APPENDIX 9

[9] https://docs.fcc.gov/public/attachments/DOC-363490A1.pdf

April 2, 2020

FCC FACT SHEET*

Unlicensed Use of the 6 GHz Band
Report and Order and Further Notice of Proposed Rulemaking
ET Docket No. 18-295; GN Docket No. 17-183

Background: Unlicensed devices relying on Wi-Fi and other technical standards have become indispensable for providing low-cost wireless connectivity in countless products used by American consumers. This Report and Order would make 1,200 megahertz of spectrum available for unlicensed use in the 5.925-7.125 GHz (6 GHz) band while ensuring that incumbent licensed services are able to thrive throughout the band. The Further Notice proposes to expand how unlicensed users can access the 6 GHz band and seeks comment on the potential for using higher power levels than those adopted in the Report and Order. Expanding spectrum use by unlicensed devices will advance the Commission's efforts to make broadband connectivity available to all Americans, especially those in rural and underserved areas.

What the Report and Order Would Do:

- Permit two types of unlicensed operations tailored to protect incumbent services that operate in distinct parts of the 6 GHz band:
    - Across the entire 1,200 megahertz of the 6 GHz band, unlicensed access points would be permitted to operate at lower power restricted to indoor use, without an automated frequency control (AFC) system.
        - The combination of lower power and indoor operations would protect all 6 GHz band licensed services (which include point-to-point microwave links as well as broadcast auxiliary and cable television relay licenses) from harmful interference.
    - In the 5.925-6.425 GHz and 6.525-6.875 GHz sub-bands, unlicensed access points would be permitted to transmit both indoors and outdoors under the control of an AFC system at standard power levels that are currently permitted in the 5 GHz band.
        - These frequencies are heavily used by licensed point-to-point microwave links. The AFC system would identify which frequencies are available to unlicensed devices without causing harmful interference to fixed point-to-point microwave receivers.
        - Licensed fixed satellite systems using these frequencies operate in the Earth-to-space direction. The rules would protect these operations by limiting outdoor device antenna elevation angles to ensure that they do not point towards the geostationary satellite arc.
- Permit client devices to operate across the 6 GHz band only under the control of either a standard power (indoors or outdoors) or low power indoor access point.

What the Further Notice of Proposed Rulemaking Would Do:

- Propose to permit unlicensed devices to operate both indoors and outdoors across the entire 6 GHz band at very low power to prevent harmful interference to licensed services.
- Seek comment on increasing the transmit power of indoor access points that operate without an AFC.

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* This document is being released as part of a "permit-but-disclose" proceeding. Any presentations or views on the subject expressed to the Commission or its staff, including by email, must be filed in ET Docket No. 18-295, which may be accessed via the Electronic Comment Filing System (https://www.fcc.gov/ecfs/). Before filing, participants should familiarize themselves with the Commission's *ex parte* rules, including the general prohibition on presentations (written and oral) on matters listed on the Sunshine Agenda, which is typically released a week prior to the Commission's meeting. *See* 47 CFR § 1.1200 *et seq.*

Before the
Federal Communications Commission
Washington, D.C. 20554

In the Matter of	)	
	)	
Unlicensed Use of the 6 GHz Band	)	ET Docket No. 18-295
	)	
Expanding Flexible Use in Mid-Band Spectrum Between 3.7 and 24 GHz	)	GN Docket No. 17-183

REPORT AND ORDER AND FURTHER NOTICE OF PROPOSED RULEMAKING[*]

Adopted: [] **Released: []**

Comment Date: 30 days after Federal Register publication
Reply Comment Date: 60 days after Federal Register publication

By the Commission:

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Heading Paragraph #

[*] This document has been circulated for tentative consideration by the Commission at its April 2020 open meeting. The issues referenced in this document and the Commission's ultimate resolutions of those issues remain under consideration and subject to change. This document does not constitute any official action by the Commission. However, the Chairman has determined that, in the interest of promoting the public's ability to understand the nature and scope of issues under consideration, the public interest would be served by making this document publicly available. The Commission's ex parte rules apply and presentations are subject to "permit-but-disclose" *ex parte* rules. *See, e.g.*, 47 CFR §§ 1.1206, 1.1200(a). Participants in this proceeding should familiarize themselves with the Commission's *ex parte* rules, including the general prohibition on presentations (written and oral) on matters listed on the Sunshine Agenda, which is typically released a week prior to the Commission's meeting. See 47 CFR §§ 1.1200(a), 1.1203.

I. INTRODUCTION

1. Unlicensed devices that employ Wi-Fi and other unlicensed standards have become indispensable for providing low-cost wireless connectivity in countless products used by American consumers. In this Report and Order, we seize the opportunity to expand unlicensed broadband operations into the 6 GHz band to benefit the American public. In creating this opportunity for innovators to provide new and advanced services, we are also ensuring that licensed incumbent operations in the band are protected from harmful interference and continue to deliver the high value services on which Americans rely. In making broad swaths of 6 GHz band spectrum available for unlicensed use, we envision new innovative technologies and services that will advance the Commission's goal of making broadband connectivity available to all Americans, especially those in rural and underserved areas. Unlicensed devices operating in this band are expected to work in concert with new licensed 5G services by providing consumers' ubiquitous connectivity to a full range of services regardless of location. Our actions taken in this Report and Order will help secure U.S. leadership in the next generation of wireless services.

2. The demand for wireless broadband continues to grow at a phenomenal pace. Cisco projects that mobile data traffic will more than double between now and 2022.[1] According to Ericsson the average amount of data per month used by a smartphone will increase from 7 gigabytes in 2018 to 39 gigabytes by 2024.[2] A large proportion of this mobile data traffic is delivered on an unlicensed basis through Wi-Fi, Bluetooth and similar protocols. In fact, according to Cisco, 59% of mobile data traffic will be offloaded to Wi-Fi by 2022.[3] To meet this demand, we are adopting rules to make 1200 megahertz of spectrum available for unlicensed use in the 6 gigahertz (GHz) band (5.925-7.125 GHz). Unlicensed devices will share this spectrum with incumbent licensed services under rules that are carefully crafted to protect those licensed services and to enable both unlicensed and licensed operations to thrive throughout the band. Our actions here will provide additional spectrum to complement spectrum where Wi-Fi is presently deployed to ease any existing and anticipated congestion so that businesses and consumers can take advantage of new data intensive applications.

3. We authorize two different types of unlicensed operations—standard-power and indoor low-power operations. We authorize standard-power access points using an automated frequency coordination (AFC) system. These access points can be deployed anywhere as part of hotspot networks, rural broadband deployments, or network capacity upgrades where needed. We also authorize indoor low-power access points across the entire 6 GHz band. These access points will be ideal for connecting devices in homes and businesses such smartphones, tablet devices, laptops, and Internet-of-things (IoT) devices to the Internet. As has occurred with Wi-Fi in the 2.4 GHz and 5 GHz bands, we expect that 6 GHz unlicensed devices will become a part of most peoples' everyday lives. The rules we are adopting will also play a role in the growth of the IoT; connecting appliances, machines, meters, wearables, and other consumer electronics as well as industrial sensors for manufacturing.[4]

4. As a consequence of the Commission's proposals for the 6 GHz band, industry has been proactive in developing standards for more efficient protocols that can be used in the 6 GHz band. IEEE 802.11ax is the latest version of the ubiquitous Wi-Fi standard and like its predecessor 802.11ac, features channels as large as 160 megahertz.[5] 3GPP has been developing the 5G NR-U standard which will enable unlicensed 5G networks.[6] Our actions will spur new innovation and allow consumers to experience faster internet connections and new applications. The new rules will also enable cable companies and wireless carriers to expand their Wi-Fi hotspot networks to provide customers' access to even higher speed data connections when away from home than they experience today[7] and expand their networks in areas where they need additional capacity. By making this spectrum available for unlicensed

[1] Cisco Systems, *Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2017-2022* at 31 (Feb. 2019) https://s3.amazonaws.com/media.mediapost.com/uploads/CiscoForecast.pdf (*Cisco VNI*).

[2] Ericsson, *Ericsson Mobility Report* at 17 (June 2019) https://www.ericsson.com/en/mobility-report/reports/june-2019 (*Ericsson Mobility*).

[3] *Cisco VNI* at 17.

[4] Ericsson, *The Connected Future: Internet of Things Forecast*, https://www.ericsson.com/en/mobility-report/internet-of-things-forecast (last visited Oct. 1, 2018).

[5] Afaqui et al., *IEEE 802.11ax: Challenges and Requirements for Future High Efficiency WiFi*, IEEE Wireless Communications, June 2017, 130, 133; National Instruments, *Introduction to 802.11ax High-Efficiency Wireless* (Mar. 5, 2019) http://www.ni.com/en-us/innovations/white-papers/16/introduction-to-802-11ax-high-efficiency-wireless.html#section-1277099502 Ryan Jones, *What is Wi-Fi 6 and how fast is it?* Trusted Reviews (Oct. 2, 2019) https://www.trustedreviews.com/news/wifi-6-routers-speed-3442712.

[6] Monica Alleven, *3GPP Approves Work Item to Bring 5G NR into Unlicensed Spectrum*, FierceWireless (Dec. 14, 2018) https://www.fiercewireless.com/wireless/3gpp-approves-work-item-to-bring-5g-nr-into-unlicensed-spectrum.

[7] AT&T, *Wi-Fi from AT&T*, https://www.att.com/wi-fi/ (last visited Oct. 1, 2018); Xfinity, *Xfinity WiFi Hotspot Overview*, https://www.xfinity.com/support/articles/about-xfinity-wifi-internet (last visited Oct. 1, 2018).

use, we are satisfying the American public's need for additional network capacity while safeguarding the licensed systems that will continue to use the 6 GHz band.

5. In addition to the Report and Order, we issue a Further Notice of Proposed Rulemaking proposing to permit very low power devices to operate across the entire 6 GHz band. This proposed action would make a contiguous 1200-megahertz block of spectrum available for the development of new and innovative high-speed, short range devices. We also explore ways in which we could enhance the offerings available to the American public by seeking comment on allowing additional power for low power indoor access points.

II. BACKGROUND

6. The demand for wireless broadband continues to grow at a phenomenal pace, as American citizens and businesses increasingly rely on Internet connectivity. To meet this demand, the Commission continuously evaluates spectrum use and seeks to enable more efficient usage using a variety of methods, including unlicensed operations.

7. *Incumbent services.* The 6 GHz band is comprised of allocations for Fixed Services, Mobile Services, and Fixed Satellite Services (FSS) across four sub-bands.[8] Fixed microwave service licensees, specifically those operating point-to-point microwave links that support a variety of critical services provided by utilities, commercial and private entities, and public safety agencies, are the largest user group in the 6 GHz band.[9] These fixed microwave service licensees make significant use of the U-NII-5 and U-NII-7 bands, and also operate in relatively smaller numbers in the U-NII-8 band.[10] The band is used to provide backhaul for commercial wireless providers (such as traffic between commercial wireless base stations and wireline networks), and links for coordination of railroad train movements, control of natural gas and oil pipelines, management of electric grids, and long-distance telephone service.[11]

8. The Broadcast Auxiliary Service and Cable Television Relay Service operate in the U-NII-6 band on a mobile basis, and in the U-NII-8 band on both a fixed and mobile basis.[12] Licensees use broadcast auxiliary service and Cable Television Relay Service pick-up stations to transmit programming material from special events or remote locations, including electronic news gathering, back to the studio or other central receive locations.[13] Television broadcast related microwave links, such as television studio transmitter links, television inter-city relay links, and television translator relay links, operate primarily one-way point-to-point systems in the U-NII-8.[14] Additionally, Low Power Auxiliary Stations, which operate on an itinerant basis, are authorized to operate in the U-NII-8 band on a secondary basis for uses such as portable cameras, wireless microphones, cues, and backstage communications.[15]

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[8] *Unlicensed Use of the 6 GHz Band*, Notice of Proposed Rulemaking, 33 FCC Rcd 10496, 10499-501, paras. 8-13 (2018) (Notice).

[9] Notice, 33 FCC Rcd at 10499, para. 8, Figure 1.

[10] As of March 31, 2020, the FCC databases indicate there were 30,679 call signs for fixed microwave links in U-NII-5, 17,225 in U-NII-7, and 124 in U-NII-8.

[11] Fixed Wireless Communications Coalition Comments at 3 (Oct. 2, 2017).

[12] 47 CFR §§ 74.602(a), (i), 78.18(a)(5), 78.18(a)(7).

[13] 47 CFR §§ 74.631, 78.11(e).

[14] Most systems are comprised of a single point-to-point link without a corresponding return link. 47 CFR § 74.631 and review of ULS TV Studio Transmitter (TS), TV Intercity Relay (TI), and TV Translator Relay (TT) licenses.

[15] 47 CFR § 74.802(a)(1); § 74.803(c). Wireless microphone users may operate on a licensed basis under Part 74 in the 6.875-7.125 GHz band, where eligibility is limited to broadcasters, broadcast network entities, and large venue owners/operators or professional sound companies that routinely operate 50 or more wireless microphones for major

(continued….)

9. The Fixed Satellite Service (FSS) Earth-to-space is allocated in all four sub-bands, except for the 7.075-7.125 GHz portion of the U-NII-8 band.[16] FSS operations are heaviest in the U-NII-5 band, which is paired with the 3.7-4.2 GHz space-to-Earth frequency band to comprise the "conventional C-band."[17] Predominant FSS uses of these frequencies include content distribution to television and radio broadcasters, including transportable antennas to cover live news and sports events, cable television and small master antenna systems, and backhaul of telephone and data traffic.[18] The 7.025-7.075 GHz portion of the U-NII-8 band also hosts feeder uplinks to satellite digital audio radio service space stations.[19] Additionally, FSS space-to-Earth stations operate in portions of the U-NII-7 and U-NII-8 bands for mobile-satellite service feeder links between 6.700 GHz and 7.075 GHz. However, the 7.025-7.075 GHz allocation is limited to two grandfathered satellite systems with three grandfathered locations.[20]

10. In addition to these licensed incumbents, an allocation table footnote urges that we take "all practicable steps" to protect the radio astronomy service observations in 6.650-6.6752 GHz.[21] Finally, low-power unlicensed ultra-wideband (UWB) and wideband systems operate in the 6 GHz band under our Part 15 rules.[22] Like all other Part 15 devices, UWB and wideband devices operate on a non-interference basis and are not permitted to cause harmful interference to licensed services.[23]

11. *The Notice*. In its October 2018 Notice of Proposed Rulemaking (Notice), the Commission sought comment on how best to provide new opportunities for unlicensed use in the 5.925-7.125 GHz (6 GHz) band while also ensuring that licensed services that operate in the band continue to thrive. Recognizing that a variety of incumbent licensed services occupy different portions of the 6 GHz band, the Commission proposed to permit two different types of unlicensed devices—"standard-power" access points and "low-power" access points—to operate in four different sub-bands (as indicated below).[24] These four sub-bands—which the Notice referred to as U-NII-5, U-NII-6, U-NII-7, and U-NII-8, respectively—were derived based on the prevalence and characteristics of incumbent licensed services that operate in the sub-bands.[25]

(Continued from previous page)
events/productions. *See Promoting Spectrum Access for Wireless Microphone Operations*, Report & Order 30 FCC Rcd 8739, 8789-90, paras. 131-32 (2015).

[16] 47 CFR § 2.106.

[17] 47 CFR § 25.103. We note that the Commission has recently adopted a Report and Order to eventually sunset fixed satellite service operations in the 3.7-4.0 GHz band and limit fixed satellite service operations to only the 4.0-4.2 GHz band. *See Expanding Flexible Use of the 3.7 to 4.2 GHz Band*, Report and Order and Order of Proposed Modification, FCC 20-22 (rel. Mar. 3, 2020).

[18] Notice, 33 FCC Rcd at 10501, para. 12.

[19] 47 CFR § 25.214(c)(5).

[20] 47 CFR § 2.106 footnotes NG172 and 5.458B. The space-to-Earth allocation is limited to non-geostationary mobile-satellite service feeder links and earth stations receiving in this band are limited to locations within 300 meters of coordinates in Brewster, WA, Clifton, TX, and Finca Pascual, PR.

[21] 47 CFR § 2.106 5.458A.

[22] 47 CFR § 15.250; 47 CFR Part 15, subpart F. Unlicensed UWB operations are permitted in many different frequency bands. *See* 47 CFR Part 15, subpart F. Wideband operations are mostly limited to the 6 GHz band. 47 CFR § 15.250 (limiting wideband operations to the 5.925-7.250 GHz band). For both the wideband and ultra-wideband systems permitted under the Part 15 rules, the maximum EIRP allowed is – 41.3 dBm/MHz except for certain vehicular radar systems which are restricted to an EIRP of – 61.3 dBm/MHz. *See* 47 CFR § 15.250(d)(1) and Subpart F.

[23] 47 CFR § 15.5(b).

[24] Notice, 33 FCC Rcd at 10504-05, para. 20-21.

[25] Notice, 33 FCC Rcd at 10499-501, 10503-04, paras. 8-12, 20.

Table 1: Predominant Uses of the 6 Gigahertz Band

Sub-band	Frequency Range (GHz)	Primary Allocation	Predominant Licensed Services
U-NII-5	5.925-6.425	Fixed FSS	Fixed Microwave FSS (uplinks)
U-NII-6	6.425-6.525	Mobile FSS	Broadcast Auxiliary Service Cable Television Relay Service FSS (uplinks)
U-NII-7	6.525-6.875	Fixed FSS	Fixed Microwave FSS (uplinks/downlinks)
U-NII-8	6.875-7.125	Fixed Mobile FSS	Broadcast Auxiliary Service Fixed Microwave Broadcast Auxiliary Service Cable Television Relay Service FSS (uplinks/downlinks) (6.875-7.075 GHz only)

12. To promote compatibility between unlicensed devices and the variety of licensed 6 GHz incumbents, the Commission proposed to tailor unlicensed operation by band. Specifically, for the U-NII-5 and U-NII-7 sub-bands (totaling 850 megahertz), which support a large number of high reliability point-to-point microwave links, the Commission proposed to permit unlicensed "standard-power access points" to operate under the control of an automated frequency coordination (AFC) system.[26] Under this proposal, the AFC system would determine the frequencies on which access points could operate without causing harmful interference to incumbent microwave receivers, and then make those frequencies available for use by the access points.[27] In the U-NII-6 and U-NII-8 bands (totaling 350 megahertz), where many of the incumbent operations are mobile, the Commission proposed that "low-power access points" be permitted to operate indoors without any AFC system.[28] The Commission also proposed to permit unlicensed "client devices" (i.e., a U-NII device whose transmissions are under the control of an access point and that is not capable of initiating a network[29]) to operate in all of the sub-bands at lower power levels than the respective access points.[30]

13. In the Notice, the Commission also sought comment on other unlicensed operation alternatives. In particular, it sought comment on whether to also permit indoor "low-power" access point operations in the U-NII-5 and U-NII-7 bands under the same conditions as proposed for operations in the U-NII-6 and U-NII-8 bands, without any AFC requirement, thereby permitting indoor operations across the entire 6 GHz band. It further sought comment on whether there were any other operational requirements, rules, or mitigation techniques that would allow low-power access points to operate in the U-NII-5 and U-NII-7 bands without the use of an AFC system.[31] The Commission also requested comment on whether to permit standard-power access points also to operate across the U-NII-6 and U-NII-8 bands under the control of an AFC system as proposed for the U-NII-5 and U-NII-7 bands, thereby

[26] Notice, 33 FCC Rcd at 10504, para. 20.

[27] *Id*. at 10505-06, paras. 23, 25.

[28] *Id*. at 10518, para. 59.

[29] Notice, 33 FCC Rcd at 1505, para. 23 & n.68.

[30] *Id*. at 10516, para. 53, 10521, para. 69, 10524, para. 78.

[31] *Id*. at 10522, para. 73.

permitting such operation across the entire 6 GHz band.[32] The Commission's proposals are summarized in Table 2.

Table 2: Proposed 6 GHz Unlicensed Use

Device Class	Operating Bands	Maximum Conducted Power (dBm)	Maximum EIRP (dBm)[33]	Maximum Power Spectral Density (dBm/MHz) EIRP
Standard-Power (AFC Controlled)	U-NII-5 U-NII-7 *(Sought comment on also permitting in U-NII-6 & U-NII-8)*	30 dBm	36 dBm	23 dBm
Low-power (indoor only)	U-NII-6 U-NII-8 *(Sought comment on also permitting in U-NII-5 & U-NII-7)*	24 dBm	30 dBm	17 dBm
Client (Anywhere)	All	18 dBm	24 dBm	11 dBm

14. *The record.* The Commission received comments from numerous proponents in favor of permitting unlicensed operations in the 6 GHz band, parties representing the interests of incumbent licensees raising particular concerns about potential harmful interference from proposed unlicensed operations, representatives of wireless providers requesting that portions of the 6 GHz band instead be made available for new licensed services, and other parties requesting that the Commission address various particular concerns relating to the proposals for unlicensed operations in the band. More than 150 parties commented.[34]

15. In response to the Notice, proponents of authorizing unlicensed operations in the 6 GHz band—including Apple, Broadcom, et al.,[35] the Wi-Fi Alliance, the Wireless Internet Service Providers Association (WISPA), the Dynamic Spectrum Alliance (DSA), Comcast, Charter Communications, and CableLabs—support the Commission's proposal for authorizing standard-power as well as lower power unlicensed device operations in the band. They emphasize the continued growth in spectrum demand for unlicensed operations.[36] Specifically, these commenters support the Commission's proposal to permit higher powered unlicensed standard-power operations in the U-NII-5 and U-NII-7 bands, subject to use of

[32] *Id*. at 10522-23, paras. 73-74.

[33] The proposed rules specified power in terms of a conducted power and conducted power spectral density. If an antenna with a gain greater than 6 dBi is used, the conducted power and power spectral density must be reduced by the amount the antenna gain is greater than 6 dBi. Notice, 33 FCC Rcd at 10524, para. 78.

[34] A list of commenters is presented in Appendix D.

[35] *See* Apple, Broadcom, et al. Comments (a group of companies that include Apple, Broadcom, Cisco Systems, Facebook, Google, Hewlett Packard Enterprise, Intel, Marvell Semiconductor, Microsoft, Qualcomm, and Ruckus). This specific group submitted several joint filings in this proceeding. Several of these companies also have submitted individual filings on behalf of their companies. We also note that, at times, joint filings made by Apple, Broadcom, and other companies include variations in the composition of the group, depending on the particular filing(s).

[36] *See, e.g.,* Apple, Broadcom, et al. Comments at 7-14; Wi-Fi Alliance Comments at 2-9; Open Technology Institute, et al. Comments at 2-13.

an AFC system,[37] and several also proposed permitting these operations in the lower 100 megahertz of the U-NII-8 band.[38] Unlicensed proponents also broadly support low power indoor operations, and request that such operations not be limited to the U-NII-6 and U-NII-8 sub-bands and instead be permitted across the entire 6 GHz band.[39] In addition, many support permitting "very low power" device operations across the entire 6 GHz band.[40] These commenters assert that technical rules can be established that protect incumbents from harmful interference while maximizing the utility of the 6 GHz band for innovative unlicensed devices that will provide enormous benefits to the American consumer.[41] They submitted various technical studies to support their recommendations.[42]

16. Commenters representing incumbents expressed various concerns about the potential for harmful interference to their operations from the standard-power, low power indoor, and very low power unlicensed operations. Commenting parties included the Fixed Wireless Communications Coalition, AT&T, the Utilities Technology Council, Edison Electric Institute et al., and APCO on behalf of fixed microwave incumbents,[43] Intelsat and SES Americom, Globalstar, and Sirius XM Radio representing fixed satellite service incumbents,[44] the National Association of Broadcasters (NAB) and the Society of Broadcast Engineers among others for broadcast auxiliary service incumbents,[45] and the National Academy of Sciences' Committee on Radio Frequencies regarding radio astronomy observatories.[46] Several of these commenters also submitted technical studies to support their positions.[47] The Ultra Wide Band Alliance and other UWB advocates express concern that unlicensed 6 GHz devices could potentially have adverse impacts on their systems.[48] In addition, commercial wireless interests, including CTIA and others, ask the Commission not to make all of the 6 GHz spectrum available for unlicensed operations, and instead relocate some of the incumbent licensees to make the upper portion of the 6 GHz

[37] *See, e.g.*, Apple, Broadcom, et al. Comments at 5; Cambrium Comments at 3; Charter Comments at 2; DSA Comments at 1; CompTIA Comments at 2; Facebook Comments at 2; Microsoft Comments at 13-15; Open Technology Institute et al. Comments at 2; Sony Comments at 1-2; Verizon Comments at 2-5; Wi-Fi Alliance Comments at 10; WISPA Comments at 2.

[38] *See, e.g.*, Apple, Broadcom et al. Comments at 4; Wi-Fi Alliance Comments at 10; WISPA Comments at 2.

[39] *See, e.g.*, Apple, Broadcom et al. Comments at 3-4; Facebook Comments at 2; Cisco Comments at 2; Charter Comments at 3; Hewlett Packard Enterprise Comments at 7; Netgear Comments at 2-3; Open Technology Institute, et al. Comments at 2; Wi-Fi Alliance Comments at 10-19; WISPA Comments at 3; Microsoft Comments at 1, 5, 8; Qualcomm Comments at 3.

[40] *See, e.g.*, Apple, Broadcom et al. Comments at 4; Facebook Comments at 2; Hewlett Packard Enterprise Comments at 7.

[41] *See, e.g.*, Apple, Broadcom et al. Comments at 3; Consumer Technology Association Comments at 1-3; Open Technology Institute et al. Comments at 5-13.

[42] Appendix E.

[43] *See, e.g.*, Fixed Wireless Communications Coalition Comments at 8-37; APCO Comments at 6-8; AT&T Comments at 6-8, 9-14; NPSTC Comments at 3-6; Utilities Technology Council, Edison Electric Institute, et al. (a group of commenters including the Utilities Technology Council, the Edison Electric Institute, the American Public Power Association, the National Rural Electric Cooperative, the American Petroleum Institute, and the American Water Works Association); Comments at 4-15; Los Angeles County Comments at 6.

[44] *See, e.g.*, Intelsat and SES Americom Comments at 5-15; Globalstar Comments at 8-16; Sirius XM Radio Comments at 11-24.

[45] *See, e.g.*, NAB Comments at 4-20; NCTA Comments at 8-9; Society of Broadcast Engineers Comments at 2-12.

[46] National Academy of Sciences Committee on Radio Frequencies Comments at 1-9.

[47] Appendix E.

[48] *See, e.g.*, Ultra Wide Band Alliance Comments at 6-8; Decawave Comments at 5-15; Zebra Technology Comments at 3-6.

band available for licensed wireless service providers through competitive bidding.[49] Finally, the Commission received comments from various parties on other specific issues, such as protecting incumbent operations in the adjacent 5.9 GHz band, permitting mobile operations, and permitting low power unlicensed operations in certain aircraft.[50]

III. REPORT AND ORDER

17. After review of the technical issues before us and an examination of the record, we are authorizing two types of unlicensed operations in the 6 GHz band. *First*, we authorize unlicensed standard-power access points in the U-NII-5 and U-NII-7 bands through use of an AFC system. This will permit operations at the same power levels already permitted in the 5 GHz U-NII-1 and U-NII-3 bands (5.150-5.250 GHz and 5.725-5.850 GHz bands, respectively), enabling synergistic use of both the 5 GHz and 6 GHz bands for promoting unlicensed broadband deployment.

18. *Second*, we are opening the entire 6 GHz band for unlicensed indoor low power access points. By authorizing use of the entire 6 GHz band for this type of use, we provide opportunities for up to unlicensed operations to use up to 320-megahertz channels to expand capacity and performance capabilities. This forward-looking action anticipates the next generation of unlicensed devices and advances the U.S.'s role as an innovator and global spectrum policy leader.[51] Client devices communicate using power levels that depend on the type of access point—either the standard-power or the indoor low-power access point—to which they are connected.

Table 3: Expanded Unlicensed Use of the 6 Gigahertz Band

Device Class	Operating Bands	Maximum EIRP	Maximum EIRP Power Spectral Density
Standard-Power Access Point (AFC Controlled)	U-NII-5 (5.925-6.425 GHz) U-NII-7 (6.525-6.875 GHz)	36 dBm	23 dBm/MHz
Client Connected to Standard-Power Access Point		30 dBm	17 dBm/MHz
Low-Power Access Point (indoor only)	U-NII-5 (5.925-6.425 GHz) U-NII-6 (6.425-6.525 GHz) U-NII-7 (6.525-6.875 GHz) U-NII-8 (6.875-7.125 GHz)	30 dBm	5 dBm/MHz
Client Connected to Low-Power Access Point		24 dBm	-1 dBm/MHz

19. The rules we adopt today are designed to optimize unlicensed access to the 6 GHz band while also protecting incumbent services so that they continue to thrive in the band. In our analysis below, we account for the concerns raised by parties representing the various incumbent services that operate in the 6 GHz band, weigh the various technical studies presented by proponents of unlicensed operations as well as representatives of incumbent services, and address how the rules we are adopting

[49] *See, e.g.*, CTIA Comments at 2-11; Ericsson Comments at 4.

[50] *See, e.g.*, 5GAA Comments at 2-6; Boeing Comments at 3.

[51] *See* D. Lopez-Perez, A. Garcia-Rodriguez, L. Galati-Giordano, M. Kasslin and K. Doppler, "IEEE 802.11be Extremely High Throughput: The Next Generation of Wi-Fi Technology Beyond 802.11ax," in IEEE Communications Magazine, vol. 57, no. 9, pp. 113-119, September 2019(stating that 320-megahertz bandwidth is a leading candidate for inclusion in the 802.11be standard), available at https://ieeexplore.ieee.org/document/8847238.

will enable unlicensed operations to operate in the 6 GHz band and protect the various incumbent services that operate in the band.

A. Standard-Power Operations in U-NII-5 and U-NII-7 Bands

20. In the Notice, the Commission proposed to make the U-NII-5 and U-NII-7 bands (5.925-6.425 GHz and 6.525-6.875 GHz, respectively) available for unlicensed operations under technical rules generally consistent with the existing rules for unlicensed device operations in the nearby U-NII-1 and U-NII-3 bands (5.150-5.250 GHz and 5.725-5.850 GHz bands, respectively).[52] Under this proposal, the power levels permitted for "standard-power access points" would be set at 36 dBm EIRP.[53] This is based on the power spectral density (PSD) of 23 dBm /MHz EIRP.[54] To protect incumbent fixed microwave operations in these bands, the Commission proposed that unlicensed devices at these power levels only be permitted access to spectrum under the control of an Automated Frequency Coordination (AFC) system, which would establish exclusion zones where unlicensed devices could not operate.[55] The Commission proposed that, prior to transmitting, a standard-power access point would be required to obtain from an AFC system a list of permissible frequencies or a list of prohibited frequencies on which it cannot transmit.[56] The Commission also proposed to allow unlicensed "client devices," which would operate at a 30 dBm EIRP maximum of based on a 17 dBm/MHz EIRP maximum PSD; these devices would be required to obtain a list of permissible operating frequencies from a standard-power access point and restrict operation to those frequencies.[57] In the Notice, the Commission tentatively concluded that the AFC would only be needed to protect fixed service microwave links and would not be necessary to protect incumbent fixed-satellite operations.[58]

21. The Commission's proposals were designed to address incumbents' stated requirements regarding reliable service as well as the increasing need for spectrum for innovative uses.[59] With respect to unlicensed standard-power access through the AFC system, the Commission sought extensive comment on the framework, design, and operation of the AFC system (e.g., the AFC system database, information on the incumbent microwave links and the unlicensed standard-power access points, how the system would determine permissible operating frequencies, updating frequency availability

[52] Notice, 33 FCC Rcd at 10505, para. 22.

[53] Notice, 33 FCC Rcd at 10524, para. 78.

[54] Notice, 33 FCC Rcd at 10524, para. 78. The U-NII-1 and U-NII-3 rules permit unlicensed devices to operate with up to 30 dBm conducted power into a 6 dBi antenna for a total of 36 dBm EIRP, regardless of bandwidth. *See* (47 CFR § 15.407(a)(1)(i); 15.405(a)(3). The 802.11 standards for the 5 GHz U-NII bands specify bandwidths of 20, 40, 80 and 160-megahertz (*See*, *e.g.*, M. Gong, B. Hart, M. Shiwen, "Advanced Wireless LAN Technologies: IEEE 802.11AC and Beyond," in GetMobile: Mobile Computing and Communications, January 2015 available at: https://dl.acm.org/doi/abs/10.1145/2721914.2721933). Because the maximum power is fixed the highest spectral density occurs for the narrowest channel; i.e., 20-megahertz and 36 dBm/20-megahertz is equivalent to 23 dBm/megahertz.

[55] Notice, 33 FCC Rcd at 10505, para. 23; *see also id.* at 10509, para. 37. As with the procedures that the Commission adopted for other shared-use bands, such as white spaces and the Citizens Broadband Radio Service, this process would be automated. *Id.* at 1505, para. 23. White space and Citizens Broadband Radio Service devices are required to access a database system that determines the available frequencies at a device's location prior to operation. 47 CFR §§ 15.711(c)(2), 96.39(c) 96.59(a). A device may transmit only on frequencies that the database system indicates are available for use. *Id.* §§ 15.711(c)(2), 96.39(c) 96.59(a).

[56] Notice, 33 FCC Rcd at 10506, para. 25.

[57] Notice, 33 FCC Rcd at 10524, para 78. *See* 47 CFR § 15.403(g) of the proposed rules.

[58] Notice, 33 FCC Rcd at 10506, para. 24, 10517, para. 55.

[59] Notice, 33 FCC Rcd at 10497, 10505, paras. 1-2, 22.

determinations, the AFC system security requirements, and AFC operator requirements).[60] It also sought specific comment on the appropriate interference protection parameters that the AFC system would use to protect incumbent fixed services from harmful interference from standard power access points (e.g., signal propagation model, signal fade characteristics, interference protection criteria),[61] and how client devices would operate under the control of the standard-power access point.[62] In addition, the Commission requested comment on its tentative conclusion that the AFC system was not necessary to protect fixed satellite service receivers, and whether it should adopt antenna pointing limitations on unlicensed standard-power access points to protect the satellite space station receivers.[63]

22. Based on the record before us, we adopt the proposal set forth in the Notice to permit standard power unlicensed operations in the U-NII-5 and U-NII-7 bands to operate outdoors or indoors with similar power levels as permitted for unlicensed portions of the 5 GHz band through use of an AFC system to protect incumbent fixed microwave operations from harmful interference. Specifically, we authorize standard-power access points to operate in these bands at power levels up to 36 dBm EIRP (PSD of 23 dBm /MHz EIRP), and client devices to operate at up to 30 dBm EIRP (PSD of 17 dBm/MHz EIRP). The rules we adopt for these unlicensed device operations will protect incumbent fixed microwave, radio astronomy, and fixed-satellite operations, add much needed capacity to meet the rapidly increasing demands of the wireless industry, and promote innovation and investment in new wireless unlicensed technologies. To protect incumbent fixed microwave operations from harmful interference, unlicensed access to these bands is only permitted on frequencies and locations determined by an AFC system based on the exclusion zones that it establishes. We also will protect certain radio astronomy observatories through the AFC system. Finally, in affirming the Commission's tentative conclusion that the AFC system is not necessary to protect incumbent fixed satellite service operations, we also adopt a restriction on unlicensed standard-power access point to prevent them from pointing toward the space station receivers.

1. AFC-Based Access to Protect Fixed Microwave Services

23. Consistent with the framework proposed in the Notice, the AFC mechanism, combined with the technical and operational rules that we are adopting, will protect incumbent fixed microwave operations from the potential of harmful interference from unlicensed standard-power operations in the U-NII-5 and U-NII-7 bands.[64] As noted by the Commission, the use of an automated system to control access to spectrum is not new. The Commission has previously used this approach to protect television reception from unlicensed white space devices in the TV bands and to protect satellite earth stations and government radars from devices of the Citizens Broadband Radio Service in the 3550-3700 MHz band.[65] Commenters generally acknowledge that a properly designed AFC system in the U-NII-5 and U-NII-7 bands will protect incumbent operations, though they often differ on particular design and features of that system.[66]

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[60] Notice, 33 FCC Rcd at 10506-09, 10514-15, paras. 25-36, 50-52.

[61] Notice, 33 FCC Rcd at 10509-14, paras. 37-49.

[62] Notice, 33 FCC Rcd at 10516-17, paras. 53-54.

[63] Notice, 33 FCC Rcd at 10517-18, paras. 55-58.

[64] Notice, 33 FCC Rcd at 10505, para. 22.

[65] Notice, 33 FCC Rcd at 10505, para. 22-23 & n. 66; 47 CFR § 15.713; *Amendment of the Commission's Rules with Regard to Commercial Operations in the 3550-3650 MHz Band,* Report and Order and Second Further Notice of Proposed Rulemaking, 30 FCC Rcd 3959, 4035-4069, paras. 246-378 (2015).

[66] *See, e.g.*, Fixed Wireless Communications Coalition Comments at 13; APCO Comments at 2; National Spectrum Managers Association Comments at 32 (arguing that all U-NII-5 and U-NII-7 operation must be under the control of an AFC); AT&T Reply at 15-19.

24. The AFC-based system for permitting unlicensed standard power operations in the 6 GHz bands will consist of several components which, when taken together, will determine the specific exclusion zones that will protect incumbent operations. These components include (1) the framework, design, and operation of AFC system; (2) the operational requirements that we establish regarding standard-power access points (e.g., geolocation capabilities, antenna-related restrictions); and (3) the interference protection parameters that protect the incumbent fixed service operations.

a. The AFC System Framework and Database

25. In the Notice, the Commission envisioned an AFC system that would involve a simple database that would be easy to implement and sought comment on the capabilities that should be incorporated into the system.[67] It asked whether the system should be a centralized model, i.e., where all data and computations are performed in a central location,[68] or whether the architecture should be based on a de-centralized model where the standard-power access point maintains a local database and performs the necessary computations.[69] The Commission proposed that the AFC system would use data from the Universal Licensing System (ULS) database for determining the location of incumbent fixed microwave operations for purposes of establishing the exclusion zones, and sought comment on the extent to which that information would be sufficient in identifying incumbent fixed microwave operations that would be protected by the AFC system.[70] It also sought comment on the requirements for determining the location of standard-power access points, as well as their antenna heights, which would be used by the AFC system in establishing exclusion zones.[71] In addition, the Commission asked whether the AFC system should determine frequency availability for the standard-power access points by using the maximum permissible power level for the standard-power access point, or instead determine availability at power levels less than the maximum by calculating a list of available frequencies and the maximum power level permitted at each one (similar to the white spaces database system).[72]

26. *Centralized approach.* Proponents of unlicensed operations in the band, including Microsoft, WISPA, and Hewlett Packard Enterprise, request that the Commission permit both a centralized and de-centralized AFC model to increase flexibility for access point manufacturers.[73] However, several commenters including those representing fixed microwave interest support permitting

[67] Notice, 33 FCC Rcd at 10506, para. 25.

[68] In the centralized model, each standard-power access point establishes a connection with the AFC system and provide its location and technical details. Notice, 33 FCC Rcd at 10506, para. 25. The AFC system communicates the list of permissible frequencies (or a list of prohibited frequencies) back to the standard-power access point. *Id.*

[69] In the de-centralized model, each standard-power access point performs the AFC function itself, *i.e.* it calculates frequency availability based on its location and information that it has in memory such as exclusion zones or the technical parameters of microwave systems. *See* Notice, 33 FCC Rcd at 10506, para. 25.

[70] Notice, 33 FCC Rcd at 10509-10, paras. 39-41.

[71] Notice, 33 FCC Rcd at 10514-15, paras. 50-52.

[72] Notice, 33 FCC Rcd at 10506, para. 26.

[73] *See, e.g.*, Hewlett Packard Enterprise Comments at 23 ("[T]he FCC should permit innovation so that protocols and configuration will look different from one AFC operator to another and from one AP to another."); WISPA Comments at 16 ("equipment manufacturers should not be prohibited from developing access points that will perform the same function at the local level as an alternative to (not a replacement for) the centralized model[…]"); Microsoft Comment at 18 ("Microsoft urges the Commission to allow both centralized and decentralized AFC models"); Teradek/Amimom Comments at 3 (arguing the AFC should support both options of centralized and de-centralized architecture; this will ease the AP design challenges); PIO Comments at 26 (commenting that the Commission should allow both centralized and decentralized models).

only a centralized approach for simplicity, consistency and uniformity.[74]

27. We will require the AFC to use a centralized model where each standard-power access point remotely accesses an AFC to obtain a list of available frequency ranges in which it is permitted to operate and the maximum permissible power in each frequency range. *First*, this approach is consistent with the centralized model the Commission has already employed with both the white space database system and the Citizens Band Radio Service spectrum access systems.[75] In our experience, this model has effectively facilitated widespread deployment of new services while protecting incumbents.

28. *Second*, the centralized model will facilitate Commission oversight to ensure that each AFC system provides accurate frequency availability information to standard-power access points, whereas such management would be more complicated in a de-centralized system where each access point performs the AFC function itself. For example, if there are any concerns about an AFC's frequency availability determinations, a centralized AFC model would allow the Commission to more easily investigate the cause by contacting an AFC system operator to determine the incumbent data it is using and how it is calculating the protection zones and direct the AFC operator to make any necessary corrections promptly. By contrast, we are concerned a de-centralized architecture could make such enforcement actions more difficult. The de-centralized approach may also lead to varying update times for different access points and new microwave links not being adequately protected until all access points are able to complete their updates.

29. *Third*, a centralized database approach reduces design complexity, allows for simplicity as envisioned in the Notice and enables faster development and implementation of the AFC systems. We are concerned that allowing both architectures (centralized and de-centralized) could create problematic or unforeseen complications in operational management of AFC systems and devices and thereby could delay unlicensed deployment in this band. Thus, we decline to permit use of a dual AFC architecture as some parties have suggested.

30. *Use of ULS for information on incumbent operations.* As proposed in the Notice, we will require that the AFC system rely on the Commission's Universal Licensing System (ULS) for fixed microwave link data when calculating and establishing the exclusion zones to protect those microwave links from harmful interference.[76] The Universal Licensing System is the official licensing database for microwave links in the U-NII-5 and U-NII-7 bands and contains extensive technical data for site-based licenses including transmitter and receiver locations, frequencies, bandwidths, polarizations, transmitter EIRP, antenna height, and the make and model of the antenna and equipment used. Thus, the Universal Licensing System contains the information necessary for AFC systems to protect fixed service links. Several commenters, including APCO, the Dynamic Spectrum Alliance, the Open Technology Institute et al., Apple, Broadcom et al., and Wi-Fi Alliance support using the ULS system for this purpose.[77] To

[74] *See, e.g.*, Cambium Networks Comments at 5 (arguing that a centralized location can easily be updated any time a new device is to be included in the protected services list, or if a device is no longer using resources.); MidContinent Comments at 14; Sony Comments at 3 (contending that a centralized model will minimize the cost, complexity, and resource demands of access points and client devices, thereby encouraging market adoption.); Northeast Colorado Cellular Comments at 2; NPSTC Comments at 10 (pointing out that, if the AFC is centralized, the algorithms and protocols can be updated as needed rather easily, as compared to updating every deployed access point and associated client device); City of Austin Comments at 2; City of New York Comments at 3; El Paso Electric Comments at 3 ("any registration requirement should include a centralized AFC system operated by a single organization for the sake of consistency and uniformity"); Idaho Power Comments at 6; Ultra Wideband Alliance Comments at 8.

[75] 47 CFR §§ 15.711(c)(2)(i), 96.39(c).

[76] Notice, 33 FCC Rcd at 10509, para. 39.

[77] APCO Comments at 10 (ULS contains data sufficient for the AFC system's purposes, and would have the added benefit of providing a single, authoritative source of licensees' information); Nokia Reply at 2 (the Commission's ULS database can be used as long as the ULS information is accurate, up-to-date and covers the necessary fixed link (continued….)

ensure that AFC systems have the most recent information on fixed service links, we will require AFC systems to download the database on a daily basis.

31. We recognize the concerns of some parties that information used by the AFC systems must be accurate and up-to-date,[78] and note that there may currently be some inaccurate or incomplete data in the Universal Licensing System database.[79] Because ULS is the official Commission compendium of license records, licensees are obligated under the terms of their licenses to keep their information filed with the Commission current and complete. Thus, licensees have the responsibility, as well as significant incentive, to maintain the continued accuracy of data in the Universal Licensing System to ensure that they are protected from harmful interference not only from new unlicensed devices, but also from new fixed microwave links that may access the band.[80] To the extent licensees determine that their actual operations differ from the Commission's licensing records, they should modify those records to ensure they are properly protected from harmful interference from any other spectrum users, and we direct the Wireless Telecommunications Bureau to issue a public notice following release of this order reminding such licensees of the importance of maintaining accurate information in that system.[81]

32. Microwave links may begin operation prior to obtaining a license so long as certain criteria are met, such as completing successful frequency coordination and filing an application that appears in the Universal Licensing System as pending.[82] Because such a filing may indicate that a new station is operational, or soon will be, we will require the AFC system to protect pending as well as granted facilities. In addition, temporary fixed microwave links may be authorized by a blanket authorization, in which case the licensee is not required to obtain approval from the Commission prior to operating at specific locations or report the technical details of their operation to the Commission.[83] Because the AFC system must have knowledge of the location of temporary fixed links in order to protect them from harmful interference, we will require the operators of temporary fixed stations to register the

(Continued from previous page)
parameters); Dynamic Spectrum Alliance Reply at 8-10 (the Universal Licensing System is fully capable of supplying accurate and up-to-date information to AFCs); Open Technology Institute, et al. Comments at 28 (agreeing with Commission's proposal that AFC systems use data from ULS); Apple, Broadcom, et al. Comments at C-5 (ULS location information is generally accurate but corrections should be encouraged); APCO Comments at 10 (ULS contains data sufficient for the AFC system's purposes and would have the added benefit of providing a single, authoritative source of licensees' information); Wi-Fi Alliance Comments at 21 (ULS contains all the necessary data fields for 6 GHz licensed incumbents for an AFC to determine where frequencies may be available for unlicensed use).

[78] *See, e.g.*, Dakota County, New Mexico Comments at 1; Cook County Sheriff's Police Department Comments at 2-3; Washington County Sheriff's Office in Minnesota Comments at 1-2; City of Portland, Oregon Comments at 1; Bastrop County, Texas Comments at 1; County of St. Croix, Wisconsin Comment at 1; Lucas County Sheriff's Office Comment at 1; Lincoln County, Oregon Comments at 1; EcliptixNet Broadband Comments at 1; Singer Executive Development Comments at 1; Comsearch Comments at 16-17; Fixed Wireless Communications Coalition Comments at 33; City of Los Angeles Reply Comments at 8.

[79] *See* Comsearch Comments at 17-20 (the ULS is primarily an administrative rather than a technical database and is of limited utility in informing interference analysis necessary to allow additional use in the band by unlicensed devices); Fixed Wireless Communications Coalition Reply at 34 (receiver data in ULS is error-prone and unreliable; more complete and accurate fixed microwave receiver databases exist).

[80] Notice, 33 FCC Rcd at 10509, para. 39.

[81] Some parties argue that if the Commission uses ULS as a data source it should allow a temporary waiver of filing fees for data corrections before the AFC becomes operational. FWCC Comments at 28, Microsoft Reply at 17, Dynamic Spectrum Alliance Reply at 8-10. Filing fees are mandated by statute and cannot be waived by the Commission. 47 U.S.C. § 158(a).

[82] 47 CFR § 101.31(b); Notice, 33 FCC Rcd at 10510, para. 41.

[83] 47 CFR § 101.31(a)(2); Notice, 33 FCC Rcd at 10510, para. 41.

details of their operations (transmitter and receiver location, antenna height, antenna azimuth, antenna make and model, etc.) in the Universal Licensing System prior to transmission if they desire to be protected from potentially receiving harmful interference from standard-power access points in the U-NII-5 and U-NII-7 bands.[84] Because temporary fixed links are not mobile and intended to operate at a specified location for up to a year,[85] we do not believe this registration requirement poses a significant burden on licensees.

33. *Information on microwave operations in border areas near Canada and Mexico*. As required by international agreements, and consistent with actions regarding white spaces and the CBRS, we will require the AFC to protect microwave operations in Canada and Mexico near the United States border.[86] We recognize that the ULS does not contain information on microwave operations in these countries. We therefore intend to work with the governments of Canada and Mexico to obtain information on microwave systems in those countries and a method for providing it to AFC operators for incorporation into their systems.

34. *Information on location and antenna height of standard-power access points.* The AFC system also will make use of data concerning the location and antenna height of standard-power access points when calculating the availability of frequencies and channels of operations. We establish particular operational requirements for access points in this Order that ensure the accuracy of this data.

35. *Use of specified interference protection parameters.* The AFC system will apply the specified interference protection parameters established in this Order to protect fixed microwave operations from harmful interference. These include use of specified propagation models and a conservative interference protection criterion when calculating exclusion zones, and the methodology for addressing adjacent channel operations.

36. *Determining frequency and channel availability based on unlicensed device power levels*. As suggested by several commenters, we will require that the AFC have the capability to determine frequency availability at the maximum permissible power of 36 dBm for standard-power access points, as well as at lower power levels.[87] Because the minimum required separation distance from a fixed service receiver, among other factors, is a function of the access point power, lower power devices do not have to meet as large a separation distance to provide the same level of protection as higher power devices. This means that more spectrum may be available for access points that operate with power levels below the maximum, especially in congested areas where spectrum is more heavily used by the fixed microwave services. This action is consistent with the Commission's white space rules in which white space devices operating at power levels less than the maximum have shorter required separation distances from protected services, and the white space database provides devices with a list of available frequencies and the maximum permissible power on each.[88]

37. We will require that the AFC system be capable of determining frequency availability in

[84] The capability to register temporary fixed links does not currently exist in the ULS system. That functionality will be developed upon adoption of this Order and its availability will be announced by Public Notice.

[85] 47 CFR § 101.3.

[86] 47 CFR §§ 15.712(g), 15.713(j)(1), 96.19.

[87] *See, e.g.* Midcontinent Communications Comments at 17 (contending that the AFC system should calculate a list of available frequencies and the maximum power permitted on each frequency); Sony Comments at 4 (maintaining that the AFC system should determine frequency availability at power levels less than the maximum, and then calculate a list of available frequencies and the maximum power permitted on each one); Teradek/Amimon Comments at 4; Wi-Fi Alliance Comments at 21 (maintaining that the AFC should provide the device with a list of permissible frequencies at various transmit power levels and allow the device to select appropriate options); Wi-Fi Alliance Reply at 21-22.

[88] 47 CFR §§ 15.712(a)(2), 15.715(e).

steps of no greater than 3 dB below the maximum 36 dBm permissible EIRP, down to a minimum level of 21 dBm. While commenters did not suggest a specific interval between power levels or a minimum power level, we believe 3 dB is an appropriate step size because it is large enough to be significant (i.e. a factor of two), and will allow the AFC to determine frequency availability at multiple power levels so a device can select its optimum frequency and power level combination. Our requirement that an AFC only consider power levels as low as 21 dBm is predicated on our expectation that outdoor access points will generally operate at the higher power levels to maximize coverage area or throughput or both. However, because certain situations or applications may not need that much power, there may be a need for AFCs to evaluate additional power levels. We will not preclude AFC operators from determining frequency availability at additional power levels, e.g., below 21 dBm or in smaller step sizes; we are simply establishing minimum AFC performance requirements. Consistent with the white space rules, the AFC will provide a list of available frequencies and power levels to standard-power access points but will not select the frequency or control the power level of a device.[89] Rather, each access point will select its operating frequency and power level from the list provided by the AFC.

b. Operational Requirements for Access Points

38. As discussed in the Notice, the AFC system requires a device's geographic coordinates—along with the accuracy of those coordinates—and the device's antenna height above ground, in order to determine which frequencies are available for use at its location.[90] The Commission sought comment on whether it should require all standard power access points to incorporate a geo-location capability, or whether there are other means that could be used to obtain location information, such as a street address and floor number.[91] It also sought comment on the degree of location accuracy necessary to protect the fixed service, and whether it would be more appropriate to instead determine the uncertainty of the computed location, and then have the AFC adjust the separation distance between the standard-power access point and fixed service receivers based on the location uncertainty.[92] The Commission further sought comment on the appropriate method for determining the antenna height above ground, and whether to require that every standard-power access point be professionally installed.[93]

39. Several commenters support the use of automated geo-location, but suggest that we allow professional installation as an alternative,[94] while others support requiring professional installation in all cases.[95] NAB supports requiring automatic geo-location and opposes relying on professional installation

[89] 47 CFR § 15.711(c)(2).

[90] Notice, 33 FCC Rcd at 10514-16, paras. 50-52.

[91] Notice, 33 FCC Rcd at 10516, para. 52.

[92] Notice, 33 FCC Rcd at 10514-15, para. 50.

[93] Notice, 33 FCC Rcd at 10515, para. 51-52.

[94] *See, e.g.*, Microsoft Comments at 19 (arguing the Commission should permit, but not mandate, professional installation); Qualcomm Comments at 17 (arguing professional installation is one means of ensuring reliable geolocation information and should be allowed, but the Commission should not require professional installation because there are other reliable means by which location can be determined).

[95] *See, e.g.*, Midcontinent Communications Comments at 7 (supporting professional installation and certification program); Sony Electronics Comments at 5 (The Commission should require professional installation of all access point that operate in the U-NII-5 and U-NII-7 bands because it will facilitate verification of these parameters and the accuracy of the access point geolocation.); APCO Comments at 14 (contending professional installation may be necessary for obtaining reliable location information in some situations); NSMA Comments at 31 (endorsing a "professionally installed" requirement for standard-power access points).

as a means of verifying the accuracy of data.[96] Several commenters, including Comsearch, APCO, Apple, Broadcom, et al., and Dynamic Spectrum Alliance, discussed the geo-location capabilities that they believe are appropriate.[97]

40. *Incorporated geo-location.* We will require all standard-power access points to include an internal geo-location capability to determine their geographic coordinates, rather than relying on a professional installer to determine them. Additionally, an incorporated geo-location capability provides a means for a device to automatically re-establish its coordinates if they are lost or altered due to a power outage or equipment reboot.

41. As suggested by Comsearch, we will require a device's internal geo-location capability to determine its location uncertainty and report it to the AFC system, which will use this information to determine the minimum required separation distances from fixed service receivers.[98] While commenters did not specifically address the appropriate accuracy level for the geo-location uncertainty measurement, we will require that it be determined, in meters, with 95% confidence level, which is consistent with the rules for white space devices which operate with similar geo-location requirements to those we are adopting for AFC controlled standard-power access points.[99] Our experience with this rule confirms that it reliably ensures protection against harmful interference, at reasonable cost.

42. We recognize that geo-location technologies such as GPS do not work at locations where satellite signals are blocked by obstructions such as tall buildings and trees, or deep within buildings.[100] To ensure that standard power access points can accurately determine their coordinates and provide them to the AFC in these situations, without the need for professional installation, we are providing additional flexibility for manufacturers and device operators by making provisions for standard-power access points that operate in locations where an incorporated geo-location capability may not work. The Commission provides similar flexibility in other services where it requires devices to accurately determine their location.[101] In this regard, we will allow standard-power access points to obtain their geographic

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[96] NAB Comments at 17 (recommending that the Commission not allow professional installation as a means of verifying the accuracy of data); NAB Reply at 11 ("[T]he geographic coordinates of the access point should be automatically determined by GPS or a similarly reliable method except in the most unusual circumstances.").

[97] *See, e.g.*, Comsearch Comments at 27 (arguing each unlicensed device must be able to determine the accuracy of its position; this location accuracy would be used to determine the worst-case position of the unlicensed device with respect to the microwave receiver exclusion zone); APCO Comments at 14 (supporting a geolocation capability requirement for standard-power access points; professional installation may be necessary for obtaining reliable location information in some situations); Apple, Broadcom et al. Comments at 54 (maintaining GPS could provide location information for AFC-controlled devices to allow effective operation of the protection mechanism); Dynamic Spectrum Alliance Comments at 12 (arguing the Commission should allow geolocation strategies to adapt to the diversity of users and cost points in the unlicensed device market).

[98] Comsearch Comments at 27; *see also* APCO Comments at 14 ("The AFC system should evaluate the worst-case value based on sufficiently stringent uncertainty measurements in each dimension.").

[99] *See* 47 CFR § 15.711(b)(1), (c). White space devices also provide their coordinates, location uncertainty and antenna height to a database that determines the available frequencies at a location. 47 CFR § 15.711(b)(1).

[100] APCO Comments at 14 (supporting a geolocation capability requirement for standard-power access points and maintaining that professional installation may be necessary for obtaining reliable location information in some situations).

[101] *Amendment of Part 15 of the Commission's Rules for Unlicensed White Space Devices; Amendment of Part 15 of the Commission's Rules for Unlicensed Operations in the Television Bands, Repurposed 600 MHz Band, 600 MHz Guard Bands and Duplex Gap, and Channel 37; Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions,* ET Docket Nos. 16-56 and 14-165 and GN Docket No. 12-268, Report and Order and Order on Reconsideration, 34 FCC Rcd 1827, 1833, para. 17 (*White Spaces Report and Order and Order on Reconsideration*); 47 CFR § 15.711(c)(1).

coordinates through an external geo-location source when they are used at locations where their internal geo-location capability does not function.[102] We will allow an external geo-location source to be connected to an access point through either a wired or a wireless connection and will allow a single geo-location source to provide location information to multiple access points.[103] We will require that an external geo-location source be connected to an access point using a secure connection to ensure that only an external geo-location source approved for use with a device provides geographic coordinates to that device.[104] Additionally, we will allow the use of extender cables to connect a remote receive antenna to a geo-location receiver within a fixed device.[105] In cases where equipment uses a remote geo-location source, the separation distance between the access point transmit antenna and geo-location source must be included in the location uncertainty reported to the AFC system.[106] Based on our experience, we believe these provisions will increase the manufacturers' flexibility to develop devices that can be used in a wide variety of locations while ensuring that devices accurately determine their location and report it to the AFC to prevent harmful interference to protected services.

43. Considering the geo-location requirements that we are adopting, we are not requiring professional installation. We agree with Microsoft and Qualcomm that a professional installation requirement is not necessary because manufacturers can incorporate a variety of location technologies into their devices; many of these, such as GPS, are widely available at low cost.[107] Further, we believe that requiring professional installation of all standard-power access points would be burdensome and that requiring devices to incorporate automatic geo-location will ensure that the information provided to the AFC system is accurate.

44. *Antenna height above ground.* For the AFC to accurately calculate exclusion zones to protect fixed service receivers, it requires the antenna height above ground of a standard-power access point. Consistent with the rules for white space devices, we will permit this information to be provided to the AFC either automatically by the device, or manually by the installer or operator of the device but will not require it to be determined by a professional installer.[108]

45. Because automated geo-location methods such as GPS may not accurately provide height information in all cases, we will allow a device installer to manually determine the antenna height above ground and provide it to the AFC. As the Commission noted with respect to white space devices, installers with simple measuring equipment should be able to accurately determine antenna height above ground.[109] However, because improvements in technology in the future could enable devices to automatically determine their antenna height above ground with more precision, we are providing the option for standard-power access points to automatically do so.[110] We expect that industry groups will

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[102] 47 CFR § 15.711(c)(1)(iii).

[103] *See id.*

[104] A smartphone with appropriate software loaded could conceivably be used as an external geo-location source, provided the applicant for equipment authorization can demonstrate that it will reliably supply accurate coordinates to a standard-power access point.

[105] 47 CFR § 15.711(c)(1)(iii).

[106] This requirement will be enforced through the equipment certification process.

[107] Microsoft Comments at 19 (the Commission should permit, but not mandate, professional installation); Qualcomm Comments at 17 (professional installation is one means of ensuring reliable geolocation information and should be allowed, but do not require professional installation because there are other reliable means by which location can be determined).

[108] 47 CFR § 15.711(c).

[109] *White Spaces Report and Order and Order on Reconsideration*, 34 FCC Rcd at 1838, para. 32 & n. 77.

[110] We note that the Commission has rules and a separate proceeding on determining the vertical location (z-axis) accuracy of wireless handsets for Enhanced 911 (E911) calls. 47 CFR §20.18(i)(2)(ii) and PS Docket No. 07-114.

(continued….)

work on developing methods for automatic height determination that could be used for standard-power access points or other applications where the antenna height above ground must be known.

46. *Frequency availability re-check interval*. The Notice proposed to require devices to periodically verify whether frequency availability has changed and sought comment on the maximum permissible interval for verifying frequency availability.[111] As supported by a number of commenters and consistent with the requirements for white space devices, we will require a standard-power access point to contact an AFC system at least once per day to obtain the latest list of available frequencies at its location.[112] We find that once per day is an appropriate re-check interval because the Commission's Universal Licensing System, from which the AFC system will obtain data, is updated on a daily basis. We disagree with recommendation of Comsearch, Apple, Broadcom, et al., Hewlett Packard Enterprise and Wi-Fi Alliance that of a 30-day re-check interval be instituted.[113] While the likelihood is low that a new microwave link will become operational on any given day at a given location, when 6 GHz devices are widely deployed there will be situations where new microwave links are licensed in the vicinity of co-channel standard-power access points. To ensure that an unlicensed device quickly ceases operation on a frequency that becomes licensed for a microwave link near its location, we are requiring all standard-power access points to re-check their frequency availability on a daily basis, i.e., the same as the Universal Licensing System update interval.

47. We recognize that there may be situations when an AFC system is temporarily unavailable due to a sustained power loss, an Internet outage, or other circumstances that disrupt a device's ability to contact an AFC system.[114] Consistent with the Commission's actions in other proceedings, we will permit an access point that cannot contact the AFC system during any given day to continue operating until 11:59 p.m. of the following day at which time it must cease operations until it re-establishes contact with the AFC system and re-verifies its list of available frequencies.[115] We do not believe that a one-day grace period is likely to result in harmful interference to fixed service links because an access point being unable to contact the AFC system for a day is likely to be a relatively infrequent occurrence, and the probability that it will occur at the same time in the same place where a new microwave link commences operation is low.

c. Multi-Stakeholder Group

48. In the Notice, the Commission noted that parties suggested that a multi-stakeholder group could administer AFC system requirements and standards through interaction with AFC system operators

(Continued from previous page)
An applicant for equipment authorization of a standard-power access point that relies on automatic means to determine the antenna height above ground will be required to describe the method used as well as its accuracy in its application.

[111] Notice, 33 FCC Rcd at 10507, para. 30.

[112] *See* 47 CFR §§ 15.711(c)(2)(iii) (requiring daily check-ins by white space devices to verify that the operating channel is still available); Fixed Wireless Communications Coalition Comments at 13 (require each radio local area network (RLAN) to update its permissions at least once every 24 hours); APCO Comments at 7 (access points should be required to periodically verify whether frequency availability has changed at least once every 24 hours); Teradek/Amimon Comments at 2 (database re-check no more than once every 24 hours); National Spectrum Management Association Comments at 14 (frequency availability should be verified daily as the FCC database is updated daily).

[113] Wi-Fi Alliance Comments at 23; Apple, Broadcom, et al. Comments at 49 and C-4; Hewlett Packard Enterprise Reply at 27; Comsearch Reply at 8.

[114] *Unlicensed Operation in the TV Broadcast Bands and Additional Spectrum for Unlicensed Devices Below 900 MHz and in the 3 GHz Band*, ET Docket Nos. 04-186 and 02-380, Second Report and Order, 23 FCC Rcd 16807, 16879, para. 206 (2008).

[115] 47 CFR § 15.711(c)(2)(iii), (h).

and sought comment on this suggestion, and on the appropriate mechanism for ensuring Commission oversight of such a multi-stakeholder group.[116] The record supports formation of an industry led multi-stakeholder group to study technical and operational issues in the 6 GHz Band.[117] Such groups have been successful in the past in providing the Commission with valuable insights and useful information regarding new spectrum uses.[118] We believe that a similar multi-stakeholder group focused on the 6 GHz band could provide valuable insight into its complex coexistence issues and provide a forum for the industry to work cooperatively towards efficient technical solutions. We encourage the industry to convene a group of interested stakeholders to address issues such as interference detection and mitigation, AFC system and standard power access point security measures, AFC system testing and certification procedures and ensuring that AFC systems contain complete and up-to-date incumbent data. To ensure that all viewpoints are considered, we encourage industry to include representatives of wireless service providers, network equipment manufacturers, potential AFC operators, fixed service vendors and operators, existing 6 GHz band incumbent licensees, and other parties with an interest in 6 GHz band operations. We do not, however, take a position on the exact makeup or organizational structure of any such stakeholder group.

49. The Commission's Office of Engineering and Technology (OET) will act as a liaison for the Commission with any such multi-stakeholder group so formed. In particular, we expect the Office to observe the functioning of any such group and the technical concerns that it is considering. We also expect OET to provide guidance to any such group on the topics on which it would be most helpful for the Commission to receive input and a sense of the time frames in which such input would be helpful.

d. Designating AFC Operators

50. *Operator approval and system certification process.* Consistent with the Commission's actions regarding white spaces and the CBRS, we direct the Chief of the Office of Engineering and Technology (OET) to designate AFC system operators and oversee operation of their systems.[119]

51. OET will designate AFC operators using a multi-stage review process similar to that it used for designating white space database and SAS administrators.[120] As the first step, the OET will issue a public notice inviting prospective AFC system operators to submit proposals describing how their

[116] Notice, 33 FCC Rcd at 10508, para. 34.

[117] Dynamic Spectrum Alliance Reply at 13 (technical implementation details can be delegated to an expert multi-stakeholder group); Federated Wireless Comments at 9 (the Commission should rely on cross-industry stakeholder groups to develop consensus standards for the performance of the AFC); Midcontinent Communications Comments at 14 (supports a multi-stakeholder group taking the lead on AFC system certifications with oversight from the Commission); Comsearch Comments at 23 (a neutral multi-stakeholder group will help ensure that the AFC is developed and managed more quickly and efficiently); WinnForum Comments at 2; Motorola Solutions Comments at 4; Open Technology Institute et al. Comments at 27 (protection criteria and many other technical details can be, and likely should be, delegated to a multi-stakeholder process; Nokia Reply at 2 (the Commission and/or a group of stakeholders should define the requirements of the AFC system in detail).

[118] For example, after the Commission created the Citizen's Broadband Radio Service, the Wireless Innovation Forum stood up the Spectrum Sharing Committee to serve as a common industry and government standards body to support the development and advancement of Citizen's Broadband Radio Service Standards. *See* https://cbrs.wirelessinnovation.org/about.

[119] 47 CFR § 0.241(h), (j).

[120] *Unlicensed Operation in the TV Broadcast Bands and Additional Spectrum for Unlicensed Devices Below 900 MHz and in the 3 GHz Band*, Order, 26 FCC Rcd 554 (2011); *Unlicensed Operation in the TV Broadcast Bands and Additional Spectrum for Unlicensed Devices Below 900 MHz and in the 3 GHz Band*, Order, 26 FCC Rcd 10599 (2011); *Amendment of the Commission's Rules with Regard to Commercial Operations in the 3550-3650 MHz Band*, Report And Order and Second Further Notice of Proposed Rulemaking, 30 FCC Rcd 3959, 4067, para. 369-372 (2015).

systems would comply with all Commission AFC rules.[121] The public will have an opportunity to review and comment on these AFC system proposals. OET will conditionally approve applicants that demonstrate that their proposed systems would comply with all AFC requirements. Applicants that receive a conditional approval will then be required to provide a test system that will be subject to a public trial period to provide interested parties an opportunity to check that it provides accurate results. This trial period will include thorough testing, both in a controlled environment (e.g., lab testing) and through demonstration projects (e.g., field testing).

52. We intend to work with industry stakeholder groups as necessary to develop appropriate procedures for thoroughly testing AFC systems prior to use. We will not grant final approval for an AFC system operator to begin providing service until after the operator satisfactorily demonstrates that standard-power access points can operate under the control of its system without causing harmful interference to fixed wireless services.

53. *Multiple AFC Operators.* As proposed in the Notice, we will allow multiple AFC operators to be designated.[122] Commenters support designating multiple AFC system operators and no parties opposed this proposal.[123] This action is consistent with the rules for white spaces and the CBRS.[124] As the Commission previously noted in regard to white spaces databases, this would prevent a single party from obtaining monopoly control over the AFC systems, could provide an incentive for AFC system operators to provide additional services beyond those required by the rules, and is more likely to result in lower costs to consumers.[125]

54. We will permit AFC functions, such as a data repository, registration, and query services, to be split among multiple entities, as is done for white spaces and the CBRS.[126] No parties commented on this specific issue. This approach will allow greater flexibility in AFC system design and potential cost savings by allowing multiple operators to share the costs of running parts of an AFC systems.[127] However, to ensure that the Commission can effectively oversee the AFC system operation, we will require that entities designated as AFC system operators be held accountable for all aspects of system administration, including any functions performed by third parties.

55. *Term of AFC Designation*. The Commission proposed that an AFC system operator be required to serve for a five-year term which can be renewed by the Commission based on performance during the operating term.[128] It further proposed that if an AFC system ceases operation, it must provide a minimum of 30-days' notice to the Commission and transfer its registration data to another AFC system operator.[129] Several commenters including Wi-Fi Alliance support the Commission's proposal for a five-

[121] For example, see *Office of Engineering and Technology Invites Proposals from Entities Seeking to be Designated TV Band Device Database Managers*, Public Notice, 24 FCC Rcd 14136 (OET 2009).

[122] Notice, 33 FCC Rcd at 10507, para 33.

[123] *See, e.g.*, Comsearch Comments at 25; Dynamic Spectrum Alliance Comments at 12; Federated Wireless Comments at 11; Quantenna Comments at 5; Sony Comments at 7; WISPA Comments at 19; Motorola Comments at 4; Open Technology Institute et al. Comments at 26.

[124] 47 CFR §§ 15.715, 96.63.

[125] *Unlicensed Operation in the TV Broadcast Bands and Additional Spectrum for Unlicensed Devices Below 900 MHz and in the 3 GHz band*, ET Docket Nos. 04-186 and 02-380, Second Memorandum Opinion and Order, 25 FCC Rcd 18661, 18704-05, para. 104 (2010) (*White Spaces Second MO&O*).

[126] 47 CFR §§ 15.715, 96.63.

[127] Several parties requested that we allow flexibility in AFC system design. *See* Apple Comments at 6; Broadcom Comments at 4; HP Comments at 24; Microsoft Comments at 17; Qualcomm Comments at 12.

[128] Notice, 33 FCC Rcd at 10508, para. 35.

[129] *Id.*

year term.[130] However, Wi-Fi Alliance claims that it is impractical to require an AFC operator to transfer registration information at the end of the term and that an AFC operator should have the flexibility to discontinue operations at its discretion.[131]

56. To ensure a stable operating environment for standard-power access points and consistent with both the white space and CBRS rules, we adopt our proposal for a five-year term which, at the Commission's discretion, may be renewed.[132] Similar to the requirements for the white space database and SAS administrators, in the event an AFC system operator does not wish to continue to provide services , or if its term is not renewed, the system operator will be required to transfer its database along with the information necessary to access the database to another designated AFC system and will be permitted to charge a reasonable fee for the transfer of this information.[133] Transferring this information assures operational continuity for existing devices; otherwise in the event an AFC discontinues service, devices would be denied operating frequencies and cut-off from providing services until it established a connection to a new database. This action allows that new connection to occur automatically.

57. We disagree with Wi-Fi Alliance that it would be burdensome for an AFC operator to transfer its registration data to another AFC system operator since the data that must be transferred (e.g., location, antenna height, device FCC ID and serial number) is relatively simple. We are also adopting our proposal that an AFC system operator must provide a minimum of 30 days' notice to the Commission when it plans to cease operation. Because standard-power access points must be able to access an AFC in order to operate, we do not believe that the Commission should designate AFC system operators that could cease operation at any time with no notice as that could leave users with equipment that ceases operating unexpectedly.

58. *Fees.* The Commission proposed in the Notice that an AFC system operator be permitted to charge a fee for providing registration and channel availability functions.[134] It further noted that fees could be charged on a transaction basis every time a device is registered, or when it receives an update from an AFC system.[135] Many commenters support permitting AFC system operators to charge a reasonable transaction fee for providing registration and channel availability functions.[136] However, Open Technology Institute, et al. state that while cost recovery is a given, the Commission should also strive to minimize transaction costs and arrangements that exclude or deter ordinary consumers.[137] Consistent with the rules for white space database and CBRS SAS administrators and as supported in the

[130] *See, e.g.,* WISPA Comments at 20; Wi-Fi Alliance Comments at 29; Sony Comments at 8; Midcontinent Communications Comments at 14.

[131] Wi-Fi Alliance Comments at 29.

[132] 47 CFR §§ 15.715(h), 96.63(e).

[133] 47 CFR §§ 15.715, 96.63.

[134] Notice, 33 FCC Rcd at 10508, para. 36.

[135] *Id.*

[136] Comsearch Comments at 25-26; Dynamic Spectrum Alliance Comments at 12; Quantenna Communications; Comments at 4; Microsoft Comments at 18; Wi-Fi Alliance Comments at 30 (arguing AFC system operators should be permitted to charge market-based fees); Midcontinent Communications Comment at 14.

[137] Open Technology Institute et al. Comments at 4. It also argues that that if low power and indoor-only use of the 850 megahertz in the U-NII-5 and 7 bands would be subject to AFC control and professional installation rules, consumers and small business would be swept up in cumbersome registration process and fees. Because we are not requiring AFC for such uses, this concern is moot.

record, we will permit AFC operators to charge fees for the provision of service.[138]

59. Because we are allowing multiple AFC operators to be designated, we believe that competition among them will serve to keep fees reasonable and will allow for multiple business models that could benefit consumers, e.g., device manufacturers or a trade association could fund an AFC system as part of its business and no individual transaction fees would be charged.[139] However, as with white space databases and the CBRS SAS, we will permit parties to petition the Commission to review fees and require changes to the fees if they are found to be excessive.[140]

60. *AFC to AFC synchronization requirements.* In the Notice, the Commission sought comment on whether each AFC system could operate autonomously or whether there would be a need for them to communicate any information with each other, and if so, what information would need to be exchanged.[141] The National Spectrum Management Association and NAB request that AFC operators be required to share data that can be used in interference mitigation and to ensure that all databases contain the same information on protected entities.[142] However, Apple, Broadcom, et al. and the Dynamic Spectrum Alliance argue that there is no need to require AFC operators to synchronize data because such a requirement would impose substantial burdens on the AFC systems with no corresponding benefit.[143]

61. We conclude that, under the AFC system that we are adopting, there is no need to require AFC systems to synchronize their data with each other. Unlike white space database systems that must accept and share registration information from protected entities, e.g., cable headends and licensed wireless microphone operators, that cannot be obtained from Commission databases, AFC systems will obtain their data on protected entities from a single source (the ULS).[144] Therefore, there will be no need for AFC operators to synchronize protected entity information between different systems as NAB suggests. Additionally, because we are not requiring AFC systems to consider aggregate interference from multiple standard-power access points when determining frequency availability, there is no need for the AFC systems to share information about registered standard-power access points.

e. Interference Protection Analyses and Parameters

62. As proposed in the Notice, we will protect fixed microwave operations from harmful interference by using an AFC system that establishes location and frequency-based exclusion zones for standard-power unlicensed devices around fixed microwave receivers operating in the U-NII-5 and U-NII-7 bands.[145] Under this AFC system, individual unlicensed devices will not be permitted to operate on certain frequencies within the exclusion zone. Below, we discuss technical parameters that the AFC system will use to calculate these exclusion zones.

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[138] Comsearch Comments at 26 (supporting the Commission's proposal to permit AFC operators to collect fees); Dynamic Spectrum Alliance Comments at 12 (the Commission should permit but not require AFC system operators to charge fees); Quantenna Communications Comments at 4; 47 CFR §§ 15.714, 96.65.

[139] Notice, 33 FCC Rcd at 10508-09, para. 36.

[140] 47 CFR §§ 15.714(c), 96.65(b).

[141] Notice, 33 FCC Rcd at 10508, para. 33.

[142] National Spectrum Management Association Comment at 14; NAB Reply at 11.

[143] Dynamic Spectrum Alliance Reply at 12-14; Apple, Broadcom et al. Comments at 67 (arguing further that these burdens would grow exponentially as additional AFC systems are certified).

[144] Under the white space rules, protected entities not listed in Commission databases, e.g., cable headends and licensed wireless microphones, may register their operational parameters with a single white space database administrator, which must then synchronize this information with all other white space databases. 47 CFR §§ 15.713(b)(2), 15.715(l).

[145] *See* Notice, 33 FCC Rcd at 10505, 10509, paras. 23, 37.

63. *Propagation models.* As proposed in the Notice, evaluating potential harmful interference from U-NII-5 and U-NII-7 unlicensed standard-power access point devices depends on the propagation models assumed for both fixed microwave signals and unlicensed devices. The propagation model that we adopt will, in turn, be used by the AFC system as one of the factors when determining the exclusion zones.

64. The Commission sought comment in the Notice on different propagation models, including use of a free space path loss model as well as the WINNER II and Irregular Terrain Model and ITU-R P.2108 models.[146] Commenters expressed widely divergent opinions. Apple, Broadcom, et al., the Wi-Fi Alliance, and CableLabs recommend use of propagation models that are combinations of WINNER II, Irregular Terrain Model, and ITU clutter models (including ITU-R P.2108 for urban and suburban areas, and ITU-R P.452-16 for rural areas).[147] In contrast, the Fixed Wireless Communications Coalition, the Southern Company, AT&T, and others contend that terrain and clutter losses should not be assumed using a statistical model and that the appropriate propagation model should be free-space path-loss.[148] NAB, representing broadcast auxiliary service incumbents operating in the U-NII-6 and U-NII-8 bands, also supports use of free-space path-loss model.[149]

65. After considering the record, we believe an approach which combines different propagation models is most appropriate for evaluating necessary separation distances of 6 GHz unlicensed devices from fixed microwave links. More specifically, because propagation models have been developed to accommodate a variety of environments and over various distances, we find that using a combination of models optimized for the varying propagation conditions that will be encountered is the best way to balance unlicensed device access and incumbent protection in the 6 GHz band. That is, it is most appropriate to use a set of propagation models keyed to specific separation distances between an unlicensed device and a fixed service receiver to determine appropriate exclusion zone size. Under this approach, we use the free-space model for short distances, where it accurately predicts signal path loss, use WINNER II for medium distances, and the Irregular Terrain Model for longer distances to more realistically account for terrain and clutter losses.

66. Under our general approach, we find that for separation distances of 30 meters or less, the free space pathloss model is the appropriate model. The free space pathloss model generates the greatest possible path loss to account for the possibility of direct line-of-sight from a standard-power access point to a microwave receiver. The free space pathloss model though theoretically simple, has a limited range of applicability because it ignores environmental clutter and over long distances can result in extremely conservative calculations that under predict the amount of actual path loss.

67. Incumbents generally recommend use of free space propagation model for all separation distances regardless of environment,[150] while proponents of unlicensed operations advocate use of a combination of propagation models that specifically consider the propagation environment(s).[151] Beyond

[146] Notice at 33 FCC Rcd 10513-14, paras. 48-49.

[147] Apple, Broadcom, et al. Comments at 43-45, Attachment at A-7 (for clutter models, recommending ITU-R P.2108 for urban and suburban areas, and ITU-R P.452-16 for rural areas); Wi-Fi Alliance Comments at 25 (for clutter, recommending ITU-R P.2108); CableLabs Dec. 20, 2019 *Ex Parte* 20.

[148] Fixed Wireless Communications Coalition Comments at 14; *see also* Southern Company Comments at 14; AT&T Nov. 12, 2019 *Ex Parte* at 5; CTIA Mar. 16, 2020 *Ex Parte* at 5; Rignet July 11, 2019 *Ex Parte* at 21.

[149] NAB Comments at 15.

[150] *See* Southern Company Feb 6, 2020 *Ex Parte*, Attach. at 4; Fixed Wireless Communications Coalition Aug. 22, 2019 *Ex Parte*, Attach. A 1.

[151] *See, e.g.*, Apple, Broadcom et al. Comments at 43-45, Attachment at A-2-A-9 (recommending, for distances within the first kilometer and beyond a 30-meter exclusion zone around fixed microwave receivers, use of the WINNER II model for urban and suburban environments and the Irregular Terrain Model combined with ITU-R

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30 meters and up to one kilometer from an unlicensed device to a microwave receiver, we find that the most appropriate propagation model is the Wireless World Initiative New Radio phase II (WINNER II) model for urban, suburban, and rural environments.[152] At these distances, the WINNER II model accounts for obstructions by urban and suburban clutter, which the free space model does not. We make this decision recognizing that the WINNER II model is one of the most widely used and well-known channel models in the world[153] and was developed from measurements conducted by the WINNER organization, as well as results from academic literature.[154] We will require the use of site-specific information, including buildings[155] and terrain data, for determining the line-of-sight/non-line-of-sight path component in the WINNER II model where this information is available. For evaluating paths where this data is not available, we will require probabilistic combining of the line-of-sight and non-line-of-sight path into a single path-loss.[156] Based on our experience, as well as evaluation of the various technical analyses in the record before us, we conclude that using the well-understood WINNER II propagation model for these separation distances will provide the best prediction of actual pathloss between unlicensed devices and fixed service receivers as it accounts for environmental information not considered in the free space model.

68. The Irregular Terrain Model[157] is a propagation model that specifically takes into account the effects of terrain on radio propagation but does not include clutter losses.[158] The model accounts for transmission loss relative to free space loss for distances between 1 km and 2000 km.[159] For separation distances greater than one kilometer, we find that the Irregular Terrain Model combined with a clutter model depending on the environment is the most appropriate model. Consistent with Commission use of propagation models in other proceedings,[160] we will require use of 1 arc-second digital elevation terrain

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P.452 Model for clutter model for rural environments); Wi-Fi Alliance Comments at 25 (proposing use of WINNER II for short ranges, and the Irregular Terrain Model and ITU-R P2018 for beyond line of site); Federated Wireless Nov. 22, 2019 *Ex Parte* at 2 (supporting a hybrid propagation model that combines WINNER II with the Irregular Terrain Model best suited for larger distances and rural environments); CableLabs Dec. 20, 2019 *Ex Parte* at 20 (recommending use of WINNER II for urban environments).

[152] The urban, suburban, and rural WINNER II channel models are referred to as C2, C1, and D1, respectively. WINNER II Channel Models Part 1, at Table 2-1 (propagation scenarios) and Table 4-4 (path-loss models). https://www.cept.org/files/8339/winner2%20-%20final%20report.pdf.

[153] Patrick Marsch et al., "5G System Design: Architectural and Functional Considerations and Long-Term Research", 2018, at 57.

[154] Martin Döttling et al., "Radio Technologies and Concepts for IMT-Advanced," 2010, at 75.

[155] See, for example, OSM building data. https://osmbuildings.org/data/.

[156] When site-specific information regarding line-of-sight/non-line-of-sight is not available then path losses of line-of-sight(LOS) and non-line-of-sight(NLOS) paths can be combined into a single loss using the following formula: Path-loss (L) = Σ_i P(i) * L_i = P_{LOS} * L_{NLOS} + P_{NLOS} * L_{NLOS}, where P_{LOS} is the probability of line-of-sight, L_{LOS} is the line-of-sight path loss, P_{NLOS} is the probability of non-line-of sight, L_{NLOS} is the non-line-of-sight path loss, and L is the combined path loss. The WINNER II path loss models include a formula to determine P_{LOS} as a function of antenna heights and distance. P_{NLOS} is equal to (1-P_{LOS}).

[157] The Irregular Terrain Model guide, which dates to 1982, is available at: https://www.ntia.doc.gov/files/ntia/publications/ntia_82-100_20121129145031_555510.pdf.

[158] *See, e.g.*, 47 CFR Part 24 Appx. I, Subpart E ("A Procedure for Calculating PCS Signal Levels at Microwave Receivers") (using irregular terrain models).

[159] *See* "A Guide to the Use of the ITS Irregular Terrain Model in the Area Prediction Mode" at 7. https://www.ntia.doc.gov/files/ntia/publications/ntia_82-100_20121129145031_555510.pdf.

[160] *See, e.g.*, 47 CFR § 27.1310 (OET Bulletin 74). *See also In the Matter of Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions*, Report and Order, 29 FCC Rcd 6637, para. 150 (2014) ("The one arc-second dataset, which is derived from smaller scale topographic maps with more granular

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data and,[161] for locations where such data is not available, we will require use of the most granular digital elevation terrain data available.[162] To account for the effects of clutter, such as from buildings and foliage, we will require that the Irregular Terrain Model be combined with a statistical clutter model ITU-R P.2108[163] for urban and suburban environments, and ITU-R P.452-16 clutter model for rural environments.[164] ITU-R P.452-16 should use village center as the default clutter category.[165] We specify the Irregular Terrain Model because it has been widely available and accepted since the early 1980s, has been used by the Commission for interference prediction in other proceedings,[166] and in our experience has served reliably as a propagation model. The Irregular Terrain Model is the propagation model currently used to determine spectrum availability in the spectrum access systems (SAS) used to manage access to the 3550-3700 MHz band in the Citizens Broadband Radio Service.[167] Several commenters support the Commission's use of the Irregular Terrain Model as one part of a hybrid propagation model.[168] In our approach, we note that we depart from the suggestion by Apple, Broadcom et al. to use the Irregular Terrain Model combined with ITU-R P.452 for rural environments for distances from 30 to 1000 meters because the Irregular Terrain Model is only valid for distances between 1 km and 2000 km.[169]

69. We disagree with those commenters that claim that a free space model must be used in all cases where clutter and terrain data are not known.[170] While a free space model is appropriate for short

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elevation data than datasets used by earlier implementations …, will allow for more accurate calculation of the effect of terrain on propagation."). *See also, e.g.*, 47 CFR § 101.21, requiring position location accuracy of no less than one arc-second for antenna sites.

[161] "The 1 arc-second NED layer provides seamless coverage of the conterminous United States, Hawaii, Mexico, Canada, Puerto Rico, other territorial islands, and in limited areas of Alaska." https://www.sciencebase.gov/catalog/item/5825a0c3e4b01fad86db66dc.

[162] Alaska 2 Arc-second Digital Elevation Models. https://catalog.data.gov/dataset/national-elevation-dataset-ned-alaska-2-arc-second-downloadable-data-collection-national-geosp. Digital Elevation Model (DEM) terrain files are available for areas in the United States at https://viewer.nationalmap.gov/basic/.

[163] ITU Recommendation P.2108 §3.2 provides a statistical model for clutter loss distributions for urban and suburban environments.

[164] As noted, Apple, Broadcom et al. recommends use of ITU-R P.452-16 for rural environments. Apple, Broadcom, et al. Comments, Attach. at A-7.

[165] *See* Table 4 of ITU-R P.452-16, Prediction procedure for the evaluation of interference between stations on the surface of the Earth at frequencies above about 0.1 GHz. https://www.itu.int/dms_pubrec/itu-r/rec/p/R-REC-P.452-16-201507-I!!PDF-E.pdf.

[166] Use of this model was agreed upon through stakeholder consensus agreement. *See Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions*, Third Report and Order and First Order on Reconsideration, 30 FCC Rcd 12049, 12103, App. C n.1 (2015); *Longley-Rice Methodology for Evaluating TV Coverage and Interference*, OET Bulleting No. 69 (Feb. 4, 2004), https://transition.fcc.gov/bureaus/oet/info/documents/bulletins/oet69/oet69.pdf.

[167] *Requirements for Commercial Operation in the U.S. 3550-3700 MHz Citizens Broadband Radio Service Band*, Wireless Innovation Forum, Document WINNF-TS-0112, at 11 (June 25, 2019) https://winnf.memberclicks.net/assets/CBRS/WINNF-TS-0112.pdf.

[168] *See, e.g.*, Apple, Broadcom et al. Comments at 43-45, Attachment at A-2-A-9; Wi-Fi Alliance Comments at 25; Federated Wireless Nov. 22, 2019 *Ex Parte* at 2.

[169] *See* Apple, Broadcom et al. Comments, Attach. A, at A-9; "A Guide to the Use of the ITS Irregular Terrain Model in the Area Prediction Mode" at 7. https://www.ntia.doc.gov/files/ntia/publications/ntia_82-100_20121129145031_555510.pdf.

[170] *See, e.g.*, Fixed Wireless Communications Coalition Comments at 14; *see also* Southern Company Comments at 14; AT&T Nov. 12, 2019 *Ex Parte* at 5; CTIA Mar. 16, 2020 *Ex Parte* at 5; Rignet July 11, 2019 *Ex Parte* at 21.

distances, based on our experience it drastically underpredicts path loss for longer distances because, as a practical matter, there is almost always interaction with the environment that reduces the signal level below the free space level. We also disagree with those commenters who claim that propagation models should not be used.[171] Propagation models are tools that are widely used by radio frequency engineers to make interference predictions and the use of an AFC system employing such models will permit the 6 gigahertz band to be more efficiently used.

70. *Interference protection criterion.* In the Notice, the Commission proposed that exclusion zones would be based, in part on the AFC using a specific interference protection criterion to prevent harmful interference to fixed microwave link receivers.[172] The Commission sought comment on possible metrics for this criterion, including whether it could be based on the ratio of interference to noise power (I/N ratio) or the ratio of the carrier to interference power (C/I ratio), where the interference is the signal from the unlicensed devices, the carrier is the signal strength of the received fixed service transmission, and noise is the background noise level.[173] The Commission noted a less stringent interference protection criterion would result in a smaller exclusion zone.[174] It encouraged commenters to provide technical analyses to support their preferred metric.[175]

71. In their comments, the Fixed Wireless Communications Coalition, the Utilities Technology Council et al., and other representatives of fixed microwave incumbents, support using a -6 dB I/N as the appropriate metric.[176] Although Apple, Broadcom et al., the Wi-Fi Alliance, and WISPA contend that a 0 dB I/N would offer sufficient protection against harmful interference to microwave receivers, they provide an extra margin against potential interference in their analyses by using a more conservative -6 dB I/N criterion.[177] Moreover, most commenters employ this metric in their analysis. Motorola and the National Public Safety Telecommunications Council (NPSTC) supports use of an even more conservative -12 dB I/N.[178] There was little support for use of a C/I ratio.[179]

72. Based on the extensive record compiled in this proceeding, we will require the prescribed AFC system to use an I/N metric rather than C/I for determining the exclusion zones. The I/N ratio was used by most commenters in their analyses as the interference protection metric and is more straightforward to implement, and thus is more consistent with one of our major goals for the AFC

[171] *See, e.g.*, National Spectrum Management Association Comments at 4.

[172] Notice, 33 FCC Rcd at 10509, para. 37, 10511, para. 43.

[173] Notice, 33 FCC Rcd at 10510, para. 42.

[174] Notice, 33 FCC Rcd at 10511, para. 43.

[175] Notice, 33 FCC Rcd at 10510-11, para. 43.

[176] *See, e.g.*, Fixed Wireless Communications Coalition Comments at 17, 22; Utilities Technology Council et al. Comments at 15; Association of American Railroads Comments at 12; Tucson Electric Power Comments at 10-11; National Spectrum Managers Association Comments at 16. A -6 dB I/N is equivalent to 1 dB rise over the background noise level.

[177] Apple, Broadcom et al. Comments at 15-16 (in technical analyses, assumes a "very low" interference protection threshold of -6 dB I/N, which is "more than adequate to protect [fixed service] links, even under the worst conditions" and is "very conservative"); Wi-Fi Alliance Comments at 24 (even though I/N of 0 dB offers sufficient harmful interference protection to the microwave receiver, to further reduce interference potential, the Wi-Fi Alliance proposes that the AFC should determine the exclusion zone using a more conservative I/N of -6 dB); WISPA Comments at 20 (asserting that I/N of 0 dB is appropriate because microwave links operate with a "very high fade margin")

[178] Motorola Comments at 4; NPSTC Reply at 11.

[179] *See, e.g.*, NE Colorado Cellular Comments at 2-3.

system—simplicity of implementation.[180] As the Wi-Fi Alliance points out, use of a C/I ratio would entail additional implementation complexities.[181] In particular, calculating the C/I ratio would require calculating the power arriving at the microwave receiver from its corresponding transmitter in addition to estimating the signal level from the access point. This would require knowledge of the microwave link characteristics including the instantaneous transmitted power as well as the modulation and coding scheme used, which is information that is not available in ULS.

73. As for the specific interference protection criterion, we are specifying a I/N of -6 dB I/N. As discussed above, several microwave incumbents support use of this particular I/N metric,[182] and Apple, Broadcom, et al., and the Wi-Fi Alliance used same this metric in their studies.[183] By specifying that AFC exclusion zone calculations will be based on this particular interference protection criterion, we are taking a conservative approach, as suggested by commenting parties, to ensure that the potential for harmful interference is minimized and important fixed microwave services in the 6 GHz band are protected. We are not, however making a determination that any signal received with an I/N greater than -6 dB would constitute "harmful interference."[184] No commenter provides technical justification for using a particular I/N level as the actual level necessary to protect fixed microwave receivers against harmful interference. In determining to apply -6 dB I/N as the interference protection criterion, we do not find the need to establish a specific industry multi-stakeholder group to establish the appropriate metric on this issue, as some have suggested.[185]

74. *Aggregate interference*. The Commission did not propose, nor do we find that there is any need, to consider the effect of aggregate interference from multiple access points to point-to-point microwave links, as suggested by AT&T, CTIA, and Comsearch.[186] As the Fixed Wireless Communications Coalition notes, the risk of interference from large numbers of standard power access points would not be due to signal aggregation from multiple unlicensed devices, but from a single standard-power access point in or near the main beam of a microwave link receive antenna with little or no intervening clutter.[187] The Fixed Wireless Communications Coalition further states that in the event that two or more access points could cause interference to the same microwave receiver, the signal from

[180] Notice, 33 FCC Rcd at 10506, para. 25 (envisioning an AFC system with a "simple database that is easy to implement").

[181] Wi-Fi Alliance Comments at 24.

[182] *See, e.g.*, Fixed Wireless Communications Coalition Comments at 17, 22; Utilities Technology Council et al. Comments at 15.

[183] Apple, Broadcom et al. Comments at 15-16; Wi-Fi Alliance Comments at 24.

[184] The Commission defines harmful interference as "[i]nterference which endangers the functioning of a radionavigation service or of other safety services or seriously degrades, obstructs, or repeatedly interrupts a radiocommunication service operating in accordance with ITU Radio Regulations." 47 CFR § 2.1(c). *See also* 15 CFR § 15.3(m).

[185] Open Technology Institute et al. Comments at 27; Comsearch Reply at 12. As discussed below, we nonetheless encourage AFC multi-stakeholder industry working groups that focus on complex technical and operational issues that could provide valuable information and help promote the efficient ecosystem in the 6 GHz band. *See* Section III.A.3.e, below.

[186] Letter from Michael P. Goggin, AT&T Services, to Marlene H. Dortch, Secretary, FCC, ET Docket No. 18-295, at 3 (filed Aug. 8, 2019); Letter from Jennifer L. Oberhausen, Director of Regulatory Affairs, CTIA, to Marlene H. Dortch, Secretary, FCC, ET Docket No. 18-295, Appendix at 12 (filed Oct. 8, 2019); Comsearch Comments at 21-22.

[187] Letter from Donald J. Evans and Mitchell Lazarus, Counsel for the Fixed Wireless Communications Coalition, Fletcher Heald and Hildreth, to Marlene H. Dortch, Secretary, FCC, ET Docket No. 18-295, at 3 (filed July 25, 2019).

the nearest would dominate over the others and make the others irrelevant to the analysis.[188] We agree and will not require the AFC to consider aggregate interference when determining exclusion zones.

75. *Adjacent channel protection.* In the Notice, the Commission did not propose to protect fixed links from adjacent channel unlicensed operations, noting that suppression from out-of-band emission (OOBE) limits should be sufficient to protect the fixed service links.[189] In comments, several incumbent fixed service representatives, including the Fixed Wireless Communications Coalition, the National Spectrum Managers Association, and APCO, contend that we should protect against potential interference from standard power access point operations in adjacent channels,[190] and the Fixed Wireless Communications Coalition also submitted a technical analysis supporting this position.[191] Apple, Broadcom et al. oppose adopting adjacent channel restrictions on standard power operations, asserting that such restrictions are not needed to protect incumbent fixed microwave receivers and would significantly and unnecessarily diminish the spectrum available for unlicensed use.[192] Apple, Broadcom et al. believe that filters used in microwave receivers do not adequately distinguish between energy within their channel and energy present in other nearby channels and as a result, regardless of how stringently unlicensed devices limit their out-of-band emissions, they will still need to use huge guard bands in order to accommodate the supposedly poor adjacent-channel filtering performance of microwave receivers.[193]

76. The Fixed Wireless Communications Coalition contends, based on its technical analysis examining the boresight of a point-to-point microwave antenna, and assumed guard band and the path of a proposed unlicensed device, that a relative exclusion angle would be necessary to protect fixed service stations.[194] Under this approach, the smaller this exclusion angle is, the stronger the signal received from the hypothetical unlicensed device, and therefore a higher likelihood for harmful interference to the adjacent channel microwave receiver. Apple, Broadcom et al. dispute this analysis, claiming that it fails to consider several important factors such as the probable interference geometry and propagation conditions, and that it is unrealistic that the typical receiver would exhibit such poor adjacent-channel rejection.[195]

77. We are not persuaded by the Fixed Wireless Communications Coalition's analysis, and share some of the concerns raised by Apple, Broadcom et al. The Fixed Wireless Communications Coalition's analysis fails to provide any receiver information (including model and manufacturer data), cites an unpublished document in support of the receiver filter mask performance, and uses an interference limit that is 13 dB higher than the blocking limit set by the Commission for protecting fixed satellite service earth stations in the 3.600-3.700 GHz band, a service that is more sensitive to blocking

[188] Letter from Donald J. Evans and Mitchell Lazarus, Counsel for the Fixed Wireless Communications Coalition, Fletcher Heald and Hildreth, to Marlene H. Dortch, Secretary, FCC, ET Docket No. 18-295, at 9 (filed Oct. 31, 2019).

[189] Notice, 33 FCC Rcd at 10511, para. 44.

[190] *See, e.g.*, Fixed Wireless Communications Coalition Comments at 25, 27 (recommending that the Commission institute a guard band equal to half of the nominal microwave channel based on tentative calculations, because the necessary guard band is sensitive to the distribution of energy from unlicensed device operation across its bandwidth); National Spectrum Managers Association Comments at 16-23; APCO Comments at 7-8.

[191] Fixed Wireless Communications Coalition Comments, Attachment C.

[192] Apple, Broadcom et al. Comments at Reply at 26-30.

[193] Apple, Broadcom et al. Comments at Reply at 26-30.

[194] Fixed Wireless Communications Coalition Comments Attachment C at 9-14.

[195] Apple, Broadcom, et al. Reply at 28-29 (stating that, in their analysis, "with only 2 MHz frequency separation, an outdoor standard-power access point would not cause interference to exceed -6 dB I/N at any distance, even assuming line-of-sight propagation conditions, considering only FS receive filter performance.").

than microwave receivers.[196] Using a receiver filter mask instead of an actual receiver filter significantly distorts the receiver's ability to distinguish between energy within its channel and energy present in other nearby channels. Also, the analysis uses the free space path loss propagation model for all distances,[197] and ignores typical polarization loss (3 dB) and feeder and other losses (3 dB), as pointed out by Apple, Broadcom et al.[198]

78. Another factor that the Fixed Wireless Communications Coalition fails to consider is that angular separation occurs naturally as a result of the expected height difference between microwave receiver antennas and outdoor standard-power access point antennas.[199] In cases where the unlicensed device is close to the microwave receiver the large angular separation results in a small microwave antenna gain in the direction of the unlicensed device and thus the received signal would generally be below a level that could cause harmful interference. At greater distances the pathloss as indicated by the WINNER II model shows that harmful interference is unlikely to occur. Support for angular separation analysis can be found in the study by Edison Electric Institute study, an opponent of unlicensed use, that shows 99% of 6.77 million access points in the Houston MSA have an I/N ratio -5.5 dB or better.[200] It should be noted that this study uses a very conservative propagation model (free space) that tends to exaggerate potential interference.

79. Although we believe that the risk of adjacent channel interference to fixed service microwave receivers is low, we nevertheless will include some protection as we are taking a conservative approach to enabling new unlicensed devices in the 6 GHz band. Thus, in addition to the AFC calculating a co-channel exclusion zone, we will also require it to determine an adjacent channel exclusion zone.[201] We expect these adjacent channel zones will be small and not significantly impact the amount of spectrum available to unlicensed devices at any given location. Also, because the AFC will need to calculate co-channel exclusion zones for all nearby fixed service stations, the incremental burden to also calculate adjacent channel exclusion zones should be minimal. To this end, we will require the AFC to determine an adjacent channel exclusion zone based on the out-of-band emission mask we are adopting for unlicensed devices which is designed to keep energy outside an unlicensed device's operating channel to low levels and the same protection criterion we are using to determine co-channel exclusion zones; that is the I/N ratio must be calculated to be -6 dB or less. This requirement will protect fixed microwave receivers from harmful interference due to unlicensed devices out-of-band emissions.

f. Other AFC System Issues

80. *Security Issues.* In the Notice, the Commission sought comment on the types of security

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[196] Fixed Wireless Communications Coalition Comments Attachment C at 7; *see Amendment of the Commission Rules with Regard to Commercial Operations in the 3550-3650 MHz Band*, Second Report and Order and Order on Reconsideration, 31 FCC Rcd at 5091-5092, paras. 272-273 (adopting a -60 dBm RMS as the median blocking limit from aggregate adjacent CBSDs to protect fixed satellite earth station receivers in the 3.4-4.2 GHz band) .

[197] As the vast majority of standard-power outdoor access points will be deployed in the urban setting, the propagation model that should be employed for this analysis is the WINNER II urban model. The Irregular Terrain Model would not be appropriate here because the calculation is not being done for a specific geographic location—*i.e*. there is no terrain data to use for the analysis.

[198] *See* Apple, Broadcom et al. Reply at 29.

[199] For example, a height difference of 50 meters provides an angular separation of 27° at a distance of 100 meters from the microwave receiver, which will significantly reduce the gain of the microwave antenna. See Fixed Wireless Communications Coalition Comment, Attach. C at 9.

[200] *See* Edison Electric Institute Jan. 13, 2020 *Ex Parte* at 14.

[201] The adjacent channel exclusion zone defines a zone under which any standard power access point is prevented from operating adjacent to an FS receiver within one-half channel bandwidth of the access point.

measures that should be adopted with respect to standard-power devices and the AFC database.[202] Reliable and secure communications between AFC systems and access points are essential for the success of standard-power access point operations and incumbents' protection and should be protected with up-to-date security measures. Both representatives of incumbent microwave services and proponents of unlicensed operations strongly support including robust security protocols for the AFC system stored data and communications.[203] Commenters state the Commission should ensure that performance-based security safeguards are in place so that device-based software cannot be easily modified to allow operation on frequencies other than those that the AFC indicates are available, the link between the AFC system and access point should be secure and encrypted, and AFC operator(s) should be required to use the best industry security measures and be audited periodically.[204]

81. We require that AFC systems and standard-power access points employ protocols and procedures to ensure that all communications and interactions between the AFC and standard-power access points are accurate and secure and that unauthorized parties cannot access or alter the database or the list of available frequencies and power levels sent to an access point. These requirements are similar to those adopted for the white space database and the Citizens Broadband Radio Service spectrum access system.[205]

82. We are not mandating specific security models. Instead, we will require AFC system operators to use advanced security standards and demonstrate that their systems contain communication and information security features during the AFC system certification process. These security protocols will be subject to the Commission's review and approval. We anticipate that industry-wide multi-stakeholder groups will take the lead on this process and develop security protocols that AFC administrators may consider for their operation, subject to Commission review and approval. We also expect that security models will be updated as needed to reflect state-of-the-art protection against new security threats. The Commission will review any modifications or updates in the security protocols AFC system operators or multi-stakeholder groups propose to implement.

83. *AFC device registration.* The Commission sought comment in the Notice on whether it should require a standard-power access point to register with the AFC by transmitting identifying information along with its location to the AFC system before receiving a list of permissible frequencies,

[202] Notice, 33 FCC Rcd at 10507, paras. 31-32.

[203] Comsearch Comments at 15-16 (arguing an AFC system must incorporate reliable security); Quantenna Communications Comments at 5 (maintaining that an AFC system should always provide the list of available frequencies and respective power levels after authentication of the interested device's credentials); Wi-Fi Alliance Comments at 30 (arguing the Commission should consider imposing non-burdensome security obligations on AFC operators, similar to those for the CBRS and white spaces); NE Colorado Cellular Comments at 2; El Paso Electric Comments at 4; Apple Inc. Reply at 6-7; Utilities Technology Council et al. Reply at 20; Sony Comments at 7 (recommending that the Commission adopt security requirements that are similar to those already specified in Part 15 Subpart H for white spaces devices and in Part 96 for CBRS); APCO Comments at 10 (supporting a requirment that security measures be imposed on similar services, e.g., white spaces); CTIA Reply at 17; NPSTC Comments at 11 (arguing that AFC providers should be required to use the best industry security measures and should be audited periodically for security practices).

[204] CTIA Reply at 17; NPSTC Comments at 11.

[205] With respect to automated coordination, white space database administrators and Citizens Broadband Radio Service SAS administrators are required to establish protocols and procedures to ensure that devices communicate only with authorized databases, that all communications and interactions between a database and devices are accurate and secure, and that unauthorized parties cannot access or alter a database, or the list of available frequencies sent to a device. 47 CFR §§ 15.715(f) and 96.63(d). They are also subject to requirements that communications between devices and the database, and between different databases, must be secure to prevent corruption or unauthorized interception of data, and that databases be protected from unauthorized data input or alteration of stored data. 47 CFR §§ 15.711(j) and 96.61(b).

or alternatively whether it should provide only its location information.[206] The record is divided over a registration requirement. Several commenters see this requirement as a way to assist in locating devices in the event that a licensee reports receiving harmful interference.[207] Others argue that device registration in the AFC system should not be required in order to keep the rules simple and flexible and because of privacy concerns.[208]

84. To further ensure the AFC ecosystem integrity, we will require standard-power access points to register with the AFC system when requesting a list of available operating frequencies and power levels. We disagree with commenters who argue that device registration in the AFC system should not be required.[209] Although we recognize that the AFC system would be simpler without a registration requirement, device registration allows for another layer of protection by ensuring only authorized devices access the spectrum and by easing the process of mitigating harmful interference if it occurs. Because the registration information would be automatically provided by the access point or network proxy to the AFC system, the registration process will require little effort by the access point user.

85. To register, a standard-power access point will be required to provide the AFC system—in addition to the technical information described above with the device's FCC identifier (FCC ID), and its serial number.[210] Although the FCC ID or the access point's serial number are not required to calculate frequency availability, the AFC will use the information for two purposes. First, the information will be used to authenticate the device, to ensure that no rogue devices are operating in the band. The AFC will verify the device's FCC ID by accessing the Commission's Equipment Authorization System.[211] Second, the information will be used for interference mitigation and enforcement purposes to identify the source if harmful interference were to occur.[212] In addition, as APCO and UTC request and as we have done in the context of the white space devices, we will require that AFC systems have the capacity to deny spectrum access to a particular registered standard-power access point upon request by

[206] Notice, 33 FCC Rcd at 10506, para. 27.

[207] CTIA Comments at 19 (arguing that access points must be required to register with an AFC by providing sufficient information to ensure accountability in the event of harmful interference); NPTSC Comments at 11 (arguing that the AFC should maintain a list of registered access points, accessible by unit ID and location, that can be accessed in the event an interference problem arises); Comsearch Comments at 29; Verizon Comments at 6 (declaring that registration with the AFC system allows for security, identification, and authentication of unlicensed access point devices); APCO Comments at 6 (maintaining that device registration will be helpful for managing standard-power access points and identifying and eliminating potential sources of interference); Association of American Railroads Reply at 7.

[208] Qualcomm Comments at 3 (arguing that the rules for the AFC need to be simple and flexible and should not require unlicensed system registration); Dynamic Spectrum Alliance Comments at 12-14; Hewlett Packard Enterprise Reply at 28 (arguing that the Commission should not require device registration or identifiers); Apple Comments at 14 (declaring that creating a log of uniquely-identified 6 GHz devices would be fundamentally inconsistent with users' privacy expectations).

[209] Qualcomm Comments at 3; Dynamic Spectrum Alliance Comments at 12-14; HP Reply at 28.

[210] This is consistent with the Commission's actions in the white spaces and CBRS proceedings in which it required devices to report the FCC ID and serial number to the database during registration. *See* 47 CFR §§ 15.713(g)(3), 96.39(c).

[211] The AFC can retrieve the FCC IDs of certified standard-power access points from the Commission's equipment authorization database using an Application Program Interface (API) or another method and determine whether the FCC ID provided by a device during registration is valid. Access to the equipment authorization database and extracting FCC IDs is a process that is used by the CBRS SAS and white space data administrators.

[212] Some commenters indicate the AFC system should register unlicensed devices, which would provide the AFC system with information that could prevent harmful interference or help resolve interference issues. Southern Company Services Reply at 9-10; Association of American Railroads Reply at 7; Fixed Wireless Communications Coalition Reply at 37; WISPA Comments at 19; Verizon Comments at 6; CTIA Comments at 19.

the Commission, in the event of harmful interference caused by a particular device or type of device.[213] We will also require that AFC operators implement procedures to respond to requests from Commission personnel for information stored or maintained by the AFC, and that they establish and follow protocols to comply with enforcement instructions from the Commission, including discontinuance of access point operations in designated geographic areas. These requirements will ensure that the Commission is able to ascertain the accuracy of information stored in the AFC, obtain information necessary to enforce the Commission's rules, and ensure that access points that do not comply with the rules are shut down in a timely manner.[214]

86. We encourage a multi-stakeholder group representing the interests of unlicensed equipment manufacturers, equipment users and point-to-point microwave providers to develop additional procedures to resolve interference concerns.[215] Regardless of the processes that stakeholders may develop for addressing interference, consistent with statute the Commission will be the final arbiter regarding cases of harmful interference.[216]

87. Individual standard-power access points will not be required to interface with the AFC system if the required registration data is communicated by a proxy device or network control device.[217] In other words, the registration information can be provided directly and individually by a single standard-power access point or by a network proxy representing multiple devices operating on the same network. The access point or its proxy must register with the AFC system via any communication link, wired or wireless, outside the U-NII-5 and U-NII-7 bands. The AFC system will then communicate back a list of permissible frequency range(s) and the maximum power in each range for standard-power access point operation. In the case of a proxy, each access point must still provide its exact location and will obtain a set of available frequencies for that location.

88. We will require the AFC system to store registered information in a secure database until an access point ceases operation at a location, which we will define as a device not contacting the AFC to verify frequency availability information for more than three months.[218] This requirement will ensure that the AFC database does not become cluttered with entries for devices that are no longer being used. To ensure the users' privacy, the AFC system will use the registered data and any other access point operational information only to protect incumbents and for potential interference mitigation.[219]

2. Radio Astronomy Observatories

89. Incumbent operations in the U-NII-7 band include several radio astronomy observatories,

[213] APCO Comments at 10; Utilities Technology Council et al. Comments at 16-17; *see also* 47 CFR § 15.715(k).

[214] We adopted similar requirements for the CBRS. *See* 47 CFR § 96.63(m).

[215] The Commission adopted a similar approach for the Citizens Broadband Radio Service. Amendment of the Commission's Rules with Regard to Commercial Operations in the 3550-3650 MHz Band, GN Docket No. 12-354, *Report and Order and Second Further Notice of Proposed Rulemaking*, 30 FCC Rcd 3959, 4080-81, paras. 413-17 (2015). For example, a stakeholder group could develop a centralized process for receiving interference reports and disseminating the reports quickly to all AFC system operators, who could then take appropriate actions such as making certain frequencies unavailable for standard-power access points in the area where reported interference is occurring.

[216] 47 U.S.C. §§ 301-303.

[217] The network management device may be the point of interface with the AFC system for multiple access points.

[218] This requirement is consistent with the rules for fixed white space devices. 47 CFR § 15.707(o).

[219] HP Reply at 28 (arguing the Commission should not require device registration or identifiers); Apple Comments at 14 (creating a log of uniquely identified 6 GHz devices would be fundamentally inconsistent with users' privacy expectations).

located in remote areas, that observe methanol spectral lines between 6.6500-6.675.2 GHz.[220] The National Academy of Sciences' Committee on Radio Frequencies requests that the AFC system protect these observatories using exclusion zones that it specifically proposes, which depend on the heights of the unlicensed devices and the radio astronomy antennas.[221]

90. We recognize the importance of these observations to the scientific community and will adopt exclusion zones to protect them from interference over the specified frequencies. In so doing, we note that there is no radio astronomy allocation for these observations requiring that they be protected from interference; the radio astronomy allocation table footnote merely provides that "all practicable steps shall be taken to protect the radio astronomy service" in this band from harmful interference).[222] As these observatories are located in remote areas we do not believe excluding standard-power access points from this 25.2 megahertz of spectrum in these areas will be a significant burden on unlicensed operations. The AFC system will determine the size of the exclusion zones by the radio line-of-sight distance between the radio astronomy antenna and the unlicensed access point, as proposed by the National Academy of Sciences' Committee on Radio Frequencies.[223]

3. Fixed-Satellite Services

91. In the Notice, the Commission tentatively concluded that the proposed radiated power limits would prevent individual unlicensed devices from causing harmful interference to the incumbent FSS space station receivers that operate in the U-NII-5 and U-NII-7 bands, and that use of an AFC system would not be necessary to protect such receivers.[224] The Commission noted that these incumbent operations are limited to Earth-to-space transmissions,[225] and that the signal levels from standard-power unlicensed devices at geosynchronous space station receivers would be so low as to have no or only a negligible effect on them such that the AFC system would not need to provide specific protection to FSS space stations.[226] Noting that it anticipated that standard-power access points might use omnidirectional or wide beamwidth antennas (such as 60 to 120 degrees) instead of highly directional antennas (such as those used by fixed microwave stations), the Commission sought comment on whether it nonetheless would be appropriate to protect the satellite receivers by adopting a restriction to prevent antennas from pointing toward the geostationary arc, similar to that required for outdoor U-NII-1 devices.[227]

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[220] Observation of methanol spectral lines is a significant contributor to research of star formation. The observatories where such research is conducted are Arecibo Observatory, the Green Bank Observatory, the Very Large Array, the 10 Stations of the Very Long Baseline Array, the Owens Valley Radio Observatory, and Allen Telescope Array. National Academy of Sciences Committee on Radio Frequencies Comments at 6.

[221] National Academy of Sciences Committee on Radio Frequencies Comments at 5-6.

[222] 47 CFR § 2.106 US342.

[223] The radio line-of-sight should be determined using 4/3 earth curvature using the following formula dkm_los = 4.12*(sqrt(Htx) + sqrt(Hrx)), where Htx and Hrx are the heights of the unlicensed access point and radio astronomy antenna in meters above ground level. *See* National Academy of Sciences Committee on Radio Frequencies Comments at 6.

[224] Notice, 33 FCC Rcd at 10517, para. 55.

[225] The Commission stated that there is an allocation for space-to-Earth satellite use of the 6.7-6.875 GHz portion of the U-NII-7 band for feeder links for non-geostationary Mobile Satellite Service systems. Notice, 33 FCC Rcd at 10518, para. 58. As the Commission noted, however, no earth stations are currently licensed to use this allocation in the space-to-Earth direction. *See id.*

[226] Notice, 33 FCC Rcd at 10517, para. 55.

[227] Notice, 33 FCC Rcd at 10517-18, paras. 55-56; *see also* 47 CFR § 15.407(a)(1); *Revision of Part 15 of the Commission's Rules to Permit Unlicensed National Information Infrastructure (U-NII) Devices in the 5 GHz Band*, First Report and Order, 29 FCC Rcd 4127, 4138, para. 37 (2014). The U-NII-1 rules permit indoor and outdoor access points to operate generally with a conducted power of 1 watt (30 dBm) and a 6 dBi gain antenna, which is

(continued….)

92. Intelsat and SES Americom, who provide fixed satellite services relying on portions of the 6 GHz band for uplinks, express concern about of potential harmful interference from aggregate unlicensed operations and request that the Commission adopt an maximum permissible aggregate power limit which would be monitored and controlled by the AFC system.[228] The Wi-Fi Alliance contends that the limits on unlicensed devices' radiated power, along with the significant separation distances between unlicensed devices and geosynchronous satellites,[229] will prevent interference to space station receivers, and that use of the AFC system to protect them would not be necessary.[230] The Wi-Fi Alliance, which at one time indicated support for limiting the power transmitted above a 30 degree elevation angle,[231] now believes that such a restriction would not be necessary.[232] Sirius XM and NCTA support adoption of an antenna pointing restriction and additional power limits.[233]

93. We adopt rules supporting the Commission's tentative conclusion that the AFC system is not needed to protect incumbent fixed-satellite operations from standard power access point operations in the U-NII-5 and U-NII-7 bands. Considering that the satellites receiving in these sub-bands are limited to geostationary orbits, approximately 35,800 kilometers above the equator, we believe it unlikely that relatively low-power unlicensed devices would cause harmful interference to the space station receivers. Intelsat and SES Americom's filing indicates a general concern about potential harmful interference, including aggregate interference, from low-power devices due to the potential that the large geographic coverage of a satellite receiver's beam could see large numbers of unlicensed devices.[234] However, they do not include any specific technical analysis for their particular position.

94. We decline to adopt Intelsat and SES Americom's s suggestion for an aggregate power limit from unlicensed devices to be enforced though the use of the AFC systems.[235] Apple, Broadcom, et al. submitted a study ("RKF Study") of projected aggregate I/N at geostationary satellites as of the year 2025 which found that I/N from unlicensed devices would never rise above -20 dB.[236] Intelsat and SES Americom argue that changes in the input variables for spectrum sharing studies such as the RKF Study can produce a wide range of results, "some of which indicate that the FSS protection criteria would be exceeded by unlicensed device deployment representing a fraction of the total numbers predicted."[237] Although we disagree in significant part with their analysis, as a precautionary measure, we will adopt a rule requiring outdoor standard-power access points to limit the maximum EIRP above a 30 degree

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equivalent to a 36 dBm EIRP, while outdoor access points used in fixed point-to-point applications may operate with up to a 23 dBi gain antenna with no reduction in conducted power. 47 CFR § 15.407(a)(1). The U-NII-1 rules limit the radiated power from outdoor access points to 21 dBm at angles of more than 30 degrees above the horizon to protect satellite receivers but place no similar restriction on indoor access points or client devices.

[228] Intelsat and SES Americom Comments at 3-13 (proposing a cap on aggregate power received at the satellite antenna of -142 dBW per channel).

[229] The geostationary satellite arc is located approximately 35,800 km above the equator.

[230] Wi-Fi Alliance Comments at 36.

[231] Wi-Fi Alliance Reply, GN Docket No. 17-183 at (Nov. 15, 2017).

[232] Wi-Fi Alliance Comments at 36.

[233] Sirius XM Comments at 23; NCTA Comments at 12-13.

[234] Intelsat and SES Americom Comments at 4-7.

[235] Intelsat and SES Americom Comments at 11 (suggesting that all AFC systems be designed to monitor and limit the aggregate interference to FSS receivers to -142 dBW per 40-megahertz channel).

[236] *See* Apple, Broadcom et al. Jan. 25, 2018 *Ex Parte* in GN Docket No. 17-183., attachment (RKF Engineering study titled "Frequency Sharing for Radio Local Area Networks in the 6 GHz Band, January 2018") (RKF Study) at p. 43.

[237] Intelsat and SES Americom Comments at 7.

elevation angle to 21 dBm, which the Commission noted in the Notice would be similar to what the Commission already requires in the U-NII-1 band to protect fixed satellite services.[238] This skyward restriction, something not considered by the RKF study, should address Intelsat and SES's concerns. We adopt this restriction rather than an aggregate power limit for two reasons. First, outdoor access points have no reason to radiate significant power skyward, and so we do not believe this requirement will impose a burden on standard-power access point manufacturers and users. Second, designing an AFC system to undertake aggregate power limit monitoring would be very complex, requiring the AFC to know how much energy is being emitted to each portion of the geostationary arc for each unlicensed device. That in turn would require the AFC to have knowledge of each outdoor access point's antenna pattern, orientation, actual transmit power levels, and percent of the time it transmits as well as similar information for unlicensed client devices operating outdoors. Given the skyward EIRP restrictions we are placing on the AFC controlled outdoor unlicensed devices and the RKF study showing a low likelihood of aggregate interference, we see no reason to require this level of complexity in the AFC systems.

4. Additional Issues

95. *Authorizing standard-power access points to operate in the U-NII-8 band.* We will not authorize standard-power access points to operate in the lower 100-megahertz portion of the U-NII-8 band, which had been requested by some unlicensed proponents, including Apple, Broadcom, et al, the Wi-Fi Alliance, and WISPA.[239] The Commission did not propose to take this approach in the Notice, and we decline to do so for a number of reasons. The U-NII-8 band is used by both fixed and mobile broadcast auxiliary service services and the lower 25-megahertz portion of the band is available for Low Power Auxiliary Stations operations such as licensed wireless microphones.[240] The geographic areas for these types of licensed operations are specified in a variety of fashions, including point/radius, countywide, statewide and nationwide. The AFC system would not be able to allow standard-power access points to operate in the band while protecting licensed operations without additional information on their exact operating locations and times, and information on mobile operations can change frequently. Even if licensees were to provide additional operational information, this would increase the complexity of the AFC system and its interactions with unlicensed devices, and still may not adequately protect mobile operations.[241] Accordingly, we are not authorizing standard-power access points to operate in the lower 100 megahertz of the U-NII-8 band.

96. *Adopting an "inclusion zone" approach.* We also decline to adopt the suggested alternative to an AFC system proposed by Encina Communications Corporation (Encina). Encina urges the Commission to permit unlicensed devices to operate in an "inclusion zone" around microwave transmitters.[242] Under this approach, an applicant for a microwave license would conduct coordination for both the licensed link and unlicensed devices within the inclusion zone; because the coordination would involve analyzing the interference potential to all other microwave receivers that would be potentially affected, the unlicensed devices would be able to operate within the inclusion zone without causing harmful interference to other microwave receivers.[243] Encina claims that this would make a lot

[238] 47 CFR § 15.407(a)(4) in Appendix A; Notice, 33 FCC Rcd at 10517-18, para. 56; *see also* 47 CFR § 15.407(a)(1).

[239] Apple, Broadcom et al. Comments at 4, 46-47; Wi-Fi Alliance Comments at 10, 33; WISPA Comments at 2.

[240] 47 CFR § 74.802(a)(1). Both the lower and upper 25 megahertz portions of the U-NII-8 band are available for Low Power Auxiliary Stations operations (6.875-6.900 GHz and 7.025-7.125 GHz).

[241] For example, unlicensed devices would have to perform frequent channel availability checks to determine whether any licensed mobile devices have begun operating in an area.

[242] Encina Comments at 4-6.

[243] Encina Reply at 6.

more spectrum available for unlicensed devices than our AFC approach.[244] No other party in the record supported this proposal.

97. In declining to adopt Encina's approach, we note that its proposal is nearly identical to the concept of auxiliary stations, which the Commission considered as part of the Wireless Backhaul proceeding.[245] The auxiliary station proposal contemplated placement of multiple lower power transmitters within the signal pattern of a microwave link.[246] These auxiliary stations would be coordinated in advance of deployment and have secondary status. The Commission rejected this proposal, one of the reasons being that the proposal would create an incentive for microwave license applicants to propose excessive power or use more diffuse antenna patterns for their primary transmitters thereby precluding use of the spectrum by other microwave operators.[247]

B. Low-Power Indoor Operations Across the Entire 6 GHz Band

98. In the Notice, the Commission proposed to allow unlicensed access points to operate indoors in the U-NII-6 and U-NII-8 bands at a conducted output power of 24 dBm (11 dBm/MHz) and 30 dBm EIRP (17 dBm/MHz PSD) achievable by using up to a 6 dBi antenna.[248] It also sought comment on whether this same type of indoor operations should be permitted in the U-NII-5 and U-NII-7 bands as well,[249] thus making the whole 6 GHz band available for this type of use.

99. Proponents of unlicensed operations widely supported the Commission's authorizing of these low-power indoor operations, under the same rules, across the entire 6 GHz band.[250] They assert that permitting these operations will enable deployment of next-generation Wi-Fi on several 160-megahertz channels across the entire band at power levels that would effectively minimize the potential for interfering with the various incumbent licensed services that operate in different portions of the band.[251] Representatives of the different incumbent services expressed concerns about the potential for interference to their services.[252] Several proponents of unlicensed low-power operations and representatives of incumbent services submitted technical analyses into the record.[253]

100. Based on the record before us, we open the entire 6 GHz band for unlicensed indoor operations without the need for AFC-controlled access. By doing so, we create new unlicensed use

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[244] Encina Comments at 4.

[245] *Amendment of Part 101 of the Commission's Rules to Facilitate the Use of Microwave for Wireless Backhaul and Other Uses and to Provide Additional Flexibility to Broadcast Auxiliary Service and Operational Fixed Microwave Licensees*, Report and Order, Further Notice of Proposed Rulemaking, and Memorandum Opinion and Order, 26 FCC Rcd 11614, 11637-43, paras. 54-68 (2011). The only real difference in the two concepts appears to be that one involves unlicensed devices while the other would license stations operating on a secondary basis.

[246] *Id*. at 11638, paras. 56-57.

[247] *Id*. at 11639, 11641-42, paras. 60, 65-66.

[248] Notice, 33 FCC Rcd at 10524, para. 78. Under the proposal client devices would be limited to an EIRP of 24 dBm (PSD of 11 dBm/MHz). *Id.*

[249] Notice, 33 FCC Rcd at 10522, para. 73.

[250] *See, e.g.*, Apple, Broadcom et al. Comments at 17-34; Wi-Fi Alliance Comments at 10; Broadcom Comments at 5-6; Hewlett Packard Enterprise Comments at 7; CableLabs, Charter, Comcast Mar. 25, 2020 *Ex Parte* at 1.

[251] *See, e.g.*, Apple, Broadcom, et al. Comments at 19, 26-30, 33-35; Wi-Fi Alliance Comments at 9, 11, 15-16; Broadcom Comments at 25-27.

[252] *See, e.g.*, Fixed Wireless Communications Coalition Reply at 29-31; NAB Comments at 1, 9-12; Utilities Technology Council et al. Comments at 14; APCO Comments at 15-16.

[253] Appendix E list the technical studies submitted by both proponents of 6 GHz unlicensed operations and representatives of incumbent Services.

opportunities in these bands—including optimizing the potential for deployment of next generation Wi-Fi that makes use of 160 MHz channels[254]—while protecting the various incumbent licensed services in the band, including fixed microwave services, various other fixed and mobile services, and fixed-satellite services.

101. Because there will be no AFC system to prevent interference to licensed services from occurring, the rules we adopt three restrictions designed to prevent harmful interference. Devices are: (1) limited to indoor operation; (2) required to use a contention-based protocol; and (3) subject to low-power operation.

102. *First*, these low-power access points must operate only indoors. The signals transmitted by these unlicensed devices will be significantly attenuated when passing through the walls of buildings. The median signal loss from a traditionally constructed building is 17 dB and newer, highly efficient buildings provide even higher signal attenuation.[255] No commenters disagreed with the ITU median signal loss value for traditional construction. This attenuation is key to providing the necessary signal reduction to prevent harmful interference from occurring to incumbents.

103. *Second*, we require that the indoor low-power devices, both access points and their associated client devices, employ a contention-based protocol. Adopting such a requirement is suggested by CableLabs, Comcast, Charter, and Cox as a means of providing assurance that incumbent operations will not be harmed.[256] A contention-based protocol allows multiple users to share spectrum by providing a reasonable opportunity for the different users to transmit. Because the weighted average airtime utilization of Wi-Fi networks today is 0.4%, Wi-Fi devices share spectrum using a contention-based protocol.[257] For IEEE's 802.11, a "listen-before talk" medium access scheme based on the Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) protocol functions as a contention-based algorithm to provide access to all traffic.[258] Before initiating any packet delivery, a station listens to the wireless medium and if the medium is idle, the station may transmit; otherwise the station must wait until the current transmission is complete before transmitting.[259] To ensure efficient and cooperative shared use of the spectrum, we require all unlicensed indoor low power operations use technology that includes a contention-based protocol.[260]

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[254] Afaqui et al., *IEEE 802.11ax: Challenges and Requirements for Future High Efficiency WiFi*, IEEE Wireless Communications, June 2017, 130, 133; National Instruments, *Introduction to 802.11ax High-Efficiency Wireless* (Mar. 5, 2019), http://www.ni.com/en-us/innovations/white-papers/16/introduction-to-802-11ax-high-efficiency-wireless.html#section-1277099502; Ryan Jones, *What is Wi-Fi 6 and how fast is it?* Trusted Reviews (Oct. 2, 2019) https://www.trustedreviews.com/news/wifi-6-routers-speed-3442712.

[255] *Predication of Building Entry Loss*, International Telecommunications Union Radiocommunications Sector, ITU-R P.2109-0 at 4 (2017). The Notice sought comment on using the 2017 version of ITU-R P.2109 for building entry loss. Notice, 30 FCC Rcd at 10521, para. 70. This has since been replaced in 2019 by ITU-R P.2109-1.

[256] CableLabs, Charter, Comcast, Cox March 20, 2020 *Ex Parte* at 2-3 (the Commission could consider requiring that 6 GHz unlicensed devices employ a contention-based protocol or listen-before-talk ("LBT") mechanism).

[257] Cablelab Dec. 20, 2029 *Ex Parte* at 5.

[258] Apple, Broadcom et al. March 20, 2020, *Ex Parte* at 2-6; *Wireless Operations in the 3650-3700 MHz Band*, Report and Order, 20 FCC Rcd 6502 at para. 57 (2005).

[259] *Id*.

[260] *Contention-based protocol.* A protocol that allows multiple users to share the same spectrum by defining the events that must occur when two or more transmitters attempt to simultaneously access the same channel and establishing rules by which a transmitter provides reasonable opportunities for other transmitters to operate. Such a protocol may consist of procedures for initiating new transmissions, procedures for determining the state of the channel (available or unavailable), and procedures for managing retransmissions in the event of a busy channel. 47 CFR § 90.7.

104. In addition to providing equal access to the spectrum for unlicensed devices, a contention-based protocol can also be used to avoid co-frequency interference with other services sharing the band.[261] Thus, this requirement can be leveraged to facilitate spectrum sharing with incumbent fixed and mobile services in the band. In addition, requiring a contention-based protocol will limit the amount of time that the low-power unlicensed device will transmit because of the need to share the spectrum with other devices. This will limit the time periods during which interference could potentially occur.[262]

105. *Third*, we limit the low-power indoor access points to lower power levels than the standard-power access points that operate under the control of an AFC. Consistent with the Commission's approach for the existing U-NII bands, we specify both a maximum power spectral density and an absolute maximum transmit power, both in terms of EIRP. Specifically, we will allow a maximum radiated power spectral density of 5 dBm per 1 megahertz and an absolute maximum radiated channel power of 30 dBm for the maximum permitted 320-megahertz channel (or 27 dBm for a 160-megahertz channel). In addition, to ensure that client devices remain in close proximity to the indoor access points, we are limiting their PSD and maximum transmit power to 6 dB below the power permitted for the access points. In adopting these power levels in our rules, we strike a balance between ensuring that indoor unlicensed devices have adequate power to be useful to the public while also protecting the licensed services in the 6 GHz band from harmful interference. In accordance with the record developed in this proceeding, we find that this power level meets these twin goals.

106. In the sections below, we first discuss the provisions we are adopting to keep these low-power access points indoors. We then discuss the technical parameters for indoor unlicensed operations in this band—the power levels different parties request, the rationale behind the power levels we adopt today, and how the technical filings in this proceeding support our conclusion that the potential for interference to incumbent services operating in the 6 GHz band is negligible. We then evaluate the probability of unlicensed devices causing harmful interference to the incumbent services in the 6 GHz band—fixed services, mobile services, FSS, and radio astronomy. We discuss the technical studies submitted to the record, most of which employ different analysis methodologies with widely varying input assumptions leading to divergent conclusions. Certain studies are based on statistical simulations while others are based on worst-case scenarios. In evaluating these studies, we discuss the methodologies and the underlying assumptions regarding propagation models, building entry loss, antenna patterns, height of unlicensed devices, activity factor and the bandwidth overlap of incumbent and unlicensed services and the associated consequences and conclusions.

1. Indoor Operations

107. We first address measures designed to restrict these operations to indoor use. Among other things, the Commission sought comment on requiring a direct connection to a power outlet, adopting equipment form-factor restrictions, or requiring devices to cease operation if a GPS signal is detected.[263]

108. Commenters express widely divergent views on whether it would be possible to restrict these devices to indoors and what measures should be included in our rules to accomplish this goal. Proponents of unlicensed low-power indoor operations generally contend that, given the nature and design of these devices, specific equipment rules are not necessary or that rules should be minimal, such as requiring direct connection to a power source, requiring integrated antennas, and adopting marketing and labeling rules.[264] Boeing suggests that access point equipment should not be water resistant.[265] NAB,

[261] Apple, Broadcom et al. Mar. 20, 2020 *Ex Parte* at 1; CableLabs March 20, 2020 *Ex Parte* at 3.

[262] Apple, Broadcom et al. Mar. 20, 2020 *Ex Parte* at 1.

[263] Notice, 33 FCC Rcd at 10521, para. 71.

[264] *See, e.g.*, Apple, Broadcom et al. Comments at 31 (contending that, given the ready availability of all-weather RLAN APs intended for outdoor use, the lower lifecycle cost of these devices, and the shrinking difference between (continued….)

APCO, Society of Broadcast Engineers among others express concern that it could be difficult to ensure that devices would stay indoors.[266]

109. Because building attenuation is instrumental in minimizing the potential for harmful interference from indoor low-power access points to licensees' receivers, we are adopting reasonable and practical measures that will restrict low power access points to indoor operations. Specifically, we adopt three equipment-related hardware requirements that are designed to keep these low-power access points indoors. *First*, as suggested by Boeing, we will require that the access point devices cannot be weather resistant.[267] We will enforce this requirement through the Commission's equipment certification program. *Second*, we will require that the low-power access points have integrated antennas and prohibit the capability of connecting other antennas to the devices, which will prevent substituting higher gain directional antennas and make the devices less capable or suitable for outdoor use as suggested by the Wi-Fi Alliance.[268] *Third*, consistent with the suggestions by Hewlett-Packard Enterprise and the Wi-Fi Alliance, we will prohibit these low-power access points from operating on battery power.[269] Furthermore, we will require that the access points be marketed as "for indoor use only" and include a label attached to the equipment stating that "FCC regulations restrict to indoor use only", thereby informing consumers of the appropriate use.

110. We find requirements will make outdoor operations impractical and unsuitable, and so we disagree with those commenters that suggest either that no requirements are needed[270] or that any requirements would be ineffective.[271] Based on the record before us, we decline to adopt Microsoft's suggestion to use GPS to determine whether a device is indoors.[272] Globalstar and Boeing persuasively argue this suggestion is impractical.[273] Furthermore, we are hesitant to require all devices to incur the cost of incorporating a GPS capability given that the effectiveness of this idea has not been demonstrated.

(Continued from previous page)
the initial purchase prices of indoor and outdoor devices, there would be little or no reason for a consumer to intentionally circumvent the Commission's indoor-only restriction); Wi-Fi Alliance Comments at 18 (maintaining there would be little reason for users to substitute indoor devices for outdoor use, particularly when indoor devices may not perform as intended outdoors); Hewlett-Packard Enterprise Comments at 21 (arguing that instances of outdoor use of indoor-only devices would be rare even without FCC rules to provide extra security).

[265] Boeing Comments at 7 (suggesting that the access points have open air vents on their casing or use materials that are not rain resistant).

[266] National Association of Broadcasters Comments at 12; National Association of Broadcasters Reply at 4 (arguing that there is no easy way to ensure that unlicensed devices stay indoors, adopting power connection requirement can be defeated by use of an extension cord and requiring a label would be ineffectual); APCO International Comments at 15; Society of Broadcast Engineers Comments at 6; Engineers for the Integrity of Broadcast Auxiliary Services Spectrum Comments at 5.

[267] Boeing Comments at 7.

[268] Wi-Fi Alliance Comments at 18 (arguing that outdoor deployments typically rely on directional antennas to cover specific areas, such as restaurant patios, parking lots, and common areas; by prohibiting those antennas the Commission could make it ineffective to use low power indoor devices for those purposes).

[269] Wi-Fi Alliance Comments at 18-19; Hewlett-Packard Enterprise Comments at 21. We prohibit operation on batteries rather than requiring connection to an AC power outlet so as to permit the use of other sources as obtaining power over a wire such as through DC powered ethernet cables.

[270] Apple, Broadcom et al. Comments at 31; Wi-Fi Alliance Comments at 18; Hewlett-Packard Enterprise Comments at 21.

[271] Motorola Solutions Comments at 6; APCO Comments at 15; NAB Comments at 12; Society of Broadcast Engineers Comments at 6.

[272] Microsoft Reply at 14.

[273] Globalstar Comments at 15; Boeing Comments at 7.

2. Power Spectral Density Limit

111. In determining the appropriate power spectral density for low power indoor unlicensed devices in this band, we have carefully reviewed the studies submitted into the record by all parties. Various analysis methodologies are used which fall into two main categories: (i) Monte Carlo simulations, which take into account probabilistic factors like Building Entry Loss, activity factor, and co-channel probability, and (ii) static link budgets with limited considerations of probabilistic dependencies. These studies result in widely varying conclusions. While the studies performed by the incumbents tend to assume worst case conditions (and ignore the very low probabilities associated with such worst case scenarios), the proponents of unlicensed usage use very low probabilities for the activity factor based on current usage measurements and do not factor future growth into their assessments. Other assumptions that vary between the models are Building Entry Loss and propagation loss, with incumbents generally assuming line of sight free space propagation and unlicensed device proponents applying industry standard models that either inherently include clutter loss or treat such loss as an additive factor determined by a separate statistical clutter model appropriate for the environment.

112. After consideration of all of the studies and the varied assumptions and the protection needs of incumbents in all of the 6 GHz U-NII bands, we adopt a 5 dBm/MHz PSD. Based on our experience with unlicensed operations and interference analysis as well as our engineering judgment, we find that 5 dBm/MHz PSD will both adequately protect all incumbents in the band as well as offer enough power to unlicensed devices, commensurate with the levels in the other U-NII bands, to sustain meaningful applications especially when using wider bandwidths. At this power limit and with the other constraints imposed on these operations, we find the risk of harmful interference to incumbent operations to be insignificant. We also note that this value is lower than the proposed 17 dBm/MHz EIRP in the NPRM and the 8 dBm/MHz EIRP sought from the unlicensed proponents—a precaution we take at this time to protect incumbent operations given the state of the record. Because a more fulsome record and further study may alleviate our concerns, we seek further comment on this issue in the attached Further Notice of Proposed Rulemaking.

113. With respect to unlicensed client devices, we find that it is not necessary for a client device to have the same power spectral density as an access point, due to the asymmetrical nature of traffic. An additional margin of 6 dB will provide protection to incumbents as client devices operate in the vicinity of access points. Accordingly, we conclude that the appropriate maximum power spectral density for low power indoor client devices in this band is 6 dB below the limit for access points (or -1 dBm/MHz based on the adopted PSD limit).

3. Protecting Incumbent Operations

a. Fixed Microwave Service

114. We find that fixed microwave receivers will be protected from harmful interference from unlicensed indoor low power devices operating at the power levels we are authorizing. We reach this conclusion based on the examination of two representative technical studies submitted to the record. First, a Monte Carlo simulation submitted by CableLabs provides a strong basis for reaching this conclusion.[274] This study assumes realistic operating conditions for both licensed and unlicensed services. Second, a link budget analysis for six particular cases submitted by AT&T illustrates that interference is not likely to occur with the proposed power levels when realistic assumptions are made regarding propagation losses and taking into account the probabilistic nature of unlicensed transmissions. Because these six cases represent microwave receiver/unlicensed device geometries that are challenging from an interference perspective, the results give us confidence that interference is unlikely to occur. We

[274] A Monte Carlo simulation uses random sampling and statistical modeling to estimate mathematical functions and mimic the operations of complex systems. Harrison RL., *Introduction To Monte Carlo Simulation*, AIP Conf Proc. 2010;1204:17–21. doi:10.1063/1.3295638.

explain in more detail the numerous other technical filings submitted and why we do not find them as significant to our conclusion.

115. Among several technical studies submitted by advocates of indoor low-power operations showing that the likelihood of interference to fixed microwave receivers is extremely low, we find the CableLabs study the most significant.[275] These studies generally perform Monte Carlo computer simulations that model a random deployment of low-power unlicensed devices and calculate statistics on the likelihood of interference occurring to microwave receivers.[276] Advocates of indoor low-power operations claim that fixed microwave links will not experience harmful interference from the unlicensed devices.[277]

116. The Fixed Wireless Communications Coalition claims that fixed microwave links are typically designed to achieve 99.999% or 99.9999% reliability and that even rare interference from unlicensed devices will reduce this reliability.[278] They object to the statistical nature of the arguments used by unlicensed proponents pointing out that even if a single access point is unlikely to cause interference, the fact that hundreds of millions of access points will be deployed means that a significant number of microwave links will receive interference.[279] The Fixed Wireless Communications Coalition points out that its concern is the anomalous access point located within the microwave receiver's main beam, close to the antenna, lacking ground clutter, and either outdoors or inside a building with an inadequate wall. Although such an access point may be rare, they claim that the hundreds of millions of unlicensed devices will make this occurrence commonplace resulting in harmful interference to a significant number of links.[280]

117. Other fixed microwave licensees have also emphasized the importance of maintaining high link reliability. Utilities claim that their microwave links are used to monitor and control the power grid and must operate in near real-time to avoid system instability and power disruptions.[281] NPSTC claims that 6 GHz microwave links are used for links to/from 911 centers and connections between public safety radio base stations and control facilities.[282] APCO points out that public safety organizations use microwave links that are designed to have downtime of no more than 30 seconds a year.[283] Other microwave licensees such as railroads and telecommunications providers also emphasize the critical nature of their links.[284] Parties representing microwave licensees submitted both simulations[285] and link

[275] CableLabs Dec. 20, 2019 *Ex Parte*; CableLabs Jan. 17, 2020 *Ex Parte*..

[276] Apple, Broadcom et al, Jan. 26, 2018 *Ex Parte*, GN Docket No. 17-183 (RKF Study); CableLabs Dec. 20, 2019 *Ex Parte*; CableLabs Feb. 21, 2020 *Ex Parte*; Apple, Broadcom et al, June 24, 2019 *Ex Parte;* Apple, Broadcom et al, Feb. 28, 2020 *Ex Parte.*

[277] Apple, Broadcom et al. Jan. 26, 2018 *Ex Parte*, GN Docket No. 17-183 (RKF Study); CableLabs Dec. 20, 2019 *Ex Parte*; CableLabs Jan. 17, 2010 *Ex Parte*.

[278] Fixed Wireless Communications Coalition May 1, 2019 *Ex Parte* at 2.

[279] *Id*. at 2-3; Fixed Wireless Communications Coalition Aug. 22, 2019 *Ex Parte* 2-3.

[280] Fixed Wireless Communications Coalition Oct. 31, 2019 *Ex Parte* 2-3.

[281] UTC Comments at 4; Tucson Electric Power Comments at 7-8; Southern Companies at 3-4; Idaho Power Comments at 4.

[282] NPSTC Comments at 5.

[283] APCO Comments at 4.

[284] Association of American Railroads Comments at 3-5; NE Colorado Cellular Comments at 1-3; AT&T Comments at 6-9.

[285] *See, e.g.,* RigNet July 11, 2019 *Ex Parte*; Edison Electric Institute Jan. 13, 2020 *Ex Parte*.

budget analyses.[286]

118. In general, any technical study pertaining to spectrum sharing should take into consideration the specific behavior of services involved and the complexity of the propagation environment where the services operate. Studies that focus on static link budgets, for example, neglect the effects of the sporadic nature of most unlicensed transmissions (activity factor) and the probability of co-channel operation of the unlicensed device and the licensed service (e.g., an 80-megahertz unlicensed channel covers less than 7% of the 6 GHz band). These factors reduce the probability of interference to the licensed service. Some of the studies based on link budgets use a single value for building entry loss,[287] while others treat the building entry loss as a probabilistic quantity with a range of building losses and associated probabilities.[288] Some of the studies present different results for traditional buildings and thermally efficient buildings[289] while others assume a mix of building types to create a combined distribution of a single attenuation loss.[290] A number of studies are based on Monte Carlo-type simulations in order to more accurately capture the sporadic nature of access point transmissions and the probabilistic nature of co-channel operation.[291] Regardless of the type of analysis, some of the studies predominately, or strictly, assume free space propagation conditions[292] while others use industry standard statistical propagation models that more accurately represent the operational environment.[293]

119. *CableLabs Study*. CableLabs submitted a technical study that models the interference potential of low-power indoor unlicensed devices to microwave receivers.[294] This Monte Carlo simulation explores the potential for interference to fixed links in the New York City area.[295] The simulation uses the WINNER II urban propagation model, the propagation model we adopt in this Report and Order for intermediate distances for AFC systems.[296] The CableLabs study selects a building entry loss between 10dB and 30 dB, which is consistent with ITU recommendation P.2109.[297] Furthermore, the

[286] Rignet July 11, 2019 *Ex Parte* at 8; *See* AT&T Nov. 12, 2019 *Ex Parte* at 5; CTIA Mar. 16, 2020 *Ex Parte* at 5; Southern Company Feb. 6, 2020 *Ex Parte* at 4; Fixed Wireless Communications Coalition Reply Appendix A.

[287] Rignet July 11, 2019 *Ex Parte* at 8; Apple, Broadcom et al, Jul. 31, 2019 *Ex Parte* at 12.

[288] AT&T Nov. 12, 2019 *Ex Parte* at 14; CTIA Mar. 16, 2020 *Ex Parte* at 10.

[289] CTIA Mar. 16, 2020 *Ex Parte* at 10; *See* AT&T Nov. 12, 2019 *Ex Parte* at 8; Southern Company Feb. 6 2020 *Ex Parte* at 11.

[290] CableLabs Jan. 20, 2020 *Ex Parte* attachment 20; Apple, Broadcom et al. Jan. 26, 2018 *Ex Parte*, GN Docket No. 17-183, at 31-32 (RKF Study).

[291] CableLabs Dec. 20, 2019 *Ex Parte at* 8; Apple, Broadcom et al. Jan. 26, 2018 *Ex Parte*, GN Docket No. 17-183 (RKF Study) at 5.

[292] Rignet July 11, 2019 *Ex Parte* at 21; *See* AT&T Nov. 12, 2019 *Ex Parte* at 5; CTIA Mar. 16, 2020 *Ex Parte* at 5; Southern Company Feb. 6, 2020 *Ex Parte* at 4; Critical Infrastructure Industry Jan. 13, 2020 *Ex Parte* at 15.

[293] CableLabs Dec. 20, 2019 *Ex Parte* at 20; Apple, Broadcom et al. Jan. 26, 2018 *Ex Parte*, GN Docket No. 17-183 (RKF Study) at 31-35.

[294] CableLabs Dec. 20, 2019 *Ex Parte*; CableLabs Feb. 14, 2020 *Ex Parte* at 5-7.

[295] CableLabs *Ex Parte* Dec. 20, 2019. The CableLabs Study assumes two microwave links with heights at the tenth percentile and ninetieth percentile of the fixed links in the New York City area. *Id*. at 18. The unlicensed access points were uniformly distributed at a density of 1000 per square mile at heights determined by LIDAR building data from New York City. *Id*. at 17.

[296] By intermediate distances we are referring to distances between 30 meters and 1 kilometer.

[297] A 70/30 mix of traditional versus thermally efficient building types would result in building entry losses in this range. We believe that a mix of 70% traditional and 30% thermally efficient building types is appropriate to use when determining a statistical probability of building entry loss, which is consistent with the technical study submitted by NAB and the report from CEPT submitted by AT&T. NAB Dec. 5, 2019 *Ex Parte* at 42; AT&T Aug.

(continued….)

simulation uses a distribution of air-time utilization based on data taken from 500,000 Wi-Fi access points to model how often each access point in the simulation transmits.[298] The simulations showed that the I/N, which reflects the potential for interference, is far below the levels where interference would be expected to occur.[299] In fact the CableLabs Study shows I/N ratios far less than the -6 dB threshold the Fixed Wireless Communications Coalition, which represents the interest of the fixed microwave licensees, uses as a threshold for harmful interference to fixed microwave links.[300]

120. We find the CableLabs' study persuasive because it uses actual air time utilization data for hundreds of thousands of Wi-Fi access points along with a statistical model for building entry loss. Since non-AFC controlled unlicensed operations in this band are limited to indoor operations only, all technical studies must account for signal attenuation due to the building entry loss. Most of the technical studies use data from ITU Recommendation P.2109, which presents cumulative distribution functions of building entry loss for both traditionally constructed buildings and thermally efficient buildings that are based on measurements.[301] These cumulative distribution functions illustrate that building entry loss attenuation is significantly larger for thermally efficient buildings and increases if the angle of incidence of the signal with the building wall is not perpendicular to the wall.[302] Some of the analyses just use a single value, such as the mean value, to represent the attenuation.[303] Others treat the building entry loss as a probabilistic quantity where the cumulative distribution function is used in a Monte Carlo simulation or use a range of building losses and associated probabilities.[304] Some of the studies present different results for traditional buildings and thermally efficient buildings while others assume a mix of building types to create a combined distribution of a single attenuation loss.[305] Rather than using a single average or median value to represent building entry loss the CableLabs' study uses attenuation values drawn from a probability distribution for each access point in the simulation.[306] In this way the simulation more accurately models the variability of the building loss than using a single number for building loss such as the median or average.

(Continued from previous page)
5, 2019 *Ex Parte* at 44 (Sharing and compatibility studies related to Wireless Access Systems including Radio Local Area Networks (WAS/RLAN) in the frequency band 5925-6425 MHz, ECC Report 302, May 29, 2019). The median value of the 70/30 building entry loss curve is 20.5 dB. *Predication of Building Entry Loss*, International Telecommunications Union Radiocommunications Sector, ITU-R P.2109 (2017).

[298] CableLabs *Ex Parte* Dec. 20, 2019.

[299] CableLabs *Ex Parte* Dec. 20, 2019. The results of the CableLabs' simulation shows that the aggregate interference power from indoor unlicensed devices is always at least 8 dB below the microwave receiver noise floor and a maximum aggregate I/N = -8.5 dB when the fixed microwave was closer to the ground and maximum aggregate I/N = -29.7 when the fixed microwave receiver was higher above ground.

[300] Fixed Wireless Communications Coalition Comments Feb. 19, 2019 at 17; Fixed Wireless Communications Coalition Reply at 26.

[301] *Predication of Building Entry Loss*, International Telecommunications Union Radiocommunications Sector, ITU-R P.2109 (2017).

[302] In general, the greater the angle of incidence from perpendicular, the more attenuation occurs. *Id*.

[303] The mean building entry loss used in Rignet and Critical Infrastructure Industry studies is 11 dB. *See* Rignet July 11, 2019 *Ex Parte* at 8; *See* Critical Infrastructure Industry Jan. 13, 2020 *Ex Parte* at 25;

[304] CableLabs Dec. 20, 2019 *Ex Parte* attachment at 20; CableLabs Jan. 17, 2020 *Ex Parte* attachment at 12; Apple, Broadcom et al. Jan. 26, 2018 *Ex Parte*, GN Docket No. 17-183 (RKF Study) at 31-32.

[305] AT&T Nov. 12, 2019 *Ex Parte* (uses both traditional and energy efficient values separately); Apple, Broadcom, et al. Jan. 26, 2018 *Ex Parte*, GN Docket No. 17-183 (RKF Study) (uses a mix of traditional and energy efficient types).

[306] CableLabs Dec. 20, 2019 *Ex Parte* at 20.

121. AT&T claims that the CableLabs Study uses an unrealistic distribution of access point powers in their study.[307] CableLabs later submitted additional simulation results that fully address AT&T's concern by assuming all access points operate at 8 dBm/MHz and that show the I/N was less than -6 dB in all instances.[308]

122. AT&T also objects to CableLabs use of measured Wi-Fi activity factor data in their simulations, on the grounds that the proposed rules do not limit use of the bands only to Wi-Fi or limit unlicensed devices' activity factor.[309] However, Wi-Fi is the predominant use of the U-NII bands, and is ubiquitous in both residences and businesses. We expect that the majority of indoor unlicensed operations in the 6 GHz band will be for Wi-Fi as well. While Wi-Fi data transmission will likely increase over time as new applications are developed, we expect that this will be counteracted in the 6 GHz band by the availability of 160 MHz or wider channels which will allow more data to be transmitted in a shorter period of time. Additionally, while the adopted rules do not limit the activity factor, we are requiring devices to use a contention-based protocol which will prevent devices from transmitting at extremely high duty cycles. For these reasons, we find that the CableLabs study is the best evidence in the record of the impact that unlicensed low-power indoor devices will have on incumbent operations—and it demonstrates that such operations will not cause harmful interference.

123. *AT&T Study*. AT&T offers six scenarios where an unlicensed device operates in close proximity to a fixed microwave receiver or where an unlicensed device operates relatively far from the microwave receiver but the terrain causes the unlicensed device to be in or close to the main receiver beam.[310] AT&T states that these situations are not uncommon in their network as microwave links are frequently used to backhaul traffic from a rural site to more urbanized areas where fiber connectivity is available.[311]

124. AT&T's technical study attempts to overcome the limitation of simple deterministic interference calculations by introducing a probability distribution around Building Entry Loss. AT&T claims that their examples properly apply building entry loss by treating it as a probabilistic quantity using the distribution from ITU-recommendation P.2109 and that prior analyses have oversimplified Building Entry Loss into a single value.[312] We conclude, however, that this step does not fully remedy the limitation of a static link budget analysis limitations. Some of the most significant elements of the AT&T link budgets are also probabilistic quantities. AT&T's link budget makes the following assumptions: (a) an EIRP of 30 dBm in an 80 MHz channel (11 dBm/MHz); (b) the maximum unlicensed device EIRP is in the direction of the microwave antenna; (c) free-space propagation for the interfering signal; (d) zero clutter loss; (e) an unlicensed device at the location is capable of 6 GHz operation and is operating co-frequency with the microwave receiver; and (f) the unlicensed device has a 100% duty cycle.[313] Clearly, there are a significant number of parameters with associated probability distributions that are missing from AT&T's link budget. For example, AT&T's use of a free-space propagation model ignores clutter that often surrounds the transmitter and receiver sites (and that may significantly reduce the risk of harmful interference).

125. Apple, Broadcom et al. claim that AT&T's assumptions, like the unlicensed device's antenna gain, bandwidth mismatch, and limited clutter and propagation losses, exaggerate interference in

[307] AT&T Jan. 23, 2020 *Ex Parte* at 11.

[308] CableLabs March 19, 2020 *Ex Parte* at 2.

[309] AT&T Jan. 23, 2020 *Ex Parte* at 10-11.

[310] *See* AT&T Nov. 12, 2019 *Ex Parte* at 7-8.

[311] AT&T Nov. 12, 2019 *Ex Parte*, at 8.

[312] AT&T Nov. 12, 2019 *Ex Parte*, at 5.

[313] *Id*. at 11-29.

all of the scenarios by more than 1000%.[314] Apple, Broadcom et al. claim that AT&T assumes maximum EIRP in the direction of the microwave receiver, even though the record clearly shows that RLAN antennas do not exhibit significant gain towards the horizon.[315] We agree with Apple, Broadcom et al. that real-world unlicensed device antenna patterns would likely result in less gain toward the horizon and that based on typical EIRP patterns of indoor enterprise and consumer access points[316] a 5dB gain reduction is appropriate for analysis purposes.[317] Based on the differing bandwidths of the microwave signals and unlicensed devices, we also agree with Apple, Broadcom et al. that a bandwidth mismatch correction factor of -4.7 dB is appropriate.[318] Apple, Broadcom et al. also argue that other correction factors would also be appropriate.[319]

126. Similarly, CableLabs claims that they simulated interactions over billions of possible parameter combinations, including the values used by AT&T and other values reflecting real-world conditions and they find that harmful interference is unlikely to occur to the microwave links presented by AT&T.[320] In their simulations CableLabs, unlike AT&T, considers the co-channel probability that an unlicensed access point is using the same channel as the AT&T victim link to better reflect real-world conditions.[321]

127. We now present a detailed comparison in Table 1 for one of AT&T's examples (Example 2) with explanations for why we assume different values for some of the parameters that are assumed by either AT&T or Apple, Broadcom et al.

Table 4: AT&T Example 2, WQPJ679 Batavia, NY. Longer distance between RLAN and FS, but RLAN closer to main beam.

	AT&T	Apple, Broadcom et al.	FCC
EIRP/BW	**30 dBm/ 80 MHz**	**30 dBm/160 MHz**	**24 dBm/80 MHz**
PSD	**11 dBm/MHz**	**8 dBm/MHz**	**5 dBm/MHz**
Antenna Gain	37.9 dB	37.9 dB	37.9 dB
Antenna Discrimination	-1.5 dB	-2.538 dB	-1.5 dB
RLAN/FS Antenna Mismatch	**0 dB**	**-5 dB**	**-5 dB**
Clutter	**0 dB**	**-25.00 dB**	**-18.4 dB (using ITU-R P.452 clutter model)**

[314] Apple, Broadcom et al. group Dec. 16, 2019 *Ex Parte*, attachment at 2; *see also* CableLabs Jan. 21, 2020 *Ex Parte*, Att.at 3 (claiming that AT&T's static analysis suffers from a host of unrealistic assumptions and errors, and that the interference analysis should simulate ranges of relevant parameters, including worst-case and real-world values).

[315] Apple, Broadcom et al. Dec. 16, 2019 *Ex Parte*, Attach. at 3.

[316] Apple, Broadcom et al. Jan. 26, 2018 *Ex Parte*, GN Docket No. 17-183 (RKF Study) at 19.

[317] Apple, Broadcom et al. Dec. 16, 2019 *Ex Parte*, Attach. at 3.

[318] AT&T uses a -3dB bandwidth mismatch but based on ratio of 30/160 MHz the bandwidth mismatch is -7.27 (10*log10(30/160), ignoring adjacent channel, leading to a correction factor of -4.27 (-7.27-(-3)). *See* AT&T Nov. 17, 2019 *Ex Parte*.

[319] Apple, Broadcom, et al. Dec. 16, 2019 *Ex Parte*, Attach. at 11.

[320] Cable Labs Jan. 21, 2020 *Ex Parte*, Attach. at 4.

[321] CableLabs Dec. 23, 2019 *Ex Parte*, Attach. at 12.

Path Loss	**-118.96 dB (free space)**	**-118.92 dB (free space)**	**-120.12 dB (ITM P2P model**
Bandwidth Mismatch	**- 3 dB (assuming 80 MHz channels)**	**-7.27 dB (assuming 160 MHz channels)**	**-4.26 (assuming 80 MHz channels)**
Noise Figure	-3.0 dB	-3.0 dB	-3.0 dB
Polarization Loss	-3.0 dB	-3.0 dB	-3.0 dB
Feeder Loss	0 dB	0 dB	0 dB
Building Entry Loss (50%)	**-17.00 dB**	**- 17.00 dB**	**-20.62 dB (70/30 mix)**
Interference (I)	**-78.76 dBm**	**-113.83 dBm**	**-114 dBm**
Noise Floor (N)	-99 dBm	-99 dBm	-99 dBm
I/N	**20.44 dB**	**- 14.83 dB**	**-15.0 dB**

128. The bold rows in the above table are parameters that were adjusted as follows:

(i) EIRP/BW: Apple, Broadcom et al. assumed a bandwidth of 160 MHz. However, our analysis assumes a nominal channel bandwidth of 80 MHz as assumed by AT&T, which results in a 5 dBm/MHz PSD limit.

(ii) RLAN/FS Antenna mismatch: We agree with Apple, Broadcom et al. that there will be an antenna pattern mismatch between the unlicensed devices and the FS antenna and that 5 dB is a reasonable assumed loss.[322]

(iii) Clutter: We agree with Apple, Broadcom et al. that a clutter loss is appropriate for this scenario. However, we disagree with their assumed figure of 25 dB value and base a more realistic value on a standard clutter model (ITU-R P.452) to derive an 18.4 dB clutter loss.

(iv) Path loss: We believe that the ITM P2P path loss model is most appropriate for this scenario because the distance from unlicensed device to microwave receiver is 3.5 km.[323]

(v) Bandwidth mismatch: We base the mismatch on an 80-megahertz bandwidth unlicensed channel. However, we assume that the mismatch factor should be -4.26 dB based on the ratio of the passband of AT&T's receiver and the bandwidth of the unlicensed channel and not a flat 3 dB as proposed by AT&T.

(vi) Building Entry Loss: We find that a 70% traditional construction/30% energy efficient construction mix of building types for determining Building Entry Loss is appropriate.[324]

129. Table 5 presents all of AT&T's six examples but substitutes more realistic technical parameters we adopt in this Report and Order and presented in Table 4.

Table 5: FCC Analysis of the AT&T Examples

	Example 1A	Example 1B	Example 2	Example 3	Example 4	Example 5
EIRP Power Spectral Density (dBm/MHz)	5	5	5	5	5	5

[322] See *supra* para. 125.

[323] This is consistent with the propagation model we have adopted for the AFC systems. See *supra* para. 68.

[324] See *supra* footnote 297.

Bandwidth (MHz)	80	80	80	80	80	80
EIRP (dBm)	24	24	24	24	24	24
RLAN Antenna Discrimination (dB)	-5	-5	-5	-5	-5	-5
BW Mismatch (80 MHz Chan.) (dB)	-4.26	-4.26	-4.26	-4.26	-4.26	-4.26
Polarization Loss (dB)	-3	-3	-3	-3	-3	-3
Propagation Model	Winner II Urban LOS	Winner II Urban LOS	ITM[325] P2P	ITM P2P	Winner II Suburban LOS	Winner II Suburban LOS
Propagation Loss (dB)	-103.6	-99.5	-120.12	-122.7	-96.1	-83.6
Clutter Loss[326] (dB)	0	0	-18.4	-18.4	0	0
MW Antenna Gain (dB)	43.2	43.2	37.9	38.8	41.3	38.8
MW Antenna Discrimination (dB)	-36	-38	-1.5	-0.9	-38	-40
Feeder Loss (dB)	-2	-2	0	0	-2	0
Building Entry Loss (70T/30E) 50th Percentile (dB)	-21.4	-21.9	-20.6	-20.6	-23.1	-24.0
Noise (dBm)	-99.0	-99.0	-99.0	-99.0	-99.0	-99.0
Noise Figure (dB)	3	3	3	3	3	3
I/N (dB)	-12.06	-10.46	-15	-16.1	-10.1	-1.06

130. Table 5 shows that when more realistic technical parameters than assumed by AT&T are used for their analysis, the I/N ratio in all but one case is below the -6 dB benchmark—a conservative benchmark that virtually assures no harmful interference in any of these five cases.[327] Significantly, because these examples represent cases where the unlicensed devices are close to the microwave receivers or have terrain features that place the unlicensed device squarely in the main beam, they are representative of the worst cases that are likely to occur. Accordingly, they do not serve to rebut the persuasive showing by CableLabs based on a reliable probabilistic assessment derived from measurements associated with hundreds of thousands of actual Wi-Fi APs.

131. In only one case does a static link budget analysis suggest a nontrivial likelihood of harmful interference (Case 5), and we do not believe this one case poses a significant potential for actual harmful interference. That's in part because a -6 dB I/N is a conservative proxy for harmful interference and in part because many statistical factors unaccounted for in this link budget analysis make the actual

[325] Irregular Terrain Model, Point to Point configuration.

[326] Based on ITU-P.452 village center clutter model.

[327] As stated earlier, we are not making a determination that any signal received with an I/N greater than -6 dB would constitute "harmful interference" but only that the statistical behavior of I/N in general should meet this criterion.

occurrence of harmful interference much less likely. For example, the I/N ratios in Table 5 do not consider the probability of an access point being co-channel with the microwave receiver. An unlicensed device operating with an 80-megahertz channel bandwidth will have 6.25% probability of operating co-channel with the microwave receiver as shown in Table 6. Another important factor that is not considered in the Table 5 analysis is the activity factor or duty cycle. For instance, in accordance with Annex F of TSB 10-F, impact of a 25% duty cycle interference source is 6 dB lower than the same interference source with 100% duty cycle.[328] CableLabs presents measurements from 500,000 Wi-Fi APs that show the average weighted activity factor is 0.4% and a similar activity factor is widely used in other simulations.[329] Combining the low probability of co-channel operation and low activity factor, we conclude that based on a 5 dBm/MHz EIRP, the low power indoor operation will have an insignificant chance of causing harmful interference to the microwave links for any of these six examples (or fixed microwave links more generally).

Table 6: Co-Channel Probabilities for Different Channel Bandwidths

Channel Bandwidth	# of Channels in 6 GHz	# of Channels in 2.4 GHz, U-NII 1 and U-NII 3	Total # of Available Channels	Pr (Co-channel in 6 GHz band)	Channel Bandwidth Distribution	Pr (overlapping)
160 MHz	7	0	7	14.29%	0.3	4.287%
80 MHz	14	2	16	6.25%	0.5	3.125%
40 MHz	29	5	34	2.94%	0.1	0.294%
20 MHz	59	12	71	2.82%	0.1	0.282%

132. CableLabs, Charter, and Comcast advocate that we permit low-power unlicensed devices to operate using 8 dBm/MHz PSD EIRP, arguing that the CableLabs' Study illustrates that harmful interference will not occur to fixed microwave links at this power level.[330] If the EIRP where increased to 8 dBm/MHz, the I/N ratios for examples 1B, 4, and 5 in Table 5 would recalculate to -7.46 dB, -7.1 dB, and 1.94 dB respectively, which would appear to be a materially higher risk of harmful interference (although still very low). Thus, we choose to adopt a conservative 5 dBm/MHz EIRP at this time to enable low-power indoor operations throughout the 6 GHz band with insignificant risk of harmful interference. To explore the potential for additional unlicensed device flexibility, we examine the possibility of higher power in the Further Notice.

133. *CTIA Study*. CTIA submitted a technical study—similar to that of AT&T—showing link budgets for five scenarios involving actual microwave links which they content will experience interference from unlicensed devices in nearby buildings.[331] We have conducted a similar analysis of the CTIA study as we did with AT&T's study and arrived at similar results—once one takes into account a more realistic link budget analysis and the effects of a number of probabilistic parameters, the likelihood of harmful interference to incumbent operations of low-power indoor operations is insignficant.

134. *Southern Companies Study.* Southern Companies also submitted a technical study

[328] TIA/EIA, Interference Criteria for Microwave Systems, Telecommunications Systems Bulletin TSB 10-F at F-7.

[329] CableLabs *Ex Parte* received Dec. 20, 2019; Apple, Broadcom, et al. Jan. 26, 2018 *Ex Parte*, GN Docket No. 17-183 (RKF Study); CEPT ECC Report 302 (https://www.ecodocdb.dk/download/cc03c766-35f8/ECC%20Report%20302.pdf); Ofcom Consultation (https://www.ofcom.org.uk/__data/assets/pdf_file/0038/189848/consultation-spectrum-access-wifi.pdf).

[330] CableLabs, Charter, Comcast, Cox, March 20, 2020 *Ex Parte* at 1.

[331] CTIA Jan. 24, 2020 *Ex Parte*.

showing link budgets for multiple points along three different microwave paths.[332] The study sums the power from multiple unlicensed access points at the locations of apartment buildings and businesses to create an aggregate interference level and also presents results assuming there was only one unlicensed access point at each location. The study claims that the probability that the I/N would be greater than -6 dB is very high in many of the locations.[333]

135. We do not find the results of this study convincing for a number of reasons. The study uses free space as the propagation model which is only appropriate when the access point is very close to the microwave receiver: This is not the case for any of the scenarios in this study.[334] Furthermore, an examination of satellite photography of the area traversed by these links shows that these are mostly rural and some suburban locations with abundant tree cover and no high-rise buildings that would rise above the clutter.[335] However, the study applies a clutter loss to only a few of the scenarios.[336] A more appropriate methodology would have been to either use a propagation model that inherently includes clutter loss (Winner II) or to incorporate clutter loss using statistical clutter model (e.g. ITU-R P.2108). Regarding the aggregate effect of multiple unlicensed devices, this analysis assumes that all of the unlicensed devices are on the same side of the building facing the microwave receivers and transmitting at the same time.[337] To evaluate the spectrum sharing potential, including aggregate interference impact, a technical analysis should instead take a statistical approach such as in Monte Carlo simulations so as to probabilistically account for many intertwined phenomena.

136. *CII User Study.* The Critical Infrastructure Industry (CII)[338] submitted a statistical study that analyzes the potential impact of 6 GHz unlicensed use on the incumbent CII and public safety providers that currently use the band.[339] The CII study is a Monte Carlo simulation that considers co-channel and adjacent interference from both indoor and outdoor Wi-Fi access points to microwave links in the Houston area. The study assumes that access points can transmit on any channel across the U-NII bands.[340] The study concludes that indoor low power (24 dBm) access point deployment would cause all microwave links in the Houston area to experience harmful interference.[341]

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[332] Southern Companies Jan. 31, 2020 (received Feb 6, 2020) *Ex Parte*.

[333] Southern Companies Jan. 31, 2020 (received Feb 6, 2020) *Ex Parte* at 9-11.

[334] The path lengths ranged from 390 m to 37 km.

[335] This satellite photography was found at Google Maps www.google.com/maps.

[336] Southern Companies Jan. 31, 2020 (received Feb 6, 2020) *Ex Parte* at 9-11.

[337] CableLabs Dec. 20, 2019 *Ex Parte* at 4-5.

[338] Edison Electric Institute, the American Gas Association, the American Public Power Association, the American Water Works Association, the National Rural Electric Cooperative Association, the Nuclear Energy Institute, and the Utilities Technology Council.

[339] Edison Electric Institute Jan. 13, 2020 *Ex- Parte* at 1.

[340] U-NII-1, U-NII-3, U-NII-5, U-NII-6, U-NII-7, or U-NII-8 bands, for a total of 1425 MHz of bandwidth. Critical Infrastructure Industry Jan. 13, 2020 *Ex Parte* at 15. Based on the available bandwidth the Study defines a Power Spectral Area Density (PSAD) in the Houston metro is equal to 0.25 W * 1 RLAN / person * 260 person / km^2 / 1425 MHz or 45.6 mW/MHz-km^2. *See* Edison Electric Institute Jan. 13, 2020 *Ex-Parte*, attachment at 1. The calculated PSAD is used as a starting point in the analysis to calculate the average aggregate interference power and I/N ratio. The study includes building entry loss, Wi-Fi activity factor, and a 0 dBi antenna gain factor for indoor access points. *See Id.* at 12-13. The propagation model used for the metropolitan Houston analysis is a line-of-sight (LOS) Free-Space Path Loss (FSPL) model (20 dB / decade) for the first kilometer and a modified path loss model (38 dB / decade) for distances beyond 1 km. *See Id.* at 15

[341] All point-to-point links in the Houston MSA to experience ratios more than 5.46 dB and up to 25.24 dB greater than a -6 dB. *See* Edison Electric Institute Jan. 13, 2020 *ExParte* Attach. at 21.

137. Apple, Broadcom et al. criticize the CII study contending that there were major mistakes in the underlying assumptions that, once corrected, completely erase any potential for harmful interference.[342] For example, they contend that using a more realistic path loss model eliminates any harmful interference predicted from indoor devices.[343]

138. We generally agree with Apple, Broadcom, et al. that the CII study has several critical flaws rendering the conclusions of the study fundamentally flawed and unreliable. Even though it incorporates specific access point behavior into the simulation, including activity factor, transmit speed, and availability of other Wi-Fi bands,[344] it also made certain assumptions that significantly detract from its value. For example, it assumes both outdoor operations and power levels that we do not allow for low-power indoor operations. As another example, in a dense urban environment like that of the city of Houston, the CII study assumes free space propagation path loss for the first kilometer,[345] and ignores the impact of buildings, trees, terrain, and other obstructions.[346] This assumption ignores real life conditions in Houston, and it is also inconsistent with the TIA TSB-10 F recommendation regarding use of a statistical propagation model that considers different environments such as medium-small city, large city, or suburban.[347] TIA TSB-10 F is a widely recognized technical standard for sharing between fixed microwave links and other services.[348] Without justification,[349] the study assumes that all buildings in the Houston areas are of traditional construction, ignoring the normal mix of traditional and thermally efficient construction expected in a 240 km^2 area.[350] This assumption leads to a significant underestimation of building entry loss. Among other noteworthy assumptions, the study assumes there is an access point for every man, woman, and child living in the Houston area,[351] each watching a 4K video streaming service.[352] Naturally, such assumptions will lead to substantial errors on the order of tens of decibels.

139. *Apple, Broadcom et al. Studies*. Apple, Broadcom et al. undertook two technical studies that used typical microwave link characteristics to determine whether indoor unlicensed devices were likely to cause interference to microwave links. They conclude that the typical microwave link characteristics make them unlikely to experience harmful interference.[353] One study examined all 292 microwave links in the New York City area.[354] Combining LIDAR[355] data for every high-rise building

[342] Apple, Broadcom et al. Feb. 7, 2020 *Ex- Parte* at 10 (correcting the assumptions would reduce the maximum interference from indoor devices to -39.44 dB I/N and reduce the maximum interference from outdoor devices to -35.63 dB I/N). Apple, Broadcom et al. identified several flaws in the CII User Study including oversimplification of RLAN/FS interaction, multiple error in use of pathloss models, overstating the number of access points, overstating the access point activity factor, underestimating building entry loss, failing to properly consider access point antenna patterns. *Id.* at 3-4, 7-9.

[343] Apple, Broadcom et al. Feb. 7, 2020 *Ex- Parte* at 10.

[344] *See generally* Apple, Broadcom et al. Feb. 7, 2020 *Ex Parte*.

[345] Edison Electric Institute Jan. 13, 2020 *Ex Parte*, attachment at 15.

[346] Apple, Broadcom et al. Feb. 7, 2020 *Ex Parte* at 2.

[347] TIA/EIA, Interference Criteria for Microwave Systems, Telecommunications Systems Bulletin TSB 10-F at F-7.

[348] Southern Company Feb. 27, 2020 *Ex Parte* Attach. E at 4.

[349] Edison Electric Institute Jan. 13, 2020 *Ex Parte* attachment at 25.

[350] *Id.* at 7.

[351] *Id.* at 14.

[352] *Id.* at 13.

[353] Apple, Broadcom et al. July 31, 2019 *Ex Parte*; Apple, Broadcom et al. July 5, 2019 *Ex Parte*.

[354] Apple, Broadcom et al., July 31, 2019 *Ex Parte* at 2.

within the 3 dB main beam of each microwave receiver antenna.[356] With a link budget analysis, the study finds that only 2.7% of the paths would experience an I/N greater than -6 dB and the worst case I/N was only -0.47 dB.[357] These numbers do not include the activity factor and bandwidth overlap probabilities that would reduce the actual likelihood of interference on these links. Furthermore, this study assumes that the unlicensed devices would have an EIRP of 11 dBm/MHz, which is 6 dB higher than what we are permitting and uses the free space propagation model which makes the results extremely conservative.[358] This study largely confirms our analysis that authorizing low-power indoor operations as we do will not create any significant risk of harmful interference.

140. The second study examined the 152 link microwave network of the Los Angeles Department of Water and Power microwave network.[359] The study finds that of the 39 of these links that could potentially experience an I/N of -6 dB or greater, only four of those links would experience a C/I that indicates their performance has the potential to be degraded.[360] However, these studies suffer from many of the same shortcomings as the AT&T study discussed above—in particular not taking into account that the probability of the microwave link and access point are operating on the same channel and the bandwidth mismatch between the two signals.

141. *Additional Considerations*. We are fully convinced, that as the Monte Carlo simulations and our examination of the link budget studies show, fixed microwave links will have an insignificant chance of experiencing harmful interference from indoor low-power unlicensed operations. Further, the non-continuous nature of the transmissions of the most widely used unlicensed systems today, like Wi-Fi makes the occurrence of harmful interference even less likely. And our rule requiring that low-power indoor access points employ a contention-band protocol ensures that none of these unlicensed devices will employ continuous transmissions. The data that CableLabs submitted collected from 500,000 Wi-Fi access points shows that 95% of access points have an activity factor of less than 2% and only 1% of access points are active more than 7% of the time. [361] This illustrates that most of the time a particular access point will not be transmitting.

142. The sporadic and bursty nature of Wi-Fi transmissions is significant for two reasons. First, it illustrates why discussions of aggregate interference from Wi-Fi devices cannot simply add the power received from the individual access points to calculate the received interference. Instead, to more accurately estimate aggregate interference a Monte Carlo simulation which accounts for the intermittent nature of the transmissions should be undertaken.

143. Second, potential degradation of a microwave link will only occur if a deep atmospheric multipath fade occurs at the same time the microwave receiver receives an excessively high powered transmission from an unlicensed device, such that natural losses due to separation distance, clutter, and terrain do not sufficiently diminish the power received from the unlicensed device. Atmospheric multipath fading is caused when stable air masses, such as warm and humid air, lead to stratification of the atmosphere[362] and the most prevalent during the 8-hour period after midnight—which does not

(Continued from previous page)

[355] Light Detection and Ranging (LIDAR) is a technology similar to RADAR that can be used to create high-resolution digital elevation models (DEMs) with vertical accuracy as good as 10 cm. LiDAR data includes terrain and clutter information for the geographic area studied. *See* U.S. Geological Survey at www.usgs.gov.

[356] Apple, Broadcom, et al. July 31, 2019 *Ex Parte*, at 3.

[357] *Id*. at 2, 12.

[358] Apple, Broadcom, et al. July 31, 2019 *Ex Parte*, at 12.

[359] Apple, Broadcom, et al. July 5, 2019 *Ex Parte*.

[360] *Id.* at 25.

[361] CableLabs Dec. 20, 2019 *Ex Parte* at 4-5 (The weighted average activity factor is 0.4%).

[362] *See* George Kizer, Digital Microwave Communication, 321-324 (2013).

overlap the 7-11 PM Wi-Fi access point peak usage time.[363] The temporal separation between when multipath fading is most likely to occur and when Wi-Fi devices are heavily used means there is low probability that Wi-Fi transmissions will overlap with multipath fading events. This assertion is corroborated by the Telecommunication Industry Association (TIA),[364] which shows an example in TSB 10-F that only considers the 8-hour period after midnight of significant consequence when considering spectrum sharing between the Personal Communications Services and Private Operation-Fixed Microwave Service.[365] Thus, consistent with this recommendation, because the Wi-Fi access point busy hour is not between the 8-hour period after midnight, we conclude that the likelihood of harmful interference to fixed service microwave links from indoor low power Wi-Fi access points is insignificant.[366]

144. The Fixed Wireless Communications Coalition has made the argument that the Commission cannot permit unlicensed devices to cause harmful interference to microwave receivers.[367] It points to the Commission's long-standing principle of requiring unlicensed devices to protect licensed services and a 2008 court decision stating that the "the Commission may permit the use of unlicensed devices only when it finds there is not a 'significant potential' for harmful interference to licensed operations."[368] It claims that under this standard an unlicensed device need not disrupt licensed communications to cause harmful interference—it need only present a significant potential for disruption.[369] It claims that the critical safety services carried by microwave links call for a stringent harmful interference standard and that if unlicensed devices do cause actual and harmful interference there will be no way to recall them.[370]

145. We disagree with the Fixed Wireless Communications Coalition to the extent that it implies that our obligation regarding harmful interference from unlicensed devices goes beyond what is enumerated in our rules. The requirements for unlicensed operation requirements codified in Part 15 applies to a wide variety of emissions and devices. When adopting Part 15 rules that apply to a particular band or application (e.g. level probing radars, U-NII devices, etc.), the Commission considers the particular technical and operational parameters necessary to minimize the potential for harmful interference to authorized services in that particular situation and acts accordingly. Thus, while as general matter harmful interference is defined as "[a]ny emission, radiation or induction that endangers the functioning of a radio navigation service or of other safety services or seriously degrades, obstructs or repeatedly interrupts a radiocommunications service operating in accordance with this chapter,"[371] the Part 15 rules apply this criteria on a case by case basis for different bands after careful consideration of the incumbent services in each band that ensures such harmful interference is unlikely to occur. We take

[363] TIA/EIA, Interference Criteria for Microwave Systems, Telecommunications Systems Bulletin TSB10-F at F-7; Apple, Broadcom, et al. Jan. 26, 2018 *Ex Parte*, GN Docket No. 17-183 (RKF Study) at 14-15.

[364] TIA/EIA, Interference Criteria for Microwave Systems, Telecommunications Systems Bulletin TSB10-F.

[365] *Id*. at F-7.

[366] We are cognizant of the Fixed Wireless Communications Coalition's claim that microwave links have no excess fade margin and that harmful interference will reduce the reliability of the microwave link. Because we have concluded based on the technical studies that harmful interference will not occur, permitting low-power indoor unlicensed devices will not reduce the reliability of the microwave links. Fixed Wireless Communications Coalition Nov. 21, 2019 *Ex Parte* at 3.

[367] Fixed Wireless Communications Coalition Reply at 7-8.

[368] Fixed Wireless Communications Coalition May 29, 2019 *Ex Parte* at 3 (citing American Radio Relay League, Inc. v. FCC, 524 F.3d 227, 234-35 (D.C. Cir. 2008)).

[369] Fixed Wireless Communications Coalition Oct. 31, 2019 *Ex Parte* at 11.

[370] *Id*. at 12.

[371] 47 CFR § 15.3(m).

the same approach here: the technical and operational limits we are adopting in this proceeding ensure that unlicensed devices will not have a significant potential for causing harmful interference to the users authorized to operate in the 6 GHz band. As the Fixed Wireless Communications Coalition admits, it is the Commission and not the parties who determines what degree of interference constitutes harmful interference.[372]

146. In a similar vein, AT&T contends that the Communications Act and the Commission's rules generally prohibit the Commission from authorizing a service or type of unlicensed operation that can cause harmful interference, regardless of whether the probability of such interference is low.[373] The Commission, however, is not required to refrain from authorizing services or unlicensed operations whenever there is any possibility of harmful interference. Indeed, such a prohibition would rule out virtually all services and unlicensed operations, given that there is virtually no type RF-emitting device that does not have the potential for causing such interference if used incorrectly. In rulemakings, the Commission may authorize operations in a manner that reduces the possibility of harmful interference to the minimum that the public interest requires, and it will then authorize the service or unlicensed use to the extent that such authorization is otherwise in the public interest.[374] We have determined that the restrictions and requirements that we are establishing for indoor use of low power access points eliminates any significant risk of causing harmful interference. Of course, as AT&T correctly points out, once interference to a protected service crosses the relevant threshold specified in section 15.3(m) for harmful interference, it is immediately actionable for enforcement purposes.[375]

147. Here, as always, we focus on identifying and protecting against actual-use cases; were we to act on every unrealistic or contrived situation that purports to show the potential for harmful interference, our rules would allow for few or no opportunities for sharing between unlicensed devices and licensed services; sharing that has allowed Wi-Fi to prosper along with continued licensed spectrum use. We emphasize, however, that under our long-established rules, Part 15 devices are not permitted to cause harmful interference.[376] This fundamental principle stands regardless of the particular band- and application-specific rules that we adopt.

b. Mobile Services

148. The 6 GHz band Mobile service allocation is limited to the U-NII-6 and U-NII-8 bands.

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[372] Fixed Wireless Communications Coalition Oct. 31, 2019 *Ex Parte* at 5.

[373] AT&T Mar. 23, 2020 *Ex Parte*.

[374] *See, e.g.,* Amendment of Part 15 of the Commission's Rules for Unlicensed Operations in the Television Bands, *et al*., and Amendment of Part 74 of the Commission's Rules for Low Power Auxiliary Stations, 30 FCC Rcd 9551, 9562-64, paras. 28-32 (2015) (authorizing expanded unlicensed operations of fixed white space devices where potential of causing harmful interference to TV reception would be minimized, while still providing increased opportunities for the provision of unlicensed service); Amendment of Part 15 regarding New Requirements and Measurement Guidelines for Access Broadband over Power Line (BPL) Systems, 26 FCC Rcd 15712, 15719-20 (2011) (despite "some potential for increased harmful interference from BPL," establishing "a regime of rules for Access BPL systems that will provide a robust environment for the development and deployment of this important new technology option for delivery of broadband internet/data services while at the same time minimizing the potential for interference to licensed services caused by leakage from power lines of the RF energy used by BPL transmissions operations"), remanded on other grounds, *American Radio Relay League, Inc. v. FCC*, 524 F.3d 227, 234-35 (D.C. Cir. 2008) (recognizing longstanding Commission interpretation of section 301 "to allow the unlicensed operation of a device that emits radio frequency energy as long as it does not 'transmit[ ] enough energy to have a significant potential for causing harmful interference' to licensed radio operators") (citing Revision of Part 15 of the Commission's Rules Regarding Ultra–Wideband Transmission Systems, 19 FCC Rcd 24558, 24589 & n.179 (2004)).

[375] AT&T Mar. 26, 2020 *Ex Parte* at 3; 47 C.F.R. § 15.3(m).

[376] 47 CFR § 15.5(b).

In these bands, the mobile service incumbents operate electronic news gathering and other Part 74 broadcast auxiliary services, as well as Part 78 Cable Television Relay Service, and Part 101 Local Television Transmission Service.[377] Incumbents operate portable camera relays to "jumbotron" screens for major sporting events at stadiums and arenas, and at musical concerts at large venues, indoors and outdoors; use the spectrum bands for video relay to production trucks at news events; and for video signal multi-hop mobile relay from newsworthy events to either a satellite news truck, a fixed receive site or a temporary relay site.[378] Low Power Auxiliary Stations, also licensed in the U-NII-8 band, operate on an itinerant basis and transmit over distances of approximately 100 meters for uses such as wireless microphones, cue and control communications, and TV camera synchronization signals.[379] Additional terrestrial uses of the band include short range video relay for video production at automobile and sailboat racing event, political conventions and golf tournaments.[380] Because of the nature of their use—breaking news, event coverage, etc.—the use of particular portions of this band by these auxiliary services is unpredictable.

149. NAB opposes allowing indoor unlicensed operations in the bands where there are broadcast auxiliary service operations (U-NII-6 and U-NII-8), unless a "robust, reliable mechanism is developed to coordinate" the unlicensed operations with the licensed uses.[381] To support of its position, NAB submitted a study which evaluates the impact of indoor and outdoor[382] unlicensed operations in the U-NII-6 and U-NII-8 bands in three different use scenarios: (i) an electronic news gathering truck transmitting to a central receive site; (ii) portable cameras transmitting to an outdoor electronic news gathering truck receive site; and (iii) portable cameras transmitting to an indoor receive site.[383]

150. NAB is the only advocate for mobile operations in U-NII-6 and U-NII-8 bands to submit a detailed technical study. NAB's study focuses on mobile electronic news gathering operations in the band but we believe the results of their study can be extrapolated to Cable Television Relay Service operations, which are similar to broadcast auxiliary service.[384] Additionally, many Local Television Transmission Service are classified as mobile stations and often operate at temporary fixed locations.[385] NAB uses statistical Monte Carlo simulation to determine the interference potential to the electronic news gathering uses. The NAB study uses LiDAR data[386] to predict line-of-sight between indoor unlicensed access points placed at a height of 1.5 meters, and electronic news gathering receive sites.[387] The study assumes only indoor locations where line-of-sight is predicted between the electronic news gathering receiver and a point outside the building, assumes 23 dBm for unlicensed device power in the direction of

[377] Society of Broadcast Engineers Comments at 3.

[378] Society of Broadcast Engineers Comments at 2.

[379] 47 CFR § 74 Subpart H.

[380] Society of Broadcast Engineers Feb. 18, 2020 *Ex Parte* at 3.

[381] NAB Comments at 2.

[382] For purposes of this Report and Order, we will not be addressing outdoor unlicensed operations in these bands since we are not considering adopting such rules.

[383] NAB Dec. 5, 2019 *Ex Parte*.

[384] 47 CFR § 78.5(a) Cable Television Relay Service definition: A fixed or mobile station used for the transmission of television and related audio signals, signals of standard and FM broadcast stations, signals of instructional television fixed stations, and cablecasting from the point of reception to a terminal point from the point of reception to a terminal point from which the signals are distributed to the public.

[385] 47 CFR § 101.815. A survey of ULS assignments in the LTTS service conducted on 3/24/2020 found that 104 out of 108 assignments had areas of operation rather than a fixed location.

[386] LiDAR data includes terrain and clutter information for the geographic area studied.

[387] NAB Dec. 5, 2019 *Ex Parte* at 6.

the receiver,[388] and uses a co-channel operation probability distribution based on low power indoor devices in the 6 GHz band being restricted to operate in U-NII-6 and U-NII-8.[389] The NAB study uses the free space path loss propagation model between the building façade and the electronic news gathering receiver, Building Entry Loss based on a mix of 70% traditional and 30% energy efficient building types,[390] a conservative I/N <= -10 dB interference criterion, and two activity factors (0.44% and 10%).[391] NAB predicts interference for each use scenario, which it claims could result in degradation or complete loss of electronic news gathering video signals.[392]

151. Though the NAB study provides some valuable information about the potential of harmful interference to electronic news gathering receive sites, we disagree with its assumptions. We disagree with NAB's use of free-space path loss for all paths based on a predicted percentage of area that is line-of-sight when in fact unlicensed devices will be placed randomly located and could very well be in areas of buildings without line-of-sight to the electronic news gathering receiver. Under more realistic conditions, we note that NAB's chosen -10 dB I/N benchmark is rarely exceeded in the electronic news gathering truck receiver case. We also disagree with its use of I/N = -10 dB as a metric for evaluating probability of harmful interference probability—considering a more reasonable -6 dB would show even better results. And taking into account the power-level and contention-based protocol limitations we adopt would show even better results.

152. Apple, Broadcom, et al. also used LiDAR data to assess line of sight probability in the same scenarios as NAB's study and concludes that a clear line-of-sight is rare, even in places where NAB claimed that as much as 90 to 100% of the population would have line-of-sight.[393] NAB disagrees, and in response submitted a picture from the base of one of their electronic news gathering central receive locations showing a view in one direction of the surrounding area.[394] However, Apple, Broadcom, et al. additionally points out that although free-space propagation may be appropriate in some locations, the average propagation loss is best approximated by an appropriate urban propagation model, which would result in far greater propagation loss due to clutter, multipath effects, and other sources of attenuation.[395] We agree with Apple, Broadcom et al. that the average propagation loss from randomly placed unlicensed devices is better approximated with an urban propagation model.

153. NAB used two specific activity factors, 0.44% and 10%, where the higher activity factor scenario shows a much higher probability of exceeding their conservative I/N threshold than the lower activity factor scenario. In contrast, CableLabs submitted a technical study of the potential for interference between indoor unlicensed devices and broadcast auxiliary service receivers[396] which uses two distributions of activity factors based on empirical data collected from over 500,000 Wi-Fi users with

[388] 23 dBm EIRP is 1 dB lower than the maximum power level we are approving for indoor use.

[389] NAB Dec. 5, 2019 *Ex Parte* Table 10 at 22. The NPRM originally proposed restricting low power indoor use to U-NII-6 and U-NII-8 bands and sought comment on low power indoor use in U-NII-5 and U-NII-7 bands. See NPRM at § C.

[390] NAB used ITU Recommendation P.2109 to calculate the appropriate Building Entry Loss.

[391] NAB Dec. 5, 2019 *Ex Parte* at 23.

[392] NAB Dec. 5, 2019 *Ex Parte* at (i).

[393] Apple, Broadcom, et al. Feb. 28, 2020 *Ex Parte* at 5.

[394] NAB March 23, 2020 *Ex Parte* at 5-6.

[395] Apple, Broadcom, et al. Jan. 14, 2020 *Ex Parte* at 2.

[396] CableLabs Feb. 21, 2020 *Ex Parte*.

weighted airtime utilizations of 0.4 and 4%.[397]

154. Finally, NAB's study includes co-channel operation probability in its statistical study but bases this probability on unlicensed devices being restricted to the U-NII-6 and U-NII-8 bands. NAB's assumption increases the probability of co-channel operations and thus, over predicts the potential for harmful interference to electronic news gathering operations.[398]

155. *Outdoor electronic news gathering central receive sites*. At the higher activity factor, NAB's study predicts that indoor unlicensed devices will cause near continuous aggregate I/N above -10 dB at the electronic news gathering central receive sites studied.[399]

156. For the reasons outlined above, we believe NAB's study overstates the potential of exceeding this very conservative I/N value and therefore also overstates the likelihood of exceeding the less conservative but still protective I/N value of -6 dB. Apple, Broadcom, et al. submitted a statistical study of the same scenarios but based on a combination of WINNER II and Irregular Terrain Model with the P.2108 propagation models.[400] The Apple, Broadcom et al. study considers two activity factors and a 70/30 mix of building entry loss based on ITU Recommendation P.2109.[401] The Apple, Broadcom et al. results indicate that aggregate signal level from indoor unlicensed devices will exceed a level 6 dB below the electronic news gathering central site receiver noise floor only 0.1% of the time. Thus, concluding that there is a negligible risk of harmful interference.[402] We find that the Apple, Broadcom et al. study uses more appropriate propagation models and therefore more accurately represents the risk of harmful interference from indoor unlicensed devices to electronic news gathering central receive sites and find that risk to be insignificant.

157. *Interference to electronic news gathering truck receivers*. Results of NAB's own study show that at the lower activity factor of 0.44% indoor unlicensed devices are unlikely to cause the I/N to exceed -10 dB. At the 10% activity factor, the electronic news gathering truck receiver results showed that between 0.2 and 49.8% of the time the aggregate I/N exceeds the -10 dB I/N threshold.[403] CableLabs' empirical activity factor data show a weighted distribution of 0.4%.[404] We conclude that it is highly unrealistic to assume that every unlicensed device in an area surrounding an electronic news

[397] CableLabs Feb. 21, 2020 *Ex Parte* at 3, 22. This distribution of activity factors has weighted average of 0.4% but includes activity factors up to 100%. CableLabs also increased the distribution of activity by an order of magnitude to 4.0%.

[398] NAB Dec. 5, 2019 *Ex Parte* Table 10 22.

[399] NAB Dec. 5, 2019 *Ex Parte* at 46.

[400] Apple, Broadcom, et al. Feb. 28, 2020 *Ex Parte*; Apple, Broadcom, et al. March 9, 2020 *Ex Parte*. WINNER II model at distances less than 1 kilometer and Irregular Terrain Model at distances greater than 1 kilometer.

[401] Apple, Broadcom, et al, considered one "high utilization" device with an activity factor of 0.44% and nine "low utilization" devices with an activity factor of 0.00022% per person. They also studied the impact of aggregate interference seen by the electronic news gathering receiver if the activity factor increases 10 times. The risk of exceeding I/N = -6 increased from 0.1% to approximately 1% across the electronic news gathering central receive sites studied. Apple, Broadcom, et al. March 9, 2020 *Ex Parte*.

[402] Apple, Broadcom, et al. Feb. 28, 2020 *Ex Parte* at 4.

[403] NAB Dec. 5, 2019 *Ex Parte* Table 12. For electronic news gathering truck receivers when activity factor is 0.44%, between 0.0 and 2.8% of the Monte Carlo samples showed aggregate I/N from indoor devices above -10 dB, depending on the azimuth of the electronic news gathering receive antenna. When the activity factor was increased to 10%, the percentage of time where the Monte Carlo samples showed aggregate I/N above -10 dB varied between 0.2 and 49.8%, again depending on the azimuth and height of the electronic news gathering receive antenna.

[404] CableLabs Feb. 21, 2020 *Ex Parte* at 3, 22. This distribution of activity factors has weighted average of 0.4% but includes activity factors up to 100%. CableLabs also increased the distribution of activity by an order of magnitude to 4.0%.

gathering truck will be transmitting at the high 10% activity factor.

158. The NAB study also concludes that the level of unwanted signal seen by the electronic news gathering truck receiver is dependent on the relationship between the height of the unlicensed device, the height of the electronic news gathering antenna and the height of the surrounding environment.[405] The same relationship between local environment and antenna heights will exist for the desired link between the electronic news gathering transmitter and truck mounted receiver, except the electronic news gathering link can be planned and the electronic news gathering truck can be positioned to achieve the best possible signal between transmitter and receiver. Given the sensitivity of potential interference to geometry coupled with NAB's unrealistic assumption that every unlicensed device in an area surrounding an electronic news gathering truck will be transmitting at the high activity factor, we conclude that the potential for harmful interference (using a more appropriate -6 dB threshold) is again insignificant for the scenario indicated.

159. CableLabs and Apple, Broadcom et al. both submitted studies indicating that harmful interference from indoor unlicensed devices to outdoor electronic news gathering truck receivers will be unlikely. CableLabs describes two intensive operational scenarios where electronic news gathering operations and unlicensed device operation may be present; an indoor case, examining Grand Central Station's main hall and an outdoor case, involving Macy's Thanksgiving Day Parade.[406] The CableLabs' study uses a 10 dB signal-to-interference-plus-noise as the relevant figure of merit.[407] CableLabs studied paths from both indoor and outdoor camera-back transmitters to an outdoor electronic news gathering receiver and found very low probability that the signal-to-interference-plus-noise of the electronic news gathering link would ever be less than 10 dB.[408] CableLabs' Broadcast Auxiliary Service study claims that throughout the millions of simulations conducted, "in nearly all cases, broadcast auxiliary service link quality was maintained at levels sufficient to deliver high-quality video."[409] CableLabs also studied the sensitivity of their results to increases in activity factor, decreases in Building Entry Loss and increases in unlicensed device EIRP and found in all cases that the probability of signal-to-interference-plus-noise falling below 10 dB was negligible.[410]

160. Broadcom similarly finds that camera-back transmitters deliver high quality video to electronic news gathering trucks at signal-to-interference-plus-noise ratios of 10 dB or greater.[411] Broadcom finds that for a 10% activity factor the electronic news gathering link required a signal-to-interference-plus-noise of between 2 and 9 dB to maintain a bit error rate less than 1e-8 and deliver high quality video.[412] Apple, Broadcom, et al. studied a camera-back transmitter located in the DC

[405] NAB Dec. 5, 2019 *Ex Parte* at 46.

[406] CableLabs Feb. 21, 2020 *Ex Parte* at 3.

[407] CableLabs Feb. 21, 2010 *Ex Parte* at 3.

[408] Cable Labs Feb. 21, 2020 *Ex Parte* 2/21/20. CableLabs assumes WINNER II LOS model and a fixed 10 dB Building Entry Loss for indoor to outdoor scenarios, otherwise it assumes a 10 to 30 dB Building Entry Loss for outdoor camera-back to outdoor receiver.

[409] CableLabs Feb. 21, 2020 *Ex Parte* at 4 (claiming that broadcast auxiliary service SINR remained above 10dB in at least 99.9991% of cases […] including under aggressive Wi-Fi parameters with higher Wi-Fi activity and stronger propagation than typical).

[410] Charter Communications, CableLabs Feb. 21, 2020 *Ex Parte*: CableLabs Mar. 9, 2020 *Ex Parte*.

[411] Broadcom March 10, 2020 *Ex Parte*. Broadcom tested interference signals with a duty cycle of 1, 2, 10 and 93% at various electronic news gathering code rates and in 8 and 10 MHz bandwidths. At 10% duty cycle worst case SINR was 9 dB.

[412] According to CableLabs, 10 dB is a conservative SINR value derived from receiver sensitivity in Vislink spec sheets and ETSI ES 202 239. CableLabs, Charter Feb. 21, 2020 *Ex Parte* at 8. This value is also supported by Broadcom. Broadcom Feb. 28, 2020 *Ex Parte*.

Metropolitan Police Department headquarters transmitting to an electronic news gathering truck receiver on the street.[413] This study looked at the signal-to-interference-plus-noise at the electronic news gathering receiver based on four nearby indoor unlicensed devices.[414] Apple, Broadcom, et al, found that the worst case signal-to-interference-plus-noise was 18 dB.[415]

161. NAB objects to the use of signal-to-interference-plus-noise instead of an I/N criterion for determining harmful interference.[416] It states that electronic news gathering systems are opportunistic and, unlike fixed point-to-point links, are not engineered for reliability and often operate at SNRs below 10 dB.[417] NAB points out that electronic news gathering signals vary in a random fashion, typically as a result of multipath propagation caused by moving objects in the environment.[418]

162. We agree with CableLabs' and Apple, Broadcom et al.'s findings, that the risk of harmful interference to outdoor electronic news gathering receivers from indoor unlicensed devices is negligible. We note that the same conditions that cause signal variations in the electronic news gathering signal will also act upon a signal from an unlicensed device. CableLabs states that 10 dB signal-to-interference-plus-noise provides an accurate basis for determining the impact of unlicensed indoor devices on broadcast auxiliary service signals.[419] Apple, Broadcom et al. asserts "[n]ews truck operators will be able to improve their link budgets by slightly adjusting the positions of their trucks or shooting locations."[420] We also note that both Apple, Broadcom et al. and CableLabs' studies assume a maximum of 30 dBm EIRP with at least an 8 dBm/MHz PSD, and we are permitting indoor unlicensed devices to transmit with only a maximum 5 dBm/MHz PSD. This 3 dB variance further reduces the probability of harmful interference to electronic news gathering trucks from unlicensed devices.

163. *Interference to indoor electronic news gathering receivers*. The final scenario studied by NAB is communication between indoor electronic news gathering transmitters, such as microphones and camera-back transmitters, and indoor electronic news gathering receivers. Although the Wi-Fi Alliance seeks to dismiss these concerns by pointing out that venue operators can exercise some control to manage the facility's radio frequency environment by either shielding licensed devices or disabling the 6 GHz unlicensed band in the access point settings,[421] NAB disputes this, pointing out that frequency coordination for large venues is accomplished via a hired frequency coordinator and not by the venue operator.[422] NAB adds that large venues do not plan for mobile phone usage with embedded wireless hotspots.[423]

164. We agree with NAB that such a scenario would present some risk of harmful interference without all of the constraints that we adopt today. However, we are not permitting client devices to be used as hotspots[424] and we are requiring 6 GHz unlicensed devices to use a contention-based protocol.[425]

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[413] Apple, Broadcom et al. Feb. 28, 2020 *Ex Parte* at 9.

[414] Apple, Broadcom, et al. March 9, 2020 *Ex Parte*: Apple, Broadcom, et al. Feb. 20, 2020 *Ex Parte*.

[415] Apple, Broadcom, et al. Mar. 9, 2019 *Ex Parte* Attach. at 5.

[416] See NAB Mar. 23, 2020 *Ex Parte* at 4.

[417] *Id*.

[418] *Id*.

[419] CableLabs Feb. 21, 2020 *Ex Parte* at 3.

[420] Apple, Broadcom et al. Feb. 28, 2020 *Ex Parte* at 10.

[421] Wi-Fi Alliance Comments at 15.

[422] NAB Mar. 23, 2020 *Ex Parte* at 3.

[423] *Id*.

[424] See Technical Rules 15.407(d)(5).

We conclude that such a protocol will allow unlicensed devices to sense the energy from nearby indoor licensed operations and avoid using that channel. Apple, Broadcom et al. points out that the 802.11 specification dictates that devices sense the energy in the channel and not transmit if they detect energy at a level greater than -62 dBm.[426] To confirm that energy sensing could be used to mitigate interference to indoor electronic news gathering receivers, Apple, Broadcom, et al. simulated the receive power level from electronic news gathering transmitters at 20 unlicensed access points operating within the US House of Representatives chamber. The results of this simulation demonstrate that, even at the lowest electronic news gathering transmit power level, all unlicensed access points would detect the electronic news gathering signal at greater than -62 dBm and therefore not transmit co-channel.[427] While we are not requiring a specific technology protocol or contention method, we conclude the results of the Apple, Broadcom, et al. study show the likely potential of contention-based protocols to protect indoor mobile links, including electronic news gathering and Low Power Auxiliary Stations. Thus, we conclude that the risk of harmful interference to indoor electronic news gathering receivers from indoor unlicensed devices is insignificant.[428]

c. Fixed-Satellite Services

165. The entire 6 GHz band is also home to a FSS allocation (Earth-to-space), while U-NII-8 has a few space-to-Earth MSS feeder downlinks.[429] In the NPRM we concluded that interference to satellite stations from low power indoor operations would not be a problem due to the low power and indoor restriction which prevents a clear line of sight to the satellites.[430]

166. Sirius XM, Intelsat and SES oppose outdoor unlicensed use without the control of an AFC but agree that indoor use will have negligible effect on aggregate interference at the satellite.[431] Globalstar, which operates earth stations receiving in the U-NII-8 band, claims that allowing unlicensed indoor use of the U-NII-8 band would cause substantial harmful interference to its existing MSS feeder downlinks, and to any additional gateways that it may consider deploying in the future.[432] Globalstar submitted a technical analysis showing aggregate interference calculations from population centers within

(Continued from previous page)

[425] See Technical Rules 15.407(d)(7).

[426] Apple, Broadcom et al. Feb. 28, 2020, *Ex Parte* at 11.

[427] Apple, Broadcom et al. Feb. 28, 2020, *Ex Parte* at 13.

[428] For this study, NAB assumes that all indoor unlicensed devices are 6 GHz capable—and using 6 GHz. NAB Dec. 5, 2019 *Ex Parte* at 37. Although we don't dispute the first consideration, we also expect that most, if not all, unlicensed devices that operate in the 6 GHz band will also have capabilities to operate in other unlicensed bands. To manage the RF environment, we expect that unlicensed devices will take advantage of all the available bands so that any single portion of the spectrum should not be overly concentrated with transmitters.

[429] 47 CFR § 2.106 footnotes NG172 and 5.458B. The space-to-Earth allocation is limited to use by non-geostationary mobile-satellite service feeder links and earth stations receiving in this band are limited to locations within 300 m of coordinates in Brewster, WA, Clifton, TX, and Finca Pascual, PR. Globalstar also operates earth station receive sites at Wasilla, AK and Seabring, FL. These last two locations are authorized to operate on a co-primary basis for feeder downlinks for FSS, except for 7.025-7.055 GHz band, where they are authorized only on an unprotected basis.

[430] *See* Notice 33 FCC Rcd at 10506, para. 25.

[431] Intelsat and SES Americom Reply at n.32 (contending that indoor use is not likely to cause interference); Sirius XM Radio Comments at 11-12 (explaining that Sirius XM operates Satellite Digital Audio Radio Service (SDARS) feeder links (Earth-to-space) in the U-NII-8 band, and claiming that limiting use to indoors and constraining the power levels would materially decrease the potential for harmful interference in the SDARS feeder link spectrum).

[432] GlobalStar Comments at 7, 9.

approximately 10 kilometers of their gateway earth stations located at Sebring, FL, Waisilla, AK,[433] Clifton, TX, and Las Palmas, PR.[434] The study concludes that Globalstar's mobile satellite services will be detrimentally affected if unlicensed indoor low power operations are introduced in U-NII-8 band.

167. We disagree with Globalstar's analysis. As Apple, Broadcom, et al. point out Globalstar's analysis represents an impossible worst-case scenario because it assumes that the earth station antenna is pointing at its minimum usable elevation angle in each of the interfering indoor access points resulting in the assumption that earth station antennas will simultaneously receive unlicensed device transmissions from all directions with the same antenna gain.[435] Globalstar also assumes all unlicensed devices are operating at the same location where the incidence angle at the building wall is always zero, yielding the least building entry loss.[436] Globalstar, uses a conservative 10% activity factor with all unlicensed activity concentrated at a small number of sites resulting in an unrealistic assumption that unlicensed transmission will always be subject to 7 dBi of earth station gain.[437] However, it is unlikely that all indoor unlicensed devices will be operating at the same location and orientation with respect to the path between the device and the earth station receiver. Instead, the elevation angle at the building façade should be considered to be variable, resulting in incidence angles greater than zero, which would increase the building entry loss value and minimize the probability of interference. Globalstar assumes line-of-sight and free-space propagation for all paths. We disagree that line of sight and free-space propagation loss is appropriate in all cases between a randomly placed unlicensed device and Globalstar's earth station.

168. Finally, Globalstar's analysis assumes all unlicensed devices are operating at the proposed maximum permissible power with the peak antenna gain directed toward its earth stations.[438] We are allowing unlicensed indoor devices to operate at a maximum 5 dBm/MHz PSD which represents at least a 3 dB/MHz reduction over the power levels assumed in the Globalstar analysis. Additionally, when considering random placement of unlicensed devices and variations in the unlicensed device antenna pattern[439], it is unlikely that the unlicensed device EIRP in the direction of the earth station will always be at maximum power, thus the risk of harmful interference is further reduced. For the reasons outlined here, we find that Globalstar's link budget analysis fails to fully consider all the probability factors that must align in order for interference to occur. We therefore find that the risk of harmful interference occurring to Globalstar's earth stations to be low.

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[433] The earth stations at Sebring, FL and Waisilla, AK are authorized to operate on a co-primary basis for feeder downlinks for FSS, except for 7025-7055 MHz band, where they are authorized only on an unprotected basis.

[434] Globalstar Comments Attachment, "Technical Analysis of Impact of Unlicensed Operations in U-NII-8 on Globalstar Mobile Satellite Service" by Roberson and Associates, LLC.

[435] Globalstar Comments Attachment at 21; Apple, Broadcom et al. Reply at 32.

[436] Globalstar Comments Attachment at 25. Globalstar applies an expected value of Building Entry Loss based on a persistent nominal angle of incidence at the building wall. This expected value of Building Entry Loss is derived from P.2109 for building either low energy efficiency ("traditional") building type or thermally efficient building types. We believe a mix of 70% traditional and 30% thermally efficient building type should be used when determining a statistical probability of building entry loss, which is consistent with the technical study submitted by NAB and the report from CEPT submitted by AT&T. NAB Dec. 5, 2019 *Ex Parte* at 42; AT&T Aug. 5, 2019 *Ex Parte* at 44 (Sharing and compatibility studies related to Wireless Access Systems including Radio Local Area Networks (WAS/RLAN) in the frequency band 5925-6425 MHz, ECC Report 302, May 29, 2019). The median value of the 70/30 Building Entry Loss curve is 20.5 dB.

[437] Apple, Broadcom et al. Reply at 32.

[438] Globalstar assumes a maximum conducted power of 250 mW with a peak antenna gain of 6 dBi yielding an EIRP of 30 dBm. This is as proposed in the NPRM.

[439] Apple, Broadcom et al. Jan. 26, 2018 *Ex Parte*, GN Docket No. 17-183 (RKF Study) at 19-20; ECC Report 302 at 149-150 have typical unlicensed device antenna patterns which show variations in the gain.

d. Radio Astronomy

169. The National Academy of Sciences Committee on Radio Frequencies, which operates four observatories in remote areas, requests that the Commission use the AFC system to protect the radio astronomy observatories.[440] We are not adopting any AFC-based requirements for unlicensed low-power indoor operations generally, and decline to adopt such a requirement here. The four radio observatories that receive in the 6 GHz band are in remote locations and it is unlikely that indoor low-power unlicensed devices will be operating nearby. Furthermore, these observatories can restrict installation of such devices at their facilities. We believe that indoor unlicensed devices do not pose any risk of harmful interference to radio astronomy operations.

C. Equipment Issues

1. Antenna Requirements

170. In the Notice, the Commission sought comment on whether it should require antennas to be integrated into a device, or whether it could permit users to choose an appropriate antenna for their application.[441] The Commission also sought comment on whether an equipment authorization grantee for devices without an integrated antenna should be required to maintain a list of permissible antennas for that device.[442]

171. Several parties, including Fixed Wireless Communications Coalition, Sirius XM, Tucson Electric Power Company and Hewlett Packard Enterprise, support a requirement for integrated antennas for either indoor devices or all devices.[443] However, other commenters oppose a requirement for integrated antennas. Cambium argues that permitting connectorized antennas would allow installers to have greater flexibility to select an antenna that is appropriate for specific deployments, and that a professional installer could enter the antenna gain information into a unit so the transmit power is properly calculated to meet the EIRP limits.[444] Mid Continent Communications argues that requiring integrated antennas and radios will unnecessarily limit the ecosystem and stifle healthy competition among manufacturers.[445] It supports a requirement for an equipment authorization grantee to provide a list of permissible antennas with its equipment authorization and maintain such information on its website.[446]

172. Low power devices. We require that all low power devices incorporate integrated antennas and explicitly prohibit externally connected antennas on the outside of the device's enclosure. Requiring an integrated antenna makes it significantly more difficult for a party to replace a device's antenna with a higher gain antenna, which could increase a device's EIRP above the limit and therefore increase the potential for a device to cause harmful interference.

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[440] National Academy of Sciences Committee on Radio Frequencies Comments at 7.

[441] Notice, 33 FCC Rcd at 10525, para. 81.

[442] *Id.*

[443] Fixed Wireless Communications Coalition Comments at 41 (the Commission should require that each unlicensed device be shipped in a factory-sealed case with integrated antennas that the end user cannot easily bypass or replace); Sirius XM Comments at 3-4 (supports the use of an integrated antenna along with other technical recommendations to ensure that certain devices stay indoors); Tucson Electric Power Company Comments at 23 (the Commission should prohibit the manufacture, import or use of unlicensed equipment with changeable antennas or external antenna connections); Hewlett Packard Enterprise Comments at 21 (recommends that the Commission prohibit the use of connectorized antennas for low power indoor devices).

[444] Cambium Comments at 7-8.

[445] Mid Continent Comments at 12-13.

[446] Mid Continent Comments at 13.

173. Standard-power devices. We will not, however, require a permanently attached antenna for standard-power access points. We find that a requirement to use a permanently attached antenna on standard power access points could be overly restrictive. These types of devices are typically used outdoors by parties such as schools, businesses and WISPs and are configured in a manner where the antenna is mounted on a mast or building and connected through a cable to a separately located transmitter. Such a requirement could be difficult to implement for these configurations. In addition, permitting such devices a choice of appropriate antennas will provide options for meeting the antenna pointing restrictions which limit outdoor devices to antenna elevation angles less than 30 degrees for devices transmitting more than 21 dBm EIRP to protect satellite operations in the band. Further, we note that devices in other U-NII bands do not have a requirement for permanently attached antennas, so adding a requirement for equipment in the 6 GHz bands could make it more difficult for manufacturers to develop devices that are capable of operating across multiple bands. Applicants for equipment authorization of standard-power access points will be required to list all antennas that will be used with a device and demonstrate that the equipment complies with the EIRP limits with all antennas.

2. Maximum channel bandwidth

174. The Commission sought comment in the Notice on how it should specify the power limits for unlicensed devices, e.g., maximum power, power spectral density, and what channel width is the appropriate basis on which to establish a maximum power limit.[447] Because we are setting a power spectral density limit of 5 dBm/MHz for low power indoor devices to limit their potential for causing interference to incumbent services, we will permit these devices to operate with a maximum channel bandwidth to 320 megahertz to permit a maximum power of up to 30 dBm. For consistency we will also specify a maximum bandwidth of 320 megahertz for AFC controlled standard-power access points.[448]

175. We find that this bandwidth requirement is appropriate for several reasons. It will permit manufacturers to develop equipment under current standards with bandwidths of up to 160 megahertz as a number of parties suggest.[449] In addition, our understanding is that industry standards under consideration such as IEEE 802.11be will specify channel bandwidths of up to 320 megahertz. Thus, the bandwidth limit we are adopting will permit future equipment development under anticipated standards without a need for additional rule changes. However, we are placing a 320-megahertz upper limit on bandwidth so as not to supplant the rules for wideband and ultrawideband operations in the 6 GHz band. These rules permit operation with bandwidths greater than 500 megahertz, but with a lower -41 dBm/MHz power spectral density.[450] We note that unlicensed proponents have not requested channels bandwidths greater than 320 megahertz and that the Commission did not provide notice of any proposed changes to the wideband or ultrawideband rules.

3. Transmitted power levels

176. *Standard power device operations in rural areas*. In the Notice, the Commission sought comment on whether we should permit operation at higher power levels in rural and underserved areas.[451] Several unlicensed proponents, including WISPA, the Open Technology Institute et al., the Dynamic

[447] Notice, 34 FCC Rcd at 10524-25, para. 80.

[448] Because standard-power access points obtain a list of available frequencies from an AFC system, they have a higher spectral density limit and can achieve their maximum power of 36 dBm in a channel bandwidth of 20-megahertz.

[449] WISPA Comments at 27-28, Broadcom Comments at 27 (allowing low-power indoor operations throughout all four 6 GHz sub-bands would create many more 160-megahertz channels to deliver gigabit speeds over Wi-Fi); Apple, Broadcom et al. Comments at 33 (Wi-Fi standard includes channels ranging in size from 20 to 160 megahertz wide, with wider channels facilitating higher speeds).

[450] 47 CFR part 15, subpart F.

[451] Notice, 33 FCC Rcd at 10524, para. 79.

Spectrum Alliance, and NCTA, request that we increase the maximum permitted power in rural areas or allow significantly higher antenna gains for point-to-point operations in any areas such as are permitted in the U-NII-3 band (5.725-5.85 GHz), claiming that the AFC would protect licensed operations.[452] However, APCO, FWCC and Sirius XM oppose permitting higher power limits.[453]

177. We will not permit higher power limits in rural areas at this time, nor will we make any specific provisions for higher power point-to-point or point-to-multipoint operations in the U-NII-5 and U-NII-7 bands as suggested by some commenters.[454] We while we recognize that establishing a single power limit of 36 dBm for standard-power access points differs from the rules for the U-NII-1 and U-NII-3 bands that permit higher power for fixed point-to-point devices, and from the white space rules that permit higher power for fixed devices in "less congested" (e.g., rural) areas, we believe that higher power limits are not appropriate for several reasons.[455] We first note that the rules we are adopting do not place an upper limit on antenna gain; the transmit limits are based solely on EIRP, and manufacturers can use any combination of transmitter power and antenna gain to reach that limit. We interpret parties' requests for higher antenna gain limits as requests for higher EIRP limits. While allowing higher power could encourage the provision of additional services in rural and other areas, it also increases the range at which harmful interference to incumbent users in the bands could potentially occur. Therefore, we are taking a conservative approach at this time and not permitting power levels greater than 36 dBm for standard-power access points.[456] In addition, permitting higher power in only certain areas would make the AFC implementation more complex because criteria for where to allow higher power operation would have to be defined and incorporated into the AFC.[457] Taking into account the directivity of standard-power access point transmit antennas as some parties suggest would make AFC calculations more complex and require

[452] WISPA Comments at 9 (if the Commission desires to maximize rural deployment, permitting higher-power operations in the U-NII-5 and U-NII-7 bands will promote that objective); Open Technology Institute at New America, American Library Association, Consumer Federation of America, Consortium for School Networking, Public Knowledge, Access Humboldt Comments at 21 (the Commission should authorize higher power limits for outdoor operations under the control of an AFC to promote rural broadband); Facebook Comments at 8 (to promote rural broadband deployment in the 6 GHz band, the Commission should allow phased array antennas with steerable beams for outdoor unlicensed operations and devices in point-to-multipoint fixed configurations); Dynamic Spectrum Alliance Comments at 15 (the Commission should align its approach in the 6 GHz band to the successful approach in existing U-NII bands by facilitating higher-gain antennas as well as steerable point-to-point and point-to-multipoint operations.); NCTA Comments at 10 (supports higher power operations on a fixed point-to-point or fixed point-to-multipoint basis in rural and underserved areas, as long as those operations would not materially increase the risk of interference to C-Band uplinks or existing Wi-Fi networks).

[453] APCO International Comments at 17-18 (opposes allowing higher power unlicensed operations in rural areas as public safety links in rural areas should be afforded the same protection as operations in other areas; and unlicensed point-to-point and point-to-multipoint operations would substantially complicate the unlicensed frequency coordination process by requiring the AFC database to take into account azimuth and elevation angles); Fixed Wireless Communications Coalition Comments at 33 (FS antenna sites in rural areas require the same level of protection as urban antennas); Sirius XM Comments at 20 (Commission should decline to permit unlicensed operations at higher power levels in the U-NII-5 band in rural or unserved areas).

[454] Notice, 33 FCC Rcd at 10524, para. 79. Dynamic Spectrum Alliance Comments at 15 (the Commission should align its approach in the 6 GHz band to the successful approach in existing U-NII bands by facilitating higher-gain antennas as well as steerable point-to-point and point-to-multipoint operations.); NCTA Comments at 10 (supports higher power operations on a fixed point-to-point or fixed point-to-multipoint basis in rural and underserved areas.).

[455] 47 CFR §§ 15.407(a)(1)(iii), 15.407(a)(3), 15.709(a)(2).

[456] 47 CFR § 15.407(a)(3).

[457] For example, the white space databases must determine the locations where higher power operation is permitted ("less congested areas"). 47 CFR § 15.703(h).

the development of a means to ensure that the antennas are pointed in the correct direction.[458]

178. *Client Devices.* We are adopting rules that limit client devices to power levels 6 dB below the power limits for access points. We conclude that this 6 dB reduction is necessary because when the client device is operating under the control of the access point, the client device may have a slightly different propagation path and interference potential to a victim receiver.[459]

179. We generally decline to increase client device power levels to the same power levels as access points, as suggested by some commenters. For instance, parties request that the Commission adopt higher client device power and power spectral density (PSD) limits--maximum conducted output power of 250 mW and maximum PSD to 21 dBm/MHz for devices not subject to AFC, and 27 dBm/MHz for devices that are subject to AFC.[460] Cambium asserts that the proposed power limit effectively predetermines the types of services that could be offered in the bands by unduly restricting availability of efficient point-to-multipoint and point-to-point deployment options.[461] Still other commenters believe that the Commission should permit fixed client devices operating at conducted power up to +18 dBm in the U-NII-5 and U-NII-7 bands to use up to 18 dB antenna gain before reducing power.[462]

180. We recognize commenters concerns regarding the power differential between access points and client devices. However, because a client device may be portable (e.g., a cell phone) and operate at different locations around its serving access point, the propagation path of its emissions could vary. This could, in turn, slightly change the potential for interference from any particular client device to incumbent operations within the area. Thus, we decline to adopt power limits for client devices commensurate with access points. However, we make a limited exception to accommodate devices such as Wi-Fi extenders and mesh networking equipment intended to work in conjunction with an access point and share the same propagation path and thus the same power requirements. We will permit such devices to operate at the same power levels as an access point provided that they comply with all the requirements we set out for low power indoor access points (i.e., the device cannot be weather resistant, must have an integrated antenna and cannot have capability of connecting other antennas, cannot be capable of operating on battery power, and must include a label regarding proper usage) and the end unit obtains its own equipment certification.[463] Under these requirements modules do not qualify for higher power nor do devices that simply incorporate modules to provide connectivity. Further, such devices may only be used within a single structure and not to connect separate buildings or structures. We believe such relief is a reasonable accommodation to keep devices consumers' often need to cover larger homes and buildings less complex and more affordable without increasing the potential of harmful interference to incumbent licensees as these devices will be installed and used in a manner analogous to an access point.

181. We do not find it necessary to restrict the power radiated upward from client devices as we are requiring for standard-power access points. We believe it is unlikely that relatively low-power unlicensed devices will cause harmful interference to receivers on geostationary satellites approximately 36,000 km above the equator. We are limiting upward power from standard-power access points merely

[458] APCO Comments at 18.

[459] Clients to standard-power access points in the U-NII-5 and 7 bands may operate with 30 dBm maximum EIRP and 17 dBm/MHz maximum power spectral density, regardless of whether the client devices are located indoors or outdoors. Client devices that operate under the control of a low power indoor access point in the UNII-5 through U-NII-8 bands may operate with 24 dBm maximum EIRP (with a 320-megahertz bandwidth) and a -1 dBm/MHz maximum power spectral density.

[460] NCTA Comments at 18-19, Charter Comments at 3-4, Facebook Comments at 2, Cambium Comments at 4, Netgear Comments at 2-3, Quantenna Communications Comments at 7, Wi-Fi alliance Comments at 10.

[461] Cambium Comments at 4.

[462] WISPA Comments at 13-16; Starry, Comments at 3.

[463] These devices are referred to as subordinate access points in the rules.

as a precautionary measure as they are more likely to operate outdoors and with higher power. We note that client devices can operate with EIRP as high as 30 dBm, but we find that they are less likely to cause interference to satellite receivers than similarly powered outdoor access points due to the nature of their operation. We first note that client devices are limited to a power level 6 dB lower than access points, but we expect them to generally operate at much lower power levels to maximize battery life and comply with RF exposure limits. In addition, client devices communicate with access points in an asymmetric nature, in that relatively little data is transmitted in the uplink direction (i.e. from the client device) as compared to the downlink direction where any single access point may be serving many client devices. Moreover, client devices typically operate with omnidirectional antennas at low antenna heights and in a mobile or portable mode (i.e., not installed in permanent outdoor locations). Thus, we expect that upwardly directed client device emissions will often be at low power levels and shielded to some extent by buildings, foliage, or other obstructions.

4. Emission Mask and Out-of-Band Emission Limits

182. *Limits in the U-NII-5 through U-NII-8 bands.* In the Notice, the Commission sought comment on the emission mask that unlicensed devices should be required to meet to protect incumbent services operating on adjacent frequencies and whether the emission mask suggested by RKF Engineering in the technical study submitted by Apple, Broadcom, et al. on January 25, 2018 is appropriate for this purpose.[464] The Wireless Internet Service Providers Association supports the proposed mask and states that the mask represents a reasonable compromise between signal purity and cost and is not difficult for high-quality Wi-Fi and WISP equipment to incorporate.[465] The Wi-Fi Alliance believes that there is no need to regulate U-NII devices' emission mask to protect incumbent services operating on adjacent frequencies within the 6 GHz band because lower power transmissions by U-NII devices will produce negligible out-of-band power levels, as demonstrated by RKF where the worst case analysis of OOBE resulted in 0.01 dB increase to the in-band noise.[466] Tarana Wireless states that the emission mask suggested by RKF Engineering should be modified to improve radio frequency co-existence where the access system density is high.[467]

183. We conclude that the emission mask suggested by RKF Engineering, with certain modifications, will protect incumbent microwave links and other services operating in the adjacent channel to unlicensed devices within the U-NII-5 through U-NII-8 bands. Accordingly, we are requiring emissions from standard power access points and low power indoor devices within the U-NII-5 through U-NII-8 bands to comply with the transmit emission mask proposed in the Notice.[468] Specifically, we are requiring 20 dB suppression of power spectral density at one megahertz outside of an unlicensed device's channel edge, 28 dB suppression of power spectral density at one channel bandwidth from an unlicensed device's channel center, and 40 dB suppression of power spectral density at one and one-half times the channel bandwidth away from an unlicensed device's channel center.[469] At frequencies between one megahertz outside an unlicensed device's channel edge and one channel bandwidth from the center of the channel, the limits must be linearly interpolated between 20 dB and 28 dB suppression, and at frequencies between one and one and one-half time an unlicensed device's channel bandwidth from the center of the channel, the limits must be linearly interpolated between 28 dB and 40 dB suppression. Emissions

[464] Notice, 33 FCC Rcd at 10525, para. 83. A transmit emission mask in this case defines the required attenuation of an unlicensed device's signal outside its channel of operation, e.g., in adjacent channels. The transmit emission mask applies within the U-NII-5 through U-NII-8 bands, and OOBE limits apply outside of these bands.

[465] WISPA Comments at 24.

[466] Wi-Fi Alliance Comments at 38-39.

[467] Ryan Gardner Comments at 5.

[468] *See* Notice, 33 FCC Rcd at 10525, para. 83.

[469] RKF Study at 53.

removed from the channel center by more than one and one-half times the channel bandwidth, but within the U-NII-5 and U-NII-8 bands, must be suppressed by at least 40 dB.[470]

184. *Emission limits outside the U-NII-5 and U-NII-8 bands.* We are adopting the -27 dBm/MHz limit proposed in the Notice for emissions from all 6 GHz unlicensed devices at frequencies below the bottom of the U-NII-5 band (5.925 GHz) and above the upper edge of the U-NII-8 band (7.125 GHz), but will not require it between the sub-bands, i.e. between the U-NII-5 and U-NII-6, the U-NII-6 and U-NII-7, and the U-NII-7 and U-NII-8 bands.[471] Several parties generally support the -27 dBm/MHz emission limit,[472] although Qualcomm, 5GAA and the Association of Global Automakers, Inc. suggest limiting the operation of UNII-5 devices operating near the bottom of the band to indoor locations to protect the DSRC service.[473] Other parties suggest adopting the U-NII-3 OOBE limit which is -27 dBm/MHz generally, but higher in the first 75 megahertz above and below the band.[474] We believe that a limit of -27 dBm/MHz is necessary to protect services outside the U-NII-5 and U-NII-8 bands, including the Intelligent Transportation Service below the U-NII-5 band and federal government operations above the U-NII-8 band. We are not requiring devices to meet this emission limit between the sub-bands as suggested by Sony[475] because we are seeking to maximize spectrum use and it would stifle innovation by precluding the use of wide bandwidth channels (up to 320 megahertz) that straddle sub-bands.[476] Standards bodies have generally developed channeling plans for unlicensed devices based on technical characteristics, including devices' out-of-band emissions. Manufacturers will have the freedom to determine how they will meet this limit either by reducing power levels, through filtering or through other means, such as not enabling channels closest to the U-NII-5 and U-NII-8 band edges.

185. Finally, we address the measurement procedures for 6 GHz unlicensed devices. To protect Intelligent Transportation Services in the band below 6 GHz, 5GAA states that the -27 dBm/MHz standard we are adopting, when based on a root-mean-square (RMS) measurement is sufficient to protect those services from indoor device OOBE.[477] RLAN proponents agree that the OOBE should be verified

[470] The mask suggested by RKF Engineering contains additional breakpoints at frequencies nine times and 10.8 times the channel bandwidth (42 dB suppression and 47 dB suppression, respectively). RKF Study at 53. For wide bandwidth devices, e.g., 160-megahertz, emissions at frequencies nine or more times the channel bandwidth would fall outside the U-NII-5 through U-NII-8 bands, and for narrower bandwidth devices, e.g., 20-megahertz, the lower emission limits beyond the band edges will ensure that emissions beyond one and one-half channel bandwidths from the channel center will roll off by more than 40 dB within the U-NII-5 through U-NII-8 bands.

[471] Notice, 33 FCC Rcd at 10525, para. 82.

[472] *See e.g.*, Qualcomm Comments at 4 (recommends that the FCC adopt its proposed -27 dBm/MHz limit on 6 GHz out-of-band emissions into the licensed 5.9 GHz Intelligent Transportation Service spectrum, consistent with the rules that apply to most of the 5 GHz U-NII); Association of Global Automakers Reply at 4 (the FCC should adopt the OOBE limits proposed in the NPRM).

[473] Qualcomm Comments at 14; 5GAA Comments at 5-6; The Association of Global Automakers, Reply at 5. DSRC is a wireless system designed for automotive use across 75-megahertz of spectrum in the 5.85-5.925 GHz band. DSRC has a two-way short-to-medium-range wireless communications capability that permits very high data rate transmissions in critical communications-based active safety applications. DSRC involves vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications which can save lives by warning drivers of an impending dangerous condition or event in time to take corrective or evasive actions. The Commission grants licenses for state and regional transportation agencies to operate DSRC roadside units, while DSRC onboard units are licensed by rule under Part 95.

[474] NCTA Comments at 13; Midcontinent Communications Comments at 18.

[475] Sony Comments at 9.

[476] *See e.g.*, Apple, Broadcom et al Comments at 3 (enabling low-power indoor devices to operate across the entire 6 GHz band is fundamental to the success of the 6 GHz proceeding; a fragmented approach to spectrum access greatly reduces the potential for devices to access wider, 160-megahertz channel sizes that facilitate the higher speeds).

[477] 5GAA Mar. 26, 2020 *Ex Parte*.

using an RMS detector or other appropriate techniques for measuring average power.[478] We agree and will provide guidance to the test labs and telecommunications certification bodies which conduct equipment approval measurements and oversight that 6 GHz unlicensed device measurements may be conducted based on using an RMS detector. Because RMS measurements represent the continuous power being generated from a device as opposed to peak power which may only be reached occasionally and for short periods of time, we believe an RMS measurement is more appropriate. We note that this is a departure from the Commission's measurement guidance for similar devices in the 5 GHz band where the Commission specifies a peak measurement.[479] However, that procedure was instituted to mitigate a known interference issue with federal radars in the 5 GHz band. No such situation exists in the 6 GHz band. We will update our Knowledge Database guidance consistent with this decision.

5. Client Device Restrictions

186. As proposed in the Notice, we adopt a requirement that client devices operate either under the control of a standard-power access point or a low-power power access point.[480] The purpose of this requirement is to prevent client devices from transmitting outdoors at locations where they may cause interference to a microwave receiver or other incumbent. When client devices are under the control of a standard-power access point, they will be in close proximity to the access point and may transmit only on frequencies that the AFC system has determined will not cause interference to fixed microwave links. When a client device is under the control of a low-power indoor access point, it should also be indoors and in close proximity to the access point, and therefore avoid presenting an interference risk to licensed services. However, we also adopt an exception to this general requirement to allow a client device to transmit brief messages ("probe requests") to an access point when attempting to join its network as discussed below.

187. Several parties commented on our proposal. HP Enterprise requests that client devices be permitted to transmit brief probe requests to enable a client device to join networks.[481] HP Enterprise points out that in the U-NII-2 bands the inability to send probe requests without receiving an enabling DFS signal results in periodic client device connectivity loss.[482] According to HP Enterprise, these probe requests will be so brief that they will not cause harmful interference.[483] The Wi-Fi Alliance adds that because there will be some client devices that will only operate in the 6 GHz band, the ability to send these probe requests is essential.[484] FWCC objects claiming that these probe requests will be long enough as to be potentially highly interfering to microwave receivers.[485]

188. We recognize the utility of permitting probe requests to enable client devices to join an access point's network. However, these probe requests have the potential to cause harmful interference to licensed operations. We will therefore only permit a client device to send a probe request to an access point after it has detected a transmission from the access point. The client device will be required to send the probe request on the same frequency as the access point's transmission. This is consistent with the white space rules that permit a fixed white space device establishing a network to make brief transmissions on a frequency that it detects is in use by another fixed device prior to receiving a list of

[478] Broadcom Inc., Cisco Systems, Inc., Hewlett Packard Enterprise, Intel Corporation, Qualcomm Incorporated, and Ruckus Networks, a business segment of CommScope Mar. 26, 2020 *Ex Parte*.

[479] *See* KDB Publication No. 789033.

[480] Notice 33 FCC Rcd at 10516, 10521, 10522, paras. 53, 69, 73.

[481] HP Enterprise Comments at 30.

[482] *Id.*

[483] HP Enterprise Comments at 30 and Appendix A at 1.

[484] Wi-Fi Alliance Reply at 34-35.

[485] Fixed Wireless Communications Coalition Reply at 36.

available channels from a database.[486] Under this exception, because the client device will have to detect an access point transmission, the client device will only transmit when it is close enough to an access point to be under its control and on a frequency on which the access point has permission to transmit. This will prevent harmful interference from occurring.

189. In the Notice, the Commission sought comment on whether unlicensed devices in the UNII-5 and U-NII-7 bands should be explicitly permitted to operate either as a mobile hotspot or as a transportable device and, if so, what rules could be put in place to permit such operation while still ensuring that licensed services are protected from harmful interference.[487] While no party specifically commented on the use of client devices as mobile hotspots that could authorize the operation of other client devices, we find that we should prohibit such use. The rules we have adopted for AFC controlled operation of unlicensed access points are designed to prevent harmful interference to licensed stations by only allowing operation at locations where an access point and client devices directly communicating with it would not cause interference to licensed stations. Permitting a client device operating under the control of an access point to authorize the operation of additional client devices could potentially increase the distance between these additional client devices and the access point and increase the potential for harmful interference to fixed service receivers or electronic news gathering operations. For standard-power devices in the U-NII-5 and U-NII-7 bands hotspot operation could allow the additional client devices to transmit in locations where the AFC otherwise would prevent operation to protect incumbent service operations. With regard to low-power indoor access points, our rules are designed to prevent the low-power access points from being used outdoors which should also keep the client devices indoors. In addition, as APCO states, allowing such portable access points could make identifying and resolving interference difficult.[488]

D. Other Issues

1. Making Portions of the 6 GHz Band Available for New Licensed Services

190. We decline the request by CTIA, Ericsson, and other wireless service providers that, instead of opening the entire 6 GHz band for new unlicensed operations as proposed in the Notice, we should issue a further notice to propose repurposing significant portions of the 6 GHz band for exclusive, flexible use licenses and relocating affected incumbent services to other frequency bands.[489] Such an approach would undermine our goal of creating significant new opportunities for unlicensed operations across the 6 GHz band, and would run contrary to our approach in ensuring that existing incumbent services can continue to thrive in the 6 GHz band.[490]

191. CTIA requests that the "upper portion" of the 6 GHz band be repurposed for new licensed services, while Ericsson specifically requests that both the proposed U-NII-7 band (6.525-6.875 GHz) and U-NII-8 band (6.875-7.125 GHz) be repurposed. They contend that the 1200 megahertz of spectrum proposed for unlicensed use does not constitute a "balanced" approach considering the amount of licensed mid-band spectrum the Commission has recently proposed to make available, and they suggest that other bands may be available as a new home for incumbent operations that would need to be relocated.[491] In response, Apple, Broadcom, et al., the Wi-Fi Alliance, WISPA, the Dynamic Spectrum

[486] 47 CFR § 15.711(c)(2)(iv).

[487] Notice, 33 FCC Rcd at 10523, para. 76.

[488] APCO International Comments at 17.

[489] CTIA Comments at 9-12; Ericsson Comments at 13-16; *see also, e.g.*, Verizon Reply at 2-3 (Commission should issue a further notice to license spectrum wireless spectrum in the upper 600-megahertz of spectrum in the 6GHz band); T-Mobile Reply at 5-9; United States Cellular Reply at 3-4.

[490] *See* Notice, 33 FCC Rcd at 10497, paras. 1-2.

[491] Both CTIA and Ericsson suggest that incumbent fixed service and broadcast auxiliary service licensees be relocated using the Emerging Technologies policies the Commission has previously employed to make spectrum (continued….)

Alliance and other proponents of new unlicensed operations in the 6 GHz band contend that the proposed repurposing undermines the purpose of this proceeding to maximize the benefits of unlicensed operations.[492] Representatives of incumbent services that would be affected, including the Fixed Wireless Communications Coalition, the Critical Infrastructure Coalition, NPSTC, Intelsat and SES Americom, and Sirius XM, also strongly oppose repurposing that would affect their operations.[493]

192. We decline the requests that we repurpose substantial portions of the 6 GHz band for new licensed services in place of new unlicensed operations and existing incumbents. Most importantly, as explained in the Notice and in this Order, we believe that providing new opportunities for unlicensed operations across the entire 6 GHz band can help address the critical need for providing additional spectrum resources for unlicensed operations. Making the entire band available for these unlicensed operations enables use of wide swaths of spectrum, including several 160-megahertz channels as well as 320-megahertz channels, which promotes more efficient and productive use of the spectrum, and would also help create a larger ecosystem in the 5 GHz and 6 GHz bands for U-NII devices. Repurposing large portions of the 6 GHz band for new licensed services would diminish the benefits of such use to the American public. Accordingly, we agree the unlicensed proponents that we should reject these requests. Similarly, repurposing substantial portions of the band, as CTIA and Ericsson request, would substantially affect existing licensed services in the band. This would be contrary to the Commission's stated goal in this proceeding to ensure that existing incumbents can continue to thrive in the 6 GHz band. Representatives of the incumbent fixed microwave services also raise concerns about the reasonableness and practicality of relocation, and question whether other appropriate spectrum can be found.[494] The fixed satellite service commenters also strongly reject the contention of CTIA and Ericsson that satellite services would not need to be relocated because new licensed services would not cause harmful interference to the satellite services.[495] Further, there is no certain or clear path for achieving what CTIA and Ericsson propose, and it would take years. For all of these reasons, we will not take the approach suggested by CTIA and Ericsson to repurpose this band. By the actions we are taking today to open the entire 6 GHz band for new unlicensed operations, the American public will begin to see the benefits in the near term.

193. We also decline to reconsider the approach that we are taking to authorize unlicensed low-power operations in the U-NII-6 band. Ericsson also asks that we consider rules to make the U-NII-6 band available for licensed indoor use rather than permitting unlicensed indoor use as proposed in the Notice.[496] According to Ericsson, this would provide assurances to incumbent licensees that they will not suffer interference while enabling industrial IoT applications with high availability, reliability, and

(Continued from previous page)
available for flexible use licensing. CTIA Comments at 10-11; Ericsson Comments at 16. Both suggest that the Commission work with NTIA to make the 7.125-8.4 GHz band available as a new home for fixed service licensees that are relocated. CTIA Comments at 9-12; Ericsson Comments at 13-16.

[492] *See, e.g.*, Apple, Broadcom, et al. Reply at 13-17; Wi-Fi Alliance Reply at 35-38; WISPA Reply at 18-20; Dynamic Spectrum Alliance Reply at 16-18.

[493] *See, e.g.*, Fixed Wireless Communications Coalition Reply at 42-44 (infeasible to relocate fixed microwave); NPSTC Reply at 11;; SiriusXM Radio Feb. 22, 2020 *Ex Parte* at 2 (the 7.025-7.075 GHz band is the only spectrum available and useable by SiriusXM to uplink programming to SDARS satellites for reception by its customers).

[494] Fixed Wireless Communications Coalition Reply at 42-44 (infeasible to relocate fixed microwave); NPSTC Reply at 11; Critical Infrastructure Coalition Reply at 7.

[495] Intelsat and SES Americom Reply at 9 (stating that the 6 GHz band is heavily used by incumbents and terrestrial use would interfere with satellite receivers); SiriusXM Radio Feb. 22, 2020 *Ex Parte* at 2 (the 7.025-7.075 GHz band is the only spectrum available and useable by SiriusXM to uplink programming to SDARS satellites for reception by its customers).

[496] Ericsson Comments at 16-19.

resilience.[497] Ericsson claims that the unlicensed rules cannot provide the interference protection and guaranteed quality of service needed for industrial IoT.[498] In this Order, we have made the entire 6 GHz band available for indoor low-power operations under rules that will protect incumbent operations across the band while also enabling use of wide channels that promote efficient use of the entire band. These unlicensed devices can provide the IoT applications envisioned by Ericsson in the entire 6 GHz band while protecting incumbent operators from harmful interference.

2. Mobile Operations and Use in Moving Vehicles

194. We will not permit standard-power and low-power indoor access points in the 6 GHz band to operate while in motion, with one exception in the U-NII-5 band with respect to large passenger aircraft operating over 10,000 feet.[499] We decline to permit operation in vehicles because of the potential for increasing interference to incumbent services. As a result, the use of unlicensed access points shall not be permitted in moving vehicles such as cars, trains, boats, or small aircraft. Also, as proposed in the Notice we are prohibiting unlicensed devices in the 6 GHz band to be installed on unmanned aircraft systems.[500]

195. *General prohibition on mobile operations.* Allowing access point devices in motion to use the 6 GHz band would add complexity to the AFC system as it would need to continuously update available frequency lists for such devices. We do not believe the added complexity of enabling the AFC system to prevent interference from a moving source is worth the potential benefit as it could delay the AFC system development and prevent the American public from enjoying the benefits of expanded unlicensed use anytime soon. In addition, such use would add substantial congestion to links connecting devices to the AFC as a moving device may need to be in near constant contact with the database, potentially degrading the quality of service for the expected predominant fixed access point use.

196. Apple, Broadcom, et al. point out that portable access points are a prevalent use case today and argue that restricting portable devices would undermine the overall value of the band.[501] They claim that an AFC system can account for portable device location and velocity variations in making channel availability calculations. They point to the whitespace device rules that allow a device to preload channel availability data for multiple locations and use the data to define a region in which the device may operate without conducting additional database checks.[502] Apple points out several additional ways that an AFC system could provide channel availability to an access point in motion such as predicting the likely destination and pre-loading information about incumbent systems along the expected route or obtaining channel availability from the AFC system in near real-time.[503] Apple, Broadcom, et al. also suggest that a simple geofence could be used to enable devices in motion to be used in a large facility

[497] Ericsson Comments at 17.

[498] Ericsson Comments at 19.

[499] Commission sought comment on whether to explicitly permit unlicensed devices in the U-NII-5 and U-NII-7 bands to operate either as a mobile hotspot or as a transportable device. Notice, 33 FCC Rcd at 10523, para. 76; *see id.* at 10523, para. 76 n.161 (defining "transportable devices" as devices that "are not intended to be used in motion, but rather at stationary locations" (citing 47 CFR § 30.2)). The Commission also proposed to prohibit unlicensed access points (both standard power and low power) from operating in moving vehicles, such as cars, trains, or aircraft, and to prohibit all unlicensed devices (access point and client devices) from operating with unmanned aircraft systems. *See* Notice, 33 FCC Rcd at 10526, paras. 84-85.

[500] Notice, 33 FCC Rcd at 10526, para. 85.

[501] Apple, Broadcom, et al. Comments at 50-51.

[502] *Id.* at 51.

[503] Apple Comments at 6-7.

such as a factory or railyard.[504]

197. As the commenters have pointed out, the whitespace rules do provide a method that could enable personal/portable devices in motion to operate by obtaining channel availability information for multiple locations and using this information to define a geographic area of operation.[505] However, no whitespaces personal/portable devices have yet been certified and such devices are limited to a lower power than other whitespace devices—100 mW.[506] Given the lack of a record as to what additional restrictions such power reduction may be needed to enable a similar rule to be adopted here, we do not believe that adopting such a rule for this band would be the appropriate action to take at this time. Regarding suggestions on how an AFC system can control access points in motion, we agree with the commenters that they are theoretically possible, but each would have to be carefully tested to ensure adequate harmful interference preventions in practice. Considering that no 6 GHz AFC systems have yet been developed, we cannot predict whether any of these methods would adequately work in practice. Similarly, we reject the Wi-Fi Alliance's position that we should consider the signal attenuation provided by the vehicle or the user's body to establish appropriate power levels to enable mobile and transportable operations.[507] Unlicensed devices will have no way to determine whether they are within a car, train, or plane nor predict body loss for any given situation and therefore would not be able to adjust its output power accordingly. Thus, we do believe separate power levels can be reliably be determined to permit interference-free operation if unlicensed devices operate in various vehicles.

198. The National Academy of Sciences' Committee on Radio Frequencies notes that aeronautical transmissions are particularly troublesome source of interference to radio astronomy.[508] It states that the 6.650-6.6752 GHz band is important to radio astronomy and is protected by an allocation table footnote that states "all practicable steps shall be taken to protect radio astronomy from harmful interference."[509] To protect radio astronomy observations, it supports the Commission's proposal to prohibit airborne transmissions by unlicensed devices in the U-NII-7 band. The National Academy of Science's Committee on Radio Frequency also notes that the 6.425-7.075 GHz and 7.075-7.250 GHz bands are used for remote sensing by the earth exploration satellite service, including over oceans.[510] As already explained, we are prohibiting use of access points in cars, trains, and small aircraft because of the complications of using an AFC to control frequency access while in motion and because of the uncertain attenuation properties of these vehicles. We agree with the National Academy of Sciences' Committee on Radio Frequencies regarding earth exploration satellite service operations over oceans and will also prohibit standard-power and low-power indoor access points aboard ships and on oil platforms.

199. As proposed in the Notice, we will prohibit unlicensed devices in the 6 GHz band – whether standard-power or low-power devices – from operating on unmanned aircraft systems.[511] Unmanned aircraft systems pose similar issues as other vehicles with the added complication of operating at significant height, and we have no technical bases in the record to enable us to evaluate potential harmful interference concerns posed by these systems. For the reasons we are not permitting standard-power and low-power indoor devices generally in vehicles, we are not permitting them in unmanned

[504] Apple, Broadcom, et al. Comments at 55.

[505] 47 CFR § 15.711(d)(4).

[506] 47 CFR § 15.709(a)(2)(ii), (a)(3)(ii).

[507] Wi-Fi Alliance Comments at 34-35; Apple, Broadcom, et al. Comments at 53.

[508] The National Academy of Sciences Committee on Radio Frequencies Comments at 5-7.

[509] *Id*. at 5; 47 CFR § 2.106 US342.

[510] The National Academy of Sciences Committee on Radio Frequencies Comments at 8-9.

[511] Notice, 33 FCC Rcd at 10526, para. 85.

aircraft systems.[512]

200. *Exception for large aircraft operating above 10,000 feet.* Boeing urges that the Commission permit operation of unlicensed devices inside certain aircraft, similar to that provided to aircraft in 5 GHz band, because the signal attenuation provided by aircraft fuselage is comparable or better than that provided by buildings.[513] Specifically, Boeing requests that that the Commission permit unlicensed operations aboard large aircraft when flying above 10,000 feet.[514] To support its position, Boeing points to studies showing 10-45 dB of aircraft fuselage signal attenuation , the Commission's acknowledgment that fuselage attenuation is 40 dB in the 57-71 GHz range, and the fact that other countries have treated use in aircraft as indoor use. Boeing suggests that unlicensed devices use in aircraft be limited to multi-engine planes, presumably because smaller planes would have less signal attenuation.[515] Apple, Broadcom, et al. and other unlicensed proponents support unlicensed operations in the 6 GHz band inside commercial aircraft for purposes of airborne in-flight entertainment systems, citing certain studies by the European Telecommunications Standards Institute (ETSI) and the IEEE.[516]

201. We agree with Boeing that the fuselage of large passenger aircraft will provide significant attenuation of signals from unlicensed in-flight entertainment systems. The ETSI study on airborne, in-flight entertainment systems in large commercial aircraft, cited by Apple, Broadcom, et al., shows an average signal attenuation from the fuselage of a large aircraft at 5 gigahertz of 17 dB, which is comparable to a building of traditional construction.[517] In addition, large passenger aircraft normally fly at high altitudes which will provide additional signal attenuation preventing signals from reaching terrestrial fixed and mobile receivers.[518] The only potential area of concern would be if an aircraft flew through the main beam of a microwave link during take-off or landing. To address this concern, we will adopt Boeing's suggestion to limit the use of low-power access points for in-flight entertainment systems in aircraft to above 10,000 feet. Because the only data on the signal attenuation from aircraft fuselage submitted on the record is for large passenger aircraft, we shall also limit use to this type of aircraft.

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[512] The Association of Unmanned Vehicle Systems International contends that exclusion of use on unmanned vehicles must be limited to those operations that have a demonstrated potential to cause harmful interference or that the rules must provide exemptions for unmanned aircraft operations with established reliability and safety data or with operations that are narrow in scope and will not present interference concerns. Association of Unmanned Vehicle Systems International Comments at 1-2. Because of the potential for harmful interference and the absence of technical analyses on the nature of potential harmful interference or the means to prevent such interference, we are not authorizing use of standard-power or low-power operations in unmanned vehicles at this time.

[513] Boeing Comments at 7-11 (citing various technical studies); Boeing Reply at 2-4; Boeing Jan. 27, 2020 *Ex Parte* at 8.

[514] *See, e.g.*, Boeing Dec. 12, 2019 *Ex Parte* at 1-2; Boeing Jan. 27, 2020 *Ex Parte* at 1, 8.

[515] Boeing Sept 17, 2019 *Ex Parte*, at 11.

[516] *See, e.g.*, Apple, Broadcom, et al. Comments, Attachment at E 6 (citing ETSI, *Electromagnetic compatibility and Radio spectrum Matters (ERM); System Reference Document; Technical Characteristics for Airborne In-Flight Entertainment Systems operating in the frequency range 5 150 MHz to 5 875 MHz*, European Telecommunications Standards Institute, ETSI TR 102 631 V1.1.1. https://www.etsi.org/deliver/etsi_tr/102600_102699/102631/01.01.01_60/tr_102631v010101p.pdf.); Wi-Fi Alliance Comments at 35; Hewlett Packard Enterprise Comments at 26.

[517] *Electromagnetic compatibility and Radio spectrum Matters (ERM); System Reference Document; Technical Characteristics for Airborne In-Flight Entertainment Systems operating in the frequency range 5 150 MHz to 5 875 MHz*, European Telecommunications Standards Institute, ETSI TR 102 631 V1.1.1, https://www.etsi.org/deliver/etsi_tr/102600_102699/102631/01.01.01_60/tr_102631v010101p.pdf.

[518] Boeing reported that a simulation of Wi-Fi access points in 25 aircraft operating simultaneously at 10,000 feet produced a power level on the ground 19 dB below the long-term protection criteria in ITU-R F.758. Boeing Dec. 12, 2019 *Ex Parte* at 3.

Finally, to prevent harmful interference to radio astronomy and earth exploration satellite service, we are limiting airborne use of low-power access points to the U-NII-5 band where such passive scientific operations do not occur.[519]

3. Microwave Links in the Gulf of Mexico

202. Rignet Satcom (Rignet) operates a network of 93 fixed microwave links that connect oil platforms in the Gulf of Mexico with several points along the Gulf coast. Rignet requests that we exclude 6 GHz unlicensed operations from the Gulf of Mexico and the areas around the locations where its microwave network connects to land.[520] To support its request, Rignet submitted link budget calculations that show potential interference from outdoor standard -power unlicensed devices from 30 miles away. Rignet also submitted a technical study illustrating that the impact of potential aggregate interference from indoor access points operating at the proposed 30 dBm power to its receivers at the locations where its network connects to coast.[521]

203. Apple, Broadcom et al. claim that Rignet has made fundamental flaws in its assumptions regarding unlicensed device operation as well as operating parameters of some of Rignet's own links.[522] According to Apple, Broadcom et al., the incorrect study assumptions include significantly higher radiated power for both low power indoor and very low power devices, limiting bandwidth of all unlicensed devices to 20 MHz, and locating unlicensed devices in the middle of the path. In addition, Apple, Broadcom et al. contend that RigNet's study misstated the operating parameters of some of RigNet's own links, understating their operating bandwidth and overstating the modulation used.[523] With respect to AFC-controlled devices, Apple, Broadcom et al. states that there is no risk of harmful interference from AFC-controlled standard-power devices, because the AFC will prevent unlicensed devices from operating co-channel in locations where they could cause harmful interference.[524]

204. We do not find Rignet's technical study regarding aggregate interference from indoor unlicensed devices convincing for several reasons. Rignet's study presents a link budget analysis of aggregate interference to each of ten microwave receivers located on land.[525] In each of the link budget calculations the study assumes that a number of access points ranging from 2 to 100 are present.[526] For each receiver all the access points are assumed to be at the same distance from the microwave receiver, but this distance varies from 250 m to 5 km for the different receivers. The reason for assuming these distances and number of access points is not explained. The study assumes that the access points would transmit power at a density of 23 dBm/MHz and that there would be 11 dB of building loss.[527] Because we are only permitting access points to transmit at 5 dBm/MHz and, as discussed above, an appropriate assumption for building loss is 20.5 dB, the calculated signal from each access point should be 26.5 dB

[519] The National Academy of Sciences Committee on Radio Frequencies objects to airborne use of unlicensed devices because of interference to radio astronomy. National Academy of Sciences Committee on Radio Frequencies Comments at 7.

[520] Rignet Satcom Reply at 1; Rignet Nov. 18, 2019 *Ex Parte* at 1-2.

[521] Rignet Satcom Reply at 4-5; *Further Analysis of Impact of Unlicensed U-NII-5 Devices on Rignet 6 GHz Backhaul Network*, Rignet July 11, 2019 *Ex Parte* (*Rignet Study*).

[522] Apple, Broadcom et al. *Ex Parte* Mar. 10, 2020 at 2-3.

[523] *Id*.

[524] Apple, Broadcom et al. *Ex Parte* Mar. 10, 2020 at 3.

[525] *Rignet Study* at 5-15.

[526] *Rignet Study* at 19-30.

[527] *Id*.

lower than what the study assumes.[528] While the study does not discuss the propagation model used, from the pathloss shown in the link budgets it appears that free space was used for all cases. In addition, the study assumes that every access point was directly in the main beam of the microwave receiver, which is unrealistic considering the height of the microwave receivers compared to the likely height of the indoor access points.[529] Thus, we believe the calculated interference levels should be at least 50 dB lower than what Rignet's study finds. This is consistent with our conclusion that microwave receivers will not experience harmful interference from indoor access points or very low power devices. With respect to AFC-controlled devices, Rignet's microwave links will be protected by the AFC as would any other microwave link licensed in the 6 GHz band. Rignet's microwave network appears to be no different from any other microwave links, which our new unlicensed rules are designed to protect from harmful interference. Accordingly, our rules will not exclude the Gulf of Mexico from unlicensed operations.[530]

4. Ultra-Wideband and Wideband

205. We decline to adopt specific provisions in our 6 GHz band unlicensed rules that would provide special protections for ultra-wideband and wideband devices. As ultra-wideband and wideband devices operate under Part 15 unlicensed rules, taking such action would effectively provide those devices with a level of interference protection to which they are not entitled. Ultra-wideband and wideband devices are permitted to operate at a variety of power levels, all of which are below -41.3 dBm/MHz.[531] These devices also operate over large bandwidths that are typically allocated to a variety of services. The Ultra Wide Band Alliance, Decawave, and iRobot submitted analyses to support their contention that because of their low power level, ultra-wideband and wideband devices would receive crippling interference from unlicensed devices operating under the new rules.[532] The Ultra Wide Band Alliance, Decawave, NXP USA, and iRobot urge the Commission to place restrictions on the new unlicensed devices such as limiting them to only a portion of the 6 GHz band, reducing their power levels, and/or limiting their duty cycle in order to protect unlicensed wideband and ultra-wideband devices.[533] The Ultra Wide Band Alliance, Alteros, and Zebra Technologies request that the AFC system or exclusion beacons be used to protect ultra-wideband and wideband deployments.[534] NXP USA also suggests that ultra-wideband and wideband devices be permitted to reserve spectrum by sending a reservation request to other unlicensed devices.[535]

206. We are not persuaded by these arguments. First, ultra-wideband and wideband devices,

[528] As stated above we believe a mix of 70% traditional and 30% thermally efficient building type should be used when determining a statistical probability of building entry loss. The median value of the 70/30 building entry loss curve is 20.5 dB. *See supra* footnote 297.

[529] None of these receivers are located near high-rise buildings.

[530] However, as noted above, to protect earth exploration satellite service measurements taken over the oceans we are prohibiting the operation of standard-power and low-power indoor access points on oil platforms.

[531] 47 CFR §§ 15.250(d)(1), 15.591(d), 15.510(c)(4) & (d)(3), 15.511(c), 15.513(d), 15.515(d), 15.517(c), 15.519(c).

[532] Ultra Wide Band Alliance Comments at 9-16; Decawave Comments at 5-6; iRobot Oct. 16, 2019 *Ex Parte* at 15-16. *See also* Zebra Technologies Comments at 3 (ultra-wideband devices could suffer interference from 1 mile away).

[533] Ultra Wide Band Alliance Comments at 24-25 (limit new unlicensed devices to 5.925-6.2 GHz, limit duty cycle to 0.5%); Ultra Wide Band Alliance Reply at 4 (limit power to -21.3 dBm/MHz); Decawave Comments at 8 (limit to 0.5% duty cycle, limit power to 0 dBm); NXP USA Comments at 3 (limit power to -21.3 dBm/MHz in band and -41.3 dBm/MHz in adjacent channel, limit to 0.5% duty cycle); iRobot Comments at 3 (limit to 5.925-6.1 GHz, 0.5% duty cycle, require power control).

[534] Ultra Wide Band Alliance Comments at 26; Ultra Wide Band Alliance Reply at 6; Alteros Reply at 4; Zebra Technologies Reply at 1.

[535] NXP USA Comments at 3.

as with all unlicensed devices operating under our Part 15 rules, are subject to the condition that they may receive interference—including interference from other unlicensed devices.[536] Unlicensed Part 15 devices have no vested right in the continued use of any particular block of spectrum.[537] Moreover, ultra-wideband and wideband devices operate across a varied spectrum landscape with different types of licensed services (in this case, microwave links and satellite uplinks) that are governed by differing service and technical rules. Thus, by their nature, wideband and wideband devices must be designed to tolerate varying levels of interference with no assurance of an interference-free operating environment.

207. All of the provisions that the ultra-wideband and wideband advocates request would in effect reserve spectrum in a manner that we have not previously contemplated or proposed for such devices. We decline to let the spectrum provisions applicable to ultra-wideband and wideband devices preclude the provision of other services that we have widely permitted under the unlicensed framework applicable to the U-NII bands. Our experience with the 2.4 GHz and existing U-NII bands has shown that the adoption of technology neutral rules has resulted in an explosion of innovation and the widespread adoption of unlicensed technologies by consumers and businesses. We expect a similar experience to occur in the 6 GHz band. If we were to adopt the suggested limitations on power levels, available spectrum, and duty cycle we would limit the range and data rates of the new unlicensed devices in a way that limits their utility. We find that it would not be in the public interest to restrict the use of the 6 GHz band unlicensed devices in this way. However, we note that the contention-based protocol requirement we are adopting for low power indoor devices will limit the unlicensed device duty cycle and that it could also detect the presence of ultra-wideband and wideband devices. We encourage ultra-wideband and wideband interests to work with standards bodies to explore protocols that may enhance those devices coexistence with new 6 GHz unlicensed devices.

208. Additionally, the record provides compelling evidence of circumstances where unlicensed devices operating under both the existing and new rules will be able to peacefully co-exist. A study submitted by Broadcom indicates that wideband devices may be able to operate outdoors in areas immediately adjacent to locations where unlicensed devices operating under the new rules are deployed and that, where devices are in close proximity, users will likely be able to promote co-existence by adjusting the positioning of UWB and RLAN devices.[538] Thus, for ultra-wideband and wideband devices employed in industrial applications and other indoor locations, the facility owner will be able to exercise control over the use and placement of new unlicensed devices, and if necessary, can choose which devices to deploy to avoid unwanted interference. In addition, according to data submitted by CableLabs, the weighted average of the activity factor for Wi-Fi is 0.4%[539] which is below the 0.5% activity factor suggested by the ultra-wideband and wideband proponents to enable co-existence. Thus, we have reason to believe that in many cases ultra-wideband and wideband devices will be able to operate in the presence of new devices that will operate under the new 6 GHz unlicensed rules.

5. Synchronized Unlicensed Operation

209. Qualcomm requests that the Commission adopt a rule which it claims will permit access points that use synchronized contention windows to operate without disadvantaging other technologies.[540] Under such a framework, synchronized unlicensed devices that have information to transmit would send a request to transmit during a contention window that is synchronized among all synchronized unlicensed

[536] 47 CFR § 15.5(b).

[537] 47 CFR § 15.5(a).

[538] Broadcom Jan. 15, 2020 *Ex Parte* at 4, 6 (no degradation in ultra-wideband ranging performance at distances predicted in study submitted by iRobot).

[539] CableLabs Dec. 23, 2019 *Ex Parte* at 16.

[540] Qualcomm, Nov. 15, 2019 *Ex Parte,* at 2. Qualcomm previously suggested that U-NII-7 be reserved for unlicensed systems using a synchronized contention window. Qualcomm Comments at 23.

devices in a particular area. This will allow those unlicensed devices to reserve access to the spectrum until the beginning of the next "medium reservation period."[541] According to Qualcomm, use of synchronized contention would result in higher spectrum efficiency and enable guaranteed spectrum access for services that require a particular quality of service.[542]

210. The specific rule that Qualcomm requests would establish a synchronized mode for unlicensed devices with contention windows every 6 milliseconds.[543] Synchronized access points would be permitted to occupy the channel for 6 milliseconds unless the channel is occupied at the start of a contention window, in which case they could occupy the channel for up to 12 milliseconds. Non-synchronized access points would be able to occupy the channel for up to 10 milliseconds According to Qualcomm, this approach would be technology neutral because it would enable both synchronized and non-synchronized access points to access the channel with occupancy times that are nearly the same on average.[544] Qualcomm claims that adopting this rule would enable advanced spectrum sharing techniques that are being included in the 5G NR-U standard and a next generation Wi-Fi standard, IEEE 801.11be (EHT),[545] without prohibiting other technologies.[546]

211. The Commission has historically adopted rules that are technologically neutral and remains committed to this policy. This is reflected by our U-NII rules which do not require the use of a particular contention method for unlicensed devices to share access to spectrum. The Commission's embrace of technology neutrality has encouraged the development of a vast variety of unlicensed devices operating under our Part 15 rules. In fact, Qualcomm has recently endorsed our policy stating that this "approach to both licensed and unlicensed spectrum bands has supported perpetual innovation by the entire wireless industry" and that "[t]here is no question that the FCC should continue its successful tech neutral policy to existing and future spectrum bands."[547] While there may be ways to increase spectrum efficiency by synchronization as Qualcomm advocates, this would necessarily require restricting the flexibility that Part 15 has permitted to U-NII devices. We do not believe that this would be an acceptable tradeoff and we reject Qualcomm's request.

212. We also do not find convincing Qualcomm's contention that granting its request would be in keeping with our technology neutral policy. Qualcomm's proposed rule would limit the length of time any non-synchronous access point could continuously transmit to 10 milliseconds. We have no information as to how this limitation will affect other technologies that could potentially be deployed in the band or whether this length of transmission would be optimal. We agree with HP Enterprise that "far from being technologically neutral, the stated purpose of [Qualcomm's] proposal is to advantage one

[541] Qualcomm Comments at 22. Qualcomm's recommended approach of enabling synchronized operations uses the concept of preferred synchronized medium reservation windows, where the synchronization reference is common among cooperating nodes. The concept of the synchronous and periodic medium reservation period allows an access node, AP, or client (UE) to reserve the medium until the beginning of the next medium reservation period. *Id.*

[542] *Id*. at 20-21; Qualcomm, Nov. 15, 2019 *Ex Parte,* at 2. HP Enterprise argues that Qualcomm's claim of spectrum efficiency is incorrect. HP Enterprise Comments at 17-20.

[543] Qualcomm, Nov. 15, 2019 *Ex Parte,* at 2-3, 22-23.

[544] *Id*. at 3, 25-26.

[545] 5G NR-U is a commercial wireless standard for use in unlicensed bands under development by the 3rd Generation Partnership Project (3GPP). IEEE 801.11be (EHT) is a Wi-Fi standard under development that will be capable of much higher data rates. David Lopez-Perez, Adrian Garcia-Rodriguez, Lorenzo Galati-Giordano, Mika Kasslin, Klaus Doppler, *IEEE 802.11be Extremely High Throughput: The Next Generation of Wi-Fi Technology Beyond 802.11ax*, IEEE Communications Magazine, 113 (Sept. 2019) https://arxiv.org/pdf/1902.04320.pdf.

[546] Qualcomm Comments at 23; Qualcomm, Nov. 15, 2019 *Ex Parte,* at 2, 4.

[547] Qualcomm Comments, ET Docket No. 15-105, at 9 (June 11, 2015).

specific type of unlicensed technology over all others."[548] We also expect that technologies other than IEEE 801.11be (EHT) or 5G NR-U will be used by unlicensed devices in this band and do not see any reason to place limitations on their operation.

6. Digital Identifying Information

213. As a means of mitigating interference, the Commission sought comment on whether we should require standard-power access points, low-power access points, and their associated client devices to transmit digital identifying information.[549] Apple, Broadcom, et al. claims that this would require the Commission to mandate a specific technology to modulate the identifier, stimulate the creation of devices to identify interference, and hope licensees purchase it.[550] Apple argues that this requirement could interfere with the operation of applications that require low-latency.[551] The Fixed Wireless Communications Coalition asserts that the requirement would not be helpful as microwave licensees do not become aware of interference until a link fails and the microwave receiver would not be able to decode the identifier.[552] Apple, Broadcom et al. point out that this requirement would create a significant privacy issue because it would enable devices to be tracked.[553] Tucson Electric Power and UNS Electric respond that a transmitted identifier would be instrumental in resolving interference and that privacy concerns have no merit as Wi-Fi devices transmit a unique media access control address that can enable world-wide tracking of users today.[554] While APCO acknowledges that an identifier could be useful in the process of identifying the source of interference, they do not want microwave licensees to be required to decode the information.[555]

214. We decline to adopt a requirement that 6 GHz unlicensed devices transmit digital identifying information. As Apple, Broadcom et al. point out, imposing such a requirement would require us to mandate a modulation format for the transmitted information, which would necessarily impose restrictions on the development of unlicensed technology in the band. Given that the record has provided no details on how this requirement will help resolve interference, we do not believe that imposing this requirement can be justified. We also agree with those commenters who express concern that this requirement could intrude upon the privacy of device users by facilitating tracking of devices.

7. Benefits and Costs

215. Making available 1200 megahertz of spectrum in the 6 GHz band for new types of unlicensed use will yield important economic benefits and will allow more extensive use of technologies such as Wi-Fi and Bluetooth by American consumers. Consumers are using more and more data, on average, and this is expected to continue to grow significantly.[556] As demand for data increases, making more spectrum available for two types of unlicensed use-standard-power and low-power indoor-will provide economic benefits by relieving potential congestion, allowing more users to access these new

[548] HP Enterprise Reply at 16; *see also* Broadcom Reply at 26. Cisco Reply at 12; Dynamic Spectrum Alliance Reply at 18 (concerned that adopting Qualcomm's proposal would reserve U-NII-7 for a specific unlicensed product Qualcomm hopes to sell).

[549] Notice, 33 FCC Rcd 10526-27, para. 88.

[550] Apple, Broadcom et al. Comments at 64; Broadcom Comments at 42.

[551] Apple Comments at 16.

[552] Fixed Wireless Communications Coalition Comments at 34.

[553] Apple, Broadcom et al. Comments at 65; Apple Comments at 16-17.

[554] Tucson Electric Power and UNS Electric Reply at 20-22.

[555] APCO Comments at 19.

[556] GSMA, *The Mobile Economy, North America 2019* at 13. GSMA estimates that demand for data in North America will increase from 10 GB per subscriber per month in 2018 to 55.6 GB per subscriber per month in 2024.

bands, and potentially making new use cases possible. As noted above, the ability of unlicensed devices to use significant portions of this band may also complement new licensed 5G services by allowing providers to offer a full range of services to consumers and will help to secure U.S. leadership in the next generation of wireless services. One report cited by several commenters estimates that in 2018, the economic benefits associated with Wi-Fi in the United States was valued at almost $500 billion.[557] In some ways, unlicensed usage on the new spectrum will be more restricted than for current Wi-Fi usage due to the AFC and lower power limits. However, in the United States, Wi-Fi currently operates in different bands over nearly 700 megahertz of spectrum, none of which enables channels as large as 160 megahertz.[558] Making an additional 1200 megahertz of 6 GHz spectrum available for unlicensed use, including enabling the use of 160-megahertz channels that will lead to expanded throughput, capacity, and performance will have a significant economic benefit, comparable to the hundreds of billions of dollars of the estimate of Wi-Fi's 2018 value.

216. We note, however, that the new rules for unlicensed spectrum use could impose some economic costs if harmful interference to incumbent services occurs. As explained above, the technical and operational rules are designed to minimize the potential interference to incumbent licensed uses. While under the rules there can be interference with ultra-wideband and wideband applications, these costs will be lower than the total U.S. economic value for ultra-wideband and wideband products, which in turn, are lower than the total economic value of new unlicensed use. The CableLabs study gives us reason to believe that interference with ultra-wideband and wideband will only be intermittent, so that coexistence with new users will be possible.[559] Further, when ultra-wideband and wideband use is specific to an indoor facility, it will be feasible for facility owners to prevent interference by regulating use of unlicensed activity within the facility.[560] Thus, in most cases, the full value of ultra-wideband or wideband will be preserved, with only management costs incurred by facility owners. While we are unable to precisely estimate the value of U.S. ultra-wideband and wideband, one market research firm cited the global value of the ultra-wideband industry will be $85.4 million in 2022.[561] In addition, we note that revenues from a non-exhaustive list of U.S. firms producing ultra-wideband products, among others, imply that even if costs are incurred, they will be significantly less than the hundreds of billions of dollars of economic value created.[562] Overall, while we identify some economic costs, we believe that they are limited and do not outweigh the substantial economic benefits of making such a large amount of

[557] Letter from Alex Roytblat, Counsel to Wi-Fi Alliance, to Marlene H. Dortch, Secretary, FCC, WT Docket No. 17-200, Attach. 2 at 33 (filed Oct. 12, 2018) (Wi-Fi Oct. 12, 2018 *Ex Parte*). See Wi-Fi Alliance Comments at 5, National Cable Television Association Comments at 7, RLAN Comments at 10, and Cisco Reply Comments at 6.

[558] While 689.5 megahertz represents all spectrum that Wi-Fi could operate on in the United States, in practice, most use occurs within the 2.400-2.483.5 GHz band, the 5.150-5.250 GHz U-NII-1 band and the 5.725-5.850 GHz U-NII-3 band.

[559] *See* CableLabs Dec. 23, 2019 *Ex Parte* at 16 (the weighted average of the activity factor for Wi-Fi is 0.4%, which is below the 0.5% limit proposed by ultra-wideband and wideband).

[560] *See* Broadcom Jan. 15, 2020 *Ex Parte* at 4 (asserting that there will be no degradation in ultra-wideband ranging performance at distances predicted in the study submitted by iRobot).

[561] Markets and Market, Ultra-Wideband (UWB) Market by End-User (Healthcare, Automotive and Transportation, Manufacturing, Residential Retail), Application (RTLS/WSN, Imaging), and Geography (North America, Europe, Asia-Pacific, Rest of the World) - Global Forecast to 2022 (2017), https://www.marketsandmarkets.com/Market-Reports/ultra-wideband-market-200905786.html.

[562] For example, Zebra, a producer of ultra-wideband products, among others, had total 2019 revenues of $2.2 billion. Zebra Technologies Corporation, SEC Form 10-K, at 28 (filed Feb. 13, 2020). iRobot, which has a prototype robotic lawnmower that would work with ultra-wideband, had total U.S. revenues of $604 million. iRobot Corporation, SEC Form 10-K, at 55 (filed Feb. 12, 2020). Boeing, a user of ultra-wideband in its manufacturing and inspection processes, had a total 2019 revenue of $77 billion, of which ultra-wideband is a very small fraction. The Boeing Company, SEC Form 10-K, at 16 (filed Jan 31, 2020).

spectrum available for unlicensed use.

IV. FURTHER NOTICE OF PROPOSED RULEMAKAING

217. The Report and Order adopts rules that permit devices to operate indoors throughout the 6 GHz band with a 5 dBm/MHz power spectral density EIRP and a cap on absolute EIRP that limits 320-megahertz bandwidth channels to 30 dBm. The Report and Order further requires these devices to operate using a contention-based protocol so that 6 GHz unlicensed devices must incorporate some spectrum sensing capability to ensure the spectrum is not in use prior to transmitting and do not transmit continuously. The Report and Order finds that the potential for these low power indoor unlicensed devices to cause harmful interference to incumbent services in the bands, including Fixed Microwave Service links, the Broadcast Auxiliary Service, the Fixed Satellite Service and Radio Astronomy, is minimal.

218. In this Further Notice, we seek comment on two options for further expanding unlicensed operations without the use of an AFC. First, we propose to authorize operations that are not limited to indoor use—and, thus, must be very low power to protect incumbents. Second, we seek comment on increasing the power spectral density EIRP for low-power indoor operations from 5 dBm/MHz up to 8 dBm/MHz.

A. Very Low Power Operation

219. In the NPRM in this proceeding, the Commission sought comment on whether to permit indoor "low-power" operations in the U-NII-5 and U-NII-7 bands under the same conditions as proposed for operations in the U-NII-6 and U-NII-8 bands. The Commission also sought comment on whether there were any other operational requirements, rules, or mitigation techniques that would allow low-power access points to operate in the U-NII-5 and U-NII-7 bands without the use of an AFC system.[563]

220. In response, Apple, Broadcom et al. request that we permit very low-power unlicensed devices to operate in the U-NII-5, U-NII-7, and the lower 100 megahertz of the U-NII-8 band with no requirements that the devices be kept indoors or be under the control of an AFC system.[564] Other unlicensed proponents also request that the Commission adopt rules to permit very low-power operations across the 6 GHz band.[565] In their latest filing Apple, Broadcom, et al. request that these very low-power devices be permitted to transmit with 14 dBm EIRP and -8 dBm/MHz power spectral density EIRP.[566] Apple, Broadcom et al. claim that this device class will be critical for supporting indoor and outdoor portable use cases such as wearable peripherals including augmented reality/virtual reality and other personal-area-network applications as well as in-vehicle applications.[567] To support their claims that these very low-power devices will not cause harmful interference to microwave receivers, they submitted link budgets for four cases.[568]

221. The proponents for very low power unlicensed devices have made a compelling case for allowing such use. These devices can usher in new ways that Americans work, play, and live by enabling applications that can provide large quantities of information in near real-time. We therefore propose to

[563] Notice, 33 FCC Rcd at 10522, para. 73.

[564] Apple, Broadcom et al. Comments at 4-5.

[565] Wi-Fi Alliance Jan. 17, 2020 *Ex Parte*, at 1-2.

[566] Tying the maximum 14 dBm EIRP to a -8 dBm/MHz PSD EIRP assumes a 160-megahertz channel. The maximum EIRP would differ as the bandwidth changes (e.g., 11 dBm, 8 dBm and 5 dBm maximum EIRP for 20, 40 and 80-megahertz channels, respectively). Apple, Broadcom July 2, 2019 *Ex Parte,* at 5,7; Apple, Broadcom Dec 9, 2019 *Ex Parte,* at 8.

[567] *Id*. at 2.

[568] Apple, Broadcom et al. Nov. 12, 2019 *Ex Parte,* at 5-7; Apple, Broadcom et al. Dec 9, 2019 *Ex Parte,* at 3.

permit very low power devices to operate across the entirety of the 6 GH band (5.950-7.125 GHz), both indoors and outdoors, without using an AFC. This proposed action would make a contiguous 1200-megahertz spectrum block available for new and innovative high-speed, short range devices. We seek comment on this proposal. What are the benefits that these devices can bring to the American public? What use cases are envisioned for these devices? What form factors will be most useful for performing everyday activities? Will very low power functionality be built into existing devices such as cell phones or will they be standalone devices? What data rates are necessary to enable the enhanced applications envisioned for these devices? Over what distances will transmissions to very low power devices be necessary? Where are these devices most anticipated to be used and for what applications? The answers to these questions will drive additional comment and decisions on these devices as the fundamental decision that must be determined through this Further Notice is how much power can these very lower power devices be permitted so that the potential of causing harmful interference to incumbent 6 GHz band users is minimized.

222. We seek comment on the appropriate power level for very low power unlicensed devices in the 6 GHz band. In examining what power levels we should authorize, we note that there are many factors that need to be considered, including body loss (as we are envisioning most use cases will be for body worn devices), use of transmit power control, antenna type and radiation pattern, use of a contention-based protocol and projected activity factor. As a threshold matter, similar to our requirements for low power indoor devices, we propose to require that 6 GHz band very low power unlicensed devices incorporate an integrated antenna. We seek comment on these proposals. Using an integrated antenna will ensure that users are unable to swap out the antenna for a higher gain antenna that could increase the potential for interference. We assume that the antennas will be omnidirectional and have minimum gain? Is that a good assumption? Are there other antennas anticipated for these devices?

223. As the Commission finds for indoor low power devices, should we require a contention-based protocol that requires devices to sense or listen to the spectrum prior to transmitting to ensure all unlicensed devices have an equal opportunity to transmit as well as to protect incumbent users? Commenters should address whether protocols such as Wi-Fi's current carrier sense multiple access with collision avoidance (CSMA/CA) would be used or are there other protocols that may work here too? Apple, Broadcom et al. contend that such a protocol will protect mobile Broadcast Auxiliary Service Incumbents in the U-NII-6 and U-NII-8 bands.[569] We seek comment on the viability of relying on a contention-based protocol to protect these uses. Can this protocol also be used to protect Fixed Service microwave incumbents? What sensing levels are necessary to reliably detect incumbent services to protect them?[570] We also note that wideband and ultrawideband unlicensed devices operate in the 6 GHz band. Can the contention-based protocol be used to enable co-existence between various unlicensed device types? Commenters should provide detailed technical information on the contention-based protocol and how it can be used to protect existing 6 GHz band users (and whether a requirement to include a contention-based protocol would materially affect the spectrum very low power devices could use as well as the relevant power levels in order to protect incumbent services).

224. In determining the proper power level for very low power unlicensed devices using 160-megahertz channels, we first note that the Commission is authorizing low power indoor devices to operate with 5 dBm/MHz PSD EIRP and a maximum 27 dBm EIRP. This decision is based on an extensive record replete with multiple studies—both Monte Carlo and static link budgets. A major contributing factor to those analyses was consideration of building entry loss and the effect such propagation loss would have on protecting incumbent licensees from harmful interference. Building attenuation is a

[569] Apple, Broadcom et al. Feb. 28, 2020 at 11-23.

[570] We note that the Wi-Fi 802.11 standard incorporates a -62 dBm energy detect level for its CSMA/CA protocol. *Id*. at 11; IEEE Standards Ass'n 802.11-2016 Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications 17.3.10.6 (2016).

function of building construction type (traditional or thermally efficient) and the elevation angle of the signal path at the building façade.[571] Based on the Report and Order record, we determine that using a 20.25 dB building entry loss factor which assumes a mix of 70% traditional and 30% thermally efficient buildings is reasonable as it represents the median value for this mix of buildings.[572] Because the major difference between low power indoor unlicensed devices and very low power unlicensed devices is that for the latter device, outdoor use would not be subject to building entry loss, would it stand to reason that simply subtracting the building entry loss value from the low power indoor permitted power will provide a starting point for evaluating the proper power level for very low power unlicensed devices? Thus, would a maximum 7 dBm EIRP (for a 160-megahertz channel) be a reasonable value on which to base the proper power level? We note that the 20.25 dB value is a median value. Thus, do we need to incorporate a safety margin to account for variable building loss and increase the protection margin to incumbent operations? Is a 3dBm safety margin a reasonable assumption? We further note and the record indicates that for many anticipated use cases, use will occur near the ground and in the presence of buildings and other objects further subjecting potentially interfering emissions to clutter losses.[573] Accounting for clutter losses would infer that more power could be permitted without increasing the potential for harmful interference. How much could we increase the safe power levels to account for clutter losses? What models are appropriate for the intended use cases and locations where these devices are expected to be used? What are the appropriate values that should be used for analysis purposes? Commenters should provide detailed information and reference material to support their claims regarding appropriate clutter losses to consider.

225. Other factors that must be considered when evaluating very low power unlicensed devices is body loss and transmit power control. We anticipate that most of the devices contemplated for such operation will be body worn and subject to such losses. In their filings with technical analyses, Apple, Broadcom et al. assume that there will be at least 18 dB signal attenuation from body loss and transmit power control.[574] Is this assumption realistic? We seek comment on the correct value we should consider for body loss and transmit power control for these devices. Commenters should provide detailed technical analysis supporting the value(s) they believe we should rely on as we determine the maximum power level for very low power devices.

226. We also ask commenters to address some specific technical solutions and use situations that we believe are likely to arise through typical operation. First, we note that cell phones typically employ proximity or other sensors to determine if they are close to a body to adjust power to meet the Commission's RF exposure rules. Could such a sensor be used in conjunction with these very low power devices as a way of adjusting their power based on how much body loss might be expected? How would such a system work to both ensure the ability of devices to close their links as well as avoiding causing

[571] *Predication of Building Entry Loss*, International Telecommunications Union Radiocommunications Sector, ITU-R P.2109-0 at 2 (2017).

[572] We believe that a mix of 70% traditional and 30% thermally efficient building types is appropriate to use when determining a statistical probability of building entry loss, which is consistent with the technical study submitted by NAB and the report from CEPT submitted by AT&T. NAB Dec. 5, 2019 *Ex Parte* at 42; AT&T Aug. 5, 2019 *Ex Parte* at 44 (Sharing and compatibility studies related to Wireless Access Systems including Radio Local Area Networks (WAS/RLAN) in the frequency band 5925-6425 MHz, ECC Report 302, May 29, 2019).Apple, Broadcom et al. Feb. 7, 2020 *Ex-Parte*, at 8.

[573] Apple, Broadcom, et al. March 18, 2020 *Ex Parte* at 10.

[574] Apple, Broadcom, et al. Nov. 12, 2019 *Ex Parte,* at 8; Apple, Broadcom, et al. Dec 9, 2019 *Ex Parte,* at 2, 7-8. These link budgets rely on a combined 18 dB for body loss/transmit power control attenuation. Apple, Broadcom, et al. Nov. 12, 2019 *Ex Parte*, at 7-9, 11; Apple, Broadcom, et al. Dec 9, 2019 *Ex Parte,* at 7. But their submissions also state that the body loss is assumed to be 4.5 dB and power control reduction is 14 dB, which would result in a combined loss of 18.5 dB. Apple, Broadcom, et al. Nov. 12, 2019 *Ex Parte,* at 8; Apple, Broadcom, et al. Dec 9, 2019 *Ex Parte,* at 8.

harmful interference to incumbent licensees? Should such sensors be required on these devices? If so, what parameters are essential and what algorithms would ensure proper power level tuning? How would interference to incumbent operations be protected when a very low power unlicensed device must use higher power when facing maximum body loss in the direction of its intended receiver, but no similar losses in other directions? For example, a cell phone in a backpack may be transmitting to a body worn device where the intended signal encounters a person's full mass in that intended direction, but no losses in other directions. Is this a reasonable scenario? What are the potential consequences of such operation?

227. Alternatively, in use cases where an unlicensed device may not encounter much body loss, how would transmit power control be implemented to protect incumbent licensees? For example, if a device is mounted on a bicycle handlebar and communicating with a body worn device, there would be no body loss and little clutter. We seek comment on other use cases and whether proximity sensors could be used and how transmit power control would provide sufficient power for the application and at the same time protect incumbent licensees. How does the expected geometry between these unlicensed devices, which presumably will generally be used close to the ground and fixed service microwave links which are generally high off the ground and employ directional antennas affect the power level we can allow? What about the interaction for Broadcast Auxiliary Services?

228. We seek comment on how all these factors should be considered in analyses and the various technical solutions can work together to authorize very low power unlicensed devices across the 6 GHz band. We seek comment on the appropriate factors that should be incorporated into a link budget. We also seek comment on the appropriate way to model the potential interactions between unlicensed devices and incumbent operations. Should we rely on Monte Carlo analysis, link budget analysis, link-level simulations that take into account detailed physical layer implementations of unlicensed devices as well as incumbent devices, or a combination of these methods? Regardless of which type of analysis commenters submit, all assumptions should be fully explained and supported and all methodologies explained in detail. We also seek comment on what technological measures can be incorporated into a very low-power device to support the operations at the requested power limits and mitigate the potential for harmful interference to incumbent services?

229. In contemplating the various factors discussed, we seek comment on what power level we should authorize for very low power unlicensed devices across the 6 GHz band. In this regard, we note that we are generally considering power levels in the range of 4 dBm to 14 dBm EIRP and a corresponding power spectral density referenced to a 160-megahertz channel. Apple, Broadcom, et al contend that 14 dBm EIRP and -8 dBm/MHZ PSD EIRP is necessary to enable the applications they anticipate for these devices. We seek comment on the power level and other technical or operational rules we should consider to maximize the utility of the 6 GHz band and protect incumbent licensees. We encourage commenters to also conduct testing and measurements of protype devices to support whatever rules they advocate for. Such testing can be done under an experimental license to the extent needed. What technical measures will be effective in meeting our goals of balancing new devices against the need to protect incumbent licensees?

B. Power Spectral Density Increase for Low Power Indoor

230. We seek comment in this Further Notice on whether to allow low power indoor devices to operate at a higher power spectral density of 8 dBm/MHz with a maximum permissible EIRP of 33 dBm when a device uses a bandwidth of 320 megahertz in the U-NII-5 through U-NII-8 bands. We adopt 5 dBm/MHz in the Report and Order considering the analyses in the record based on limited measurements, Monte Carlo simulations and static link budgets, none of which fully capture a future deployment scenario involving a very large number of unlicensed devices operating in a complex interference environment. Analyses that can incorporate realistic environments, including accurate link-level and system level simulations or measurements which take into account the physical layer characteristics of both unlicensed and incumbent devices would be more convincing in determining whether a higher PSD such as 8 dBm/MHz should be adopted. For devices operating with bandwidths other than 320 megahertz, the maximum allowable total power would scale accordingly (e.g., 30 dBm

with a bandwidth of 160 megahertz, 27 dBm with a bandwidth of 80 megahertz, 24 dBm with a bandwidth of 40 megahertz, and 21 dBm with a bandwidth of 20 megahertz). We believe that these rules would be useful for many indoor devices that require high data rate transmissions such as indoor access points communicating with clients like high-performance video game controllers, and wearable video augmented reality and virtual reality devices.

231. Would the proposed power levels be useful for low power indoor devices? What are the specific benefits to consumers and users of unlicensed operations of a higher power spectral density limit? Are the proposed power limits appropriate for preventing interference to authorized users in the U-NII-5 through U-NII-8 bands? Should we adopt any other requirements in addition to power density and total EIRP limits to protect services in these bands? We seek specific comment on how a higher power spectral density limit would impact our analysis of Examples 1B, 4, and 5 from the AT&T study, as well as how common those scenarios are. Proponents of low-power indoor operations have convincingly shown that even in these examples the likelihood of harmful interference to fixed microwave services will be insignificant with a power spectral density limit of 5 dBm/MHz. Is the risk materially higher at 8 dBm/MHz? Is so, is such risk still low (or even insignificant)? And how common are such scenarios? We seek specific comment from fixed service incumbents on what fraction of their operations do each of these scenarios represent. And are we correct to surmise that these are worst case scenarios (as would be suggested by the incentives of those introducing these scenarios into the record) or do they actually represent a significant number of operations? Finally, we seek comment on the benefits and costs of our proposal. How should we quantify the potential economic benefits of authorizing higher power spectral density for low power indoor devices and the potential cost to incumbent operations should interference occur?

V. PROCEDURAL MATTERS

232. *Final Regulatory Flexibility Analysis.* — As required by the Regulatory Flexibility Act of 1980 (RFA),[575] as amended, the Commission has prepared a Final Regulatory Flexibility Analysis (FRFA) regarding the possible significant economic impact on small entities of the policies and rules adopted in this Report and Order, which is found in Appendix C. The Commission's Consumer and Governmental Affairs Bureau, Reference Information Center, will send a copy of the Report and Order, including the FRFA, to the Chief Counsel for Advocacy of the Small Business Administration.[576]

233. *Initial Regulatory Flexibility Analysis.* — As required by the RFA, the Commission has prepared an Initial Regulatory Flexibility Analysis (IRFA) of the possible significant economic impact on a substantial number of small entities of the proposals addressed in this FNPRM. The IRFA is set forth in Appendix D. Written public comments are requested on the IRFA. These comments must be filed in accordance with the same filing deadlines for comments on the FNPRM, and they should have a separate and distinct heading designating them as responses to the IRFA. The Commission's Consumer and Governmental Affairs Bureau, Reference Information Center, will send a copy of this FNPRM, including the IRFA, to the Chief Counsel for Advocacy of the Small Business Administration, in accordance with the RFA.[577]

234. *Paperwork Reduction Act Analysis*. — This document does not contain new or modified information collection requirements subject to the Paperwork Reduction Act of 1995 (PRA), Public Law 104-13. In addition, therefore, it does not contain any new or modified information collection burden for small business concerns with fewer than 25 employees, pursuant to the Small Business Paperwork Relief Act of 2002, Public Law 107-198, *see* 44 U.S.C. 3506(c)(4).

235. *Congressional Review Act*. —The Commission will submit this draft Report & Order to

[575] *See* 5 U.S.C. § 603.

[576] *See* 5 U.S.C. § 603(a). In addition, the *Notice* and RFA (or summaries thereof) will be published in the Federal Register.

[577] *See* 5 U.S.C. § 603(a).

the Administrator of the Office of Information and Regulatory Affairs, Office of Management and Budget, for concurrence as to whether this rule is "major" or "non-major" under the Congressional Review Act, 5 U.S.C. § 804(2). The Commission will send a copy of this Report & Order to Congress and the Government Accountability Office pursuant to 5 U.S.C. § 801(a)(1)(A).

236. *Further Information*. — For further information, contact Nicholas Oros of the Office of Engineering and Technology, Policy and Rules Division, at 202-418-0636 or Nicholas.Oros@fcc.gov.

237. *Ex Parte Presentations.* — This proceeding will be treated as a "permit-but-disclose" proceeding in accordance with the Commission's *ex parte* rules.[578] Persons making *ex parte* presentations must file a copy of any written presentation or a memorandum summarizing any oral presentation within two business days after the presentation (unless a different deadline applicable to the Sunshine period applies). Persons making oral *ex parte* presentations are reminded that memoranda summarizing the presentation must (1) list all persons attending or otherwise participating in the meeting at which the *ex parte* presentation was made, and (2) summarize all data presented and arguments made during the presentation. If the presentation consisted in whole or in part of the presentation of data or arguments already reflected in the presenter's written comments, memoranda or other filings in the proceeding, the presenter may provide citations to such data or arguments in his or her prior comments, memoranda, or other filings (specifying the relevant page and/or paragraph numbers where such data or arguments can be found) in lieu of summarizing them in the memorandum. Documents shown or given to Commission staff during *ex parte* meetings are deemed to be written *ex parte* presentations and must be filed consistent with rule 1.1206(b). In proceedings governed by rule 1.49(f) or for which the Commission has made available a method of electronic filing, written *ex parte* presentations and memoranda summarizing oral *ex parte* presentations, and all attachments thereto, must be filed through the electronic comment filing system available for that proceeding, and must be filed in their native format (e.g., .doc, .xml, .ppt, searchable .pdf). Participants in this proceeding should familiarize themselves with the Commission's *ex parte* rules.

VI. ORDERING CLAUSES

238. Accordingly, IT IS ORDERED, pursuant to Sections 4(i), 201, 302, and 303 of the Communications Act of 1934, as amended, 47 U.S.C. §§ 154(i), 201, 302a, 303, and Section 1.411 of the Commission's Rules, 47 C.F.R § 1.411; that this *Report and Order and Further Notice of Proposed Rulemaking*, is hereby ADOPTED.

239. IT IS FURTHER ORDERED that the amendments of the Commission's rules as set forth in Appendix A ARE ADOPTED, effective sixty days from the date of publication in the Federal Register.

240. IT IS FURTHER ORDERED that the Commission's Consumer and Governmental Affairs Bureau, Reference Information Center, SHALL SEND a copy of this *Report and Order and Further Notice of Proposed Rulemaking*, including the Initial and Final Regulatory Flexibility Analyses, to the Chief Counsel for Advocacy of the Small Business Administration.

241. IT IS FURTHER ORDERED that the Commission's Consumer and Governmental Affairs Bureau, Reference Information Center, SHALL SEND a copy of this *Report and Order and Further Notice of Proposed Rulemaking*, including the Initial and Final Regulatory Flexibility Analysis, to Congress and the Government Accountability Office pursuant to the Congressional Review Act, *see* 5 U.S.C. § 801(a)(1)(A).

[578] 47 CFR §§ 1.1200 *et seq.*

FEDERAL COMMUNICATIONS COMMISSION

Marlene H. Dortch
Secretary

APPENDIX A

Final Rules

Parts 0 and 15 of Title 47 of the Code of Federal Regulations is proposed to be amended as follows:

PART 0 – COMMISSION ORGANIZATION

1. The authority citation for Part 0 continues to read as follows:

AUTHORITY: Secs. 5, 48 Stat. 1068, as amended; 47 U.S.C. 155.

2. Section 0.241 is amended by adding new paragraph (k) to read as follows:

§ 0.241 Authority delegated.

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(k) The Chief of the Office of Engineering and Technology is delegated authority to administer the Automated Frequency Coordination (AFC) system and AFC system operator functions set forth in subpart E of part 15 of this chapter. The Chief is delegated authority to develop specific methods that will be used to designate AFC system operators; to designate AFC system operators; to develop procedures that these AFC system operators will use to ensure compliance with the requirements for AFC system operations; to make determinations regarding the continued acceptability of individual AFC system operators; and to perform other functions as needed for the administration of the AFC systems.

PART 15 – RADIO FREQUENCY DEVICES

3. The authority citation for Part 15 continues to read as follows:

AUTHORITY: 47 U.S.C. 154, 302a, 303, 304, 307, 336, 544a, and 549.

4. Section 15.401 is amended to read as follows:

§ 15.401 Scope.

This subpart sets out the regulations for unlicensed National Information Infrastructure (U-NII) devices operating in the 5.15-5.35 GHz, 5.47-5.725 GHz, 5.725-5.85 GHz, and 5.925-7.125 GHz bands.

5. Section 15.403 is amended to read as follows:

§ 15.403 Definitions.

Access Point (AP). A U-NII transceiver that operates either as a bridge in a peer-to-peer connection or as a connector between the wired and wireless segments of the network or as a relay between wireless network segments.

Automated Frequency Coordination (AFC) System. A system that automatically determines and provides lists of which frequencies are available for use by standard power access points operating in the 5.925-6.425 GHz and 6.525-6.875 GHz bands.

Available Channel. A radio channel on which a *Channel Availability Check* has not identified the presence of a radar.

Average Symbol Envelope Power. The average symbol envelope power is the average, taken over all symbols in the signaling alphabet, of the envelope power for each symbol.

Channel Availability Check. A check during which the U-NII device listens on a particular radio channel to identify whether there is a radar operating on that radio channel.

Channel Move Time. The time needed by a U-NII device to cease all transmissions on the current channel upon detection of a radar signal above the DFS detection threshold.

Client Device. A U-NII device whose transmissions are generally under the control of an access point and is not capable of initiating a network

Contention-based protocol. A protocol that allows multiple users to share the same spectrum by defining the events that must occur when two or more transmitters attempt to simultaneously access the same channel and establishing rules by which a transmitter provides reasonable opportunities for other transmitters to operate. Such a protocol may consist of procedures for initiating new transmissions, procedures for determining the state of the channel (available or unavailable), and procedures for managing retransmissions in the event of a busy channel.

Digital modulation. The process by which the characteristics of a carrier wave are varied among a set of predetermined discrete values in accordance with a digital modulating function as specified in document ANSI C63.17-1998.

Dynamic Frequency Selection (DFS) is a mechanism that dynamically detects signals from other systems and avoids co-channel operation with these systems, notably radar systems.

DFS Detection Threshold. The required detection level defined by detecting a received signal strength (RSS) that is greater than a threshold specified, within the U-NII device channel bandwidth.

Emission bandwidth. For purposes of this subpart the emission bandwidth is determined by measuring the width of the signal between two points, one below the carrier center frequency and one above the carrier center frequency, that are 26 dB down relative to the maximum level of the modulated carrier.

Indoor Access Point. For the purpose of this subpart, an access point that operates in the 5.925-7.125 GHz band, is plugged into a wall outlet, has an internally integrated antenna, is not battery powered, and does not have a weatherized enclosure.

In-Service Monitoring. A mechanism to check a channel in use by the U-NII device for the presence of a radar.

Non-Occupancy Period. The required period in which, once a channel has been recognized as containing a radar signal by a U-NII device, the channel will not be selected as an available channel.

Operating Channel. Once a U-NII device starts to operate on an Available Channel then that channel becomes the Operating Channel.

Maximum Power Spectral Density. The maximum power spectral density is the maximum power

spectral density, within the specified measurement bandwidth, within the U-NII device operating band.

Maximum Conducted Output Power. The total transmit power delivered to all antennas and antenna elements averaged across all symbols in the signaling alphabet when the transmitter is operating at its maximum power control level. Power must be summed across all antennas and antenna elements. The average must not include any time intervals during which the transmitter is off or is transmitting at a reduced power level. If multiple modes of operation are possible (e.g., alternative modulation methods), the *maximum conducted output power* is the highest total transmit power occurring in any mode.

Power Spectral Density. The power spectral density is the total energy output per unit bandwidth from a pulse or sequence of pulses for which the transmit power is at its maximum level, divided by the total duration of the pulses. This total time does not include the time between pulses during which the transmit power is off or below its maximum level.

Pulse. A pulse is a continuous transmission of a sequence of modulation symbols, during which the average symbol envelope power is constant.

RLAN. Radio Local Area Network.

Standard Power Access Point. An access point that operates in the 5.925-6.425 GHz and 6.525-6.875 GHz bands pursuant to direction from an Automated Frequency Coordination System.

Subordinate Access Point. For the purpose of this subpart, a device that operates in the 5.925-7.125 GHz band under the control of an Indoor Access Point, is plugged into a wall outlet, has an internally integrated antenna, is not battery powered, does not have a weatherized enclosure, and does not have a direct connection to the internet. Subordinate access points must not be used to connect devices between separate buildings or structures. Subordinate access points must be authorized under certification procedures in part 2 of this chapter. Modules may not be certified as subordinate access points.

Transmit Power Control (TPC). A feature that enables a U-NII device to dynamically switch between several transmission power levels in the data transmission process.

U-NII devices. Intentional radiators operating in the frequency bands 5.15-5.35 GHz, 5.470-5.85 GHz, 5.925-7125 GHz that use wideband digital modulation techniques and provide a wide array of high data rate mobile and fixed communications for individuals, businesses, and institutions.

6. Section 15.407 is amended by redesignating paragraph (a)(4) as (a)(11) and revising paragraph (a)(5) and redesignating it as paragraph (a)(12), adding new paragraphs (a)(4), through (10), redesignating paragraphs (b)(5) through (8) as (b)(7) through (10), adding new paragraphs (b)(5) and (b)(6), revising paragraph (d) and adding new paragraphs (k) through (n) to read as follows.

§ 15.407 General technical requirements.

(a) * * *

(4) For a standard power access point operating in the 5.925-6.425 GHz and 6.525-6.875 GHz bands, the maximum power spectral density must not exceed 23 dBm e.i.r.p in any 1-megahertz band. In addition, the maximum e.i.r.p. over the frequency band of operation must not exceed 36 dBm. The maximum e.i.r.p. at any elevation angle above 30 degrees as measured from the horizon must not exceed

125 mW (21 dBm).

(5) For an indoor access point operating in the 5.925-7.125 GHz band, the maximum power spectral density must not exceed 5 dBm e.i.r.p.in any 1-megahertz band. In addition, the maximum e.i.r.p. over the frequency band of operation must not exceed 30 dBm.

(6) For a subordinate access point operating under the control of an indoor access point in the 5.925-7.125 GHz band, the maximum power spectral density must not exceed 5 dBm e.i.r.p in any 1-megahertz band, the maximum e.i.r.p. over the frequency band of operation must not exceed 30 dBm, and must not operate with more power than its associated access point.

(7) For client devices operating under the control of a standard power access point in 5.925-6.425 GHz and 6.525-6.875 GHz bands, the maximum power spectral density must not exceed 17 dBm e.i.r.p.in any 1-megahertz band, and the maximum e.i.r.p. over the frequency band of operation must not exceed 30 dBm and the device must limit its power to no more than 6 dB below its associated standard power access point's transmit power.

(8) For client devices operating under the control of an indoor access point in the 5.925 -7.125 GHz bands, the maximum power spectral density must not exceed -1 dBm e.i.r.p. in any 1-megahertz band, the maximum e.i.r.p. over the frequency band of operation must not exceed 24 dBm, and the device must limit its power to no more than 6 dB below its associated access point's transmit power.

(9) Access points operating under the provisions of paragraphs (a)(5) and(a)(6) of this section must employ an integrated antenna. The use of external connectorized antennas is expressly prohibited.

(10) The maximum transmitter channel bandwidth for U-NII devices in the 5.925 – 7.125 GHz band is 320 megahertz

* * *

(12) Power spectral density measurement. The maximum power spectral density is measured as either a conducted emission by direct connection of a calibrated test instrument to the equipment under test or a radiated measurement. Measurements in the 5.725-5.85 GHz band are made over a reference bandwidth of 500 kHz or the 26 dB emission bandwidth of the device, whichever is less. Measurements in all other bands are made over a bandwidth of 1 MHz or the 26 dB emission bandwidth of the device, whichever is less. A narrower resolution bandwidth can be used, provided that the measured power is integrated over the full reference bandwidth.

(b) * * *

(5) For transmitters operating within the 5.925-7.125 GHz band: Any emissions outside of the 5.925-7.125 GHz band must not exceed an e.i.r.p. of -27 dBm/MHz.

(6) For transmitters operating within the 5.925-7.125 GHz bands: power spectral density must be suppressed by 20 dB at 1 MHz outside of channel edge, by 28 dB at one channel bandwidth from the channel center, and by 40 dB at one- and one-half times the channel bandwidth away from channel center. At frequencies between one megahertz outside an unlicensed device's channel edge and one channel bandwidth from the center of the channel, the limits must be linearly interpolated between 20 dB and 28 dB suppression, and at frequencies between one and one- and one-half times an unlicensed device's channel bandwidth, the limits must be linearly interpolated between 28 dB and 40 dB suppression. Emissions removed from the channel center by more than one- and one-half times the channel bandwidth

must be suppressed by at least 40 dB.
* * * * *

(d) *Operational restrictions for 6 GHz U-NII devices.*

(1) Operation of standard access points and indoor access points in the 5.925-7.125 GHz band is prohibited in vehicles and aircraft except that indoor access points are permitted to operate in the 5.925-6.425 GHz bands in aircraft while flying above 10,000 feet.

(2) Operation of transmitters in the 5.925-7.125 GHz band is prohibited for control of or communications with unmanned aircraft systems.

(3) Transmitters operating under the provisions of paragraphs (a)(5), (a)(6), (a)(7) and (a)(8) of this section are limited to indoor locations.

(4) Indoor access points and subordinate access points as well as client devices designed to work with indoor access points in the 5.925-7.125 GHz band must bear the following statement in a conspicuous location on the device and in the user's manual: FCC regulations restrict operation of this device to indoor use only. The operation of this device is prohibited in vehicles and aircraft except that operation of this device is permitted in aircraft while flying above 10,000 feet.

(5) In the 5.925-7.125 GHz band, client devices must operate under the control of a standard power access point, indoor access point or subordinate access point; Subordinate access points must operate under the control of an indoor access point. In all cases, an exception exists for transmitting brief messages to an access point when attempting to join its network after detecting a signal that confirms that an access point is operating on a particular channel. Access points and subordinate access points may connect to other access points or subordinate access points. Client devices are prohibited from connecting directly to another client device.

(6) Indoor access points, subordinate access points and client devices operating in the 5.925-7.125 GHz band must employ a contention-based protocol.

* * * * *

(k) *Automated frequency coordination (AFC) system.*

(1) Standard power access points operating under paragraph (a)(4) of this section must access an AFC system to determine the available frequencies and the maximum permissible power in each frequency range at their geographic coordinates prior to transmitting. Standard power access points may transmit only on frequencies and at power levels that an AFC system indicates as available.

(2) An AFC system must be capable of determining the available frequencies in steps of no greater than 3 dB below the maximum permissible e.i.r.p of 36 dBm, and down to at least a minimum level of 21 dBm.

(3) An AFC system must obtain information on protected services within the 5.925-6.425 GHz and 6.525-6.875 GHz bands from Commission databases and use that information to determine frequency availability for standard power access points based on protection criteria specified in paragraph (l)(2) of this section.

(4) An AFC system must use the information supplied by standard power access points during

registration, as set forth in this section, to determine available frequencies and the maximum permissible power in each frequency range for a standard power access point at any given location. All such determinations and assignments must be made in a non-discriminatory manner, consistent with this part.

(5) An AFC system must store registered information in a secure database until a standard power access point ceases operation at a location. For the purpose of this paragraph, a standard power access point is considered to have ceased operation when that device has not contacted the AFC system for more than three months to verify frequency availability information.

(6) An AFC system must verify the validity of the FCC identifier (FCC ID) of any standard power access point seeking access to its services prior to authorizing the access point to begin operation. A list of standard power access points with valid FCC IDs and the FCC IDs of those devices must be obtained from the Commission's Equipment Authorization System.

(7) The general purposes of AFC system include:

(i) Enacting all policies and procedures developed by the AFC system operators pursuant to this section.

(ii) Registering, authenticating, and authorizing standard power access point operations, individually or through a network element device representing multiple standard power access points from the same operating network.

(iii) Providing standard power access points with the permissible frequencies and the maximum permissible power in each frequency range at their locations using propagation models and interference protection criteria defined in paragraph (l) of this section.

(iv) Obtaining updated protected sites information from Commission databases.

(8) A standard power access point:

(i) Must register with and be authorized by an AFC system prior to the standard power access point’s initial service transmission, or after a standard power access point changes location, and must obtain a list of available frequencies and the maximum permissible power in each frequency range at the standard power access point’s location.

(ii) Must register with the AFC system by providing the following parameters: geographic coordinates (latitude and longitude referenced to North American Datum 1983 (NAD 83)), antenna height above ground level, FCC identification number, and unique manufacturer’s serial number. If any of these parameters change, the standard power access point must provide updated parameters to the AFC system. All information provided by the standard power access point to the AFC system must be true, complete, correct, and made in good faith.

(iii) Must provide the registration information to the AFC system either directly and individually or by a network element representing multiple standard power access points from the same operating network. The standard power access point or its network element must register with the AFC system via any communication link, wired or wireless, outside 5.925-6.425 GHz and 6.525-6.875 GHz bands.

(iv) Must contact an AFC system at least once per day to obtain the latest list of available frequencies and the maximum permissible power the standard power access point may operate with on each frequency at the standard power access point’s location. If the standard power access point fails to successfully contact the AFC system during any given day, the standard power access point may continue

to operate until 11:59 p.m. of the following day at which time it must cease operations until it re-establishes contact with the AFC system and re-verifies its list of available frequencies and associated power levels.

(v) Must incorporate adequate security measures to prevent it from accessing AFC systems not approved by the FCC and to ensure that unauthorized parties cannot modify the device to operate in a manner inconsistent with the rules and protection criteria set forth in this section and to ensure that communications between standard power access points and AFC systems are secure to prevent corruption or unauthorized interception of data. Additionally, the AFC system must incorporate security measures to protect against unauthorized data input or alteration of stored data, including establishing communications authentication procedures between client devices and standard power access points.

(9) Standard power access point geo-location capability:

(i) A standard power access point must include an internal geo-location capability to automatically determine the standard power access point's geographic coordinates and location uncertainty (in meters), with a confidence level of 95%. The standard power access point must report such coordinates and location uncertainty to an AFC system at the time of activation from a power-off condition.

(ii) A standard power access point may obtain its geographic coordinates through an external geo-location source when it is used at a location where its internal geo-location capability does not function. An external geo-location source may be connected to a standard power access point through either a wired or a wireless connection. A single geo-location source may provide location information to multiple standard power access points.

(iii) An external geo-location source must be connected to a standard power access point using a secure connection that ensures that only an external geo-location source approved for use with a standard power access point provides geographic coordinates to that standard power access point. Alternatively, an extender cable may be used to connect a remote receive antenna to a geo-location receiver within a standard power access point.

(iv) The applicant for certification of a standard power access point must demonstrate the accuracy of the geo-location method used and the location uncertainty. For standard power access points that may not use an internal geo-location capability, this uncertainty must account for the accuracy of the geo-location source and the separation distance between such source and the standard power access point.

(10) An AFC system operator will be designated for a five-year term which can be renewed by the Commission based on the operator's performance during the term. If an AFC system ceases operation, it must provide at least 30-days' notice to the Commission and transfer any registration data to another AFC system operator.

(11) The Commission will designate one or more AFC system operators to provide service in the 5.925-6.425 GHz and 6.525-6.875 GHz bands.

(12) The Commission may permit the functions of an AFC system, such as a data repository, registration, and query services, to be divided among multiple entities; however, entities designated as AFC system operators will be held accountable for the overall functioning and system administration of the AFC system.

(13) The AFC system must ensure that all communications and interactions between the AFC system and standard power access points are accurate and secure and that unauthorized parties cannot

access or alter the database, or the list of available frequencies and associated powers sent to a standard power access point.

(14) An AFC system must implement the terms of international agreements with Mexico and Canada.

(15) Each AFC system operator designated by the Commission must:

(i) Maintain a regularly updated AFC system database that contains the information described in this section, including incumbent's information and standard power access points registration parameters.

(ii) Establish and follow protocols and procedures to ensure compliance with the rules set forth in this part.

(iii) Establish and follow protocols and procedures sufficient to ensure that all communications and interactions between the AFC system and standard power access points are accurate and secure and that unauthorized parties cannot access or alter the AFC system, or the information transmitted from the AFC system to standard power access points.

(iv) Provide service for a five-year term. This term may be renewed at the Commission's discretion.

(v) Respond in a timely manner to verify, correct, or remove, as appropriate, data in the event that the Commission or a party presents to the AFC system Operator a claim of inaccuracies in the AFC system. This requirement applies only to information that the Commission requires to be stored in the AFC system.

(vi) Establish and follow protocols to comply with enforcement instructions from the Commission, including discontinuance of standard power access point operations in designated geographic areas.

(16) An AFC system operator may charge fees for providing service in registration and channel availability functions. The Commission may, upon request, review the fees and can require changes to those fees if the Commission finds them unreasonable.

(l) *Incumbent Protection by AFC system: Fixed Microwave Services:*

A standard power access point must not cause harmful interference to fixed microwave services authorized to operate in the 5.925-6.425 GHz and 6.525-6.875 GHz bands. Based on the criteria set forth below, an AFC system must establish location and frequency-based exclusion zones (both co-channel and adjacent channel) around fixed microwave receivers operating in the 5.925-6.425 GHz and 6.525-6.875 GHz bands. Individual standard power access points must not operate co-channel to fixed microwave system frequencies within co-channel exclusion zones, or on adjacent channel frequencies within adjacent channel exclusion zones.

(1) Propagation Models: Propagation models to determine appropriate separations distances are based on the separation distance between a standard power access point and an incumbent fixed microwave service receiver. For separations distances:

(i) Up to 30 meters, the AFC system must use the free space path-loss model.

(ii) More than 30 meters and up to and including one kilometer, the AFC system must use the

Wireless World Initiative New Radio phase II (WINNER II) model. The AFC system must use site-specific information, including buildings and terrain data, for determining the line-of-sight/non-line-of-sight path component in the WINNER II model, where such data is available. For evaluating paths where such data is not available, the AFC system must use a probabilistic model combining the line-of-sight path and non-line-of-sight path into a single path-loss as follows:

Path-loss (L) = Σ_i P(i) * L_i = P_{LOS} * L_{NLOS} + P_{NLOS} * L_{NLOS}, where P_{LOS} is the probability of line-of-sight, L_{LOS} is the line-of-sight path loss, P_{NLOS} is the probability of non-line-of sight, L_{NLOS} is the non-line-of-sight path loss, and L is the combined path loss. The WINNER II path loss models include a formula to determine P_{LOS} as a function of antenna heights and distance. P_{NLOS} is equal to (1-P_{LOS}).

In all cases, the AFC system will use the correct WINNER II parameters to match the morphology of the path between a standard power access point and a fixed microwave receiver (i.e., Urban, Suburban, or Rural).

(iii) More than one kilometer, the AFC system must use Irregular Terrain Model (ITM) combined with the appropriate clutter model. To account for the effects of clutter, such as buildings and foliage, that the AFC system must combine the ITM with the ITU-R P.2108-0 (06/2017) clutter model for urban and suburban environments and the ITU-R P.452-16 (07/2015) clutter model for rural environments. The AFC system must use the village center as the default category for the computation of ITU-R P.452 clutter. An AFC system may use other clutter categories upon proper justification. The AFC system must use 1 arc-second digital elevation terrain data and, for locations where such data is not available, the most granular available digital elevation terrain data.

(2) Interference Protection Criteria:

(i) The AFC system must use -6 dB I/N as the interference protection criteria in determining the size of the co-channel exclusion zone where I (interference) is the co-channel signal from the standard power access point at the fixed microwave service receiver, and N (noise) is background noise level at the fixed microwave service receiver.

(ii) The AFC system must use -6 dB I/N as the interference protection criteria in determining the size of the adjacent channel exclusion zone, where I (interference) is the signal from the standard power access point's out of channel emissions at the fixed microwave service receiver and N (noise) is background noise level at the fixed microwave service receiver. The adjacent channel exclusion zone must be calculated based on the emissions requirements of paragraph (b)(6) of this section.

(m) *Incumbent Protection by AFC system: Radio Astronomy Services*

The AFC system must enforce an exclusion zones to the following radio observatories that observe between 6650-6675.2 MHz: Arecibo Observatory, the Green Bank Observatory, the Very Large Array (VLA), the 10 Stations of the Very Long Baseline Array (VLBA), the Owens Valley Radio Observatory, and the Allen Telescope Array. The exclusion zone sizes are based on the radio line-of-sight and determined using 4/3 earth curvature and the following formula: dkm_los = 4.12*(sqrt(Htx) + sqrt(Hrx)), where Htx and Hrx are the heights of the unlicensed standard power access point and radio astronomy antenna in meters above ground level. Coordinate locations of the radio observatories are listed in section 2.106, notes US 131 and US 385 of this part.

(n) *Incumbent Protection by AFC system: Fixed-Satellite Services*

Standard power access points must limit their maximum e.i.r.p. at any elevation angle above 30 degrees as measured from the horizon to 21 dBm (125 mW) to protect fixed satellite services.

APPENDIX B

FINAL REGULATORY FLEXIBLE ANALYSIS

1. As required by the Regulatory Flexibility Act (RFA),[1] a Supplemental Initial Regulatory Flexibility Analysis (Supplemental IRFA) was incorporated in the Report & Order and Further Notice of Proposed Rulemaking (FNPRM) in ET Docket No. 18-295. [2] The Commission sought written public comment on the proposals in the NPRM, including comment on the supplemental IRFA. [3] This present Final Regulatory Flexibility Analysis (FRFA) conforms to the RFA.

A. Need for, and Objectives of, the Proposed Rules

2. This *Report & Order (Order)* continues the Commission efforts to expand unlicensed use of the 5.925-7.125 GHz (6 GHz) band under our Part 15 rules. In the *Unlicensed Use of the 6 GHz Band, Report and Order*, the Commission focused on unlicensed use of this band due to the band's proximity to the Unlicensed National Information Infrastructure (U-NII) bands, which have hosted extensive unlicensed device innovation and deployment. The adopted rules are intended to provide an opportunity for devices such as smartphones, Wi-Fi routers, and IoT devices to be economically designed to operate across both the 6 GHz and the U-NII bands. We are encouraged by the fact that the 6 GHz band shares virtually identical propagation properties to the U-NII bands, which have proven suitable for many unlicensed applications.

B. Summary of Significant Issues Raised by Public Comments in Response to the Supplemental IRFA

3. In the Supplemental IRFA, we stated that any rule changes would impose minimum burdens on small entities, including the rules the Commission proposed in the NPRM were designed to protect important incumbent licensed services that operate (and continue to grow) in various sub-bands of this spectrum. Under the adopted rules, the Commission believes that unlicensed use of the band would be compatible with these incumbent licensed services. To do this, the Commission will divide the 6 GHz band into four sub-bands based on the prevalence and characteristics of the incumbent services that operate in that spectrum. Unlicensed access points under the proposed rules would fall into two categories depending on the sub-bands in which they would operate:

- *5.925-6.425 GHz sub-band and 6.525-6.875 GHz sub-band (totaling 850 megahertz)* – unlicensed operations at the power levels permitted for unlicensed use in the U-NII-1 & -3 bands[4]—referenced herein as "standard-power access points"—with the operating frequencies determined by an automated frequency control (AFC) mechanism that protects the incumbent services in this spectrum from harmful interference; and.
- *6.425-6.525 GHz sub-band and 6.875-7.125 GHz sub-band (totaling 350 megahertz)* – unlicensed operations at the lower more restricted power levels applicable to operations in the U-NII-2 bands [5]—referenced herein as "low-power access points"— limited to

[1] *See* 5 U.S.C. § 603. The RFA, *see* 5 U.S.C. §§ 601-612, has been amended by the Small Business Regulatory Enforcement Fairness Act of 1996, (SBREFA) Pub. L. No. 104-121, Title II, 110 Stat. 857 (1996).

[2] *Notice of Proposed Rulemaking*, 33 FCC Rcd 10496, Appendix C, Paras. 1-24.

[3] *See* 5 U.S.C. § 603(a).

[4] The U-NII-1 band is the 5.15-5.25 GHz band, while the U-NII-3 band is the 5.725-5.85 GHz band. *Revision of Part 15 of the Commission's Rules to Permit Unlicensed National Information Infrastructure (U-NII) Devices in the 5 GHz Band*, First Report and Order, 29 FCC Rcd 4127, 4128-4129, para. 4 (2014).

[5] The U-NII-2 bands include the 5.25-5.35 GHz (U-NII-2A) and 5.47-5.725 GHz (U-NII-2C) bands. *Id*.

indoor operation (with no AFC requirement) to prevent harmful interference to the incumbent services in this spectrum.

In addition, the adopted rules would permit client devices to operate across the entire 6 GHz band while under the control of either a standard-power access point or a low-power access point. This two-class approach can expand unlicensed use of the spectrum without causing harmful interference to the incumbent services that will continue to be authorized to use this spectrum.

C. Description and Estimate of the Number of Small Entities To Which Rules Will Apply

4. The RFA directs agencies to provide a description of, and where feasible, an estimate of the number of small entities that may be affected by adopted rules.[6] The RFA generally defines the term "small entity" as having the same meaning as the terms "small business," "small organization," and "small governmental jurisdiction."[7] In addition, the term "small business" has the same meaning as the term "small business concern" under the Small Business Act.[8] A "small business concern" is one which: (1) is independently owned and operated; (2) is not dominant in its field of operation; and (3) satisfies any additional criteria established by the Small Business Administration (SBA).[9]

5. The 5.925-6.425 GHz and 6.525-6.875 GHz sub-bands are predominantly used by fixed microwave links and by the fixed-satellite service (FSS) for Earth-to-space transmissions. To protect incumbent fixed microwave operations from harmful interference, unlicensed access to these bands will only be permitted on frequencies and locations determined by an AFC system based on the exclusion zones that it establishes. The AFC system will also be used to protect certain radio astronomy observatories. The AFC system will use a centralized model where each standard-power access point remotely accesses an AFC system to obtain a list of available frequency ranges in which it is permitted to operate and the maximum permissible power in each frequency range. To protect incumbent fixed satellite service operations, the rules also adopt a restriction on unlicensed standard-power access points to prevent them from pointing toward space station receivers.

6. The 6.425-6.525 GHz and 6.875-7.125 GHz sub-bands are used for mobile stations in the Broadcast Auxiliary Service and the Cable Television Relay Service as well as fixed microwave links. Because these sub-bands have mobile operations, an AFC system would not be able to determine exclusion zones to protect all of these services. Instead, the proposed rules would allow the unlicensed operations at a lower power level and restrict their operations to indoors to prevent harmful interference to the services operating in these sub-bands.

7. Under the adopted rules the client devices would only be allowed to transmit under the control of a standard-power access point or low-power access point, depending on which sub-band they operate in, and would be restricted to operation at an even lower power than the low-power access point.

8. The RFA directs agencies to provide a description of, and, where feasible, an estimate of the number of small entities that may be affected by the proposed rules and policies, if adopted.[10] The RFA generally defines the term "small entity" as having the same meaning as the terms "small business,"

[6] *See* 5 U.S.C. § 603(b)(3).

[7] 5 U.S.C. § 601(6).

[8] 5 U.S.C. § 601(3) (incorporating by reference the definition of "small-business concern" in the Small Business Act, 15 U.S.C. § 632). Pursuant to 5 U.S.C. § 601(3), the statutory definition of a small business applies "unless an agency, after consultation with the Office of Advocacy of the Small Business Administration and after opportunity for public comment, establishes one or more definitions of such term which are appropriate to the activities of the agency and publishes such definition(s) in the Federal Register."

[9] 15 U.S.C. § 632.

[10] 5 U.S.C. § 603(b)(3).

"small organization," and "small governmental jurisdiction."[11] In addition, the term "small business" has the same meaning as the term "small business concern" under the Small Business Act.[12] A "small business concern" is one which: (1) is independently owned and operated; (2) is not dominant in its field of operation; and (3) satisfies any additional criteria established by the SBA.[13]

9. *Small Businesses, Small Organizations, Small Governmental Jurisdictions*. Our actions, over time, may affect small entities that are not easily categorized at present. We therefore describe here, at the outset, three broad groups of small entities that could be directly affected herein.[14] First, while there are industry specific size standards for small businesses that are used in the regulatory flexibility analysis, according to data from the SBA's Office of Advocacy, in general a small business is an independent business having fewer than 500 employees.[15] These types of small businesses represent 99.9% of all businesses in the United States which translates to 28.8 million businesses.[16]

10. Next, the type of small entity described as a "small organization" is generally "any not-for-profit enterprise which is independently owned and operated and is not dominant in its field."[17] Nationwide, as of August 2016, there were approximately 356,494 small organizations based on registration and tax data filed by nonprofits with the Internal Revenue Service (IRS).[18]

11. Finally, the small entity described as a "small governmental jurisdiction" is defined generally as "governments of cities, counties, towns, townships, villages, school districts, or special districts, with a population of less than fifty thousand."[19] U.S. Census Bureau data from the 2012 Census of Governments[20] indicate that there were 90,056 local governmental jurisdictions consisting of general

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[11] 5 U.S.C. § 601(6).

[12] 5 U.S.C. § 601(3) (incorporating by reference the definition of "small-business concern" in the Small Business Act, 15 U.S.C. § 632). Pursuant to 5 U.S.C. § 601(3), the statutory definition of a small business applies "unless an agency, after consultation with the Office of Advocacy of the Small Business Administration and after opportunity for public comment, establishes one or more definitions of such term which are appropriate to the activities of the agency and publishes such definition(s) in the Federal Register."

[13] 15 U.S.C. § 632.

[14] *See* 5 U.S.C. § 601(3)-(6).

[15] *See* SBA, Office of Advocacy, "Frequently Asked Questions, Question 1 – What is a small business?" https://www.sba.gov/sites/default/files/advocacy/SB-FAQ-2016_WEB.pdf (June 2016).

[16] *See* SBA, Office of Advocacy, "Frequently Asked Questions, Question 2- How many small businesses are there in the U.S.?" https://www.sba.gov/sites/default/files/advocacy/SB-FAQ-2016_WEB.pdf (June 2016).

[17] 5 U.S.C. § 601(4).

[18] Data from the Urban Institute, National Center for Charitable Statistics (NCCS) reporting on nonprofit organizations registered with the IRS was used to estimate the number of small organizations. Reports generated using the NCCS online database indicated that as of August 2016 there were 356,494 registered nonprofits with total revenues of less than $100,000. Of this number, 326,897 entities filed tax returns with 65,113 registered nonprofits reporting total revenues of $50,000 or less on the IRS Form 990-N for Small Exempt Organizations and 261,784 nonprofits reporting total revenues of $100,000 or less on some other version of the IRS Form 990 within 24 months of the August 2016 data release date. *See* http://nccs.urban.org/sites/all/nccs-archive/html//tablewiz/tw.php where the report showing this data can be generated by selecting the following data fields: Report: "The Number and Finances of All Registered 501(c) Nonprofits"; Show: "Registered Nonprofits"; By: "Total Revenue Level (years 1995, Aug to 2016, Aug)"; and For: "2016, Aug" then selecting "Show Results".

[19] 5 U.S.C. § 601(5).

[20] *See* 13 U.S.C. § 161. The Census of Government is conducted every five (5) years compiling data for years ending with "2" and "7." *See also* Program Description Census of Government *https://factfinder.census.gov/faces/affhelp/jsf/pages/metadata.xhtml?lang=en&type=program&id=program.en.COG#*.

purpose governments and special purpose governments in the United States.[21] Of this number there were 37,132 General purpose governments (county,[22] municipal and town or township[23]) with populations of less than 50,000 and 12,184 Special purpose governments (independent school districts[24] and special districts[25]) with populations of less than 50,000. The 2012 U.S. Census Bureau data for most types of governments in the local government category show that the majority of these governments have populations of less than 50,000.[26] Based on this data we estimate that at least 49,316 local government jurisdictions fall in the category of "small governmental jurisdictions."[27]

12. *Fixed Microwave Services.* Microwave services include common carrier,[28] private-operational fixed,[29] and broadcast auxiliary radio services.[30] They also include the Upper Microwave Flexible Use Service,[31] Millimeter Wave Service,[32] Local Multipoint Distribution Service (LMDS),[33] the

[21] *See* U.S. Census Bureau, 2012 Census of Governments, Local Governments by Type and State: 2012 - United States-States. https://factfinder.census.gov/bkmk/table/1.0/en/COG/2012/ORG02.US01. Local governmental jurisdictions are classified in two categories - General purpose governments (county, municipal and town or township) and Special purpose governments (special districts and independent school districts).

[22] *See* U.S. Census Bureau, 2012 Census of Governments, County Governments by Population-Size Group and State: 2012 - United States-States. https://factfinder.census.gov/bkmk/table/1.0/en/COG/2012/ORG06.US01. There were 2,114 county governments with populations less than 50,000.

[23] *See* U.S. Census Bureau, 2012 Census of Governments, Subcounty General-Purpose Governments by Population-Size Group and State: 2012 - United States – States. https://factfinder.census.gov/bkmk/table/1.0/en/COG/2012/ORG07.US01. There were 18,811 municipal and 16,207 town and township governments with populations less than 50,000.

[24] *See* U.S. Census Bureau, 2012 Census of Governments, Elementary and Secondary School Systems by Enrollment-Size Group and State: 2012 - United States-States. https://factfinder.census.gov/bkmk/table/1.0/en/COG/2012/ORG11.US01. There were 12,184 independent school districts with enrollment populations less than 50,000.

[25] *See* U.S. Census Bureau, 2012 Census of Governments, Special District Governments by Function and State: 2012 - United States-States. https://factfinder.census.gov/bkmk/table/1.0/en/COG/2012/ORG09.US01. The U.S. Census Bureau data did not provide a population breakout for special district governments.

[26] *See* U.S. Census Bureau, 2012 Census of Governments, **C**ounty Governments by Population-Size Group and State: 2012 - United States-States - https://factfinder.census.gov/bkmk/table/1.0/en/COG/2012/ORG06.US01; Subcounty General-Purpose Governments by Population-Size Group and State: 2012 - United States–States - https://factfinder.census.gov/bkmk/table/1.0/en/COG/2012/ORG07.US01; and Elementary and Secondary School Systems by Enrollment-Size Group and State: 2012 - United States-States. https://factfinder.census.gov/bkmk/table/1.0/en/COG/2012/ORG11.US01. While U.S. Census Bureau data did not provide a population breakout for special district governments, if the population of less than 50,000 for this category of local government is consistent with the other types of local governments the majority of the 38, 266 special district governments have populations of less than 50,000.

[27] *Id.*

[28] *See* 47 CFR Part 101, Subparts C and I.

[29] *See* 47 CFR Part 101, Subparts C and H.

[30] Auxiliary Microwave Service is governed by Part 74 of Title 47 of the Commission's Rules. *See* 47 CFR Part 74. Available to licensees of broadcast stations and to broadcast and cable network entities, broadcast auxiliary microwave stations are used for relaying broadcast television signals from the studio to the transmitter, or between two points such as a main studio and an auxiliary studio. The service also includes mobile TV pickups, which relay signals from a remote location back to the studio.

[31] *See* 47 CFR Part 30.

[32] *See* 47 CFR Part 101, Subpart Q.

[33] *See* 47 CFR Part 101, Subpart L.

Digital Electronic Message Service (DEMS),[34] and the 24 GHz Service,[35] where licensees can choose between common carrier and non-common carrier status.[36] At present, there are approximately 66,680 common carrier fixed licensees, 69,360 private and public safety operational-fixed licensees, 20,150 broadcast auxiliary radio licensees, 411 LMDS licenses, 33 24 GHz DEMS licenses, 777 39 GHz licenses, and five 24 GHz licenses, and 467 Millimeter Wave licenses in the microwave services.[37] The Commission has not yet defined a small business with respect to microwave services. The closest applicable SBA category is Wireless Telecommunications Carriers (except Satellite) and the appropriate size standard for this category under SBA rules is that such a business is small if it has 1,500 or fewer employees.[38] For this industry, U.S. Census data for 2012 show that there were 967 firms that operated for the entire year.[39] Of this total, 955 firms had employment of 999 or fewer employees and 12 had employment of 1000 employees or more.[40] Thus, under this SBA category and the associated size standard, the Commission estimates that a majority of fixed microwave service licensees can be considered small.

13. *Public Safety Radio Licensees.* As a general matter, Public Safety Radio Pool licensees include police, fire, local government, forestry conservation, highway maintenance, and emergency medical services.[41] Because of the vast array of public safety licensees, the Commission has not developed a small business size standard specifically applicable to public safety licensees. The closest applicable SBA category is Wireless Telecommunications Carriers (except Satellite) which encompasses business entities engaged in radiotelephone communications. The appropriate size standard for this category under SBA rules is that such a business is small if it has 1,500 or fewer employees.[42] For this industry, U.S. Census data for 2012 show that there were 967 firms that operated for the entire year.[43] Of this total, 955 firms had employment of 999 or fewer employees and 12 had employment of 1000

[34] *See* 47 CFR Part 101, Subpart G.

[35] *See id.*

[36] *See* 47 CFR §§ 101.533, 101.1017.

[37] These statistics are based on a review of the Universal Licensing System on September 22, 2015.

[38] *See* 13 CFR § 121.201, NAICS code 517312.

[39] U.S. Census Bureau, *2012 Economic Census of the United States*, Table EC1251SSSZ5, Information: Subject Series, "Estab and Firm Size: Employment Size of Firms for the U.S.: 2012 NAICS Code 517210" (rel. Jan. 8, 2016). https://factfinder.census.gov/bkmk/table/1.0/en/ECN/2012_US/51SSSZ5//naics~517210.

[40] *Id*. Available census data do not provide a more precise estimate of the number of firms that have employment of 1,500 or fewer employees; the largest category provided is for firms with "1000 employees or more."

[41] *See* subparts A and B of Part 90 of the Commission's Rules, 47 C.F.R. §§ 90.1-90.22. Police licensees serve state, county, and municipal enforcement through telephony (voice), telegraphy (code), and teletype and facsimile (printed material). Fire licensees are comprised of private volunteer or professional fire companies, as well as units under governmental control. Public Safety Radio Pool licensees also include state, county, or municipal entities that use radio for official purposes. State departments of conservation and private forest organizations comprise forestry service licensees that set up communications networks among fire lookout towers and ground crews. State and local governments are highway maintenance licensees that provide emergency and routine communications to aid other public safety services to keep main roads safe for vehicular traffic. Emergency medical licensees use these channels for emergency medical service communications related to the delivery of emergency medical treatment. Additional licensees include medical services, rescue organizations, veterinarians, persons with disabilities, disaster relief organizations, school buses, beach patrols, establishments in isolated areas, communications standby facilities, and emergency repair of public communications facilities.

[42] *See* 13 CFR § 121.201, NAICS code 517312.

[43] U.S. Census Bureau, *2012 Economic Census of the United States*, Table EC1251SSSZ5, Information: Subject Series: Estab and Firm Size: Employment Size of Firms for the U.S.: 2012 NAICS Code 517210 (rel. Jan. 8, 2016). https://factfinder.census.gov/bkmk/table/1.0/en/ECN/2012_US/51SSSZ5//naics~517210.

employees or more.[44] Thus, under this category and the associated size standard, the Commission estimates that the majority of firms can be considered small. With respect to local governments, in particular, since many governmental entities comprise the licensees for these services, we include under public safety services the number of government entities affected. According to Commission records, there are a total of approximately 133,870 licenses within these services.[45] There are 3,548 licenses in the 4.9 GHz band, based on an FCC Universal Licensing System search as of March 29, 2017.[46] We estimate that fewer than 2,442 public safety radio licensees hold these licenses because certain entities may have multiple licenses.

14. *Satellite Telecommunications.* This category comprises firms "primarily engaged in providing telecommunications services to other establishments in the telecommunications and broadcasting industries by forwarding and receiving communications signals via a system of satellites or reselling satellite telecommunications."[47] Satellite telecommunications service providers include satellite and earth station operators. The category has a small business size standard of $32.5 million or less in average annual receipts, under SBA rules.[48] For this category, U.S. Census Bureau data for 2012 show that there were a total of 333 firms that operated for the entire year.[49] Of this total, 299 firms had annual receipts of less than $25 million.[50] Consequently, we estimate that the majority of satellite telecommunications providers are small entities.

15. *Wireless Telecommunications Carriers (except Satellite).* This industry comprises establishments engaged in operating and maintaining switching and transmission facilities to provide communications via the airwaves. Establishments in this industry have spectrum licenses and provide services using that spectrum, such as cellular services, paging services, wireless Internet access, and wireless video services.[51] The appropriate size standard under SBA rules is that such a business is small if it has 1,500 or fewer employees.[52] For this industry, U.S. Census Bureau data for 2012 show that there were 967 firms that operated for the entire year.[53] Of this total, 955 firms had employment of 999 or

[44] *Id*. Available census data do not provide a more precise estimate of the number of firms that have employment of 1,500 or fewer employees; the largest category provided is for firms with "1000 employees or more."

[45] This figure was derived from Commission licensing records as of June 27, 2008. Licensing numbers change on a daily basis. We do not expect this number to be significantly smaller today. This does not indicate the number of licensees, as licensees may hold multiple licenses. There is no information currently available about the number of public safety licensees that have less than 1,500 employees.

[46] Based on an FCC Universal Licensing System search of March 29, 2017. Search parameters: Radio Service = PA – Public Safety 4940-4990 MHz Band; Authorization Type = Regular; Status = Active.

[47] U.S. Census Bureau, 2017 NAICS Definitions, "517410 Satellite Telecommunications"; https://www.census.gov/cgi-bin/sssd/naics/naicsrch?input=517410&search=2017+NAICS+Search&search=2017.

[48] 13 CFR § 121.201, NAICS code 517410.

[49] U.S. Census Bureau, *2012 Economic Census of the United States*, Table EC1251SSSZ4, Information: Subject Series - Estab and Firm Size: Receipts Size of Firms for the United States: 2012, NAICS code 517410 https://factfinder.census.gov/bkmk/table/1.0/en/ECN/2012_US/51SSSZ4//naics~517410.

[50] *Id*.

[51] U.S. Census Bureau, 2012 NAICS Definitions, "517210 Wireless Telecommunications Carriers (Except Satellite)," *See* https://factfinder.census.gov/faces/affhelp/jsf/pages/metadata.xhtml?lang=en&type=ib&id=ib.en./ECN.NAICS2012.517210.

[52] 13 CFR § 121.201, NAICS code 517312.

[53] U.S. Census Bureau, *2012 Economic Census of the United States*, Table EC1251SSSZ5, Information: Subject Series: Estab and Firm Size: Employment Size of Firms for the U.S.: 2012 NAICS Code 517210. https://factfinder.census.gov/bkmk/table/1.0/en/ECN/2012_US/51SSSZ5//naics~517210.

fewer employees and 12 had employment of 1000 employees or more.[54] Thus, under this category and the associated size standard, the Commission estimates that the majority of wireless telecommunications carriers (except satellite) are small entities.

16. The Commission's own data—available in its Universal Licensing System—indicate that, as of May 17, 2018, there are 264 Cellular licensees.[55] The Commission does not know how many of these licensees are small, as the Commission does not collect that information for these types of entities. Similarly, according to internally developed Commission data, 413 carriers reported that they were engaged in the provision of wireless telephony, including cellular service, Personal Communications Service (PCS), and Specialized Mobile Radio (SMR) Telephony services.[56] Of this total, an estimated 261 have 1,500 or fewer employees, and 152 have more than 1,500 employees.[57] Thus, using available data, we estimate that the majority of wireless firms can be considered small.

17. *Auxiliary, Special Broadcast and Other Program Distribution Services.* This service involves a variety of transmitters, generally used to relay broadcast programming to the public (through translator and booster stations) or within the program distribution chain (from a remote news gathering unit back to the station). Neither the SBA nor the Commission has developed a size standard applicable to broadcast auxiliary licensees. The closest applicable SBA category and small business size standard falls under Radio Stations and Television Broadcasting.[58] U.S. Census Bureau data for 2012 show that 2,849 radio station firms operated during that year.[59] Of that number, 2,806 firms operated with annual receipts of less than $25 million per year, 17 with annual receipts between $25 million and $49,999,999 million and 26 with annual receipts of $50 million or more.[60] For Television Broadcasting the SBA small business size standard is such businesses having $38.5 million or less in annual receipts.[61] U.S. Census Bureau data show that 751 firms in this category operated in that year.[62] Of that number, 656 had annual receipts of $25,000,000 or less, 25 had annual receipts between $25,000,000 and $49,999,999 and 70 had annual receipts of $50,000,000 or more.[63] Accordingly, based on the U.S. Census Bureau data for Radio Stations and Television Broadcasting, the Commission estimates that the majority of Auxiliary, Special Broadcast and Other Program Distribution Services firms are small.

18. *Fixed Satellite Transmit/Receive Earth Stations.* Neither the SBA nor the Commission

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[54] *Id*. Available census data does not provide a more precise estimate of the number of firms that have employment of 1,500 or fewer employees; the largest category provided is for firms with "1000 employees or more."

[55] *See* http://wireless.fcc.gov/uls. For the purposes of this IRFA, consistent with Commission practice for wireless services, the Commission estimates the number of licensees based on the number of unique FCC Registration Numbers.

[56] *See* Federal Communications Commission, Wireline Competition Bureau, Industry Analysis and Technology Division, Trends in Telephone Service at Table 5.3 (Sept. 2010) (*Trends in Telephone Service*), https://apps.fcc.gov/edocs_public/attachmatch/DOC-301823A1.pdf.

[57] *See id*.

[58] 13 C.F.R. 121.201, NAICS codes 515112 and 515120.

[59] U.S. Census Bureau, Table No. EC1251SSSZ4, *Information: Subject Series – Establishment and Firm Size: Receipts Size of Firms for the United States: 2012* NAICS Code 515112, https://factfinder.census.gov/bkmk/table/1.0/en/ECN/2012_US/51SSSZ4//naics~515112.

[60] *Id*.

[61] 13 C.F.R. § 121.201; 2012 NAICS code 515120.

[62] U.S. Census Bureau, Table No. EC1251SSSZ4, *Information: Subject Series - Establishment and Firm Size: Receipts Size of Firms for the United States: 2012* (515120 Television Broadcasting). https://factfinder.census.gov/bkmk/table/1.0/en/ECN/2012_US/51SSSZ4//naics~515120.

[63] *Id*.

has developed a size standard specifically applicable to Fixed Satellite Transmit/Receive Earth Stations. The closest applicable category and SBA size standard is for Satellite Telecommunications which has a small business size standard of $32.5 million or less in average annual receipts.[64] For this category, U.S. Census Bureau data for 2012 show that there were a total of 333 firms that operated for the entire year.[65] Of this total, 299 firms had annual receipts of less than $25 million.[66] Thus, under this category and the associated size standard, the Commission estimates that the majority of Fixed Satellite Transmit/Receive Earth Station licensees are small entities. There are approximately 4,303 earth station authorizations, a portion of which are Fixed Satellite Transmit/Receive Earth Stations. We do not request nor collect annual revenue information and are therefore unable to estimate the number of earth stations that would constitute a small business under the SBA definition. However, the majority of these stations could be impacted by our actions.

D. Description of Projected Reporting, Recordkeeping, and other Compliance Requirements for Small Entities

19. In this Report and Order the Commission expects that all the filing, recordkeeping and reporting requirements associated with the adopted rules would be the same for large and small businesses; however, we sought comment on any steps that could be taken to minimize any significant economic impact on small businesses. The adopted rules would require that standard-power access points use an AFC system to obtain a list of frequencies upon which they may operate. However, we believe that this rulemaking, by expanding the availability of unlicensed devices in the 6 GHz band, would provide an advantage to small entities, as these entities would benefit from being able to access this spectrum without the complication or cost of needing to obtain a license. On balance, this would constitute a significant benefit for small businesses.

E. Steps Taken to Minimize the Significant Economic Impact on Small Entities, and Significant Alternatives Considered

20. The RFA requires an agency to describe any significant, specifically small business, alternatives that it has considered in reaching its approach, which may include the following four alternatives (among others): "(1) the establishment of differing compliance or reporting requirements or timetables that take into account the resources available to small entities; (2) the clarification, consolidation, or simplification of compliance or reporting requirements under the rule for small entities; (3) the use of performance, rather than design, standards; and (4) an exemption from coverage of the rule, or any part thereof, for small entities."[67]

21. The reporting, recordkeeping, and other compliance requirements of the rules adopted in the Report & Order would apply to all entities in the same manner. The Commission believes that applying the same rules equally to all entities in this context promotes fairness. The Commission does not believe that the costs and/or administrative burdens associated with the adopted rules would unduly burden small entities. The rules the Commission adopts should benefit small entities by giving them more options for gaining access to valuable wireless spectrum. We seek comment on whether any of burdens of the proposed rules can be further minimized for small businesses.

22. Many of the entities holding licenses for use of the 6 GHz band qualify as small entities. The adopted rules for unlicensed operation in this band are designed to prevent the unlicensed devices

[64] 13 CFR § 121.201, NAICS code 517410.

[65] U.S. Census Bureau, *2012 Economic Census of the United States*, Table EC1251SSSZ4, Information: Subject Series - Estab and Firm Size: Receipts Size of Firms for the United States: 2012, NAICS code 517410 https://factfinder.census.gov/bkmk/table/1.0/en/ECN/2012_US/51SSSZ4//naics~517410.

[66] *Id*.

[67] 5 U.S.C. § 604(a)(6).

from causing harmful interference to the licensed services operating in the band. Consequently, we do not expect that the current and future licensees in the band, including small entities, would experience a significant economic impact from additional unlicensed use of the spectrum that would be permitted under the adopted rules.

23. Because users of devices operating under our Part 15 rules do not need to obtain a Commission license, we expect that small entities would find the unlicensed use of the 6 GHz bands under the adopted rules convenient and economical. In adopting these rules, we have sought to minimize the compliance burden to both small and large entities. For example, the adopted rules would allow for the deployment of low-power access point that do not require use of an AFC system in two sub-bands to provide an opportunity for deployment of unlicensed devices at lower cost in those portions of the spectrum where the current licensed uses make this practical.

F. Report to Congress

24. The Commission will send a copy of the *Report and Order*, including this FRFA, in a report to Congress pursuant to the Congressional Review Act.[68] In addition, the Commission will send a copy of the *Report and Order*, including this FRFA, to the Chief Counsel for Advocacy of the SBA. A copy of the *Report and Order*, and FRFA (or summaries thereof) will also be published in the Federal Register.[69]

[68] *See* 5 U.S.C. § 801(a)(1)(A).

[69] *See* 5 U.S.C. § 604(b).

APPENDIX C

Initial Regulatory Flexibility Analysis

1. As required by the Regulatory Flexibility Act (RFA) of 1980, as amended, the Commission has prepared this present Initial Regulatory Flexibility Analysis (IRFA) of the possible significant economic impact on a substantial number of small entities by the policies and rules proposed in this Further Notice of Proposed Rulemaking (Further Notice). [1] Written public comments are requested on this IRFA. Comments must be identified as responses to the IRFA and must be filed by the deadlines for comments as specified in the FNPRM. The Commission will send a copy of the FNPRM, including this IRFA, to the Chief Counsel for Advocacy of the Small Business Administration (SBA).[2] In addition, the FNPRM and IRFA (or summaries thereof) will be published in the Federal Register.[3]

A. Need for, and Objectives of, the Proposed Rules

2. In this Further Notice of Proposed Rulemaking (*Further Notice*) we propose to permit very low power devices to operate in the U-NII-5, through the U-NII-8 bands at any location – indoors or outdoors – without using an AFC. This proposed action would make a contiguous 1200-megahertz spectrum block available, which would enable the use of very wide bandwidths and thus high data rates for new and innovative high-speed, short range devices**.** We believe that these rules would be particularly useful for applications that require high data rate transmissions over short distances such as connections between smartphones and computers, high-performance video game controllers, and wearable video augmented reality and virtual reality devices.

In proposing to permit very low power devices to operate across the entirety of the 6 GHz band (5.950-7.125 GHz) without using an AFC, the Further Notice seeks comment on the design and use cases anticipated for such devices, as well as the power limits that have been proposed by their proponents. The Commission is generally considering power levels in the range of 4 dBm up to 14 dBm (for a 160-megahertz channel). This record will be used to determine how much power very lower power devices will be permitted so that the potential of causing harmful interference to incumbent 6 GHz band users can be minimized. The Further Notice also seeks comment on technical rules that will govern the use of very low power devices and proposes to require that very low power unlicensed devices in the 6 GHz band incorporate an integrated antenna and be required to use a contention-based protocol.

3. The Further Notice of the Commission also proposes to increase the power spectral density of low power indoor devices in the U-NII-5 through U-NII-8 bands from 5 dBm/MHz to 8 dBm/MHz. It also proposes to limit the maximum total power to 33 dBm EIRP, which would occur when the operating bandwidth is 320 megahertz. For devices operating with bandwidths other than 320 megahertz, the maximum allowable total power would scale accordingly (e.g., 30 dBm with a bandwidth of 160 megahertz, 27 dBm with a bandwidth of 80 megahertz, 24 dBm with a bandwidth of 40 megahertz, and 21 dBm with a bandwidth of 20 megahertz). We believe that these rules would be useful for many indoor devices that require high data rate transmissions such as indoor access points communicating with clients for the development of new and innovative high-speed indoor devices**.**

4. To do this, the Commission seek comment on these proposals. Would the proposed power levels be useful for low-power short-range devices? What types of devices could operate under these proposed rules? Are the proposed power limits appropriate for preventing interference to authorized users in the U-NII-6 and U-NII-8 bands? Should we adopt any requirements in addition to power density

[1] *See* 5 U.S.C. § 603. The RFA, *see* 5 U.S.C. §§ 601-612, has been amended by the Small Business Regulatory Enforcement Fairness Act of 1996, (SBREFA) Pub. L. No. 104-121, Title II, 110 Stat. 857 (1996).

[2] *See* 5 U.S.C. § 603(a).

[3] *See* 5 U.S.C. § 603(a).

and total EIRP limits to protect services in these bands? For example, would a listen-before-talk mechanism help prevent interference? If so, what technical requirements would we need to specify, such as detection threshold and bandwidth, monitoring time, re-check interval, etc.? Are any other protection requirements necessary?

B. Legal Basis

5. The proposed action is authorized pursuant to Sections 4(i), 201, 302, and 303 of the Communications Act of 1934, as amended, 47 U.S.C. §§ 154(i), 201, 302a, 303.

C. Description and Estimate of the Number of Small Entities to Which the Proposed Rules Will Apply

6. The RFA directs agencies to provide a description of, and, where feasible, an estimate of the number of small entities that may be affected by the proposed rules and policies, if adopted.[4] The RFA generally defines the term "small entity" as having the same meaning as the terms "small business," "small organization," and "small governmental jurisdiction."[5] In addition, the term "small business" has the same meaning as the term "small business concern" under the Small Business Act.[6] A "small business concern" is one which: (1) is independently owned and operated; (2) is not dominant in its field of operation; and (3) satisfies any additional criteria established by the SBA.[7]

7. *Small Businesses, Small Organizations, Small Governmental Jurisdictions*. Our actions, over time, may affect small entities that are not easily categorized at present. We therefore describe here, at the outset, three broad groups of small entities that could be directly affected herein.[8] First, while there are industry specific size standards for small businesses that are used in the regulatory flexibility analysis, according to data from the SBA's Office of Advocacy, in general a small business is an independent business having fewer than 500 employees.[9] These types of small businesses represent 99.9% of all businesses in the United States which translates to 28.8 million businesses.[10]

8. Next, the type of small entity described as a "small organization" is generally "any not-for-profit enterprise which is independently owned and operated and is not dominant in its field."[11] Nationwide, as of August 2016, there were approximately 356,494 small organizations based on registration and tax data filed by nonprofits with the Internal Revenue Service (IRS).[12]

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[4] 5 U.S.C. § 603(b)(3).

[5] 5 U.S.C. § 601(6).

[6] 5 U.S.C. § 601(3) (incorporating by reference the definition of "small-business concern" in the Small Business Act, 15 U.S.C. § 632). Pursuant to 5 U.S.C. § 601(3), the statutory definition of a small business applies "unless an agency, after consultation with the Office of Advocacy of the Small Business Administration and after opportunity for public comment, establishes one or more definitions of such term which are appropriate to the activities of the agency and publishes such definition(s) in the Federal Register."

[7] 15 U.S.C. § 632.

[8] *See* 5 U.S.C. § 601(3)-(6).

[9] *See* SBA, Office of Advocacy, "Frequently Asked Questions, Question 1 – What is a small business?" https://www.sba.gov/sites/default/files/advocacy/SB-FAQ-2016_WEB.pdf (June 2016).

[10] *See* SBA, Office of Advocacy, "Frequently Asked Questions, Question 2- How many small businesses are there in the U.S.?" https://www.sba.gov/sites/default/files/advocacy/SB-FAQ-2016_WEB.pdf (June 2016).

[11] 5 U.S.C. § 601(4).

[12] Data from the Urban Institute, National Center for Charitable Statistics (NCCS) reporting on nonprofit organizations registered with the IRS was used to estimate the number of small organizations. Reports generated using the NCCS online database indicated that as of August 2016 there were 356,494 registered nonprofits with total revenues of less than $100,000. Of this number, 326,897 entities filed tax returns with 65,113 registered nonprofits

(continued….)

9. Finally, the small entity described as a "small governmental jurisdiction" is defined generally as "governments of cities, counties, towns, townships, villages, school districts, or special districts, with a population of less than fifty thousand."[13] U.S. Census Bureau data from the 2012 Census of Governments[14] indicate that there were 90,056 local governmental jurisdictions consisting of general purpose governments and special purpose governments in the United States.[15] Of this number there were 37,132 General purpose governments (county,[16] municipal and town or township[17]) with populations of less than 50,000 and 12,184 Special purpose governments (independent school districts[18] and special districts[19]) with populations of less than 50,000. The 2012 U.S. Census Bureau data for most types of governments in the local government category show that the majority of these governments have populations of less than 50,000.[20] Based on this data we estimate that at least 49,316 local government

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reporting total revenues of $50,000 or less on the IRS Form 990-N for Small Exempt Organizations and 261,784 nonprofits reporting total revenues of $100,000 or less on some other version of the IRS Form 990 within 24 months of the August 2016 data release date. *See* http://nccs.urban.org/sites/all/nccs-archive/html//tablewiz/tw.php where the report showing this data can be generated by selecting the following data fields: Report: "The Number and Finances of All Registered 501(c) Nonprofits"; Show: "Registered Nonprofits"; By: "Total Revenue Level (years 1995, Aug to 2016, Aug)"; and For: "2016, Aug" then selecting "Show Results".

[13] 5 U.S.C. § 601(5).

[14] *See* 13 U.S.C. § 161. The Census of Government is conducted every five (5) years compiling data for years ending with "2" and "7." *See also* Program Description Census of Government *https://factfinder.census.gov/faces/affhelp/jsf/pages/metadata.xhtml?lang=en&type=program&id=program.en.COG#*.

[15] *See* U.S. Census Bureau, 2012 Census of Governments, Local Governments by Type and State: 2012 - United States-States. https://factfinder.census.gov/bkmk/table/1.0/en/COG/2012/ORG02.US01. Local governmental jurisdictions are classified in two categories - General purpose governments (county, municipal and town or township) and Special purpose governments (special districts and independent school districts).

[16] *See* U.S. Census Bureau, 2012 Census of Governments, County Governments by Population-Size Group and State: 2012 - United States-States. https://factfinder.census.gov/bkmk/table/1.0/en/COG/2012/ORG06.US01. There were 2,114 county governments with populations less than 50,000.

[17] *See* U.S. Census Bureau, 2012 Census of Governments, Subcounty General-Purpose Governments by Population-Size Group and State: 2012 - United States – States. https://factfinder.census.gov/bkmk/table/1.0/en/COG/2012/ORG07.US01. There were 18,811 municipal and 16,207 town and township governments with populations less than 50,000.

[18] *See* U.S. Census Bureau, 2012 Census of Governments, Elementary and Secondary School Systems by Enrollment-Size Group and State: 2012 - United States-States. https://factfinder.census.gov/bkmk/table/1.0/en/COG/2012/ORG11.US01. There were 12,184 independent school districts with enrollment populations less than 50,000.

[19] *See* U.S. Census Bureau, 2012 Census of Governments, Special District Governments by Function and State: 2012 - United States-States. https://factfinder.census.gov/bkmk/table/1.0/en/COG/2012/ORG09.US01. The U.S. Census Bureau data did not provide a population breakout for special district governments.

[20] *See* U.S. Census Bureau, 2012 Census of Governments, **C**ounty Governments by Population-Size Group and State: 2012 - United States-States - https://factfinder.census.gov/bkmk/table/1.0/en/COG/2012/ORG06.US01; Subcounty General-Purpose Governments by Population-Size Group and State: 2012 - United States–States - https://factfinder.census.gov/bkmk/table/1.0/en/COG/2012/ORG07.US01; and Elementary and Secondary School Systems by Enrollment-Size Group and State: 2012 - United States-States. https://factfinder.census.gov/bkmk/table/1.0/en/COG/2012/ORG11.US01. While U.S. Census Bureau data did not provide a population breakout for special district governments, if the population of less than 50,000 for this category of local government is consistent with the other types of local governments the majority of the 38, 266 special district governments have populations of less than 50,000.

jurisdictions fall in the category of "small governmental jurisdictions."[21]

10. *Fixed Microwave Services.* Microwave services include common carrier,[22] private-operational fixed,[23] and broadcast auxiliary radio services.[24] They also include the Upper Microwave Flexible Use Service,[25] Millimeter Wave Service,[26] Local Multipoint Distribution Service (LMDS),[27] the Digital Electronic Message Service (DEMS),[28] and the 24 GHz Service,[29] where licensees can choose between common carrier and non-common carrier status.[30] At present, there are approximately 66,680 common carrier fixed licensees, 69,360 private and public safety operational-fixed licensees, 20,150 broadcast auxiliary radio licensees, 411 LMDS licenses, 33 24 GHz DEMS licenses, 777 39 GHz licenses, and five 24 GHz licenses, and 467 Millimeter Wave licenses in the microwave services.[31] The Commission has not yet defined a small business with respect to microwave services. The closest applicable SBA category is Wireless Telecommunications Carriers (except Satellite) and the appropriate size standard for this category under SBA rules is that such a business is small if it has 1,500 or fewer employees.[32] For this industry, U.S. Census data for 2012 show that there were 967 firms that operated for the entire year.[33] Of this total, 955 firms had employment of 999 or fewer employees and 12 had employment of 1000 employees or more.[34] Thus, under this SBA category and the associated size standard, the Commission estimates that a majority of fixed microwave service licensees can be considered small.

11. *Public Safety Radio Licensees.* As a general matter, Public Safety Radio Pool licensees include police, fire, local government, forestry conservation, highway maintenance, and emergency medical services.[35] Because of the vast array of public safety licensees, the Commission has not

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[21] *Id.*

[22] *See* 47 CFR Part 101, Subparts C and I.

[23] *See* 47 CFR Part 101, Subparts C and H.

[24] Auxiliary Microwave Service is governed by Part 74 of Title 47 of the Commission's Rules. *See* 47 CFR Part 74. Available to licensees of broadcast stations and to broadcast and cable network entities, broadcast auxiliary microwave stations are used for relaying broadcast television signals from the studio to the transmitter, or between two points such as a main studio and an auxiliary studio. The service also includes mobile TV pickups, which relay signals from a remote location back to the studio.

[25] *See* 47 CFR Part 30.

[26] *See* 47 CFR Part 101, Subpart Q.

[27] *See* 47 CFR Part 101, Subpart L.

[28] *See* 47 CFR Part 101, Subpart G.

[29] *See id*.

[30] *See* 47 CFR §§ 101.533, 101.1017.

[31] These statistics are based on a review of the Universal Licensing System on September 22, 2015.

[32] *See* 13 CFR § 121.201, NAICS code 517312.

[33] U.S. Census Bureau, *2012 Economic Census of the United States*, Table EC1251SSSZ5, Information: Subject Series, "Estab and Firm Size: Employment Size of Firms for the U.S.: 2012 NAICS Code 517210" (rel. Jan. 8, 2016). https://factfinder.census.gov/bkmk/table/1.0/en/ECN/2012_US/51SSSZ5//naics~517210.

[34] *Id*. Available census data do not provide a more precise estimate of the number of firms that have employment of 1,500 or fewer employees; the largest category provided is for firms with "1000 employees or more."

[35] *See* subparts A and B of Part 90 of the Commission's Rules, 47 C.F.R. §§ 90.1-90.22. Police licensees serve state, county, and municipal enforcement through telephony (voice), telegraphy (code), and teletype and facsimile (printed material). Fire licensees are comprised of private volunteer or professional fire companies, as well as units under governmental control. Public Safety Radio Pool licensees also include state, county, or municipal entities that use

(continued….)

developed a small business size standard specifically applicable to public safety licensees. The closest applicable SBA category is Wireless Telecommunications Carriers (except Satellite) which encompasses business entities engaged in radiotelephone communications. The appropriate size standard for this category under SBA rules is that such a business is small if it has 1,500 or fewer employees.[36] For this industry, U.S. Census data for 2012 show that there were 967 firms that operated for the entire year.[37] Of this total, 955 firms had employment of 999 or fewer employees and 12 had employment of 1000 employees or more.[38] Thus, under this category and the associated size standard, the Commission estimates that the majority of firms can be considered small. With respect to local governments, in particular, since many governmental entities comprise the licensees for these services, we include under public safety services the number of government entities affected. According to Commission records, there are a total of approximately 133,870 licenses within these services.[39] There are 3.121 licenses in the 4.9 GHz band, based on an FCC Universal Licensing System search of March 29, 2017.[40] We estimate that fewer than 2,442 public safety radio licensees hold these licenses because certain entities may have multiple licenses.

12. *Satellite Telecommunications.* This category comprises firms "primarily engaged in providing telecommunications services to other establishments in the telecommunications and broadcasting industries by forwarding and receiving communications signals via a system of satellites or reselling satellite telecommunications."[41] Satellite telecommunications service providers include satellite and earth station operators. The category has a small business size standard of $32.5 million or less in average annual receipts, under SBA rules.[42] For this category, U.S. Census Bureau data for 2012 show that there were a total of 333 firms that operated for the entire year.[43] Of this total, 299 firms had annual

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radio for official purposes. State departments of conservation and private forest organizations comprise forestry service licensees that set up communications networks among fire lookout towers and ground crews. State and local governments are highway maintenance licensees that provide emergency and routine communications to aid other public safety services to keep main roads safe for vehicular traffic. Emergency medical licensees use these channels for emergency medical service communications related to the delivery of emergency medical treatment. Additional licensees include medical services, rescue organizations, veterinarians, persons with disabilities, disaster relief organizations, school buses, beach patrols, establishments in isolated areas, communications standby facilities, and emergency repair of public communications facilities.

[36] *See* 13 CFR § 121.201, NAICS code 517312.

[37] U.S. Census Bureau, *2012 Economic Census of the United States*, Table EC1251SSSZ5, Information: Subject Series: Estab and Firm Size: Employment Size of Firms for the U.S.: 2012 NAICS Code 517210 (rel. Jan. 8, 2016). https://factfinder.census.gov/bkmk/table/1.0/en/ECN/2012_US/51SSSZ5//naics~517210.

[38] *Id*. Available census data do not provide a more precise estimate of the number of firms that have employment of 1,500 or fewer employees; the largest category provided is for firms with "1000 employees or more."

[39] This figure was derived from Commission licensing records as of June 27, 2008. Licensing numbers change on a daily basis. We do not expect this number to be significantly smaller today. This does not indicate the number of licensees, as licensees may hold multiple licenses. There is no information currently available about the number of public safety licensees that have less than 1,500 employees.

[40] Based on an FCC Universal Licensing System search of March 29, 2017. Search parameters: Radio Service = PA – Public Safety 4940-4990 MHz Band; Authorization Type = Regular; Status = Active.

[41] U.S. Census Bureau, 2017 NAICS Definitions, "517410 Satellite Telecommunications"; https://www.census.gov/cgi-bin/sssd/naics/naicsrch?input=517410&search=2017+NAICS+Search&search=2017.

[42] 13 CFR § 121.201, NAICS code 517410.

[43] U.S. Census Bureau, *2012 Economic Census of the United States*, Table EC1251SSSZ4, Information: Subject Series - Estab and Firm Size: Receipts Size of Firms for the United States: 2012, NAICS code 517410 https://factfinder.census.gov/bkmk/table/1.0/en/ECN/2012_US/51SSSZ4//naics~517410.

receipts of less than $25 million.[44] Consequently, we estimate that the majority of satellite telecommunications providers are small entities.

13. *Wireless Telecommunications Carriers (except Satellite).* This industry comprises establishments engaged in operating and maintaining switching and transmission facilities to provide communications via the airwaves. Establishments in this industry have spectrum licenses and provide services using that spectrum, such as cellular services, paging services, wireless Internet access, and wireless video services.[45] The appropriate size standard under SBA rules is that such a business is small if it has 1,500 or fewer employees.[46] For this industry, U.S. Census Bureau data for 2012 show that there were 967 firms that operated for the entire year.[47] Of this total, 955 firms had employment of 999 or fewer employees and 12 had employment of 1000 employees or more.[48] Thus, under this category and the associated size standard, the Commission estimates that the majority of wireless telecommunications carriers (except satellite) are small entities.

14. The Commission's own data—available in its Universal Licensing System—indicate that, as of May 17, 2018, there are 264 Cellular licensees.[49] The Commission does not know how many of these licensees are small, as the Commission does not collect that information for these types of entities. Similarly, according to internally developed Commission data, 413 carriers reported that they were engaged in the provision of wireless telephony, including cellular service, Personal Communications Service (PCS), and Specialized Mobile Radio (SMR) Telephony services.[50] Of this total, an estimated 261 have 1,500 or fewer employees, and 152 have more than 1,500 employees.[51] Thus, using available data, we estimate that the majority of wireless firms can be considered small.

15. *Auxiliary, Special Broadcast and Other Program Distribution Services.* This service involves a variety of transmitters, generally used to relay broadcast programming to the public (through translator and booster stations) or within the program distribution chain (from a remote news gathering unit back to the station). Neither the SBA nor the Commission has developed a size standard applicable to broadcast auxiliary licensees. The closest applicable SBA category and small business size standard falls under Radio Stations and Television Broadcasting.[52] U.S. Census Bureau data for 2012 show that

[44] *Id*.

[45] U.S. Census Bureau, 2012 NAICS Definitions, "517210 Wireless Telecommunications Carriers (Except Satellite)," *See* https://factfinder.census.gov/faces/affhelp/jsf/pages/metadata.xhtml?lang=en&type=ib&id=ib.en./ECN.NAICS2012.517210.

[46] 13 CFR § 121.201, NAICS code 517312.

[47] U.S. Census Bureau, *2012 Economic Census of the United States*, Table EC1251SSSZ5, Information: Subject Series: Estab and Firm Size: Employment Size of Firms for the U.S.: 2012 NAICS Code 517210. https://factfinder.census.gov/bkmk/table/1.0/en/ECN/2012_US/51SSSZ5//naics~517210.

[48] *Id*. Available census data does not provide a more precise estimate of the number of firms that have employment of 1,500 or fewer employees; the largest category provided is for firms with "1000 employees or more."

[49] *See* http://wireless.fcc.gov/uls. For the purposes of this IRFA, consistent with Commission practice for wireless services, the Commission estimates the number of licensees based on the number of unique FCC Registration Numbers.

[50] *See* Federal Communications Commission, Wireline Competition Bureau, Industry Analysis and Technology Division, Trends in Telephone Service at Table 5.3 (Sept. 2010) (*Trends in Telephone Service*), https://apps.fcc.gov/edocs_public/attachmatch/DOC-301823A1.pdf.

[51] *See id*.

[52] 13 C.F.R. 121.201, NAICS codes 515112 and 515120.

2,849 radio station firms operated during that year.[53] Of that number, 2,806 firms operated with annual receipts of less than $25 million per year, 17 with annual receipts between $25 million and $49,999,999 million and 26 with annual receipts of $50 million or more.[54] For Television Broadcasting the SBA small business size standard is such businesses having $38.5 million or less in annual receipts.[55] U.S. Census Bureau data show that 751 firms in this category operated in that year.[56] Of that number, 656 had annual receipts of $25,000,000 or less, 25 had annual receipts between $25,000,000 and $49,999,999 and 70 had annual receipts of $50,000,000 or more.[57] Accordingly, based on the U.S. Census Bureau data for Radio Stations and Television Broadcasting, the Commission estimates that the majority of Auxiliary, Special Broadcast and Other Program Distribution Services firms are small.

16. *Fixed Satellite Transmit/Receive Earth Stations.* Neither the SBA nor the Commission has developed a size standard specifically applicable to Fixed Satellite Transmit/Receive Earth Stations. The closest applicable category and SBA size standard is for Satellite Telecommunications which has a small business size standard of $32.5 million or less in average annual receipts.[58] For this category, U.S. Census Bureau data for 2012 show that there were a total of 333 firms that operated for the entire year.[59] Of this total, 299 firms had annual receipts of less than $25 million.[60] Thus, under this category and the associated size standard, the Commission estimates that the majority of Fixed Satellite Transmit/Receive Earth Station licensees are small entities. There are approximately 4,303 earth station authorizations, a portion of which are Fixed Satellite Transmit/Receive Earth Stations. We do not request nor collect annual revenue information and are therefore unable to estimate the number of earth stations that would constitute a small business under the SBA definition. However, the majority of these stations could be impacted by our actions.

D. Description of Projected Reporting, Recordkeeping, and other Compliance Requirements for Small Entities

17. Under the proposal set forth in the Further Notice, and consistent with the Commission's general approach expects that all the filing, recordkeeping and reporting requirements associated with the proposed rules would be the same for large and small businesses; however, we seek comment on any steps that could be taken to minimize any significant economic impact on small businesses. The proposed rules would require that standard-power access points use an AFC system to obtain a list of frequencies upon which they may operate. However, we believe that this rulemaking, by expanding the availability of unlicensed devices in the 6 GHz band, would provide an advantage to small entities, as these entities would benefit from being able to access this spectrum without the complication or cost of needing to obtain a license. On balance, this would constitute a significant benefit for small businesses.

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[53] U.S. Census Bureau, Table No. EC1251SSSZ4, *Information: Subject Series – Establishment and Firm Size: Receipts Size of Firms for the United States: 2012* NAICS Code 515112, https://factfinder.census.gov/bkmk/table/1.0/en/ECN/2012_US/51SSSZ4//naics~515112.

[54] *Id.*

[55] 13 C.F.R. § 121.201; 2012 NAICS code 515120.

[56] U.S. Census Bureau, Table No. EC1251SSSZ4, *Information: Subject Series - Establishment and Firm Size: Receipts Size of Firms for the United States: 2012* (515120 Television Broadcasting). https://factfinder.census.gov/bkmk/table/1.0/en/ECN/2012_US/51SSSZ4//naics~515120.

[57] *Id*.

[58] 13 CFR § 121.201, NAICS code 517410.

[59] U.S. Census Bureau, *2012 Economic Census of the United States*, Table EC1251SSSZ4, Information: Subject Series - Estab and Firm Size: Receipts Size of Firms for the United States: 2012, NAICS code 517410 https://factfinder.census.gov/bkmk/table/1.0/en/ECN/2012_US/51SSSZ4//naics~517410.

[60] *Id*.

E. Steps Taken to Minimize the Significant Economic Impact on Small Entities, and Significant Alternatives Considered

18. The RFA requires an agency to describe any significant, specifically small business, alternatives that it has considered in reaching its approach, which may include the following four alternatives (among others): "(1) the establishment of differing compliance or reporting requirements or timetables that take into account the resources available to small entities; (2) the clarification, consolidation, or simplification of compliance or reporting requirements under the rule for small entities; (3) the use of performance, rather than design, standards; and (4) an exemption from coverage of the rule, or any part thereof, for small entities."[61]

19. The Commission does not believe that its proposed changes will have a significant economic impact on small entities. The reporting, recordkeeping, and other compliance requirements of the rules proposed in the Further Notice would apply to all entities in the same manner. We believe that applying the same rules equally to all entities in this context promotes fairness. The Commission does not believe that the costs and/or administrative burdens associated with the proposed rules would unduly burden small entities. The rules the Commission adopts should benefit small entities by giving them more options for gaining access to valuable wireless spectrum. The Commission expects to more fully consider the economic impact and alternatives for small entities following the review of comments filed in response to the Further Notice.

F. Federal Rules that May Duplicate, Overlap, or Conflict with the Proposed Rules

20. None.

[61] 5 U.S.C. § 604(a)(6).

APPENDIX D

List of Commenters

Comments

5G Automotive Association
Alteros, Inc.
American Electric Power (AEP)
APCO International (APCO)
Apple Inc. (Apple)
Apple Inc., Broadcom Inc.,Cisco Systems, Inc., Facebook, Inc., Google LLC, Hewlett Packard Enterprise, Intel Corporation, Marvell Semiconductor, Inc., Microsoft Corporation, Qualcomm Incorporated, Ruckus Networks, and ARRIS Company (Apple, Broadcom, et al.)
Association of Federal Communications Consulting Engineers
AT&T Services, Inc. (AT&T)
Austin Scheib - City of Madison Wisconsin
B.J. Battig
Bastrop County, Texas
Broadcom Inc.
Cambium Networks, Ltd.
Charter Communications, Inc.
Chelan County Public Utility District
Cisco Systems, Inc.
City of Austin, Texas
City of Clearwater, Florida
City of Los Angeles, California
City of Portland, Oregon
CompTIA (The Computing Technology Industry Association)
Comsearch
County of Baltimore
County of Sheboygan Wisconsin Sheriff's Office
CTIA
Decawave
Don Cameron
Dynamic Spectrum Alliance
EcliptixNet Broadband Inc.
Engineers for the Integrity of Broadcast Auxiliary Services Spectrum (EIBASS)
El Paso Electric Company
Electro Systems Engineers, Inc. (d.b.a. ESEI)
Encina Communications Corporation (Encina)
Ericsson
Facebook, Inc.
Federated Wireless, Inc.
Fixed Wireless Communications Coalition
Friday Institute for Educational Innovation
GCI Communication Corp.

GE Healthcare
Globalstar, Inc.
Government Wireless Technology & Communications Association,Los Angeles County, California,City and County of Denver, Colorado,San Bernardino County, California,Ozaukee County, Wisconsin,The Regional Wireless Cooperative,City of Kansas City, Missouri
Hewlett Packard Enterprise Company
HP Inc.
Idaho Power Company
IEEE 802 LAN/MAN Standards Committee
Imperial Irrigation District
Intelsat License LLC and SES Americom, Inc. (Intelsat and SES Americom
iRobot Corp.
Joseph H. Leikhim III,Leikhim and Associates LLC
Joshua Marvel
Lincoln County
Lucas County Emergency Medical Service
Lucas County Sheriff's Office
Mark Atkins
Marquardt GmbH
Microsoft Corporation
Midcontinent Communications
Modesto Irrigation District
Motorola Solutions, Inc.
Nassau Country Police Department

National Academy of Sciences Committee on Radio Frequencies
National Association of Broadcasters (NAB)
National Public Safety Telecommunications Council (NPSTC)
National Spectrum Management Association
NCTA - The Internet & Television Association (NCTA)
NE Colorado Cellular, Inc. dba Viaero Wireless
NETGEAR, Inc.
Nokia
Novelda US, Inc.
NXP USA, Inc.
Peter Stallone
Public Interest Organizations
Qualcomm Incorporated (Qualcomm)
Quantenna Communications, Inc. (Quantenna)
R Street Institute

RigNet Satcom, Inc. (RigNet)
Riverbend Communications LLC
Ryan Gardner
Singer Executive Development

Sirius XM Radio Inc. (Sirius XM)
Small UAV Coalition
Society of Broadcast Engineers, Incorporated
Sony Electronics Inc.
Southern California Public Power Authority
Southern Company Services, Inc.
St. Croix County, Wisconsin
Starry, Inc.
State of Florida Department of Management Services, Division of Telecommunications, Bureau of Public Safety
Teradek LLC,Amimon, Inc. (Teradek)
Texas New Mexico Power Company
Thanh K. Nguyen
The Association for Unmanned Vehicle Systems International
The Association of American Railroads
The Boeing Company (Boeing)
The City of New York
The Critical Infrastructure Coalition
The Leading Builders of America
The Wireless Innovation Forum
The Wireless Internet Service Providers Association (WISPA)
Toyota Motor Corporation
Tucson Electric Power Company, UNS Electric, Inc.
Ubiquiti Networks, Inc.
Ultra Wide Band (UWB) Alliance
Utilities Technology Council, Edison Electric Institute, National Rural Cooperative Association, American Public Power Association, American Petroleum Institute and American Water Works Association
Valerie West on behalf of Sania Radcliffe
Verizon
Volkswagen Group of America Inc.
Walter J. Klinger County Police Director, Cook County Sheriff's Police Department
Washington County Sheriff’s Office in Minnesota
Wi-Fi Alliance
Xcel Energy Services Inc.
Zebra Technologies

Reply Comments

Alliance of Automobile Manufacturers
Alteros, Inc.
American Association of State Highway and Transportation Officials
Apple Inc.

Apple Inc.,Broadcom Inc.,Cisco Systems, Inc.,Facebook, Inc.,Google LLC,Hewlett Packard Enterprise,Intel Corporation,Marvell Semiconductor, Inc.,Microsoft Corporation,Qualcomm Incorporated,Ruckus Networks, an ARRIS Company (Apple, Broadcom, et al.)
AT&T Services, Inc. (AT&T)
Broadcom Inc.
CenturyLink
Charter Communications, Inc.
Cisco Systems, Inc.
City of Los Angeles, California
Comsearch
County of Riverside
CTIA
Decawave
Dr. Doug Roberts
Dynamic Spectrum Alliance
EIBASS
Encina Communications Corporation (Encina)
Enterprise Wireless Alliance
Federated Wireless, Inc.
Fixed Wireless Communications Coalition
Frontier Communications, Windstream
GCI Communication Corp.
GeoLinks
GridWise Alliance
Hewlett Packard Enterprise
Intelligent Transportation Society of America
Intelsat License LLC and SES Americom, Inc. (Intelsat and SES Americom)
Marquardt GmbH
Microchip Technology, Inc
Microsoft Corporation (Microsoft)
Midco
National Association of Broadcasters (NAB)
National Football League
National Public Safety Telecommunications Council (NPSTC)
National Spectrum Management Association
NCTA - The Internet & Television Association
Nokia
NXP USA, Inc.
P & R Communications Service, Inc.
Pacific Gas & Electric
Panasonic Corporation of North America
Public Interest Organizations
RKF Engineering Solutions LLC
SHLB Coalition
Sirius XM Radio Inc.

Sony Electronics Inc.
Southern Company Services, Inc.
Steffen Lehr
The Association of American Railroads
The Association of Global Automakers, Inc.
The BMW Group
The Boeing Company
The Critical Infrastructure Coalition
The Wireless Internet Service Providers Association
T-Mobile USA, Inc.
Tucson Electric Power Company, UNS Electric, Inc.
Ultra Wide Band Alliance
United States Cellular Corporation
Utilities Technology Council, Edison Electric Institute, American Public Power Association, National Rural Electric Cooperative Association, American Petroleum Institute and the American Water Works Association
Verizon
Wi-Fi Alliance
Zebra Technologies

APPENDIX E

Technical Studies Submitted

Proponents of Unlicensed Operations

Apple Inc., Broadcom Inc., *et al*

- Analysis of CTIA's Specific Examples Reveals Extensive Errors (Appendix A of *Ex Parte* Comments Received March 10, 2020)
- VLP Summary (Attachment to March 9, 2020 *Ex Parte* Comments)
- NAB Response (Attachment to *Ex Parte* Comments Received March 9, 2020)
- *Ex Parte* Comments Received Feb. 28, 2020 (RLAN NAB Study)
- VLP Use Cases (Attachment to *Ex Parte* Comments Received Jan. 31, 2020)
- Correcting the Record on RLAN-FS Interactions (Attachment to *Ex Parte* Comments Received Dec. 16, 2019 (RLAN Group Comments))
- VLP Coexistence Analysis; Duty Cycle Data by Broadcom (Attachments to *Ex Parte* Comments Received Dec. 9, 2019)
- VLP Coexistence Analysis (Attachment to *Ex Parte* Comments Received Nov. 12, 2019)
- Multipath Fading (Attachment to *Ex Parte* Comments Received Oct. 7, 2019)
- 6 GHz FS/WiFi coexistence testing; FS outdoor testing in progress (Attachments to *Ex Parte* Comments Received Aug. 23, 2019)
- Lidar Study of High-Rise Buildings in Fixed Service 3dB Beams in New York Metropolitan Area (Attachment to *Ex Parte* Comments Received July 31, 2019)
- 6 GHz Spectrum Sharing: Los Angeles Dep't of Water & Power Interference Protection Case Study (Attachment to *Ex Parte* Comments Received July 5, 2019)
- The FCC can Accelerate 5G Services while Protecting Incumbent Operations by Enabling Very Low Power Portable Class Devices in 6 GHz (Attachment to *Ex Parte* Comments Received July 2, 2019)
- 6 USC Presentation to the Office of Engineering and Technology RLAN-FS Interactions (Attachment to *Ex Parte* Comments Received June 24, 2019)
- The FCC's 6 GHz proceeding: Enabling the next wave of unlicensed innovation (Attachment to *Ex Parte* Comments Received April 26, 2019)
- Measured Attenuation from a Large Building Wall at 6.0, 6.5 and 7 GHz by Brian R. Jones, QRC 720E. brjones@qti.qualcomm.com (Appendix A of Reply Comments Received March 18, 2019)
- Declaration of Dr. Vinko Erceg (Appendix A of Comments Received Feb. 15, 2019)
- Declaration of Fred Goldstein Regarding Fixed Service Operations (Appendix B of Comments Received Feb. 15, 2019)
- Declaration of Fred Goldstein Regarding Automatic Frequency Coordination and the Universal Licensing System Database (Appendix C of Comments Received Feb. 15, 2019)
- Characteristics of Enterprise Deployments Using IEEE 802.11 Equipment: Joint Declaration of Matt McPherson, Chuck Lucaszewski, and Sundar Sankarn (Appendix of D Comments Received Feb. 15, 2019)
- Building and Vehicle Attenuation (Appendix E of Comments Received Feb. 15, 2019)
- Frequency Sharing for Radio Local Area Networks in the 6 GHz Band prepared by RKF Engineering Services, LLC (RKF Report) (Attachment to Comments in GN Docket No. 17-183 Received Jan. 26, 2018)
- Coexistence Study for Radio Local Area Networks in the 6 GHz Band in the Continental United States (Attachment to Comments in GN Docket No. 17-183 Received Jan. 26, 2018)

The Boeing Company

- 6 GHz Unlicensed Devices in Aircraft (Attachment to *Ex Parte* Comments Received Jan. 27, 2020)

Broadcom Inc.
- ENG Blocker Performance (March 6, 2020) (Attachment to *Ex Parte* Comments Received March 10, 2020)
- 6 GHz EU Update (Attachment to *Ex Parte* Comments Received Aug. 14, 2019)

CableLabs, Broadcom Inc.
- 6 GHz Low Power Indoor (LPI) Wi-Fi / Fixed Service Coexistence Study (Attachment to *Ex Parte* Comments Received Dec. 20, 2019)

CableLabs, Charter Communications, Inc., Comcast Corporation
- Low Power Indoor (LPI) Wi-Fi Will Not Cause Harmful Interference or Impact Availability of 6 GHz Fixed Service (FS) Incumbents (Attachment to *Ex Parte* Comments Received Jan. 17, 2020)

CableLabs, Charter Communications, Comcast Corporation, Cox Communications
- Wi-Fi Power Sensitivity Analysis Shows No Harmful Interference from Low-Power Indoor Wi-Fi to FS and BAS in 6 GHz (Attachment to *Ex Parte* Comments Received March 9, 2020)

Charter Communications, Inc. and CableLabs
- 30 dBm Low Power Indoor (LPI) Wi-Fi Will Not Cause Harmful Interference to Broadcast Auxiliary Systems (BAS) in 6 GHz (Attachment to *Ex Parte* Comments Received Feb. 21, 2020)

Comcast Corporation
- FS Protection Concerns Have Been Addressed (Attachment to *Ex Parte* Comments Received March 5, 2020)

Comsearch
- Sharing in the 6 GHz Band by Unlicensed Low-power Indoor Devices (Attachment to Comments Received Feb. 15, 2019)

Dynamic Spectrum Alliance
- AUTOMATED FREQUENCY COORDINATION An Established Tool for Modern Spectrum Management (Appendix A of Reply Comments Received March 18, 2019)

Encina Communications Corporation
- An Immediate Need for a Report and Order to Allow the Safe Flexible Use of Mid-Band 6 GHz Spectrum (Exhibit A of *Ex Parte* Comments Received Feb. 26, 2020)

Federated Wireless, Inc.
- 6 GHz Spectrum Availability Study Results (Attachment to *Ex Parte* Comments Received Feb. 10, 2020)

5GAA
- Technical Response to FCC 6 GHz NPRM (Appendix B of Comments Received Feb 15., 2019)
- 6 GHz Out-of-Band Emissions (OOBE) Limits – Testing of Impact of Proposed U-NII-5 Unlicensed Devices on C-V2X Receiver Sensitivity (Attachment to *Ex Parte* Comments Received Dec. 9, 2019)

iPosi, Inc.
- iPosi Loss Measurements applied to 6 GHz Fixed Microwave (and more) protection from LTE/5G (Attachment to *Ex Parte* Comments Received Aug. 12, 2019)

Microsoft Corporation
- Overview of Internet service provider technology considerations for rural broadband deployments (Attachment to *Ex Parte* Comments Received Dec. 23, 2019)

MidContinent Communications
- C-Band, 6 GHz, and RDOF (Attachment to *Ex Parte* Comments Received Dec. 9, 2019, Nov. 21, 2019, Nov. 20, 2019)
- Closing the Digital Divide Fiber and Fixed Wireless (Attachment to *Ex Parte* Comments Received Sept. 19, 2019)

Qualcomm Incorporated
- 5G NR-Unlicensed in the new 6 GHz unlicensed band (Attachment to *Ex Parte* Comments Received Nov. 15, 2019)
- 5G NR in unlicensed and shared spectrum (Attachment to *Ex Parte* Comments Received March 8, 2019)

Wi-Fi Alliance
- Analysis of U-NII Interference to Geostationary Fixed Satellite Service Receivers in the 6 GHz Band (Annex to Wi-Fi Alliance Comments Received Feb. 15, 2020)
- 6 GHz Update (Attachment to *Ex Parte* Comments Received Aug. 12, 2019)
- Unlicensed Use of the 6 GHz Band (Attachment to *Ex Parte* Comments Received May 2, 2019, April 18, 2019)

WISPA
- Technical Analysis (Attachment to *Ex Parte* Comments Received Feb. 4, 2020)

Representatives of Incumbent Services

AT&T Services, Inc.
- Theoretical Near Field/Far Field Pattern Comparisons (Exhibit A of *Ex Parte* Comments Received Jan. 23, 2020)
- Antenna Near Field Power Density (Exhibit B of *Ex Parte* Comments Received Jan. 23, 2020)
- Radio Local Area Network (RLAN) to Fixed Service (FS) Microwave Interference in the 6 GHz Band Analysis of Select Real World Scenarios (Attachment to *Ex Parte* Comments Received Nov. 21, 2019)
- Radio Local Area Network (RLAN) to Fixed Service (FS) Microwave Interference in the 6 GHz Band Analysis of Select Real World Scenarios (Exhibit A of *Ex Parte* Comments Received Nov. 12, 2019)
- CEPT ECC Report 302 Sharing and compatibility studies related to Wireless Access Systems including Radio Local Area Networks (WAS/RLAN) in the frequency band 5925-6425 MHz (Attachment to *Ex Parte* Comments Received Aug. 5, 2019)

CTIA
- 6 GHz Interference Analysis (Attachment to *Ex Parte* Comments Received March 5, 2020)
- International Comparison: Licensed, Unlicensed, and Shared Spectrum, 2017-2020 (Attachment to *Ex Parte* Comments Received Feb. 3, 2020)

Decawave
- Sharing Study Results (Annex to Comments Received Feb. 15, 2019)

Edison Electric Institute, *et al*

- Impact of Proposed Wi-Fi Operations on 6 GHz Microwave Links by Roberson and Associates, LLC (Attachment to *Ex Parte* Comments Received Jan. 24, 2020)
- Impact of Proposed Wi-Fi Operations on Microwave Links at 6 GHz by Roberson and Associates, LLC (Critical Infrastructure Industry (CII) User Study) (Attachment to *Ex Parte* Comments Received Jan. 13, 2020)

Engineers for the Integrity of Broadcast Auxiliary Services Spectrum (EIBASS) (Attachments to Comments Received Feb. 15, 2019)

- Maps showing operational areas of 6.5 and 7 GHz Part 74, Subpart F, TV Pickup stations.
- eBay add for 8-watt 2.4 GHz Wi-Fi power amplifier.
- Map showing Phoenix-area electronic news gathering-RO sites.
- Comparison of noise floors at 2 vs. 2.5 GHz for the South Mountain electronic news gathering-RO site.

Ericsson

- Balanced Approach to 6 GHz (Attachment to *Ex Parte* Comments Received April 23, 2019, June 14, 2019, Oct. 16, 2019)

Fixed Wireless Communications Coalition

- Harmful Interference from Uncontrolled RLANs into Fixed Service (Attachment A of *Ex Parte* Comments Received Dec. 20, 2019)
- Question: how does a 10 dB change in path fade margin affect the multipath fading outage time? (Attachment B of *Ex Parte* Comments Received Dec. 20, 2019)
- Response to RLAN Group Filing on Multipath Fading in ET Docket No. 18-295, dated October 3, 2019 (Attachment A of *Ex Parte* Comments Received Nov. 21, 2019)
- What future for the unlicensed and licensed services in the 6 GHz band? (Attachment to *Ex Parte* Comments Received Sept. 26, 2019)
- Overview of ECC Report 302 Sharing and Compatibility Studies Related to Wireless Access Systems including Radio Local Area Networks (WAS/RLAN) in the Frequency Band 5925-6425 MHz by George Kizer (Attachment to *Ex Parte* Comments Received Sept. 3, 2019)
- RLAN Interference Estimator by George Kizer (Attachment A of *Ex Parte* Comments Received Aug. 22, 2019)
- Deploying 6 GHz RLANs While Protecting the Fixed Service (Attachment to *Ex Parte* Comments Received June 28, 2019 and June 19, 2019)
- Authorizing RLANs While Protecting the Fixed Service (Attachment to *Ex Pate* Comments Received May 3, 2019)
- Calculating Interference from an RLAN in the Main beam of a Category A or B1 FS Antenna by George Kizer (Appendix A of Reply Comments Received March 18, 2019)
- Determining the Impact of Non-Coordinated Indoor 6 GHz RLAN Interference on Fixed Service Radars by George Kizer (Attachment A of Comments Received Feg. 15, 2019)
- Need for Adjacent Channel Interference Protection by George Kizer (Attachment B of Comments Received Feb. 15, 2019)
- RLAN/FS Guard Band Analysis by George Kizer (Attachment C of Comments Received Feb. 15, 2019)
- Indoor 6 GHz RLAN Interference into Fixed Service Receivers Based on Wi-Fi Alliance Assumptions by George Kizer (Attachment to *Ex Parte* Comments Received Oct. 2, 2018)

Globalstar, Inc.

- Technical Analysis of Impact in U-NII-8 on Globalstar Mobile Satellite Service by Roberson and Associates, LLC (Attachment to Comments Received Feb. 15, 2019)

iRobot Corp.

- iRobot Technical Appendix (Appendix A of *Ex Parte* Comments Received Feb. 7, 2020)
- iRobot Protecting Innovation Terra UWB and Wi-Fi Coexistence Analysis (Attachment to *Ex Parte* Comments Received Nov. 1, 2019)
- Impact of Proposed High-Power Wi-Fi Operations on iRobot Ultra Wide Band Devices at 6 GHz by Roberson and Associates, LLC (Attachment to *Ex Parte* Comments Received Oct. 17, 2019)

National Association of Broadcasters

- Broadcast Use of 6 GHz (Attachment to *Ex Parte* Comments Received Feb. 7, 2020)
- Analysis of Interference to Electronic News Gathering Receivers from Proposed 6 GHz RLAN Transmitters prepared by Mark Gowans and Martin Macrae, Alion Science and Technology (NAB Study) (Attachment to *Ex Parte* Comments Received Dec. 5, 2019)

Nokia

- Automated Frequency Co-Coordinator (AFC) for N-NII-5 and U-NII-7 Band by Milind M. Buddhikot, Prakash Moorut (Attachment to *Ex Parte* Comments Received April 10, 2019)
- Automated Frequency Coordination (AFC) System by Milind M. Buddhikot, Prakash Moorut, Nokia Bell Labs & CTO (Technical Appendix to Reply Comments Received March 18, 2019)
- Coexistence of Unlicensed National Information Infrastructure (U-NII) Devices with Fixed Links at 6 GHz, Authors: Lauri Sormunen, Antti Piipponen, Prakash Moorut, Nokia Bell Labs & CTO (Technical Appendix to Comments Received Feb. 15, 2019)

RigNet Inc.

- RigNet Revised Detailed Exclusion Zone Gulf of Mexico; RigNet Revised Exclusion Zone Overview (Attachments to *Ex Parte* Comments Received Feb. 7, 2020, Nov. 18, 2019)
- Further Analysis of Impact of Unlicensed U-NII-5 Devices on RigNet 6 GHz Backhaul Network v1.0 by Roberson and Associates, LLC (Attachment to *Ex Parte* Comments Received July 11, 2019)
- Chart of Gulf of Mexico 6 GHz Network (Exhibit A of *Ex Parte* Comments Received May 15, 2019)
- Chart of WiMAX Coverage (Exhibit B of *Ex Parte* Comments Received May 15, 2019)

Southern Company Services, Inc.

- Methodology Used to Predict Impact of Radio Local Area Networks (RLANS) on Southern Microwave Network (Revised) (Attachment A of *Ex Parte* Comments Received Feb. 27, 2020)
- Study of the Impact of Unlicensed use of 6GHz Spectrum on Southern Licensed Columbus site (Attachment B of *Ex Parte* Comments Received Feb. 27, 2020)
- Lockard & White: 6GHz Analysis for Southern Company Services (Attachment A of *Ex Parte* Comments Received Feb. 14, 2020)
- Lockard & White Unlicensed 6GHz Impact Study Methodology (Attachment B of *Ex Parte* Comments Received Feb. 14, 2020)
- Prediction Models for Interference with Point to Point (Fixed Station) Microwave (Attachment C of *Ex Parte* Comments Received Feb. 14, 2020)
- FCC 6GHz NPRM Analysis for Southern Company Services Inc. (Attachment to *Ex Parte* Comments Received Feb. 6, 2

Utilities Technology Council

- Potential Interference to Utility and CII 6 GHz Systems from Unlicensed Operations (Attachment to *Ex Parte* Comments Received June 28, 2019, May 31, 2019, May 28, 2019, May 24, 2019)

Ultra Wide Band (UWB) Alliance

- Supporting Coexistence in the 6 GHz Band (Attachment to *Ex Parte* Comments Received May 8, 2019, April 10, 2019)
- Details on Coexistence Suggestions (Attachment to Comments Received Feb. 19, 2019, Feb. 15, 2019)

Zebra Technologies

- Unlicensed use of the 6 GHz Band (Attachment to *Ex Parte* Comments Received Feb. 18, 2020, Dec. 18, 2019, April 4, 2019)