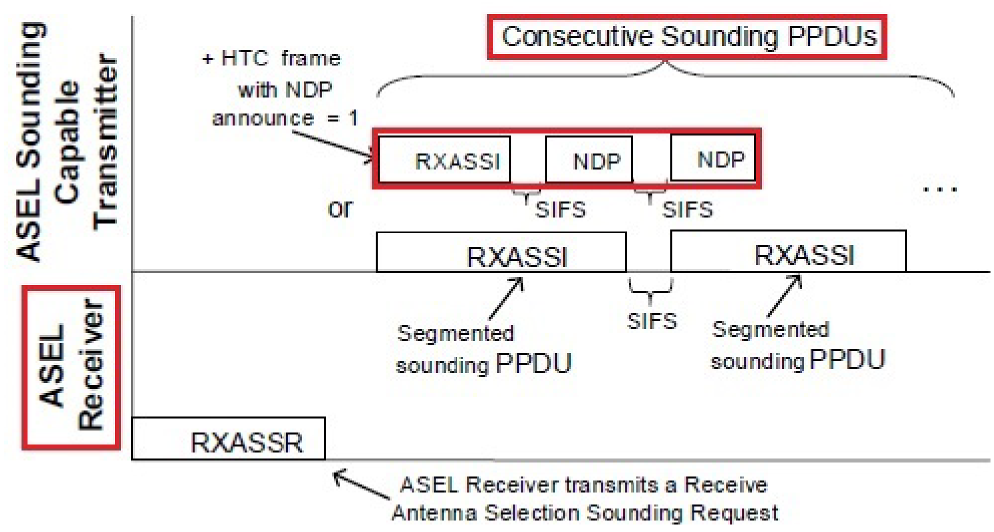

Figure 10-51—Receive ASEL

Source: IEEE 802.11-2016 Standard (Page 1484)

When the MIMO channel measurements become available at STA B, STA B shall send one or more CSI frames that contain the CSI report (Step 2 in Figure 10-47). This CSI report shall have full precision, i.e, *Ng*=1 (no grouping) and *Nb*=3 (8 bits). In these CSI frames, the Calibration Sequence subfields in HT Control fields shall be set to the same value that is indicated in the Calibration Sounding Complete frame. These CSI frames shall have a frame type of Management Action +HTC.

Source: IEEE 802.11-2016 Standard (Page 1477)

9.6.12.6 CSI frame format

The CSI frame is an Action or an Action No Ack frame of category HT. The format of its Action field is defined in Table 9-338.

Table 9-338—CSI frame Action field format

Order	Information
1	Category
2	HT Action
3	MIMO Control (see 9.4.1.27)
4	CSI Report (see 9.4.1.28)

Source: IEEE 802.11-2016 Standard (Page 1214)

9.4.1.28 CSI Report field

The CSI Report field is used by the CSI frame (see 9.6.12.6) to carry explicit channel state information to a transmit HT beamformer, as described in 10.32.3.

The CSI Matrix subfields in the CSI Report field shown in Table 9-52 and Table 9-53 are matrices whose elements are taken from the CHAN_MAT parameter of RXVECTOR (see Table 19-1).

Table 9-52—CSI Report field (20 MHz)

Field	Size (bits)	Meaning
SNR in receive chain 1	8	Signal-to-noise ratio in the first receive chain of the STA sending the report.
...		
SNR in receive chain *Nr*	8	Signal-to-noise ratio in the *Nr*'th receive chain of the STA sending the report.
CSI Matrix for carrier –28	$3+2\times Nb\times Nc\times Nr$	CSI matrix (see Figure 9-95)
...		

Source: IEEE 802.11-2016 Standard (Page 746)

Table 19-1—TXVECTOR and RXVECTOR parameters

Parameter	Condition	Value	TXVECTOR (See NOTE 1)	RXVECTOR (See NOTE 1)
CHAN_MAT	CHAN_MAT_TYPE is COMPRESSED_SV	Contains a set of compressed beamforming feedback matrices as defined in 19.3.12.3.6 based on the channel measured during the training symbols of the received PPDU. The number of elements depends on the number of spatial streams and the number of transmit chains.	N	Y
	CHAN_MAT_TYPE is NON_COMPRESSED_SV	Contains a set of noncompressed beamforming feedback matrices as defined in 19.3.12.3.5 based on the channel measured during the training symbols of the received PPDU. The number of complex elements is $N_{ST} \times N_r \times N_c$ where N_{ST} is the total number of subcarriers, N_c is the number of columns, and N_r is the number of rows in each matrix.	N	Y
	CHAN_MAT_TYPE is CSI_MATRICES	Contains a set of CSI matrices as defined in 19.3.12.3.2 based on the channel measured during the training symbols of the received PPDU. The number of complex elements is $N_{ST} \times N_r \times N_c$ where N_{ST} is the total number of subcarriers, N_c is the number of columns, and N_r is the number of rows in each matrix.	N	Y
	Otherwise	Not present	N	N
CHAN_MAT_TYPE	FORMAT is HT_MF or HT_GF	Enumerated type: COMPRESSED_SV indicates that CHAN_MAT is a set of compressed beamforming vector matrices. NON_COMPRESSED_SV indicates that CHAN_MAT is a set of noncompressed beamforming vector matrices. CSI_MATRICES indicates that CHAN_MAT is a set of channel state matrices.	N	Y
	Otherwise	Not present	N	N

Source: IEEE 802.11-2016 Standard (Pages 2340-41)

49. The accused products include a selecting unit configured to select a subset of antennas according to the channel matrix, wherein the receiver is further configured to receive a non-ZLF+HTC control packet immediately followed by plural consecutive zero length frame (ZLF) sounding packets, the non-ZLF+HTC packet having an antenna selection control (ASC) field including a receive antenna selection sounding indication (RXASSI) signal to initiate antenna selection and a number N of the plural consecutive ZLF sounding packets.

50. For example, the ASEL receiver station, after receiving the consecutive sounding packets, estimates the Channel State Information (CSI) and generates a Channel State Information report (CSI report), which includes channel matrices. Based on the channel

matrices, the set of antennas to be used for MIMO communication is selected ("select a subset of antennas").

51. During the antenna selection process, the ASEL sounding-capable transmitter station transmits consecutive sounding PPDUs in which at least one of the PPDUs contains a +HTC frame ("non-ZLF+HTC packet"), with the ASEL Command subfield set to RXASSI ("Receive Antenna Selection Sounding Indication"). After receiving all the sounding PPDUs, e.g., sounding NDPs ("plural consecutive zero length frame (ZLF) sounding packets") at the ASEL receiver, channel state information for all channels is measured, and the channel matrix is estimated. Based on the estimated channel matrix, the ASEL receiver performs antenna selection.

> **Antenna Selection.** There are M columns and N rows in the CSI matrix **H**; each corresponds to one transmit or receive antenna. To compute the Effective CSI that would be used under a particular antenna selection, we simply pick the subset of rows and columns that correspond to the desired antennas. Note that this includes both transmit antenna selection (e.g., when $S < M$, pick the best S of the M transmit antennas to send with) and receive antenna selection (e.g., when $N > S$, turn off the least useful of the excess antennas in order to reduce power consumption).

Source: https://arxiv.org/ftp/arxiv/papers/1301/1301.6644.pdf (Page 76)

10.33 Antenna selection (ASEL)

10.33.1 Introduction

The procedures in this subclause apply only to HT and non-HT PPDUs for which the HT Control field, if present, is the HT variant HT Control field.

ASEL is a time-variant mapping of the signals at the RF chains onto a set of antenna elements when the number of RF chains is smaller than the number of antenna elements. The mapping might be chosen based on instantaneous or averaged CSI. ASEL requires the training of the full size channel associated with all antenna elements, which is obtained by transmitting or receiving sounding PPDUs over all antennas. These sounding PPDUs should be sent within a single TXOP. To avoid channel distortions, these sounding PPDUs shall be transmitted consecutively. The training information is exchanged using the HT Control field. When both transmitter and receiver have ASEL capabilities, training of transmit and receive antennas might be done one after another. ASEL supports up to eight antennas and up to four RF chains.

Source: IEEE 802.11-2016 Standard (Page 1481)

The frame exchange sequence for receive ASEL is shown in Figure 10-51, where the term *ASEL receiver* identifies the STA that is conducting receive ASEL, and the term *ASEL sounding-capable transmitter* identifies the STA sending the consecutive sounding PPDUs used for receive ASEL calculations. The frame exchange comprises the following steps:

— The ASEL receiver transmits a +HTC frame with the MAI subfield set to ASELI, the ASEL Command subfield set to Receive Antenna Selection Sounding Request (RXASSR), and the ASEL Data subfield set to the number of sounding PPDUs required.

NOTE— For example, in the case of sounding over all disjointed antenna sets, the number of total consecutive sounding PPDUs or NDPs equals the smallest integer that is greater than or equal to the number of antennas divided by the number of RF chains.

— The ASEL sounding-capable transmitter responds with the corresponding number of sounding PPDUs in its subsequent TXOP. These PPDUs are separated by SIFS. When using non-NDP sounding, each PPDU contains a +HTC frame in which the MAI subfield is set to ASELI, the ASEL Command subfield is set to Receive Antenna Selection Sounding Indication (RXASSI), and the ASEL Data subfield is set to the remaining number of sounding PPDUs to be transmitted. When using NDP sounding, the PPDU that precedes the first NDP contains a +HTC frame in which the NDP Announce field is set to 1, the MAI subfield is set to ASELI, the ASEL Command subfield is set to RXASSI, and the ASEL Data subfield is set to the remaining number of sounding PPDUs to be transmitted.

Source: IEEE 802.11-2016 Standard (Page 1484)

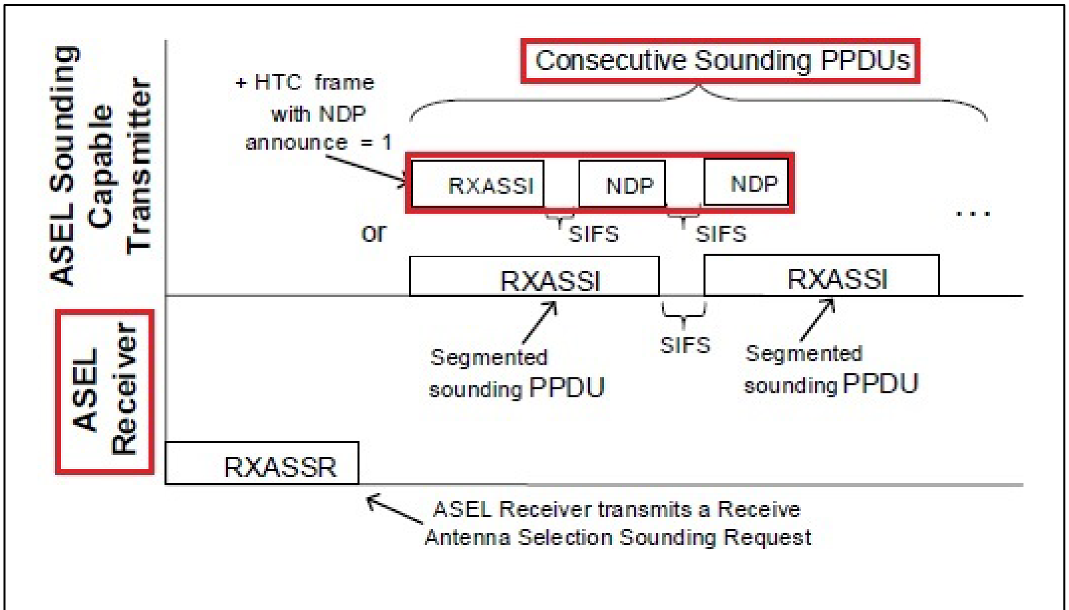

Figure 10-51—Receive ASEL

Source: IEEE 802.11-2016 Standard (Page 1484)

> The ASEL receiver uses different antenna sets to receive these sounding PPDUs, estimates CSI after receiving all these sounding PPDUs, and conducts the ASEL.

Source: IEEE 802.11-2016 Standard (Page 1484)

> When the MIMO channel measurements become available at STA B, STA B shall send one or more CSI frames that contain the CSI report (Step 2 in Figure 10-47). This CSI report shall have full precision, i.e, *Ng*=1 (no grouping) and *Nb*=3 (8 bits). In these CSI frames, the Calibration Sequence subfields in HT Control fields shall be set to the same value that is indicated in the Calibration Sounding Complete frame. These CSI frames shall have a frame type of Management Action +HTC.

Source: IEEE 802.11-2016 Standard (Page 1477)

9.6.12.6 CSI frame format

The CSI frame is an Action or an Action No Ack frame of category HT. The format of its Action field is defined in Table 9-338.

Table 9-338—CSI frame Action field format

Order	Information
1	Category
2	HT Action
3	MIMO Control (see 9.4.1.27)
4	CSI Report (see 9.4.1.28)

Source: IEEE 802.11-2016 Standard (Page 1214)

9.4.1.28 CSI Report field

The CSI Report field is used by the CSI frame (see 9.6.12.6) to carry explicit channel state information to a transmit HT beamformer, as described in 10.32.3.

The CSI Matrix subfields in the CSI Report field shown in Table 9-52 and Table 9-53 are matrices whose elements are taken from the CHAN_MAT parameter of RXVECTOR (see Table 19-1).

Table 9-52—CSI Report field (20 MHz)

Field	Size (bits)	Meaning
SNR in receive chain 1	8	Signal-to-noise ratio in the first receive chain of the STA sending the report.
...		
SNR in receive chain Nr	8	Signal-to-noise ratio in the Nr'th receive chain of the STA sending the report.
CSI Matrix for carrier –28	$3+2\times Nb\times Nc\times Nr$	CSI matrix (see Figure 9-95)
...		

Source: IEEE 802.11-2016 Standard (Page 746)

Table 19-1—TXVECTOR and RXVECTOR parameters

Parameter	Condition	Value	TXVECTOR	RXVECTOR
			See NOTE 1	
CHAN_MAT	CHAN_MAT_TYPE is COMPRESSED_SV	Contains a set of compressed beamforming feedback matrices as defined in 19.3.12.3.6 based on the channel measured during the training symbols of the received PPDU. The number of elements depends on the number of spatial streams and the number of transmit chains.	N	Y
	CHAN_MAT_TYPE is NON_COMPRESSED_SV	Contains a set of noncompressed beamforming feedback matrices as defined in 19.3.12.3.5 based on the channel measured during the training symbols of the received PPDU. The number of complex elements is $N_{ST} \times N_r \times N_c$ where N_{ST} is the total number of subcarriers, N_c is the number of columns, and N_r is the number of rows in each matrix.	N	Y
	CHAN_MAT_TYPE is CSI_MATRICES	Contains a set of CSI matrices as defined in 19.3.12.3.2 based on the channel measured during the training symbols of the received PPDU. The number of complex elements is $N_{ST} \times N_r \times N_c$ where N_{ST} is the total number of subcarriers, N_c is the number of columns, and N_r is the number of rows in each matrix.	N	Y
	Otherwise	Not present	N	N
CHAN_MAT_TYPE	FORMAT is HT_MF or HT_GF	Enumerated type: COMPRESSED_SV indicates that CHAN_MAT is a set of compressed beamforming vector matrices. NON_COMPRESSED_SV indicates that CHAN_MAT is a set of noncompressed beamforming vector matrices. CSI_MATRICES indicates that CHAN_MAT is a set of channel state matrices.	N	Y
	Otherwise	Not present	N	N

Source: IEEE 802.11-2016 Standard (Pages 2340-41)

52. PPDUs are MAC frames that include a set of fields. The High Throughput (HT) control field is in the MAC frame format and present only in certain frame types and subtypes. A frame that contains the HT Control Field is referred to as a "+HTC Frame" ("non-ZLF+HTC packet").

> A frame that contains the HT Control field is referred to as a *+HTC frame*. A Control Wrapper frame is a +HTC frame.

Source: IEEE 802.11-2016 Standard (Page 637)

9.2.3 General frame format

The MAC frame format comprises a set of fields that occur in a fixed order in all frames. Figure 9-1 depicts the general MAC frame format. The first three fields (Frame Control, Duration/ID, and Address 1) and the last field (FCS) in Figure 9-1 constitute the minimal frame format and are present in all frames, including reserved types and subtypes. The fields Address 2, Address 3, Sequence Control, Address 4, QoS Control, HT Control, and Frame Body are present only in certain frame types and subtypes. Each field is defined in 9.2.4. The format of each of the individual subtypes of each frame type is defined in 9.3. The components of management frame bodies are defined in 9.4. The formats of Action frames are defined in 9.6.

Octets: 2	2	6	0 or 6	0 or 6	0 or 2	0 or 6	0 or 2	0 or 4	variable	4
Frame Control	Duration /ID	Address 1	Address 2	Address 3	Sequence Control	Address 4	QoS Control	HT Control	Frame Body	FCS

MAC header

Figure 9-1—MAC frame format

Source: IEEE 802.11-2016 Standard (Pages 637-38)

9.2.4.6 HT Control field

9.2.4.6.1 General

The HT Control field is always present in a Control Wrapper frame and is present in QoS Data and Management frames as determined by the +HTC/Order subfield of the Frame Control field as defined in 9.2.4.1.10.

NOTE—The only control frame subtype for which HT Control field is present is the Control Wrapper frame. A Control frame that is described as +HTC (e.g., an RTS+HTC, CTS+HTC, BlockAck+HTC or BlockAckReq+HTC frame) implies the use of the Control Wrapper frame to carry that Control frame.

The format of the 4-octet HT Control field is shown in Figure 9-8.

	B0	B1 … B29	B30	B31
	VHT	HT Control Middle	AC Constraint	RDG/More PPDU
Bits	1	29	1	1

Figure 9-8—HT Control field

The HT Control field has two forms, the HT variant and the VHT variant. The two forms differ in the format of the HT Control Middle subfield, described in 9.2.4.6.2 for the HT variant and in 9.2.4.6.3 for the VHT variant and in the value of the VHT subfield.

The VHT subfield of the HT Control field indicates whether the HT Control Middle subfield is the VHT Variant or the HT Variant. The VHT subfield is set to 1 to indicate that the HT Control Middle subfield is the VHT Variant and is set to 0 to indicate that the HT Control Middle subfield is the HT Variant.

Source: IEEE 802.11-2016 Standard (Page 654)

53. The +HTC frame includes an LAC subfield, which allows the station to perform antenna selection. The LAC frame format includes the MAI subfield (MCS request or ASEL Indication). When MAI is set to "14," the MFB/ASELC subfield (MCS Feedback/Antenna Selection Command) is used as the Antenna Selection Command. Also, the frame format of ASELC subfield contains ASEL Command and ASEL Data subfields.

54. As an example, when ASEL Command is "2," it is interpreted as RXASSI signal ("including a receive antenna selection sounding indication (RXASSI) signal"), and the ASEL Data field contains the number of remaining sounding PPDUs to be received ("a number N of the plural consecutive ZLF sounding packets"). NDP sounding can be indicated by the HT NDP announcement subfield (when set to 1) in the HT Control field.

null data packet (NDP): A physical layer (PHY) protocol data unit (PPDU) that carries no Data field.

Source: IEEE 802.11-2016 Standard (Page 157)

9.2.4.6.2 HT variant

The format of the HT Control Middle subfield of the HT variant HT Control field is shown in Figure 9-9.

	B1 B15	B16 B17	B18 B19	B20 B21	B22 B23	B24	B25 B28	B29
	Link Adaptation Control	Calibration Position	Calibration Sequence	Reserved	CSI/ Steering	HT NDP Announce ment	Reserved	DEI
Bits:	15	2	2	2	2	1	4	1

Figure 9-9—HT Control Middle subfield of the HT variant HT Control field

The format of the Link Adaptation Control subfield of the HT variant HT Control field is defined in Figure 9-10.

	B1	B2 B5	B6 B8	B9 B15
	TRQ	MAI	MFSI	MFB/ASELC
Bits:	1	4	3	7

Figure 9-10—Link Adaptation Control subfield

Source: IEEE 802.11-2016 Standard (Page 655)

Table 9-12—Subfields of Link Adaptation Control subfield

Subfield	Meaning	Definition
TRQ	Training request	Set to 1 to request the responder to transmit a sounding PPDU. Set to 0 to indicate that the responder is not requested to transmit a sounding PPDU. See 10.32.2 and 10.34.2.
MAI	MCS request (MRQ) or ASEL indication	Set to 14 (indicating ASELI) to indicate that the MFB/ASELC subfield is interpreted as ASELC. Otherwise, the MAI subfield is interpreted as shown in Figure 9-11, and the MFB/ASELC subfield is interpreted as MCS feedback (MFB).
MFSI	MCS feedback sequence identifier	Set to the received value of MSI contained in the frame to which the MFB information refers. Set to 7 for unsolicited MFB.
MFB/ASELC	MCS feedback and antenna selection command/data	When the MAI subfield is equal to the value ASELI, this subfield is interpreted as defined in Figure 9-12 and Table 9-14. Otherwise, this subfield contains recommended MFB. A value of 127 indicates that no feedback is present.

The structure of the MAI subfield of the Link Adaptation Control subfield is defined in Figure 9-11. The subfields of the MAI subfield are defined in Table 9-13.

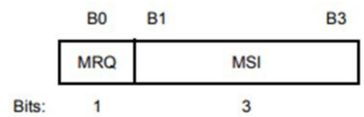

Figure 9-11—MAI subfield

Source: IEEE 802.11-2016 Standard (Page 656)

The ASELC subfield of the Link Adaptation Control subfield contains the ASEL Command and ASEL Data subfields, as shown in Figure 9-12. The encoding of these subfields is shown in Table 9-14.

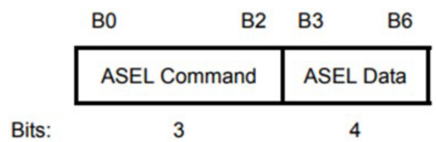

Figure 9-12—ASELC subfield

Source: IEEE 802.11-2016 Standard (Page 657)

NOTE—If the HT variant HT Control field is carried in a sounding PPDU, then the value of the ASEL Data field contains the remaining number of sounding frames following the current one. If null data packet (NDP) sounding frame is used, then the value in the ASEL Data field contains the number of NDPs following a non-NDP+HTC. The HT NDP Announcement subfield in the HT Control field is set to 1 to indicate NDP sounding.

Source: IEEE 802.11-2016 Standard (Page 657)

Table 9-14—ASEL Command and ASEL Data subfields

ASEL Command	Interpretation of ASEL Command	ASEL Data
0	Transmit Antenna Selection Sounding Indication (TXASSI)	Number of remaining sounding PPDUs to be transmitted 0 to 15 See NOTE
1	Transmit Antenna Selection Sounding Request (TXASSR) or Transmit ASEL Sounding Resumption	0 when the command is Transmit ASEL Sounding Request A number in the range 1 to 15, the number being the number of the first sounding PPDU to be transmitted when the command is Transmit ASEL Sounding Resumption, where 0 corresponds to the first sounding PPDU in the original ASEL training sequence
2	Receive Antenna Selection Sounding Indication (RXASSI)	Number of remaining sounding PPDUs to be received 0 to 15 See NOTE
3	Receive Antenna Selection Sounding Request (RXASSR)	Number of sounding PPDUs required 0 to 15
4	Sounding Label	Sequence number of the sounding PPDU corresponding to a channel state information (CSI) frame in ASEL feedback 0 to 15
5	No Feedback Due to ASEL Training Failure or Stale Feedback	A number in the range 0 to 15, the number being the number of the first sounding PPDU that was not received properly, where 0 corresponds to the first sounding PPDU in the ASEL training sequence, or 0 if no sounding PPDUs were received properly, or 0 if this is a request for a full retraining sequence
6	Transmit Antenna Selection Sounding Indication requesting feedback of explicit CSI (TXASSI-CSI)	Number of remaining sounding PPDUs to be transmitted 0 to 15 See NOTE
7	Reserved	Reserved

Source: IEEE 802.11-2016 Standard (Page 657)

55. Altice directly infringes the '686 Patent when, for example, it and/or its agents use the accused products, including during testing of the accused products. Altice also directly infringes the '686 Patent when the accused products are used after purchase by a customer or end user. For example, the accused products are built with hardware and/or software components that control the operation of the accused products. These components cause the accused products to perform the steps of the claimed invention after, for example, receiving sounding packets. Altice also directly infringes the '686 Patent by exercising direction or control over the use of the accused products by others, including its affiliates, its subsidiaries, its business

partners (including certification and testing organizations), and/or its customers and end-users. Altice contracts with, advises, and/or encourages such persons to engage in conduct satisfying one or more elements of the asserted claims, deriving a financial or other benefit (e.g., improved wireless communications) from doing so. Altice conditions these benefits on, for example, such persons performing certain activities involving the accused products during specified conditions that cause the accused products to perform the steps of the claimed method (e.g., after receiving sounding packets).

56. Altice has had knowledge of the ’686 Patent at least as of the date when it was notified of the filing of this action.

57. Freedom Patents has been damaged as a result of the infringing conduct by Altice alleged above. Thus, Altice is liable to Freedom Patents in an amount that adequately compensates it for such infringements, which, by law, cannot be less than a reasonable royalty, together with interest and costs as fixed by this Court under 35 U.S.C. § 284.

58. Freedom Patents has neither made nor sold unmarked articles that practice the ’686 Patent, and is entitled to collect pre-filing damages for the full period allowed by law for infringement of the ’686 Patent.

COUNT II

DIRECT INFRINGEMENT OF U.S. PATENT NO. 8,374,096

On February 12, 2013, United States Patent No. 8,374,096 (“the ’096 Patent”) was duly and legally issued by the United States Patent and Trademark Office for an invention entitled “Method for Selecting Antennas and Beams in MIMO Wireless LANs.”

59. Freedom Patents is the owner of the ’096 Patent, with all substantive rights in and to that patent, including the sole and exclusive right to prosecute this action and enforce the ’096 Patent against infringers, and to collect damages for all relevant times.

60. Altice used products and/or systems including, for example, its Altice Fiber Gateway Wi-Fi 6 (with 4x4 MIMO) family of products and other products[7] that implement MIMO Wi-Fi capabilities ("accused products"):

Source: https://www.alticelabs.com/wp-content/uploads/2022/10/FL_GPON_FGW-Wi-Fi6_EN.pdf

Model	Ports									
	FXS	Ethernet	RF	Wi-Fi 6 Dual Concurrent		USB	PON			
		1GE	Band: (47 … 870MHz)	Antennas	Power* (dBm EIRP)	Type C	Type	Class	Bit rate (Gbps)	Wavelength (nm)
GR141DG	1x	4x	1x	2.4GHz: 4x4 Mimo 5GHz: 4x4 MIMO	2.4Ghz: up to +20 (ETSI) or up to +34 (FCC) 5GHz: up to +30 (ETSI) or up to +34 (FCC)	1x	GPON	B+, C+,D	DS: 2.488 US: 1.244	DS:1480-1500 US:1260-1360
GR140DG	1x	4x	-	2.4GHz: 4x4 Mimo 5GHz :4x4 MIMO	2.4Ghz: up to +20 (ETSI) or up to +34 (FCC) 5GHz: up to +30 (ETSI) or up to +34 (FCC)	1x				

Source: https://www.alticelabs.com/wp-content/uploads/2022/10/FL_GPON_FGW-Wi-Fi6_EN.pdf (page 2)

[7] *See, e.g.*, Fiber Gateway 4×4 (GR240BG), Fiber Gateway Wi-Fi 5, Smart Mesh Wi-Fi AP extenders, Optimum Amplify, Altice One router, Altice One Mini router, Fast 3965CV, F@st 5260CV, etc.

2.4.1.5.1 Interfaces and features

- Concurrent mode 2.4GHz + 5GHz via 4 dual-band internal antennas
- 2.4GHz: Compatible with IEEE 802.11b 1x1 SISO and 802.11g/n/ax 4x4 MIMO
- 5GHz: Compatible with IEEE 802.11 a/n/ac/ax 4x4 MIMO
- Channel bandwidth: 20, 40, 80 MHz
- Multi User MIMO for best performance per user

2.4.1.5.3 Antennas

- 4x4 MIMO antennas
- Internal antennas with 4~5dBi antenna gain

Source: https://fccid.io/2ACJF-FGW-GR140DG/User-Manual/User-Manual-5082170.pdf (page 24)

61. By doing so, Altice has directly infringed (literally and/or under the doctrine of equivalents) at least Claim 1 of the '096 Patent. Altice's infringement in this regard is ongoing.

62. The Altice Fiber Gateway Wi-Fi 6 is an exemplary accused product.

63. Altice has infringed the '096 Patent by using the accused products and thereby practicing a method for selecting antennas in a multiple-input, multiple-output wireless local area network including a plurality of stations, each station includes a set of antennas.

64. For example, the Altice Fiber Gateway Wi-Fi 6 communicates with other stations using the IEEE 802.11 protocol and includes a set of antennas that are used for both transmitting and receiving data to and from the other stations over a WLAN. The transmission and reception of data using multiple antennas simultaneously is known as MIMO ("multiple-input, multiple-output"). The stations communicating using MIMO implement antenna selection by initially transmitting or receiving sounding packets with each other to estimate the channel characteristics between them. The sounding packets correspond to a set of antennas that are available from a larger number of antennas.

Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications

1. Overview

1.1 Scope

The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area.

Source: IEEE 802.11-2016 Standard (Page 122)

An HT STA has PHY features consisting of the modulation and coding scheme (MCS) set described in 19.3.5 and physical layer (PHY) protocol data unit (PPDU) formats described in 19.1.4. Some PHY features that distinguish an HT STA from a non-HT STA are referred to as *multiple input, multiple output (MIMO) operation*; spatial multiplexing (SM); spatial mapping (including transmit beamforming); space-time block coding (STBC); low-density parity check (LDPC) encoding; and antenna selection (ASEL). The allowed PPDU formats are non-HT format, HT-mixed format, and HT-greenfield format (see 19.1.4). The PPDUs can be transmitted with 20 MHz bandwidth and might be transmitted with 40 MHz bandwidth.

Source: IEEE 802.11-2016 Standard (Page 197)

multiple input, multiple output (MIMO): A physical layer (PHY) configuration in which both transmitter and receiver use multiple antennas.

Source: IEEE 802.11-2016 Standard (Page 136)

multi-user multiple input, multiple output (MU-MIMO): A technique by which multiple stations (STAs), each with one or more antennas, either simultaneously transmit to a single STA or simultaneously receive from a single STA independent data streams over the same radio frequencies.

NOTE—IEEE Std 802.11 supports only downlink (DL) MU-MIMO. *See* **downlink multi-user multiple input, multiple output (DL-MU-MIMO)** (in 3.2).

Source: IEEE 802.11-2016 Standard (Page 136)

10.31 Link adaptation

10.31.1 Introduction

To fully exploit MIMO channel variations and transmit beamforming on a MIMO link, a STA can request that another STA provide MIMO channel sounding and MFB.

Source: IEEE 802.11-2016 Standard (Page 1463)

10.30 Sounding PPDUs

The behavior described in this subclause is specific to the use of the HT variant HT Control field.

A sounding PPDU is a PPDU for which the SOUNDING parameter of the corresponding RXVECTOR or TXVECTOR has the value SOUNDING. Sounding PPDUs are transmitted by STAs to enable the receiving STAs to estimate the channel between the transmitting STA and the receiving STA.

A STA transmits sounding PPDUs when it operates in the following roles:

- MFB requester (see 10.31.2)
- HT beamformee responding to a training request, calibration initiator, or responder involved in implicit transmit beamforming (see 10.32.2.2, 10.32.2.3, and 10.32.2.4)
- HT beamformer involved in explicit transmit beamforming (see 10.32.3)
- ASEL transmitter and ASEL sounding-capable transmitter involved in ASEL (see 10.33.2)

A STA receives sounding PPDUs when it operates in the following roles:

- MFB responder (see 10.31.2)
- HT beamformer sending a training request, calibration initiator, or responder involved in implicit transmit beamforming (see 10.32.2.2, 10.32.2.3, and 10.32.2.4)
- HT beamformee involved in explicit transmit beamforming (see 10.32.3)
- Transmit ASEL responder and ASEL receiver involved in ASEL (see 10.33.2)

Source: IEEE 802.11-2016 Standard (Pages 1462-63)

10.33 Antenna selection (ASEL)

10.33.1 Introduction

The procedures in this subclause apply only to HT and non-HT PPDUs for which the HT Control field, if present, is the HT variant HT Control field.

ASEL is a time-variant mapping of the signals at the RF chains onto a set of antenna elements when the number of RF chains is smaller than the number of antenna elements. The mapping might be chosen based on instantaneous or averaged CSI. ASEL requires the training of the full size channel associated with all antenna elements, which is obtained by transmitting or receiving sounding PPDUs over all antennas. These sounding PPDUs should be sent within a single TXOP. To avoid channel distortions, these sounding PPDUs shall be transmitted consecutively. The training information is exchanged using the HT Control field. When both transmitter and receiver have ASEL capabilities, training of transmit and receive antennas might be done one after another. ASEL supports up to eight antennas and up to four RF chains.

Source: IEEE 802.11-2016 Standard (Page 1481)

65. The method practiced using the accused products includes the step of receiving multiple transmitted sounding packets in a station, each sounding packet corresponding to a different subset of the set of antennas.

66. For example, during the antenna selection process, the stations receive multiple consecutive sounding PPDUs ("receiving multiple transmitted sounding packets"). Each sounding PPDU corresponds to a different set of antennas from the available antennas ("a different subset of the set of antennas"). The first PPDU frame received is a +HTC frame followed by consecutive NDP (Null Data Packet) frames.

10.30 Sounding PPDUs

The behavior described in this subclause is specific to the use of the HT variant HT Control field.

A sounding PPDU is a PPDU for which the SOUNDING parameter of the corresponding RXVECTOR or TXVECTOR has the value SOUNDING. Sounding PPDUs are transmitted by STAs to enable the receiving STAs to estimate the channel between the transmitting STA and the receiving STA.

A STA transmits sounding PPDUs when it operates in the following roles:

— MFB requester (see 10.31.2)

— HT beamformee responding to a training request, calibration initiator, or responder involved in implicit transmit beamforming (see 10.32.2.2, 10.32.2.3, and 10.32.2.4)

— HT beamformer involved in explicit transmit beamforming (see 10.32.3)

— ASEL transmitter and ASEL sounding-capable transmitter involved in ASEL (see 10.33.2)

A STA receives sounding PPDUs when it operates in the following roles:

— MFB responder (see 10.31.2)

— HT beamformer sending a training request, calibration initiator, or responder involved in implicit transmit beamforming (see 10.32.2.2, 10.32.2.3, and 10.32.2.4)

— HT beamformee involved in explicit transmit beamforming (see 10.32.3)

— Transmit ASEL responder and ASEL receiver involved in ASEL (see 10.33.2)

Source: IEEE 802.11-2016 Standard (Pages 1462-63)

10.33 Antenna selection (ASEL)

10.33.1 Introduction

The procedures in this subclause apply only to HT and non-HT PPDUs for which the HT Control field, if present, is the HT variant HT Control field.

ASEL is a time-variant mapping of the signals at the RF chains onto a set of antenna elements when the number of RF chains is smaller than the number of antenna elements. The mapping might be chosen based on instantaneous or averaged CSI. ASEL requires the training of the full size channel associated with all antenna elements, which is obtained by transmitting or receiving sounding PPDUs over all antennas. These sounding PPDUs should be sent within a single TXOP. To avoid channel distortions, these sounding PPDUs shall be transmitted consecutively. The training information is exchanged using the HT Control field. When both transmitter and receiver have ASEL capabilities, training of transmit and receive antennas might be done one after another. ASEL supports up to eight antennas and up to four RF chains.

Source: IEEE 802.11-2016 Standard (Page 1481)

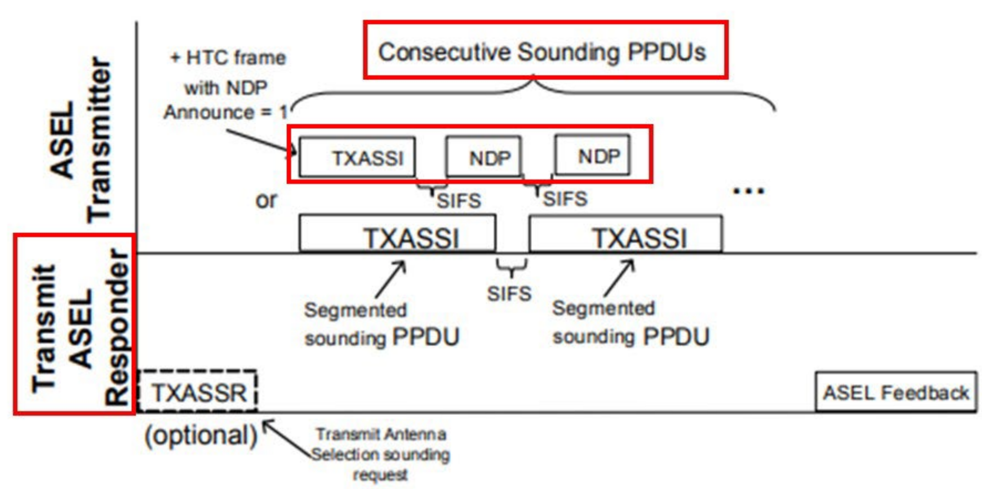

Figure 10-50—Transmit ASEL

Source: IEEE 802.11-2016 Standard (Page 1483)

physical layer (PHY) frame: The unit of data exchanged between PHY entities. *Syn:* **physical layer (PHY) protocol data unit (PPDU)**.

NOTE—In contexts in which the PHY is clearly the subject, "frame" is an implicit reference to a PHY frame.

physical layer (PHY) protocol data unit (PPDU): The unit of data exchanged between two peer PHY entities to provide the PHY data service.

Source: IEEE 802.11-2016 Standard (Page 138)

67. The method practiced using the accused products includes the step of estimating, in the station, a channel matrix for each subset of antennas.

68. For example, the transmit ASEL responder station receives the sounding PPDUs. The transmit ASEL responder station then estimates the channel state information based on the measurements from the received sounding PPDUs, each of which corresponds to a different set of antennas ("for each subset of antennas"). After the estimate is complete, a Channel State Information report (CSI report) is generated and sent to the ASEL transmitter station. The CSI report is part of the CSI frame format and is included as a CSI report field, which includes a Channel Matrix subfield.

10.30 Sounding PPDUs

The behavior described in this subclause is specific to the use of the HT variant HT Control field.

A sounding PPDU is a PPDU for which the SOUNDING parameter of the corresponding RXVECTOR or TXVECTOR has the value SOUNDING. Sounding PPDUs are transmitted by STAs to enable the receiving STAs to estimate the channel between the transmitting STA and the receiving STA.

A STA transmits sounding PPDUs when it operates in the following roles:

— MFB requester (see 10.31.2)
— HT beamformee responding to a training request, calibration initiator, or responder involved in implicit transmit beamforming (see 10.32.2.2, 10.32.2.3, and 10.32.2.4)
— HT beamformer involved in explicit transmit beamforming (see 10.32.3)
— ASEL transmitter and ASEL sounding-capable transmitter involved in ASEL (see 10.33.2)

A STA receives sounding PPDUs when it operates in the following roles:

— MFB responder (see 10.31.2)
— HT beamformer sending a training request, calibration initiator, or responder involved in implicit transmit beamforming (see 10.32.2.2, 10.32.2.3, and 10.32.2.4)
— HT beamformee involved in explicit transmit beamforming (see 10.32.3)
— Transmit ASEL responder and ASEL receiver involved in ASEL (see 10.33.2)

Source: IEEE 802.11-2016 Standard (Pages 1462-63)

19.3.13.3 Sounding PPDU for calibration

In the case of a bidirectional calibration exchange, two STAs exchange sounding PPDUs, the exchange of which enables the receiving STA to compute an estimate of the MIMO channel matrix H_k for each subcarrier k. In general, in an exchange of calibration messages, the number of spatial streams is less than the number of transmit antennas. In such cases, HT-ELTFs are used. In the case of sounding PPDUs for calibration, the antenna mapping matrix shall be as shown in Equation (19-86).

$$Q_k = C_{CSD}(k)P_{CAL} \quad (19\text{-}86)$$

Source: IEEE 802.11-2016 Standard (Page 2401)

c) The transmit ASEL responder estimates the subchannel corresponding to each sounding PPDU.

d) If the ASEL Command subfield in the sounding frames is equal to TXASSI-CSI, after receiving all of the sounding PPDUs, the transmit ASEL responder shall respond with the full size CSI in a subsequent TXOP. If the ASEL Command subfield in the sounding frames is equal to TXASSI, after receiving all of the sounding PPDUs, the transmit ASEL responder may either respond with the full size CSI in a subsequent TXOP, or conduct ASEL computation and provide the selected antenna indices in a subsequent TXOP.

   1) CSI is transported using the MIMO CSI Matrices frame defined in 9.6.12.6 contained within either an Action No Ack or Action frame. Multiple CSI frames may be required to provide the complete feedback, in which case the value of the Sounding Timestamp field within each of

Source: IEEE 802.11-2016 Standard (Page 1482)

When the MIMO channel measurements become available at STA B, STA B shall send one or more CSI frames that contain the CSI report (Step 2 in Figure 10-47). This CSI report shall have full precision, i.e, *Ng*=1 (no grouping) and *Nb*=3 (8 bits). In these CSI frames, the Calibration Sequence subfields in HT Control fields shall be set to the same value that is indicated in the Calibration Sounding Complete frame. These CSI frames shall have a frame type of Management Action +HTC.

Source: IEEE 802.11-2016 Standard (Page 1477)

9.6.12.6 CSI frame format

The CSI frame is an Action or an Action No Ack frame of category HT. The format of its Action field is defined in Table 9-338.

Table 9-338—CSI frame Action field format

Order	Information
1	Category
2	HT Action
3	MIMO Control (see 9.4.1.27)
4	CSI Report (see 9.4.1.28)

Source: IEEE 802.11-2016 Standard (Page 1214)

9.4.1.28 CSI Report field

The CSI Report field is used by the CSI frame (see 9.6.12.6) to carry explicit channel state information to a transmit HT beamformer, as described in 10.32.3.

The CSI Matrix subfields in the CSI Report field shown in Table 9-52 and Table 9-53 are matrices whose elements are taken from the CHAN_MAT parameter of RXVECTOR (see Table 19-1).

Table 9-52—CSI Report field (20 MHz)

Field	Size (bits)	Meaning
SNR in receive chain 1	8	Signal-to-noise ratio in the first receive chain of the STA sending the report.
...		
SNR in receive chain *Nr*	8	Signal-to-noise ratio in the *Nr*'th receive chain of the STA sending the report.
CSI Matrix for carrier –28	$3+2\times Nb\times Nc\times Nr$	CSI matrix (see Figure 9-95)
...		

Source: IEEE 802.11-2016 Standard (Page 746)

Table 19-1—TXVECTOR and RXVECTOR parameters

Parameter	Condition	Value	TXVECTOR	RXVECTOR
			See NOTE 1	
CHAN_MAT	CHAN_MAT_TYPE is COMPRESSED_SV	Contains a set of compressed beamforming feedback matrices as defined in 19.3.12.3.6 based on the channel measured during the training symbols of the received PPDU. The number of elements depends on the number of spatial streams and the number of transmit chains.	N	Y
	CHAN_MAT_TYPE is NON_COMPRESSED_SV	Contains a set of noncompressed beamforming feedback matrices as defined in 19.3.12.3.5 based on the channel measured during the training symbols of the received PPDU. The number of complex elements is $N_{ST} \times N_r \times N_c$ where N_{ST} is the total number of subcarriers, N_c is the number of columns, and N_r is the number of rows in each matrix.	N	Y
	CHAN_MAT_TYPE is CSI_MATRICES	Contains a set of CSI matrices as defined in 19.3.12.3.2 based on the channel measured during the training symbols of the received PPDU. The number of complex elements is $N_{ST} \times N_r \times N_c$ where N_{ST} is the total number of subcarriers, N_c is the number of columns, and N_r is the number of rows in each matrix.	N	Y
	Otherwise	Not present	N	N
CHAN_MAT_TYPE	FORMAT is HT_MF or HT_GF	Enumerated type: COMPRESSED_SV indicates that CHAN_MAT is a set of compressed beamforming vector matrices. NON_COMPRESSED_SV indicates that CHAN_MAT is a set of noncompressed beamforming vector matrices. CSI_MATRICES indicates that CHAN_MAT is a set of channel state matrices.	N	Y
	Otherwise	Not present	N	N

Source: IEEE 802.11-2016 Standard (Pages 2340-41)

69. The method practiced using the accused products includes the step of sending, by the station, a frame including a high throughput (HT) control field to initiate a selecting of antennas after estimating the channel matrix for each subset of antennas, such that a subset of the antennas is selected according to the channel matrices.

70. For example, the transmit ASEL responder station, after receiving the consecutive sounding packets, estimates the Channel State Information along with the Channel Matrix for each channel. Based on the estimated channel matrices, the set of antennas to be used for MIMO communication is selected ("a subset of the antennas is selected according to the channel matrices").

71. After estimating the channel matrices, the transmit ASEL responder station sends ("sending, by the station") the HT category CSI Frame or the HT category Antenna Selection Indices Feedback frame ("a frame including a high throughput (HT) control field") back to the ASEL transmitter.

72. The CSI Frame includes the CSI Report, which can be utilized by the ASEL transmitter to compute and select the antenna. The Antenna Selection Indices Feedback frame includes the Antenna Indices feedback. Each bit of the Antenna Indices feedback corresponds to an antenna and indicates its selection by the ASEL responder.

10.33 Antenna selection (ASEL)

10.33.1 Introduction

The procedures in this subclause apply only to HT and non-HT PPDUs for which the HT Control field, if present, is the HT variant HT Control field.

ASEL is a time-variant mapping of the signals at the RF chains onto a set of antenna elements when the number of RF chains is smaller than the number of antenna elements. The mapping might be chosen based on instantaneous or averaged CSI. ASEL requires the training of the full size channel associated with all antenna elements, which is obtained by transmitting or receiving sounding PPDUs over all antennas. These sounding PPDUs should be sent within a single TXOP. To avoid channel distortions, these sounding PPDUs shall be transmitted consecutively. The training information is exchanged using the HT Control field. When both transmitter and receiver have ASEL capabilities, training of transmit and receive antennas might be done one after another. ASEL supports up to eight antennas and up to four RF chains.

Source: IEEE 802.11-2016 Standard (Page 1481)

The frame exchange sequence for transmit ASEL is shown in Figure 10-50, where the term *ASEL transmitter* identifies the STA that is conducting transmit ASEL, and the term *transmit ASEL responder* identifies the STA that provides ASEL feedback. The frame exchange comprises the following steps:

Source: IEEE 802.11-2016 Standard (Page 1482)

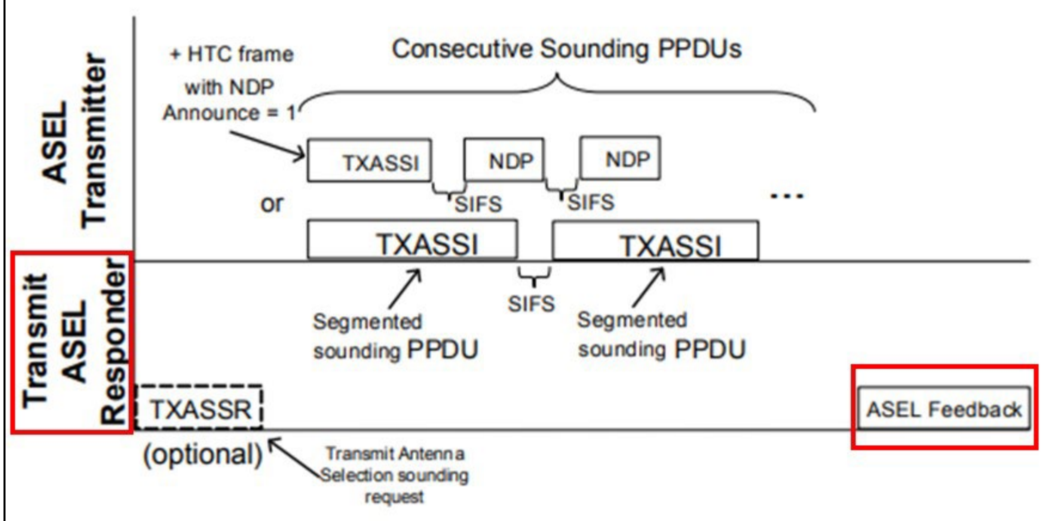

Figure 10-50—Transmit ASEL

Source: IEEE 802.11-2016 Standard (Page 1483)

73. ASEL feedback is provided either by sending a CSI frame that contains the CSI report or an Antenna Selection Indices Feedback frame that contains the selected antenna indices by the ASEL responder.

c) The transmit ASEL responder estimates the subchannel corresponding to each sounding PPDU.

d) If the ASEL Command subfield in the sounding frames is equal to TXASSI-CSI, after receiving all of the sounding PPDUs, the transmit ASEL responder shall respond with the full size CSI in a subsequent TXOP. If the ASEL Command subfield in the sounding frames is equal to TXASSI, after receiving all of the sounding PPDUs, the transmit ASEL responder may either respond with the full size CSI in a subsequent TXOP, or conduct ASEL computation and provide the selected antenna indices in a subsequent TXOP.

1) CSI is transported using the MIMO CSI Matrices frame defined in 9.6.12.6 contained within either an Action No Ack or Action frame. Multiple CSI frames may be required to provide the complete feedback, in which case the value of the Sounding Timestamp field within each of

Source: IEEE 802.11-2016 Standard (Page 1482)

1) CSI is transported using the MIMO CSI Matrices frame defined in 9.6.12.6 contained within either an Action No Ack or Action frame. Multiple CSI frames may be required to provide the complete feedback, in which case the value of the Sounding Timestamp field within each of these CSI frames shall correspond to the arrival time of the sounding frame that was used to generate the feedback information contained in the frame.

2) Antenna indices feedback is carried in the Antenna Selection Indices Feedback frame, defined in 9.6.12.9. One octet of the Antenna Selection Indices field is used to carry the selected antenna indices feedback.

Source: IEEE 802.11-2016 Standard (Pages 1482-83)

9.6.12.6 CSI frame format

The CSI frame is an Action or an Action No Ack frame of category HT. The format of its Action field is defined in Table 9-338.

Table 9-338—CSI frame Action field format

Order	Information
1	Category
2	HT Action
3	MIMO Control (see 9.4.1.27)
4	CSI Report (see 9.4.1.28)

Source: IEEE 802.11-2016 Standard (Page 1214)

9.6.12.6 CSI frame format

The CSI frame is an Action or an Action No Ack frame of category HT. The format of its Action field is defined in Table 9-338.

Table 9-338—CSI frame Action field format

Order	Information
1	Category
2	HT Action
3	MIMO Control (see 9.4.1.27)
4	CSI Report (see 9.4.1.28)

Source: IEEE 802.11-2016 Standard (Page 1214)

9.6.12.9 Antenna Selection Indices Feedback frame format

The Antenna Selection Indices Feedback frame is an Action or Action No Ack frame of category HT. The format of its Action field is defined in Table 9-341.

Table 9-341—Antenna Selection Indices Feedback frame Action field format

Order	Information
1	Category
2	HT Action
3	Antenna Selection Indices (see 9.4.1.31)

The Category field is defined in 9.4.1.11.

The HT Action field is defined in 9.6.12.1.

Source: IEEE 802.11-2016 Standard (Page 1216)

9.6.12.1 HT Action field

Several Action frame formats are defined to support HT features. An HT Action field, in the octet immediately after the Category field, differentiates the HT Action frame formats. The HT Action field values associated with each frame format within the HT category are defined in Table 9-333. The frame formats are defined in 9.6.12.2 to 9.6.12.9.

Table 9-333—HT Action field values

HT Action field value	Meaning	Time priority
0	Notify Channel Width	No
1	SM Power Save	No
2	PSMP	Yes
3	Set PCO Phase	Yes
4	CSI	Yes
5	Noncompressed Beamforming	Yes
6	Compressed Beamforming	Yes
7	ASEL Indices Feedback	Yes
8–255	Reserved	—

Source: IEEE 802.11-2016 Standard (Page 1212)

9.4.1.28 CSI Report field

The CSI Report field is used by the CSI frame (see 9.6.12.6) to carry explicit channel state information to a transmit HT beamformer, as described in 10.32.3.

The CSI Matrix subfields in the CSI Report field shown in Table 9-52 and Table 9-53 are matrices whose elements are taken from the CHAN_MAT parameter of RXVECTOR (see Table 19-1).

Source: IEEE 802.11-2016 Standard (Page 1214)

Table 19-1—TXVECTOR and RXVECTOR parameters

Parameter	Condition	Value	TXVECTOR	RXVECTOR
			See NOTE 1	
CHAN_MAT	CHAN_MAT_TYPE is COMPRESSED_SV	Contains a set of compressed beamforming feedback matrices as defined in 19.3.12.3.6 based on the channel measured during the training symbols of the received PPDU. The number of elements depends on the number of spatial streams and the number of transmit chains.	N	Y
	CHAN_MAT_TYPE is NON_COMPRESSED_SV	Contains a set of noncompressed beamforming feedback matrices as defined in 19.3.12.3.5 based on the channel measured during the training symbols of the received PPDU. The number of complex elements is $N_{ST} \times N_r \times N_c$ where N_{ST} is the total number of subcarriers, N_c is the number of columns, and N_r is the number of rows in each matrix.	N	Y
	CHAN_MAT_TYPE is CSI_MATRICES	Contains a set of CSI matrices as defined in 19.3.12.3.2 based on the channel measured during the training symbols of the received PPDU. The number of complex elements is $N_{ST} \times N_r \times N_c$ where N_{ST} is the total number of subcarriers, N_c is the number of columns, and N_r is the number of rows in each matrix.	N	Y
	Otherwise	Not present	N	N
CHAN_MAT_TYPE	FORMAT is HT_MF or HT_GF	Enumerated type: COMPRESSED_SV indicates that CHAN_MAT is a set of compressed beamforming vector matrices. NON_COMPRESSED_SV indicates that CHAN_MAT is a set of noncompressed beamforming vector matrices. CSI_MATRICES indicates that CHAN_MAT is a set of channel state matrices.	N	Y
	Otherwise	Not present	N	N

Source: IEEE 802.11-2016 Standard (Pages 2340-41)

9.4.1.31 Antenna Selection Indices field

The Antenna Selection Indices field is used within the Antenna Selection Indices Feedback frame to carry ASEL feedback, as described in 10.33.

The Antenna Selection Indices field is 1 octet in length and illustrated in Figure 9-99.

	Antenna Selection Indices
Octets:	1

Figure 9-99—Antenna Selection Indices fixed field

Bits 0 to 7 in the Antenna Selection Indices field correspond to antennas with indices 0 to 7, respectively. A value of 1 in a bit indicates the corresponding antenna is selected, and the value of 0 indicates the corresponding antenna is not selected.

Source: IEEE 802.11-2016 Standard (Page 753)

Antenna Selection. There are M columns and N rows in the CSI matrix **H**; each corresponds to one transmit or receive antenna. To compute the Effective CSI that would be used under a particular antenna selection, we simply pick the subset of rows and columns that correspond to the desired antennas. Note that this includes both transmit antenna selection (e.g., when $S < M$, pick the best S of the M transmit antennas to send with) and receive antenna selection (e.g., when $N > S$, turn off the least useful of the excess antennas in order to reduce power consumption).

Source: https://arxiv.org/ftp/arxiv/papers/1301/1301.6644.pdf (Page 76)

74. In the method practiced using the accused products, the HT control field includes a MCS selection feedback (MFB) field, and if an ASI field is set to "1" or if an MRS field is set to "111", then the MFB field is used for antenna selection, beam selection, or as a transmitter beam forming control (ASBFC) field, in which ASBFC field includes a command subfield and a data subfield, and in which the data subfield indicates a number of the multiple sounding packets.

75. For example, the ASEL feedback is a +HTC frame that includes an LAC subfield, which allows the station to perform antenna selection. The LAC frame format includes the MAI (MCS request or ASEL Indication) subfield. When MAI is set to "14," the MFB/ASELC (MCS

Feedback/Antenna Selection Command) subfield ("MFB field") is used as the Antenna Selection Command. Also, the frame format of ASELC subfield ("ASBFC field") contains ASEL Command and ASEL Data subfields ("includes a command subfield and a data subfield"). The ASEL Data field ("data subfield") contains information about the number of sounding PPDUs ("indicates a number of the multiple sounding packets").

10.33 Antenna selection (ASEL)

10.33.1 Introduction

The procedures in this subclause apply only to HT and non-HT PPDUs for which the HT Control field, if present, is the HT variant HT Control field.

ASEL is a time-variant mapping of the signals at the RF chains onto a set of antenna elements when the number of RF chains is smaller than the number of antenna elements. The mapping might be chosen based on instantaneous or averaged CSI. ASEL requires the training of the full size channel associated with all antenna elements, which is obtained by transmitting or receiving sounding PPDUs over all antennas. These sounding PPDUs should be sent within a single TXOP. To avoid channel distortions, these sounding PPDUs shall be transmitted consecutively. The training information is exchanged using the HT Control field. When both transmitter and receiver have ASEL capabilities, training of transmit and receive antennas might be done one after another. ASEL supports up to eight antennas and up to four RF chains.

Source: IEEE 802.11-2016 Standard (Page 1481)

A frame that contains the HT Control field is referred to as a *+HTC frame*. A Control Wrapper frame is a +HTC frame.

Source: IEEE 802.11-2016 Standard (Page 637)

9.2.3 General frame format

The MAC frame format comprises a set of fields that occur in a fixed order in all frames. Figure 9-1 depicts the general MAC frame format. The first three fields (Frame Control, Duration/ID, and Address 1) and the last field (FCS) in Figure 9-1 constitute the minimal frame format and are present in all frames, including reserved types and subtypes. The fields Address 2, Address 3, Sequence Control, Address 4, QoS Control, HT Control, and Frame Body are present only in certain frame types and subtypes. Each field is defined in 9.2.4. The format of each of the individual subtypes of each frame type is defined in 9.3. The components of management frame bodies are defined in 9.4. The formats of Action frames are defined in 9.6.

Octets: 2	2	6	0 or 6	0 or 6	0 or 2	0 or 6	0 or 2	0 or 4	variable	4
Frame Control	Duration /ID	Address 1	Address 2	Address 3	Sequence Control	Address 4	QoS Control	HT Control	Frame Body	FCS

MAC header (Frame Control through HT Control)

Figure 9-1—MAC frame format

Source: IEEE 802.11-2016 Standard (Pages 637-38)

9.2.4.6 HT Control field

9.2.4.6.1 General

The HT Control field is always present in a Control Wrapper frame and is present in QoS Data and Management frames as determined by the +HTC/Order subfield of the Frame Control field as defined in 9.2.4.1.10.

NOTE—The only control frame subtype for which HT Control field is present is the Control Wrapper frame. A Control frame that is described as +HTC (e.g., an RTS+HTC, CTS+HTC, BlockAck+HTC or BlockAckReq+HTC frame) implies the use of the Control Wrapper frame to carry that Control frame.

The format of the 4-octet HT Control field is shown in Figure 9-8.

	B0	B1 B29	B30	B31
	VHT	HT Control Middle	AC Constraint	RDG/More PPDU
Bits	1	29	1	1

Figure 9-8—HT Control field

The HT Control field has two forms, the HT variant and the VHT variant. The two forms differ in the format of the HT Control Middle subfield, described in 9.2.4.6.2 for the HT variant and in 9.2.4.6.3 for the VHT variant and in the value of the VHT subfield.

The VHT subfield of the HT Control field indicates whether the HT Control Middle subfield is the VHT Variant or the HT Variant. The VHT subfield is set to 1 to indicate that the HT Control Middle subfield is the VHT Variant and is set to 0 to indicate that the HT Control Middle subfield is the HT Variant.

Source: IEEE 802.11-2016 Standard (Page 654)

9.2.4.6.2 HT variant

The format of the HT Control Middle subfield of the HT variant HT Control field is shown in Figure 9-9.

	B1 B15	B16 B17	B18 B19	B20 B21	B22 B23	B24	B25 B28	B29
	Link Adaptation Control	Calibration Position	Calibration Sequence	Reserved	CSI/ Steering	HT NDP Announce ment	Reserved	DEI
Bits:	15	2	2	2	2	1	4	1

Figure 9-9—HT Control Middle subfield of the HT variant HT Control field

The format of the Link Adaptation Control subfield of the HT variant HT Control field is defined in Figure 9-10.

	B1	B2 B5	B6 B8	B9 B15
	TRQ	MAI	MFSI	MFB/ASELC
Bits:	1	4	3	7

Figure 9-10—Link Adaptation Control subfield

Source: IEEE 802.11-2016 Standard (Page 655)

Table 9-12—Subfields of Link Adaptation Control subfield

Subfield	Meaning	Definition
TRQ	Training request	Set to 1 to request the responder to transmit a sounding PPDU. Set to 0 to indicate that the responder is not requested to transmit a sounding PPDU. See 10.32.2 and 10.34.2.
MAI	MCS request (MRQ) or ASEL indication	Set to 14 (indicating ASELI) to indicate that the MFB/ASELC subfield is interpreted as ASELC. Otherwise, the MAI subfield is interpreted as shown in Figure 9-11, and the MFB/ASELC subfield is interpreted as MCS feedback (MFB).
MFSI	MCS feedback sequence identifier	Set to the received value of MSI contained in the frame to which the MFB information refers. Set to 7 for unsolicited MFB.
MFB/ASELC	MCS feedback and antenna selection command/data	When the MAI subfield is equal to the value ASELI, this subfield is interpreted as defined in Figure 9-12 and Table 9-14. Otherwise, this subfield contains recommended MFB. A value of 127 indicates that no feedback is present.

The structure of the MAI subfield of the Link Adaptation Control subfield is defined in Figure 9-11. The subfields of the MAI subfield are defined in Table 9-13.

	B0	B1 B3
	MRQ	MSI
Bits:	1	3

Figure 9-11—MAI subfield

Source: IEEE 802.11-2016 Standard (Page 656)

The ASELC subfield of the Link Adaptation Control subfield contains the ASEL Command and ASEL Data subfields, as shown in Figure 9-12. The encoding of these subfields is shown in Table 9-14.

	B0 B2	B3 B6
	ASEL Command	ASEL Data
Bits:	3	4

Figure 9-12—ASELC subfield

Source: IEEE 802.11-2016 Standard (Page 657)

Table 9-14—ASEL Command and ASEL Data subfields

ASEL Command	Interpretation of ASEL Command	ASEL Data
0	Transmit Antenna Selection Sounding Indication (TXASSI)	Number of remaining sounding PPDUs to be transmitted 0 to 15 See NOTE
1	Transmit Antenna Selection Sounding Request (TXASSR) or Transmit ASEL Sounding Resumption	0 when the command is Transmit ASEL Sounding Request A number in the range 1 to 15, the number being the number of the first sounding PPDU to be transmitted when the command is Transmit ASEL Sounding Resumption, where 0 corresponds to the first sounding PPDU in the original ASEL training sequence
2	Receive Antenna Selection Sounding Indication (RXASSI)	Number of remaining sounding PPDUs to be received 0 to 15 See NOTE
3	Receive Antenna Selection Sounding Request (RXASSR)	Number of sounding PPDUs required 0 to 15
4	Sounding Label	Sequence number of the sounding PPDU corresponding to a channel state information (CSI) frame in ASEL feedback 0 to 15
5	No Feedback Due to ASEL Training Failure or Stale Feedback	A number in the range 0 to 15, the number being the number of the first sounding PPDU that was not received properly, where 0 corresponds to the first sounding PPDU in the ASEL training sequence, or 0 if no sounding PPDUs were received properly, or 0 if this is a request for a full retraining sequence
6	Transmit Antenna Selection Sounding Indication requesting feedback of explicit CSI (TXASSI-CSI)	Number of remaining sounding PPDUs to be transmitted 0 to 15 See NOTE
7	Reserved	Reserved

NOTE—If the HT variant HT Control field is carried in a sounding PPDU, then the value of the ASEL Data field contains the remaining number of sounding frames following the current one. If null data packet (NDP) sounding frame is used, then the value in the ASEL Data field contains the number of NDPs following a non-NDP+HTC. The HT NDP Announcement subfield in the HT Control field is set to 1 to indicate NDP sounding.

Source: IEEE 802.11-2016 Standard (Page 657)

76. Altice directly infringes the ’096 Patent when, for example, it and/or its agents use the accused products, including during testing of the accused products. Altice also directly infringes the ’096 Patent when the accused products are used after purchase by a customer or end

user. For example, the accused products are built with hardware and/or software components that control the operation of the accused products. These components cause the accused products to perform the steps of the claimed invention after, for example, receiving sounding packets. Altice also directly infringes the '096 Patent by exercising direction or control over the use of the accused products by others, including its affiliates, its subsidiaries, its business partners (including certification and testing organizations), and/or its customers and end-users. Altice contracts with, advises, and/or encourages such persons to engage in conduct satisfying one or more elements of the asserted claims, deriving a financial or other benefit (e.g., improved wireless communications) from doing so. Altice conditions these benefits on, for example, such persons performing certain activities involving the accused products during specified conditions that cause the accused products to perform the steps of the claimed method (e.g., after receiving sounding packets).

77. Altice has had knowledge of the '096 Patent at least as of the date when it was notified of the filing of this action.

78. Freedom Patents has been damaged as a result of the infringing conduct by Altice alleged above. Thus, Altice is liable to Freedom Patents in an amount that adequately compensates it for such infringements, which, by law, cannot be less than a reasonable royalty, together with interest and costs as fixed by this Court under 35 U.S.C. § 284.

79. Freedom Patents has neither made nor sold unmarked articles that practice the '096 Patent, and is entitled to collect pre-filing damages for the full period allowed by law for infringement of the '096 Patent.

COUNT III

DIRECT INFRINGEMENT OF U.S. PATENT NO. 8,514,815

80. On August 20, 2013, United States Patent No. 8,514,815 ("the '815 Patent") was duly and legally issued by the United States Patent and Trademark Office for an invention entitled "Training Signals for Selecting Antennas and Beams in MIMO Wireless LANs."

81. Freedom Patents is the owner of the '815 Patent, with all substantive rights in and to that patent, including the sole and exclusive right to prosecute this action and enforce the '815 Patent against infringers, and to collect damages for all relevant times.

82. Altice used products and/or systems including, for example, its Altice Fiber Gateway Wi-Fi 6 (with 4x4 MIMO) family of products and other products[8] that implement MIMO Wi-Fi capabilities ("accused products"):

Source: https://www.alticelabs.com/wp-content/uploads/2022/10/FL_GPON_FGW-Wi-Fi6_EN.pdf

[8] *See, e.g.*, Fiber Gateway 4×4 (GR240BG), Fiber Gateway Wi-Fi 5, Smart Mesh Wi-Fi AP extenders, Optimum Amplify, Altice One router, Altice One Mini router, Fast 3965CV, F@st 5260CV, etc.

Model	Ports									
	FXS	Ethernet	RF	Wi-Fi 6 Dual Concurrent		USB	PON			
		1GE	Band: (47 … 870MHz)	Antennas	Power* (dBm EIRP)	Type C	Type	Class	Bit rate (Gbps)	Wavelength (nm)
GR141DG	1x	4x	1x	2.4GHz: 4x4 Mimo 5GHz 4x4 MIMO	2.4Ghz: up to +20 (ETSI) or up to +34 (FCC) 5GHz : up to +30 (ETSI) or up to +34 (FCC)	1x	GPON	B+, C+,D	DS: 2.488 US: 1.244	DS:1480-1500 US:1260-1360
GR140DG	1x	4x	-	2.4GHz: 4x4 Mimo 5GHz :4x4 MIMO	2.4Ghz: up to +20 (ETSI) or up to +34 (FCC) 5GHz : up to +30 (ETSI) or up to +34 (FCC)	1x				

Source: https://www.alticelabs.com/wp-content/uploads/2022/10/FL_GPON_FGW-Wi-Fi6_EN.pdf (page 2)

2.4.1.5.1 Interfaces and features

- Concurrent mode 2.4GHz + 5GHz via 4 dual-band internal antennas
- 2.4GHz: Compatible with IEEE 802.11b 1x1 SISO and 802.11g/n/ax 4x4 MIMO
- 5GHz: Compatible with IEEE 802.11 a/n/ac/ax 4x4 MIMO
- Channel bandwidth: 20, 40, 80 MHz
- Multi User MIMO for best performance per user

2.4.1.5.3 Antennas

- 4x4 MIMO antennas
- Internal antennas with 4~5dBi antenna gain

Source: https://fccid.io/2ACJF-FGW-GR140DG/User-Manual/User-Manual-5082170.pdf (page 24)

83. By doing so, Altice has directly infringed (literally and/or under the doctrine of equivalents) at least Claim 1 of the ’815 Patent. Altice’s infringement in this regard is ongoing.

84. The Altice Fiber Gateway Wi-Fi 6 is an exemplary accused product.

85. Altice has infringed the ’815 Patent by using the accused products and thereby practicing a computer implemented method for selecting antennas in a multiple-input, multiple-output wireless local area network including a plurality of stations, each station includes a set of antennas.

86. For example, the Altice Fiber Gateway Wi-Fi 6 communciates with other stations using the IEEE 802.11 protocol and includes a set of antennas that are used for both transmitting and receiving data to and from the other stations over a WLAN. The transmission and reception of data using multiple antennas simultaneously is known as MIMO ("multiple-input, multiple-output"). The stations communicating using MIMO implement antenna selection by initially transmitting or receiving sounding packets with each other to estimate the channel characteristics between them. The sounding packets correspond to a set of antennas that are available from a larger number of antennas.

> **Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications**
>
> **1. Overview**
>
> **1.1 Scope**
>
> The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area.

Source: IEEE 802.11-2016 Standard (Page 122)

> An HT STA has PHY features consisting of the modulation and coding scheme (MCS) set described in 19.3.5 and physical layer (PHY) protocol data unit (PPDU) formats described in 19.1.4. Some PHY features that distinguish an HT STA from a non-HT STA are referred to as *multiple input, multiple output (MIMO) operation*; spatial multiplexing (SM); spatial mapping (including transmit beamforming); space-time block coding (STBC); low-density parity check (LDPC) encoding; and antenna selection (ASEL). The allowed PPDU formats are non-HT format, HT-mixed format, and HT-greenfield format (see 19.1.4). The PPDUs can be transmitted with 20 MHz bandwidth and might be transmitted with 40 MHz bandwidth.

Source: IEEE 802.11-2016 Standard (Page 197)

> **multiple input, multiple output (MIMO):** A physical layer (PHY) configuration in which both transmitter and receiver use multiple antennas.

Source: IEEE 802.11-2016 Standard (Page 136)

multi-user multiple input, multiple output (MU-MIMO): A technique by which multiple stations (STAs), each with one or more antennas, either simultaneously transmit to a single STA or simultaneously receive from a single STA independent data streams over the same radio frequencies.

NOTE—IEEE Std 802.11 supports only downlink (DL) MU-MIMO. *See* **downlink multi-user multiple input, multiple output (DL-MU-MIMO)** (in 3.2).

Source: IEEE 802.11-2016 Standard (Page 136)

10.31 Link adaptation

10.31.1 Introduction

To fully exploit MIMO channel variations and transmit beamforming on a MIMO link, a STA can request that another STA provide MIMO channel sounding and MFB.

Source: IEEE 802.11-2016 Standard (Page 1463)

10.30 Sounding PPDUs

The behavior described in this subclause is specific to the use of the HT variant HT Control field.

A sounding PPDU is a PPDU for which the SOUNDING parameter of the corresponding RXVECTOR or TXVECTOR has the value SOUNDING. Sounding PPDUs are transmitted by STAs to enable the receiving STAs to estimate the channel between the transmitting STA and the receiving STA.

A STA transmits sounding PPDUs when it operates in the following roles:

— MFB requester (see 10.31.2)

— HT beamformee responding to a training request, calibration initiator, or responder involved in implicit transmit beamforming (see 10.32.2.2, 10.32.2.3, and 10.32.2.4)

— HT beamformer involved in explicit transmit beamforming (see 10.32.3)

— ASEL transmitter and ASEL sounding-capable transmitter involved in ASEL (see 10.33.2)

A STA receives sounding PPDUs when it operates in the following roles:

— MFB responder (see 10.31.2)

— HT beamformer sending a training request, calibration initiator, or responder involved in implicit transmit beamforming (see 10.32.2.2, 10.32.2.3, and 10.32.2.4)

— HT beamformee involved in explicit transmit beamforming (see 10.32.3)

— Transmit ASEL responder and ASEL receiver involved in ASEL (see 10.33.2)

Source: IEEE 802.11-2016 Standard (Pages 1462-63)

10.33 Antenna selection (ASEL)

10.33.1 Introduction

The procedures in this subclause apply only to HT and non-HT PPDUs for which the HT Control field, if present, is the HT variant HT Control field.

ASEL is a time-variant mapping of the signals at the RF chains onto a set of antenna elements when the number of RF chains is smaller than the number of antenna elements. The mapping might be chosen based on instantaneous or averaged CSI. ASEL requires the training of the full size channel associated with all antenna elements, which is obtained by transmitting or receiving sounding PPDUs over all antennas. These sounding PPDUs should be sent within a single TXOP. To avoid channel distortions, these sounding PPDUs shall be transmitted consecutively. The training information is exchanged using the HT Control field. When both transmitter and receiver have ASEL capabilities, training of transmit and receive antennas might be done one after another. ASEL supports up to eight antennas and up to four RF chains.

Source: IEEE 802.11-2016 Standard (Page 1481)

87. The method practiced using the accused products includes the step of sending a number of sounding packets that are to be sent for antenna selection training, from a station to perform the antenna selection training by receiving the sounding packets, to a station to transmit the sounding packets.

88. For example, during the antenna selection process, the ASEL receiver station ("a station to perform the antenna selection training by receiving the sounding packets") initially transmits a +HTC frame with the ASEL Command subfield set to RXASSR ("Receive Antenna Selection Sounding Request"). The ASEL Data subfield indicates the number of sounding PPDUs required ("sending a number of sounding packets that are to be sent for antenna selection training") from the ASEL sounding-capable transmitter station ("to a station to transmit the sounding packets").

10.30 Sounding PPDUs

The behavior described in this subclause is specific to the use of the HT variant HT Control field.

A sounding PPDU is a PPDU for which the SOUNDING parameter of the corresponding RXVECTOR or TXVECTOR has the value SOUNDING. Sounding PPDUs are transmitted by STAs to enable the receiving STAs to estimate the channel between the transmitting STA and the receiving STA.

A STA transmits sounding PPDUs when it operates in the following roles:

— MFB requester (see 10.31.2)

— HT beamformee responding to a training request, calibration initiator, or responder involved in implicit transmit beamforming (see 10.32.2.2, 10.32.2.3, and 10.32.2.4)

— HT beamformer involved in explicit transmit beamforming (see 10.32.3)

— ASEL transmitter and ASEL sounding-capable transmitter involved in ASEL (see 10.33.2)

A STA receives sounding PPDUs when it operates in the following roles:

— MFB responder (see 10.31.2)

— HT beamformer sending a training request, calibration initiator, or responder involved in implicit transmit beamforming (see 10.32.2.2, 10.32.2.3, and 10.32.2.4)

— HT beamformee involved in explicit transmit beamforming (see 10.32.3)

— Transmit ASEL responder and ASEL receiver involved in ASEL (see 10.33.2)

Source: IEEE 802.11-2016 Standard (Pages 1462-63)

10.33 Antenna selection (ASEL)

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Source: IEEE 802.11-2016 Standard (Page 1481)

> The frame exchange sequence for receive ASEL is shown in Figure 10-51, where the term *ASEL receiver* identifies the STA that is conducting receive ASEL, and the term *ASEL sounding-capable transmitter* identifies the STA sending the consecutive sounding PPDUs used for receive ASEL calculations. The frame exchange comprises the following steps:
>
> — The ASEL receiver transmits a +HTC frame with the MAI subfield set to ASELI, the ASEL Command subfield set to Receive Antenna Selection Sounding Request (RXASSR), and the ASEL Data subfield set to the number of sounding PPDUs required.
>
> NOTE— For example, in the case of sounding over all disjointed antenna sets, the number of total consecutive sounding PPDUs or NDPs equals the smallest integer that is greater than or equal to the number of antennas divided by the number of RF chains.

Source: IEEE 802.11-2016 Standard (Page 1484)

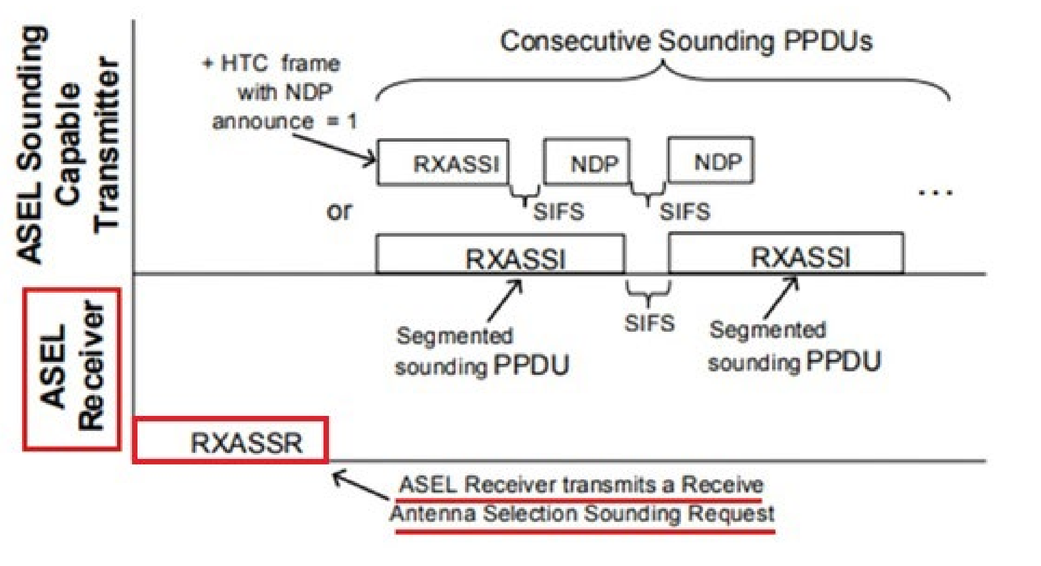

Figure 10-51—Receive ASEL

Source: IEEE 802.11-2016 Standard (Page 1484)

89. The method practiced using the accused products includes the step of transmitting multiple consecutively transmitted sounding packets, according to the number, by the station transmitting the sounding packets.

90. For example, the ASEL sounding-capable transmitter station ("station transmitting the sounding packets") receives the +HTC frame transmitted by the ASEL receiver station, which indicates the number of sounding PPDUs required for antenna selection. The ASEL sounding-capable transmitter station responds by consecutively transmitting multiple

sounding PPDUs ("transmitting multiple consecutively transmitted sounding packets") as required by the ASEL receiver to perform antenna selection.

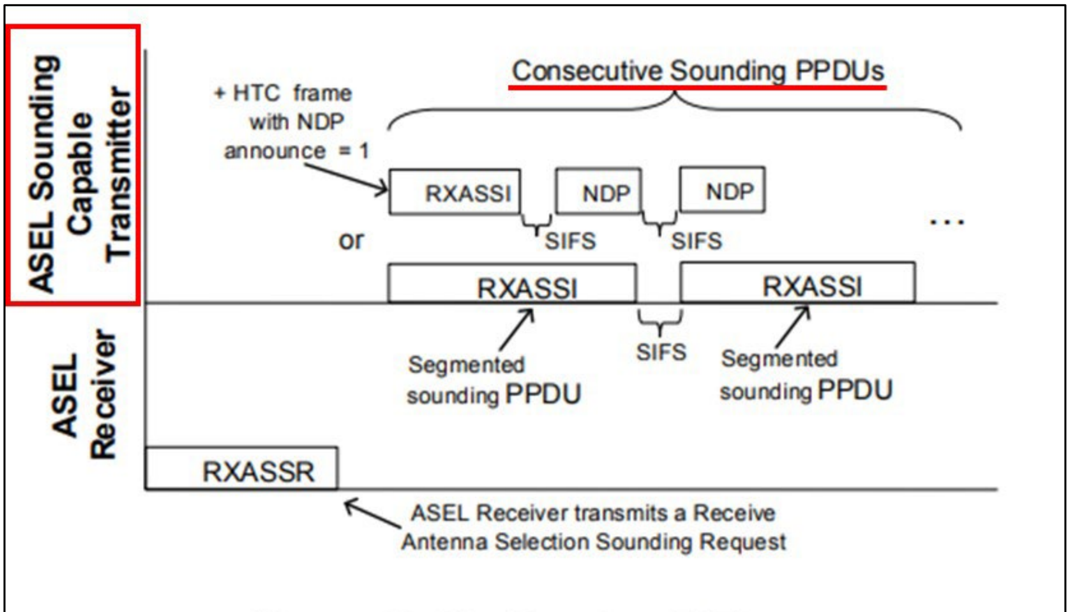

Figure 10-51—Receive ASEL

Source: IEEE 802.11-2016 Standard (Page 1484)

The frame exchange sequence for receive ASEL is shown in Figure 10-51, where the term *ASEL receiver* identifies the STA that is conducting receive ASEL, and the term *ASEL sounding-capable transmitter* identifies the STA sending the consecutive sounding PPDUs used for receive ASEL calculations. The frame exchange comprises the following steps:

— The ASEL receiver transmits a +HTC frame with the MAI subfield set to ASELI, the ASEL Command subfield set to Receive Antenna Selection Sounding Request (RXASSR), and the ASEL Data subfield set to the number of sounding PPDUs required.

NOTE— For example, in the case of sounding over all disjointed antenna sets, the number of total consecutive sounding PPDUs or NDPs equals the smallest integer that is greater than or equal to the number of antennas divided by the number of RF chains.

— The ASEL sounding-capable transmitter responds with the corresponding number of sounding PPDUs in its subsequent TXOP. These PPDUs are separated by SIFS. When using non-NDP sounding, each PPDU contains a +HTC frame in which the MAI subfield is set to ASELI, the ASEL Command subfield is set to Receive Antenna Selection Sounding Indication (RXASSI), and the ASEL Data subfield is set to the remaining number of sounding PPDUs to be transmitted. When using NDP sounding, the PPDU that precedes the first NDP contains a +HTC frame in which the NDP Announce field is set to 1, the MAI subfield is set to ASELI, the ASEL Command subfield is set to RXASSI, and the ASEL Data subfield is set to the remaining number of sounding PPDUs to be transmitted.

Source: IEEE 802.11-2016 Standard (Page 1484)

10.30 Sounding PPDUs

The behavior described in this subclause is specific to the use of the HT variant HT Control field.

A sounding PPDU is a PPDU for which the SOUNDING parameter of the corresponding RXVECTOR or TXVECTOR has the value SOUNDING. Sounding PPDUs are transmitted by STAs to enable the receiving STAs to estimate the channel between the transmitting STA and the receiving STA.

A STA transmits sounding PPDUs when it operates in the following roles:

— MFB requester (see 10.31.2)

— HT beamformee responding to a training request, calibration initiator, or responder involved in implicit transmit beamforming (see 10.32.2.2, 10.32.2.3, and 10.32.2.4)

— HT beamformer involved in explicit transmit beamforming (see 10.32.3)

— ASEL transmitter and ASEL sounding-capable transmitter involved in ASEL (see 10.33.2)

A STA receives sounding PPDUs when it operates in the following roles:

— MFB responder (see 10.31.2)

— HT beamformer sending a training request, calibration initiator, or responder involved in implicit transmit beamforming (see 10.32.2.2, 10.32.2.3, and 10.32.2.4)

— HT beamformee involved in explicit transmit beamforming (see 10.32.3)

— Transmit ASEL responder and ASEL receiver involved in ASEL (see 10.33.2)

Source: IEEE 802.11-2016 Standard (Pages 1462-63)

91. The method practiced using the accused products includes the step of receiving the multiple consecutively transmitted sounding packets in the station to perform the antenna selection training, wherein each sounding packet corresponding to a different subset of the set of antennas, and where the number of consecutive packets is predetermined.

92. For example, the ASEL receiver station receives multiple consecutive sounding PPDUs ("receiving the multiple consecutively transmitted sounding packets") sent by the ASEL sounding-capable transmitter station. The number of received multiple sounding packets corresponds to the number required to be sent by the ASEL sounding-capable transmitter ("where the number of consecutive packets is predetermined"). The ASEL receiver station receives the multiple consecutively transmitted sounding PPDUs and estimates the channel state information (along with the channel matrices for each channel) based on the measurements from

the received sounding PPDUs, each of which corresponds to a different set of antennas ("each sounding packet corresponding to a different subset of the set of antennas"). Based on the estimated channel matrices, the ASEL receiver performs antenna selection ("to perform the antenna selection training").

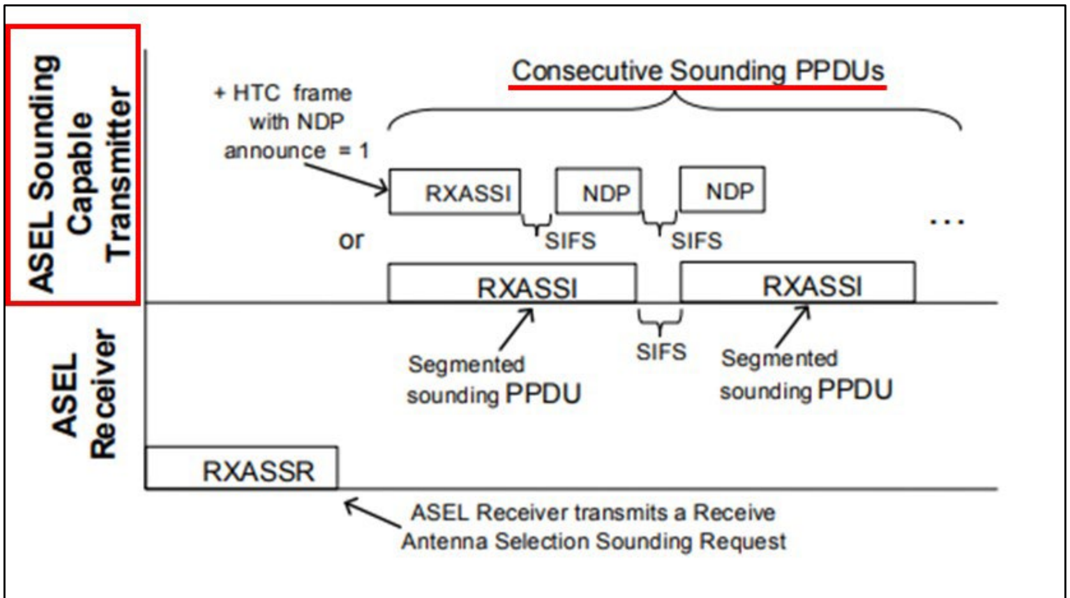

Figure 10-51—Receive ASEL

Source: IEEE 802.11-2016 Standard (Page 1484)

10.33 Antenna selection (ASEL)

10.33.1 Introduction

The procedures in this subclause apply only to HT and non-HT PPDUs for which the HT Control field, if present, is the HT variant HT Control field.

ASEL is a time-variant mapping of the signals at the RF chains onto a set of antenna elements when the number of RF chains is smaller than the number of antenna elements. The mapping might be chosen based on instantaneous or averaged CSI. ASEL requires the training of the full size channel associated with all antenna elements, which is obtained by transmitting or receiving sounding PPDUs over all antennas. These sounding PPDUs should be sent within a single TXOP. To avoid channel distortions, these sounding PPDUs shall be transmitted consecutively. The training information is exchanged using the HT Control field. When both transmitter and receiver have ASEL capabilities, training of transmit and receive antennas might be done one after another. ASEL supports up to eight antennas and up to four RF chains.

Source: IEEE 802.11-2016 Standard (Page 1481)

> The frame exchange sequence for receive ASEL is shown in Figure 10-51, where the term *ASEL receiver* identifies the STA that is conducting receive ASEL, and the term *ASEL sounding-capable transmitter* identifies the STA sending the consecutive sounding PPDUs used for receive ASEL calculations. The frame exchange comprises the following steps:
>
> — The ASEL receiver transmits a +HTC frame with the MAI subfield set to ASELI, the ASEL Command subfield set to Receive Antenna Selection Sounding Request (RXASSR), and the ASEL Data subfield set to the number of sounding PPDUs required.
>
> NOTE— For example, in the case of sounding over all disjointed antenna sets, the number of total consecutive sounding PPDUs or NDPs equals the smallest integer that is greater than or equal to the number of antennas divided by the number of RF chains.
>
> — The ASEL sounding-capable transmitter responds with the corresponding number of sounding PPDUs in its subsequent TXOP. These PPDUs are separated by SIFS. When using non-NDP sounding, each PPDU contains a +HTC frame in which the MAI subfield is set to ASELI, the ASEL Command subfield is set to Receive Antenna Selection Sounding Indication (RXASSI), and the ASEL Data subfield is set to the remaining number of sounding PPDUs to be transmitted. When using NDP sounding, the PPDU that precedes the first NDP contains a +HTC frame in which the NDP Announce field is set to 1, the MAI subfield is set to ASELI, the ASEL Command subfield is set to RXASSI, and the ASEL Data subfield is set to the remaining number of sounding PPDUs to be transmitted.

Source: IEEE 802.11-2016 Standard (Page 1484)

> The ASEL receiver uses different antenna sets to receive these sounding PPDUs, estimates CSI after receiving all these sounding PPDUs, and conducts the ASEL.

Source: IEEE 802.11-2016 Standard (Page 1484)

10.30 Sounding PPDUs

The behavior described in this subclause is specific to the use of the HT variant HT Control field.

A sounding PPDU is a PPDU for which the SOUNDING parameter of the corresponding RXVECTOR or TXVECTOR has the value SOUNDING. Sounding PPDUs are transmitted by STAs to enable the receiving STAs to estimate the channel between the transmitting STA and the receiving STA.

A STA transmits sounding PPDUs when it operates in the following roles:

— MFB requester (see 10.31.2)

— HT beamformee responding to a training request, calibration initiator, or responder involved in implicit transmit beamforming (see 10.32.2.2, 10.32.2.3, and 10.32.2.4)

— HT beamformer involved in explicit transmit beamforming (see 10.32.3)

— ASEL transmitter and ASEL sounding-capable transmitter involved in ASEL (see 10.33.2)

A STA receives sounding PPDUs when it operates in the following roles:

— MFB responder (see 10.31.2)

— HT beamformer sending a training request, calibration initiator, or responder involved in implicit transmit beamforming (see 10.32.2.2, 10.32.2.3, and 10.32.2.4)

— HT beamformee involved in explicit transmit beamforming (see 10.32.3)

— Transmit ASEL responder and ASEL receiver involved in ASEL (see 10.33.2)

Source: IEEE 802.11-2016 Standard (Pages 1462-63)

93. The method practiced using the accused products includes the step of estimating a channel matrix from the multiple consecutively transmitted sounding packets.

94. For example, the ASEL sounding-capable transmitter station transmits multiple sounding PPDUs ("multiple consecutively transmitted sounding packets") to the ASEL receiver. The ASEL receiver station estimates the channel state information based on the measurements from each of the received sounding PPDUs, which correspond to a different set of antennas. After the estimate is complete, a Channel State Information report (CSI report) is generated. The CSI report is part of the CSI frame format, and is present as a CSI Report field. The CSI Report field contains a Channel Matrix subfield, which contains the channel matrices estimated for the different channels.

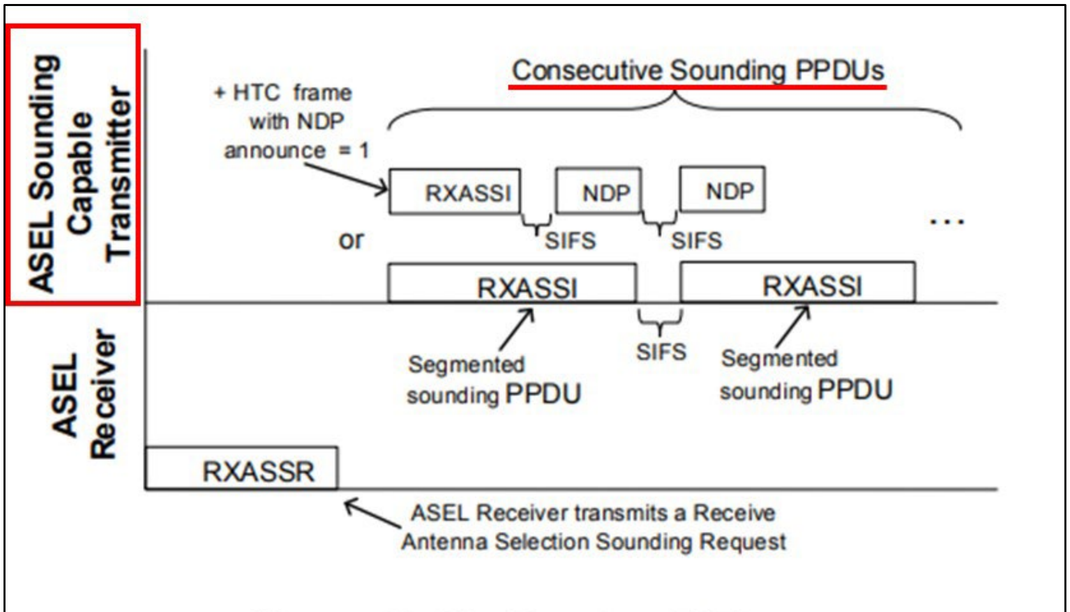

Figure 10-51—Receive ASEL

Source: IEEE 802.11-2016 Standard (Page 1484)

The ASEL receiver uses different antenna sets to receive these sounding PPDUs, estimates CSI after receiving all these sounding PPDUs, and conducts the ASEL.

Source: IEEE 802.11-2016 Standard (Page 1484)

19.3.13.3 Sounding PPDU for calibration

In the case of a bidirectional calibration exchange, two STAs exchange sounding PPDUs, the exchange of which enables the receiving STA to compute an estimate of the MIMO channel matrix H_k for each subcarrier k. In general, in an exchange of calibration messages, the number of spatial streams is less than the number of transmit antennas. In such cases, HT-ELTFs are used. In the case of sounding PPDUs for calibration, the antenna mapping matrix shall be as shown in Equation (19-86).

$$Q_k = C_{CSD}(k)P_{CAL} \quad (19\text{-}86)$$

Source: IEEE 802.11-2016 Standard (Page 2401)

When the MIMO channel measurements become available at STA B, STA B shall send one or more CSI frames that contain the CSI report (Step 2 in Figure 10-47). This CSI report shall have full precision, i.e, Ng=1 (no grouping) and Nb=3 (8 bits). In these CSI frames, the Calibration Sequence subfields in HT Control fields shall be set to the same value that is indicated in the Calibration Sounding Complete frame. These CSI frames shall have a frame type of Management Action +HTC.

Source: IEEE 802.11-2016 Standard (Page 1477)

9.6.12.6 CSI frame format

The CSI frame is an Action or an Action No Ack frame of category HT. The format of its Action field is defined in Table 9-338.

Table 9-338—CSI frame Action field format

Order	Information
1	Category
2	HT Action
3	MIMO Control (see 9.4.1.27)
4	CSI Report (see 9.4.1.28)

Source: IEEE 802.11-2016 Standard (Page 1214)

9.4.1.28 CSI Report field

The CSI Report field is used by the CSI frame (see 9.6.12.6) to carry explicit channel state information to a transmit HT beamformer, as described in 10.32.3.

The CSI Matrix subfields in the CSI Report field shown in Table 9-52 and Table 9-53 are matrices whose elements are taken from the CHAN_MAT parameter of RXVECTOR (see Table 19-1).

Table 9-52—CSI Report field (20 MHz)

Field	Size (bits)	Meaning
SNR in receive chain 1	8	Signal-to-noise ratio in the first receive chain of the STA sending the report.
...		
SNR in receive chain *Nr*	8	Signal-to-noise ratio in the *Nr*'th receive chain of the STA sending the report.
CSI Matrix for carrier –28	$3+2\times Nb\times Nc\times Nr$	CSI matrix (see Figure 9-95)
...		

Source: IEEE 802.11-2016 Standard (Page 746)

Table 19-1—TXVECTOR and RXVECTOR parameters

Parameter	Condition	Value	TXVECTOR	RXVECTOR
			See NOTE 1	
CHAN_MAT	CHAN_MAT_TYPE is COMPRESSED_SV	Contains a set of compressed beamforming feedback matrices as defined in 19.3.12.3.6 based on the channel measured during the training symbols of the received PPDU. The number of elements depends on the number of spatial streams and the number of transmit chains.	N	Y
	CHAN_MAT_TYPE is NON_COMPRESSED_SV	Contains a set of noncompressed beamforming feedback matrices as defined in 19.3.12.3.5 based on the channel measured during the training symbols of the received PPDU. The number of complex elements is $N_{ST} \times N_r \times N_c$ where N_{ST} is the total number of subcarriers, N_c is the number of columns, and N_r is the number of rows in each matrix.	N	Y
	CHAN_MAT_TYPE is CSI_MATRICES	Contains a set of CSI matrices as defined in 19.3.12.3.2 based on the channel measured during the training symbols of the received PPDU. The number of complex elements is $N_{ST} \times N_r \times N_c$ where N_{ST} is the total number of subcarriers, N_c is the number of columns, and N_r is the number of rows in each matrix.	N	Y
	Otherwise	Not present	N	N
CHAN_MAT_TYPE	FORMAT is HT_MF or HT_GF	Enumerated type: COMPRESSED_SV indicates that CHAN_MAT is a set of compressed beamforming vector matrices. NON_COMPRESSED_SV indicates that CHAN_MAT is a set of noncompressed beamforming vector matrices. CSI_MATRICES indicates that CHAN_MAT is a set of channel state matrices.	N	Y
	Otherwise	Not present	N	N

Source: IEEE 802.11-2016 Standard (Pages 2340-41)

95. The method practiced using the accused products includes the step of selecting a subset of antennas according to the channel matrix.

96. For example, the ASEL receiver station receives the sounding PPDUs, estimates the CSI, and generates a Channel State Information report (CSI report). Based on the estimated channel matrices present in the CSI report, antenna selection is performed ("selecting a subset of antennas according to the channel matrix").

When the MIMO channel measurements become available at STA B, STA B shall send one or more CSI frames that contain the CSI report (Step 2 in Figure 10-47). This CSI report shall have full precision, i.e, Ng=1 (no grouping) and Nb=3 (8 bits). In these CSI frames, the Calibration Sequence subfields in HT Control fields shall be set to the same value that is indicated in the Calibration Sounding Complete frame. These CSI frames shall have a frame type of Management Action +HTC.

Source: IEEE 802.11-2016 Standard (Page 1477)

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Source: IEEE 802.11-2016 Standard (Page 1214)

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CSI Matrix for carrier –28	$3+2\times Nb\times Nc\times Nr$	CSI matrix (see Figure 9-95)
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Source: IEEE 802.11-2016 Standard (Page 746)

10.33 Antenna selection (ASEL)

10.33.1 Introduction

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Source: IEEE 802.11-2016 Standard (Page 1481)

Antenna Selection. There are M columns and N rows in the CSI matrix **H**; each corresponds to one transmit or receive antenna. To compute the Effective CSI that would be used under a particular antenna selection, we simply pick the subset of rows and columns that correspond to the desired antennas. Note that this includes both transmit antenna selection (e.g., when $S < M$, pick the best S of the M transmit antennas to send with) and receive antenna selection (e.g., when $N > S$, turn off the least useful of the excess antennas in order to reduce power consumption).

Source: https://arxiv.org/ftp/arxiv/papers/1301/1301.6644.pdf (Page 76)

97. Altice directly infringes the ’815 Patent when, for example, it and/or its agents use the accused products, including during testing of the accused products. Altice also directly infringes the ’815 Patent when the accused products are used after purchase by a customer or end user. For example, the accused products are built with hardware and/or software components that control the operation of the accused products. These components cause the accused products to perform the steps of the claimed invention after, for example, receiving sounding packets. Altice also directly infringes the ’815 Patent by exercising direction or control over the use of the accused products by others, including its affiliates, its subsidiaries, its business partners (including certification and testing organizations), and/or its customers and end-

users. Altice contracts with, advises, and/or encourages such persons to engage in conduct satisfying one or more elements of the asserted claims, deriving a financial or other benefit (e.g., improved wireless communications) from doing so. Altice conditions these benefits on, for example, such persons performing certain activities involving the accused products during specified conditions that cause the accused products to perform the steps of the claimed method (e.g., after receiving sounding packets).

98. Altice has had knowledge of the ’815 Patent at least as of the date when it was notified of the filing of this action.

99. Freedom Patents has been damaged as a result of the infringing conduct by Altice alleged above. Thus, Altice is liable to Freedom Patents in an amount that adequately compensates it for such infringements, which, by law, cannot be less than a reasonable royalty, together with interest and costs as fixed by this Court under 35 U.S.C. § 284.

100. Freedom Patents has neither made nor sold unmarked articles that practice the ’815 Patent, and is entitled to collect pre-filing damages for the full period allowed by law for infringement of the ’815 Patent.

ADDITIONAL ALLEGATIONS REGARDING INFRINGEMENT AND PERSONAL JURISDICTION

101. Altice has also indirectly infringed the ’686 Patent, the ’096 Patent, and the ’815 Patent by inducing others to directly infringe the ’686 Patent, the ’096 Patent, and the ’815 Patent.

102. Altice has induced the end users and/or Altice’s customers to directly infringe (literally and/or under the doctrine of equivalents) the ’686 Patent, the ’096 Patent, and the ’815 Patent by using the accused products.

103. Altice took active steps, directly and/or through contractual relationships with others, with the specific intent to cause them to use the accused products in a manner that infringes one or more claims of the ’686 Patent, the ’096 Patent, and the ’815 Patent, including, for example, claims 1 and 21 of the ’686 Patent, claim 1 of the ’096 Patent, and claim 1 of the ’815 Patent.

104. Such steps by Altice included, among other things, advising or directing customers, end users, and others (including distributors and equipment services entities) to use the accused products in an infringing manner; advertising and promoting the use of the accused products in an infringing manner; and/or distributing instructions that guide users to use the accused products in an infringing manner.

105. Altice performed these steps, which constitute joint and/or induced infringement, with the knowledge of the ’686 Patent, the ’096 Patent, and the ’815 Patent and with the knowledge that the induced acts constitute infringement.

106. Altice was and is aware that the normal and customary use of the accused products by Altice’s customers would infringe the ’686 Patent, the ’096 Patent, and the ’815 Patent. Altice’s inducement is ongoing.

107. Altice has also induced its affiliates, or third-party manufacturers, shippers, distributors, retailers, or other persons acting on its or its affiliates’ behalf, to directly infringe (literally and/or under the doctrine of equivalents) at least claim 21 of the ’686 Patent by importing, selling or offering to sell the accused products.

108. Altice has a significant role in placing the accused products in the stream of commerce with the expectation and knowledge that they will be purchased by consumers in Texas and elsewhere in the United States.

109. Altice purposefully directs or controls the making of accused products and their shipment to the United States, using established distribution channels, for sale in Texas and elsewhere within the United States.

110. Altice purposefully directs or controls the sale of the accused products into established United States distribution channels, including sales to nationwide retailers and wholesalers. Altice's established United States distribution channels include one or more United States based affiliates and third-parties working on behalf of Altice.

111. Altice purposefully directs or controls the sale of the accused products online and in nationwide retailers and wholesalers, including for sale in Texas and elsewhere in the United States, and expects and intends that the accused products will be so sold.

112. Altice purposefully places the accused products—whether by itself or through subsidiaries, affiliates, or third parties—into an international supply chain, knowing that the accused products will be sold in the United States, including Texas. Therefore, Altice also facilitates the sale of the accused products in Texas.

113. Altice took active steps, directly and/or through contractual relationships with others, with the specific intent to cause such persons to import, sell, or offer to sell the accused products in a manner that infringes claim 21 of the '686 Patent.

114. Such steps by Altice included, among other things, making or selling the accused products outside of the United States for importation into or sale in the United States, or knowing that such importation or sale would occur; and directing, facilitating, or influencing its affiliates, or third-party manufacturers, shippers, distributors, retailers, or other persons acting on its or its affiliates' behalf, to import, sell, or offer to sell the accused products in an infringing manner.

115. Altice performed these steps, which constitute induced infringement, with the knowledge of the ’686 Patent, the ’096 Patent, and the ’815 Patent, and with the knowledge that the induced acts would constitute infringement.

116. Altice performed such steps in order to profit from the eventual sale of the accused products in the United States.

117. Altice’s inducement is ongoing.

118. Altice has also indirectly infringed by contributing to the infringement of the ’686 Patent, the ’096 Patent, and the ’815 Patent. Altice has contributed to the direct infringement of the ’686 Patent, the ’096 Patent, and the ’815 Patent by the end user of the accused products.

119. The accused products have special features that are specially designed to be used in an infringing way and that have no substantial uses other than ones that infringe the ’686 Patent, the ’096 Patent, and the ’815 Patent, including, for example, claims 1 and 21 of the ’686 Patent, claim 1 of the ’096 Patent, and claim 1 of the ’815 Patent.

120. The special features include, for example, hardware and/or software components especially adapted for transmitting/receiving sounding packets and estimating channel matrices for the selection of antennas in a multiple-input, multiple-output wireless network, used in a manner that infringes the ’686 Patent, the ’096 Patent, and the ’815 Patent.

121. These special features constitute a material part of the invention of one or more of the claims of the ’686 Patent, the ’096 Patent, and the ’815 Patent, and are not staple articles of commerce suitable for substantial non-infringing use.

122. Altice’s contributory infringement is ongoing.

123. Altice has had actual knowledge of the ’686 Patent, the ’096 Patent, and the ’815 Patent at least as of the date when it was notified of the filing of this action. Since at least that

time, Altice has known the scope of the claims of the ’686 Patent, the ’096 Patent, and the ’815 Patent, the products that practice the ’686 Patent, the ’096 Patent, and the ’815 Patent, and that Freedom Patents is the owner of the ’686 Patent, the ’096 Patent, and the ’815 Patent.

124. By the time of trial, Altice will have known and intended (since receiving such notice) that its continued actions would infringe and actively induce and contribute to the infringement of one or more claims of the ’686 Patent, the ’096 Patent, and the ’815 Patent.

125. Furthermore, Altice has a policy or practice of not reviewing the patents of others (including instructing its employees to not review the patents of others), and thus has been willfully blind of Freedom Patents’ patent rights. *See, e.g.*, M. Lemley, “Ignoring Patents,” 2008 Mich. St. L. Rev. 19 (2008).

126. Altice’s customers have infringed the ’686 Patent, the ’096 Patent, and the ’815 Patent. Altice encouraged its customers’ infringement.

127. Altice’s direct and indirect infringement of the ’686 Patent, the ’096 Patent, and the ’815 Patent has been, and/or continues to be willful, intentional, deliberate, and/or in conscious disregard of Freedom Patents’ rights under the patents-in-suit.

128. Freedom Patents has been damaged as a result of Altice’s infringing conduct alleged above. Thus, Altice is liable to Freedom Patents in an amount that adequately compensates it for such infringements, which, by law, cannot be less than a reasonable royalty, together with interest and costs as fixed by this Court under 35 U.S.C. § 284.

JURY DEMAND

Freedom Patents hereby requests a trial by jury on all issues so triable by right.

PRAYER FOR RELIEF

Freedom Patents requests that the Court find in its favor and against Altice, and that the Court grant Freedom Patents the following relief:

a. Judgment that one or more claims of the ’686 Patent, the ’096 Patent, and the ’815 Patent have been infringed, either literally and/or under the doctrine of equivalents, by Altice and/or all others acting in concert therewith;

b. A permanent injunction enjoining Altice and its officers, directors, agents, servants, affiliates, employees, divisions, branches, subsidiaries, parents, and all others acting in concert therewith from infringement of the ’686 Patent, the ’096 Patent, and the ’815 Patent; or, in the alternative, an award of a reasonable ongoing royalty for future infringement of the ’686 Patent, the ’096 Patent, and the ’815 Patent by such entities;

c. Judgment that Altice account for and pay to Freedom Patents all damages to and costs incurred by Freedom Patents because of Altice’s infringing activities and other conduct complained of herein, including an award of all increased damages to which Freedom Patents is entitled under 35 U.S.C. § 284;

d. That Freedom Patents be granted pre-judgment and post-judgment interest on the damages caused by Altice’s infringing activities and other conduct complained of herein;

e. That this Court declare this an exceptional case and award Freedom Patents its reasonable attorney’s fees and costs in accordance with 35 U.S.C. § 285; and

f. That Freedom Patents be granted such other and further relief as the Court may deem just and proper under the circumstances.

Dated: April 7, 2023

Respectfully submitted,

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