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

COMMENTS OF BROADCOM INC.

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INTRODUCTION AND SUMMARY

The Federal Communications Commission ("FCC" or "Commission"), Congress, and the recent Presidential Memorandum on Developing a Sustainable Spectrum Policy for America have all identified the pressing need for new spectrum resources to fuel economic growth. As the Notice of Proposed Rulemaking ("NPRM") recognizes, keeping up with America's "insatiable" appetite for wireless broadband requires new unlicensed spectrum bands.[1] Demand for unlicensed services, especially Wi-Fi, continues to grow, and the existing unlicensed spectrum in the 2.4 GHz and 5 GHz bands has become congested. Making the 6 GHz band (5.925 GHz to 7.125 GHz) available for unlicensed use will be a critical step in addressing the looming unlicensed spectrum crunch. The Commission can use the flexible, pro-innovation technical rules that have made the U-NII-3 band (5.725–5.850 GHz) such an economic powerhouse as a blueprint for maximizing the 6 GHz band's value.

Broadcom thanks the Commission for its hard work in advancing this proceeding, as well as the many parties from across the industry that contributed their resources and technical expertise to the collaborative effort that has moved this proceeding forward. Broadcom continues to partner with a wide array of semiconductor manufacturers, equipment makers, software companies, and Internet service companies that are working together in the United States and around the world to provide the engineering work needed to bring the 6 GHz band to consumers and enterprises. We join their comprehensive

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[1] *Unlicensed Use of the 6 GHz Band; Expanding Flexible Use in Mid-Band Spectrum Between 3.7 and 24 GHz*, Notice of Proposed Rulemaking, FCC 18-147, ET Docket No. 18-295, GN Docket No. 17-183, ¶ 4 (rel. Oct. 24, 2018) ("NPRM").

comments,[2] and we file these separate comments to highlight eight issues critical to making this band a real-world success.

First, the Commission should authorize low-power indoor devices to operate throughout the entire 6 GHz band.[3] The Commission has already proposed to allow low-power indoor operations in U-NII-6 (6.425–6.525 GHz) and U-NII-8 (6.875–7.125 GHz). For the same reasons that the FCC correctly determined that low-power indoor devices will not cause harmful interference to incumbents in these bands, these devices can also share the U-NII-5 (5.925–6.425 GHz) and U-NII-7 (6.875–7.125 GHz) bands. Modifying the proposal in this way is of central importance to making the entire 6 GHz band a success because it increases the number of 160-megahertz channels for low-power indoor operations from one to seven.

Second, the Commission should enable 14 dBm EIRP very-low-power portable devices to operate without Automated Frequency Coordination ("AFC") throughout the entire U-NII-5 and U-NII-7 bands, in the bottom 100 megahertz of the U-NII-8 band, and at higher frequencies in places where no BAS TV pickup licensee is authorized.[4] Devices operating at the low 14 dBm EIRP level pose no real interference risk and do not require AFC control. Among other benefits, making this change to the NPRM's proposal will

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2 Comments of Apple Inc., Broadcom Inc., Cisco Systems, Inc., Facebook, Inc., Google LLC, Hewlett Packard Enterprise, Intel Corporation, Marvell Semiconductor, Inc., Microsoft Corporation, Qualcomm Incorporated, and Ruckus Networks, an Arris Company, ET Docket No. 18-295, GN Docket No. 17-183 (filed Feb. 15, 2019) ("RLAN Group Comments").

3 These low-power devices would have power limits of 24 dBm conducted and 30 dBm radiated and a PSD limit of 21 dBm/MHz. As discussed above and in Section IV, Broadcom recommends that the Commission allow client devices to transmit up to the same power level as the access point with which they are associated.

4 Very-low-power devices, both access points and client devices, would have a power limit of 14 dBm radiated and a PSD limit of 1 dBm/MHz.

provide five 160-megahertz channels and allow augmented and virtual reality to "go mobile," unlocking exciting new use cases.

Third, the Commission should establish power spectral density ("PSD") rules that allow operators to take advantage of Orthogonal Frequency-Division Multiple Access ("OFDMA"), a key feature of the 802.11ax standard. Modifying the proposed PSD limits to allow full use of allowed Equivalent Isotropically Radiated Power ("EIRP") even in narrow 2-megahertz channels will allow OFDMA to promote spectrally efficient use of the band by leveraging multiple narrow-bandwidth sub-channels.

Fourth, the Commission should allow client devices to transmit up to the same power level as the access point ("AP") with which they are associated. The AFC system can account for client devices associated with a standard-power AP subject to AFC when identifying available channels. Client devices connected to a low-power indoor AP and operating at similar power levels, such as televisions, gaming systems, and set-top boxes, are likely to be connected to indoor power outlets and remain indoors. Thus, the same building attenuation and power levels that protect incumbent services from indoor low-power APs would also be sufficient to protect associated client devices.

Fifth, the Commission should allow standard-power AFC-controlled operations in the bottom 100 megahertz of U-NII-8 and, at higher frequencies, only in places where no Broadcast Auxiliary Service ("BAS") TV pickup licensee is authorized. Currently, Fixed Service ("FS") operations coordinate with mobile operations in this band, and an AFC can facilitate similar coordination to enable standard-power use. Opening the bottom of the U-NII-8 band to unlicensed operations will create an additional 160-megahertz channel that straddles U-NII-7 and U-NII-8. This will be especially beneficial for outdoor operations in the many areas across the country that currently do not have reliable access to broadband Internet.

Sixth, the Commission should allow higher-gain antennas for standard-power outdoor APs and client devices to facilitate Part 15 operations over longer distances. Doing so will allow Wireless Internet Service Providers ("WISPs") to leverage the band in their work to expand access to broadband and close the digital divide.

Seventh, the Commission should adopt AFC rules that enforce strict protection standards while giving engineers flexibility in designing their systems. For AFC control to be widely adopted, the systems must be simple, flexible, and customizable. Using that flexibility, operators can design AFC systems that are reliable, but that differ to address different market needs. These systems may be centralized, decentralized, on-device, cloud-based, proprietary, non-profit, or for-profit to meet the needs of many different kinds of users.

Eighth, and finally, the Commission should authorize standard-power portable devices to operate using AFC in U-NII-5, U-NII-7, and the bottom 100 megahertz of U-NII-8.[5] The AFC can protect incumbents from harmful interference from portable devices and those in vehicles through methods such as geofencing. The Commission can also rely on the spatial recheck rules it has employed in other bands to ensure the AFC protects FS operations.

The NPRM's overall structure will greatly advance wireless service in the United States and help propel the U.S. to leadership in the development of 5G.[6] We urge the Commission to implement that framework. But the modifications described in these

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5 Standard-power devices would have power limits of 30 dBm conducted and 36 dBm radiated, and a PSD limit of 27 dBm/MHz.

6 *See* Federal Communications Commission, *The FCC's 5G Fast Plan*, https://docs.fcc.gov/public/attachments/DOC-354326A1.pdf ("Recognizing that unlicensed spectrum will be important for 5G, the agency is creating new opportunities for the next generation of Wi-Fi in the 6 GHz and above 95 GHz band.").

comments are critical to making the band a success. By adopting these proposals, the Commission can maximize the utility of the 6 GHz band without causing harmful interference to incumbent operations.

I. The Commission Should Authorize Low-Power Indoor Uses Across the 6 GHz Band.

Broadcom supports the Commission's proposal to authorize low-power unlicensed operations in U-NII-6 (6.425–6.525 GHz) and U-NII-8 (6.875–7.125 GHz) without AFC control.[7] As the NPRM explains, allowing unlicensed operations to share those bands, which are near the already-successful 5 GHz unlicensed band, will "facilitate the deployment of less complex (and, thus, potentially less expensive) low-power unlicensed devices."[8]

To facilitate sharing, the NPRM proposes careful interference protection mechanisms that will more than adequately protect both terrestrial point-to-point links in the Fixed Service and Fixed Satellite Service operations from indoor low-power operations in U-NII-6 and U-NII-8.[9] Importantly, however, many of these types of incumbent operations are also present in U-NII-5 and U-NII-7, and the Commission should approve sharing in these bands using a similar regulatory structure as in U-NII-6 and U-NII-8. As these comments discuss, and the RKF Report demonstrates, the interference potential of low-power indoor unlicensed operations is extremely limited, and this class of device could be used safely throughout the 6 GHz band. The Commission should take this important step because expanding low-power operations to U-NII-5 and U-NII-7 is essential to opening enough

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7 NPRM ¶ 59.

8 *Id.* ¶ 61.

9 *Id*.

channels to make the 6 GHz indoor market opportunity large enough to support the enormous investments needed to quickly deploy consumer devices.

A. Low-power indoor devices will not cause harmful interference to incumbent operations.

Earlier in this proceeding, RKF Engineering Solutions conducted a comprehensive assessment of the potential for harmful interference between unlicensed users and the 6 GHz band's incumbents. RKF's report, even without the AFC interference-control mechanisms proposed by the NPRM and with conservative assumptions about widespread unlicensed use of the 6 GHz band, found that situations in which FS stations in the continental United States would experience a single instance of interference greater than even a very stringent -6 dB I/N were extremely rare—in all four sub-bands.[10] Notably, that analysis assumed that unlicensed devices would operate both indoors and outdoors at power levels up to 35.3 dBm (approximately 4 watts)—far above the power limits contemplated for low-power indoor devices. That analysis also overstated interference by 5 dB because it did not include a 3 dB polarization mismatch loss or 3 dB of feeder and other system loss, which are relevant to typical interference studies into FS incumbents.

Additional analysis using real-world assumptions about network geometry, building entry loss, antenna direction/polarization, and channel selection shows that interference from indoor-only devices operating with power limits of 24 dBm conducted (30 dBm radiated) is even less likely. The risk is further reduced because the worst-case scenario described by FS operators—an indoor device operating in a building that is located in the main beam of an FS receiver—is extremely uncommon. The RKF Report demonstrates that only a very small percentage of buildings are in the main beam of an FS receiver. And

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10 RKF Engineering Solutions, LLC, Frequency Sharing for Radio Local Area Networks in the 6 GHz Band 54 (Version 3 2018) ("RKF Report").

only an insignificant subset of low-power indoor devices operating in these buildings would even be positioned to possibly cause harmful interference. As a result, the risk of harmful interference from low-power indoor devices to FS operations is extremely low—a corner case within a corner case.

That is so because, to even have the possibility of causing harmful interference to FS, a low-power device would first have to be operating inside one of the very few buildings where an FS operator has somehow pointed their equipment so that the building is in their main beam—and even then would have to meet other unlikely requirements. The RLAN would need to be (1) positioned on the side of the building facing the FS receiver, (2) operating line of sight to the FS (that is near an open window with no clutter between it and the FS receiver), and also (3) operating co-channel with the FS receiver. This extremely unlikely combination should not drive overall national policy and should not preclude the Commission from opening the entire 6 GHz band to indoor low-power unlicensed uses.

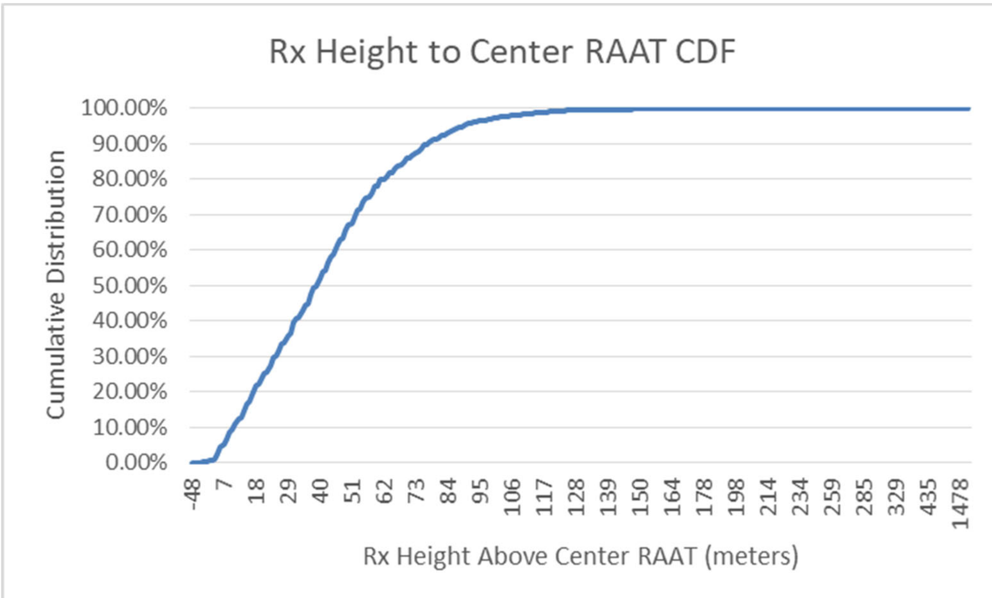
1. Factors reducing the likelihood of interference.

Network Geometry. Because their operations are so different, the typical unlicensed device is either well outside the boresight of an FS receiver or located a significant distance away. As of March 21, 2017, there were 91,618 FS receivers operating in the U-NII-5 and U-NII-7 bands. These fixed links are typically mounted on towers or tall structures, and they are typically pointed away from objects, including buildings, that would block the line of sight between transmitter and receiver.[11] Using registration data filed with the Commission about each of those sites, we calculated that the average FS receiver

[11] *See* RLAN Group Comments, Declaration of Fred Goldstein Regarding Fixed Service Operation ¶ 11.

height above the surrounding terrain is 43 meters, and the median is 39 meters. More than 80 percent of those receivers are taller than 18 meters.

Figure 1: Cumulative Distribution Function of FS Receiver Heights

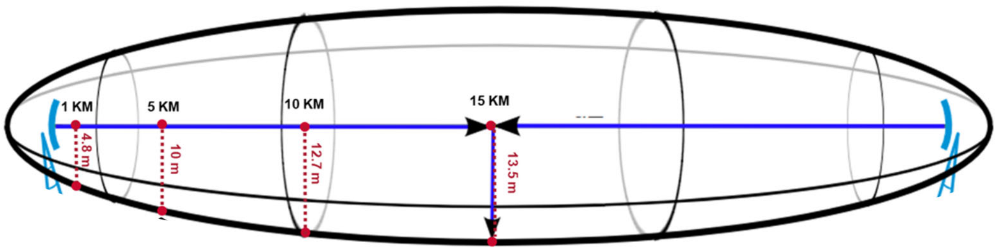


These average heights are expected, because FS links must operate above obstructions. In addition to requiring a clear line of sight from receiver to transmitter, FS links must also ensure that the Fresnel Zone around that line is largely free of obstructions in order to avoid excess fading.[12] Because the surrounding Fresnel Zone may extend for several meters around the center line of an FS link between sending and receiving FS stations, antennas mounted on relatively short installations are likely to be located in topologies high above the surrounding terrain (for example, a relatively short tower on the top of a hill) or positioned with the antenna tilted up. Where possible, link designers attempt to design the link so that it sits well above surrounding terrain. That way if new buildings are erected between the transmit and receive path, they would not interfere with the FS

[12] Campbell Scientific, Inc., *Line of Sight Obstruction* 5 (2016), https://s.campbellsci.com/documents/au/technical-papers/line-of-sight-obstruction.pdf.

operations. For example, as illustrated in Figure 2 below, the first Fresnel Zone for a 30-kilometer link operating at 6.2 GHz would, at the midpoint of the link, extend 13.5 meters toward the ground. A receiver placed less than 18 meters above ground would only operate effectively in this scenario if it were placed on high terrain surrounded by lower terrain.

Figure 2: First Fresnel Zone for 30-kilometer Link at 6.2 GHz

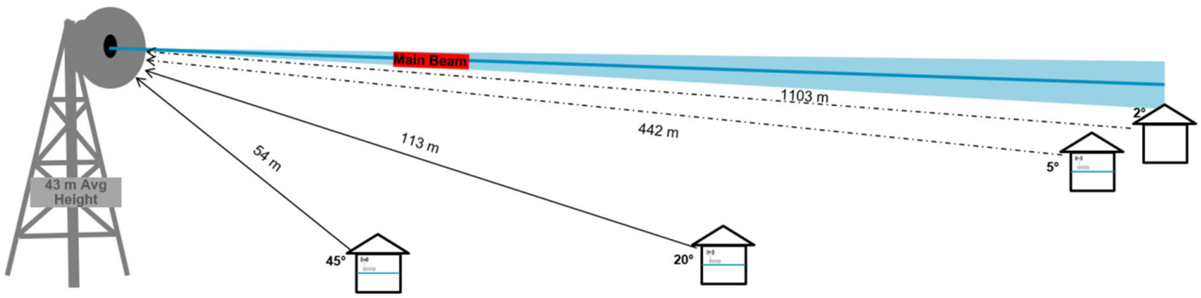


Using this height distribution information, we can make predictions about the geometric relationships between average-height FS receivers and typical Wi-Fi devices. A Wi-Fi device in a typical two-story residential home would be expected to operate 4.5 meters above terrain or less.[13] As Figure 3 below illustrates, because of this significant height differential between FS receivers and typical Wi-Fi access points, Wi-Fi devices positioned close to the FS receiver have signals that arrive at the FS receiver at high elevation angles. For example, a signal from a Wi-Fi device 222 meters away arrives at an average-height FS receiver at an angle of 10 degrees off the center of the main beam. At 10 degrees, typical high-performance six-foot FS antennas exhibit off-axis gain of almost 35 dB below peak gain. At 2 degrees off the boresight—an angle that occurs only when the Wi-Fi

13 We assume 3 meters per story with an AP positioned 1.5 meters above the floor of the second level.

device is positioned at least 1,103 meters away—typical high-performance six-foot FS antennas still exhibit off-axis gain of 13 dB below the peak.[14]

Figure 3: Network Geometry of FS Links (43 meters) and RLAN (4.5 meters)



Thus, because of the complementary geometries of FS and RLAN operations, an unlicensed device would need to be positioned more than a kilometer away from the FS receiver to fall within the boresight of an average-height FS receiver.

Building Entry Loss. In the very unusual case where an RLAN is operating in a tall building that may be located within the boresight of an FS receiver, network geometry *alone* may not be enough to protect FS links from harmful interference. The Commission should recognize, however, that those cases are *very* unusual. Because the building itself would tend to obstruct the FS signal, FS engineers design links to avoid this problem whenever possible. That job is made easier by the fact that very tall buildings are relatively rare, and in the many tall buildings that are non-residential, Wi-Fi Access Points are typically ceiling-mounted, and the antenna configuration is designed for peak EIRP in a downward direction.

14 Letter from Apple Inc., Broadcom Limited, Cisco Systems, Inc., Facebook, Inc., Google LLC, Hewlett Packard Enterprise, Intel Corporation, Microsoft Corporation, Qualcomm Incorporated, and Ruckus Networks, an ARRIS Company to Marlene H. Dortch, Secretary, Federal Communications Commission, GN Docket No. 17-183, at 9 (filed May 14, 2018) ("FS Response") (showing sidelobe rejection for UHX6-59 antenna pattern).

This would make it even more unlikely for an RLAN to cause harmful interference to an FS receiver.[15]

Moreover, in these rare cases, the buildings where unlicensed devices are operating will typically experience much higher than average attenuation because of the building materials used in these buildings—including steel, concrete, heavy insulation, and energy-efficient windows. Modern building codes, for example, require tinted energy-efficient windows in commercial buildings that increase signal attenuation. Forty states have mandated commercial and residential building energy codes that require energy conservation materials that will substantially attenuate 6 GHz signals.[16] In fact, as described in the building-entry loss declaration appended to our RLAN Group Comments, many of these materials are nearly opaque to 6 GHz signals.[17] These materials, which are now common in newly constructed buildings and renovated older buildings, have such a problematic impact on radio performance that radio-frequency engineers must employ creative solutions in other bands, including amplifiers inside buildings and vehicular repeaters outside, to ensure that signals meant to move through buildings can overcome

15 *See* RLAN Group Comments, Characteristics of Enterprise Deployments Using IEEE 802.11 Equipment: Joint Declaration of Matt MacPherson, Chuck Lucaszewski, and Sundar Sankaran ¶ 11 ("Enterprise Networking Declaration").

16 *Code Status Maps*, Building Codes Assistance Project, http://bcapcodes.org/code-status/, (last visited Feb. 13, 2019); *see also Performance Standards: Building Codes Overview*, Efficient Windows Collaborative, https://www.efficientwindows.org/standards_codeoverview.php, (last visited Feb. 13, 2019).

17 *See* RLAN Group Comments, Appendix E: Building and Vehicle Attenuation at 1–2.

the 30 to 40 dB attenuation factor associated with energy-efficient glass.[18] (Very few windows fully open in modern skyscrapers for safety reasons. If they open at all, they typically will only open a fraction or tilt out.[19]) For low-power indoor unlicensed operations, which would be required to be contained inside a building and maintain low power levels, no such measures would be permitted, and building attenuation will provide further protection to FS operations.

Antenna Direction/Polarization. The interference impact of indoor, low-power unlicensed operations is further mitigated by the limitations that antenna direction and polarization place on maximum EIRP in any single direction for unlicensed APs with multiple antennas. Most unlicensed APs use dipole antennas, which are approximately omni-directional.[20] We say approximately omni-directional because, as the radiation pattern below illustrates, the antenna pattern will only have maximum gain in the azimuth plane. In the elevation plane, there is only positive antenna gain in one-third of the pattern; the remainder all lead to a reduction in effective EIRP. There is almost a 20 percent probability of 10 dBi or more in loss for each antenna.

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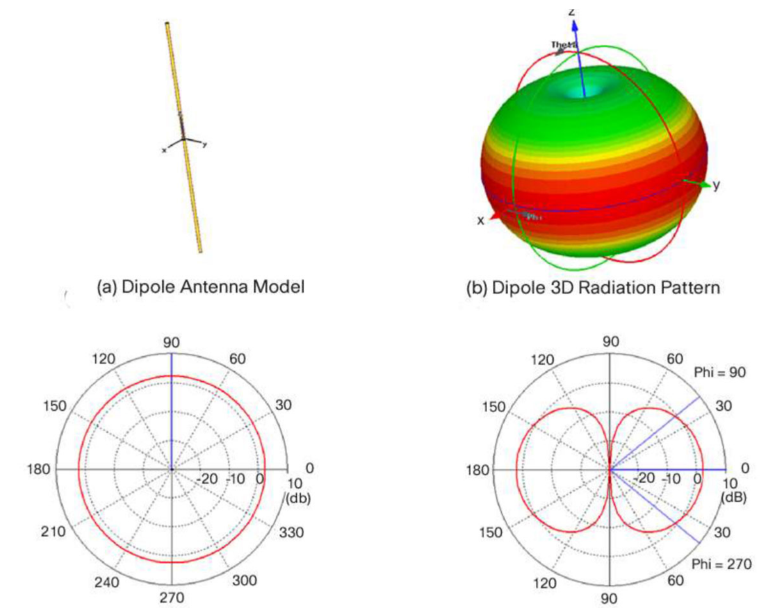
18 Urgent Communications Administrator, *When Green Will Make You Blue*, IWCE's Urgent Communications (Apr. 1, 2011), https://urgentcomm.com/2011/04/01/when-green-will-make-you-blue/.

19 Leigh Kamping-Carder, *My High-Rise Windows Only Open a Few Inches. What Gives?*, Brick Underground (Jan. 5, 2015), https://www.brickunderground.com/blog/2015/01/ask_an_expert_windows.

20 *See generally* Cisco Systems, Inc., Antenna Patterns and Their Meaning 6 (2007), https://www.cisco.com/c/en/us/products/collateral/wireless/aironet-antennas-accessories/prod_white_paper0900aecd806a1a3e.pdf (describing the performance of dipole antennas).

Figure 4: Dipole Antenna Directionality[21]



(a) Dipole Antenna Model
(b) Dipole 3D Radiation Pattern
(c) Dipole Azimuth Plane Pattern
(d) Dipole Elevation Plane Pattern

In order to maximize coverage, a multi-antenna AP will be designed such that the direction of the peak gain of the antennas are rarely correlated (often referred to as antenna pattern diversity).[22] As such, the total system (considering all antennas) will not experience maximum gain in any single direction. In fact, it is highly probable that the combined gain from all four antennas in any single direction will be negative. Working with one of its access point customers, Broadcom obtained measurements from a four-antenna system every 3 degrees phi and 3 degrees theta, amounting to 7260 individual measurement points. The gain for each single antenna at any angle ranged from a peak of 4.9 to 7.1 dBi to a trough of -19.4 to -28.6 dBi. The combined gain for the four-antenna system at any angle ranged from a peak of 5.1 to -23.6 dBi. At 82 percent of the angles measured, the gain was less than 0 dBi. At 50 percent of the angles measured, the gain was less than -3.33 dBi. The mean gain over all 7260 angles measured was -2.11 dBi.

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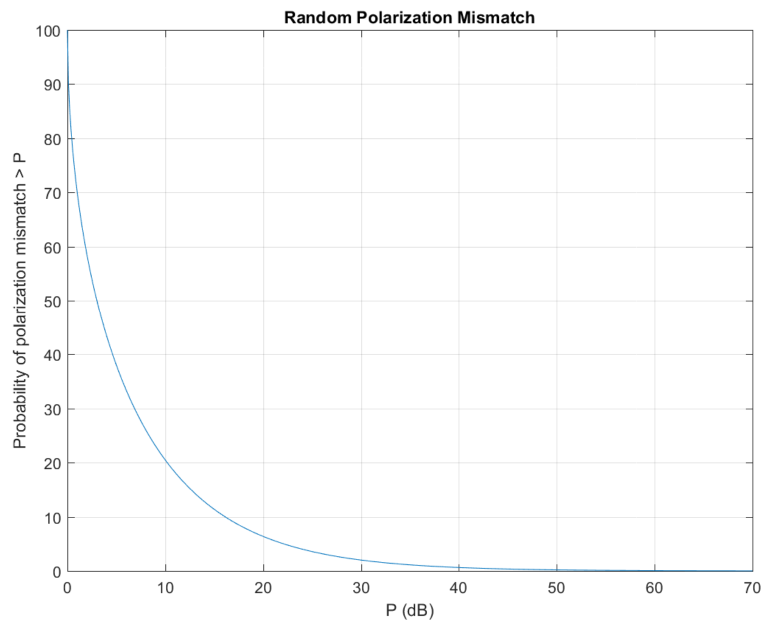
21 *See id.* at 7.

22 *See* Enterprise Networking Declaration ¶ 14.

Additionally, FS antennas are polarized, and RLAN polarization is random based on the tilt of the antenna. Therefore, because FS and RLAN polarizations will usually be mismatched, there will be an average of an additional 3 dB loss of RLAN energy going into an FS receiver from polarization mismatch.[23]

Figure 5: Polarization Mismatch



In general, AP manufacturers are increasing the number of spatial streams and antennas in each AP. While it used to be standard that most antennas could be rotated (creating the possibility of less polarization and directional gain diversity), new designs are fixing some or all of the antennas in relationship to each other to increase and ensure spatial and polarization diversity as described above.[24] In summary, given that the RLAN

[23] *See* Enterprise Networking Declaration ¶ 15.

[24] For example, the Netgear R8500 has both internal and external antennas. The internal antennas are operating at a higher gain than the external antennas. At least one of the four internal antennas appears to be rotated. In the Netgear Wi-Fi 6 Nighthawl AX8, all

device orientation is random with respect to the FS, on average there is effective antenna gain of -2 dBi and polarization mismatch loss of 3 dB.

Conducted Power. We assume that cost sensitivities will lead manufacturers to design the components of their devices to transmit up to the maximum conducted power of 24 dBm at the lowest Modulation and Coding Scheme (MCS) using BPSK modulation, but when transmitting at a typical higher MCS using 64-QAM modulation, a conducted power back-off of 3 dB would typically be applied in order to meet the transmitter error vector magnitude ("EVM") and spectral mask requirements. In addition, back-off from maximum conducted power could also be necessary if manufacturers are applying array gains from technologies such as beamforming in order to meet 1:1 power reduction when antenna gain exceeds 6 dBi as required under Part 15 regulations. We therefore assume a conducted power of 21 dBm would be typical for mainstream consumer APs for the vast majority of transmissions.

Limited Co-Channel Operations. To even be in a position to possibly cause harmful interference to an FS link, an RLAN device must have frequency overlap with that link. The more spectrum the Commission makes available for indoor low-power unlicensed operations, the less likely that scenario becomes. As shown below in Figure 13, depending on the rules the Commission ultimately adopts, there could be up to seven 160-megahertz channels and fourteen 80-megahertz channels, along with many more small channels. Because indoor low-power RLAN operations would be spread across the many channel

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four antennas are fixed. Rosensama, *Transmit Power and Antenna Gain for Nighthawk X6 and X8 Models?*, NETGEAR COMMUNITY (Jan. 19, 2016, 5:20 PM), https://community.netgear.com/t5/Nighthawk-WiFi-Routers/Transmit-power-and-antenna-gain-for-Nighthawk-x6-and-x8-models/td-p/1036834; NETGEAR Support, *Where Are the Antennas Located On My NETGEAR Nighthawk AX8 Router?*, NETGEAR, Nov. 29, 2018, https://kb.netgear.com/000060374/Where-are-the-antennas-located-on-my-NETGEAR-Nighthawk-AX8-router.

configurations the 6 GHz band would offer, the chance of interference would be further reduced by the low-probability that the RLAN and FS link would be operating on the same channel. Consequently, this co-channel factor would reduce the chance that a low-power indoor device would be operating in a way that puts it in a position to potentially cause harmful interference.

2. Propagation models and the combined impact on interference of multiple attenuating factors.

As explained in the RLAN Group Comments, the free space path loss model would severely overestimate interference under these circumstances and is inappropriate for evaluating potential interference in the 6 GHz band.[25] For distances between 30 meters and one kilometer, the models that best account for clutter loss and include both line-of-sight ("LOS") and non-line-of-sight ("NLOS") conditions are the WINNER II model for urban and suburban environments, and the Irregular Terrain Model (Shuttle Radar Topography Model) ("ITM(SRTM)") combined with the ITU-R P.452 clutter model for rural environments at distances of greater than one kilometer.[26] Here, we have used the WINNER II model to assess interference levels under real-world conditions. Taken together, network geometry, building entry loss, antenna gain, and polarization mismatch make sharing between indoor low-power RLANs and high-power outdoor FS operations safe. Figure 6 below summarizes those assumptions and others used the model below:

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[25] RLAN Group Comments, Declaration of Dr. Vinko Erceg ¶ 2 ("Erceg Declaration").

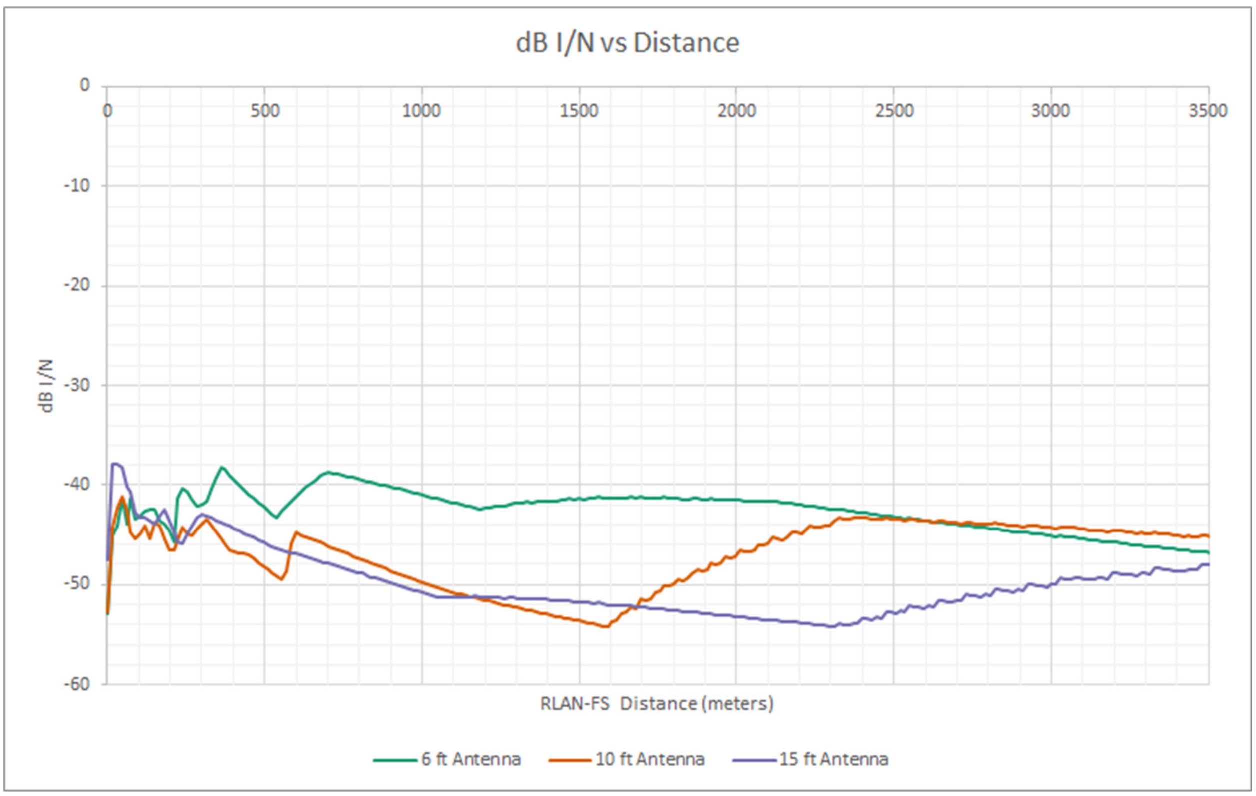
[26] Erceg Declaration ¶ 3. For longer distances, the ITM(SRTM) combined with the ITU-R P.2108 for suburban and urban environments, and ITU-R P.452 for rural environment clutter models. If the SRTM option is not available, ITM can be used in a statistical (area) prediction mode with a terrain variation parameter (Δh) set to appropriate values. *Id.* ¶ 14.

Figure 6: Assumptions Applied in Interference Analysis Using WINNER II Model

RLAN Azimuth Angle to FS	degrees	0
RLAN Bandwidth	MHz	160
RLAN Tx Power (dBm)	dBm	24
RLAN Antenna Gain	dBi	-2
RLAN Building Entry Loss	dB	20
RLAN Height	meters	4.5
Polarization Mismatch	dB	-3
FS and RLAN Feeder and System Loss	dB	-3
FS BW	MHz	30
FS Noise Figure	dB	5
FS Height	meters	43
FS Center Frequency	MHz	6200

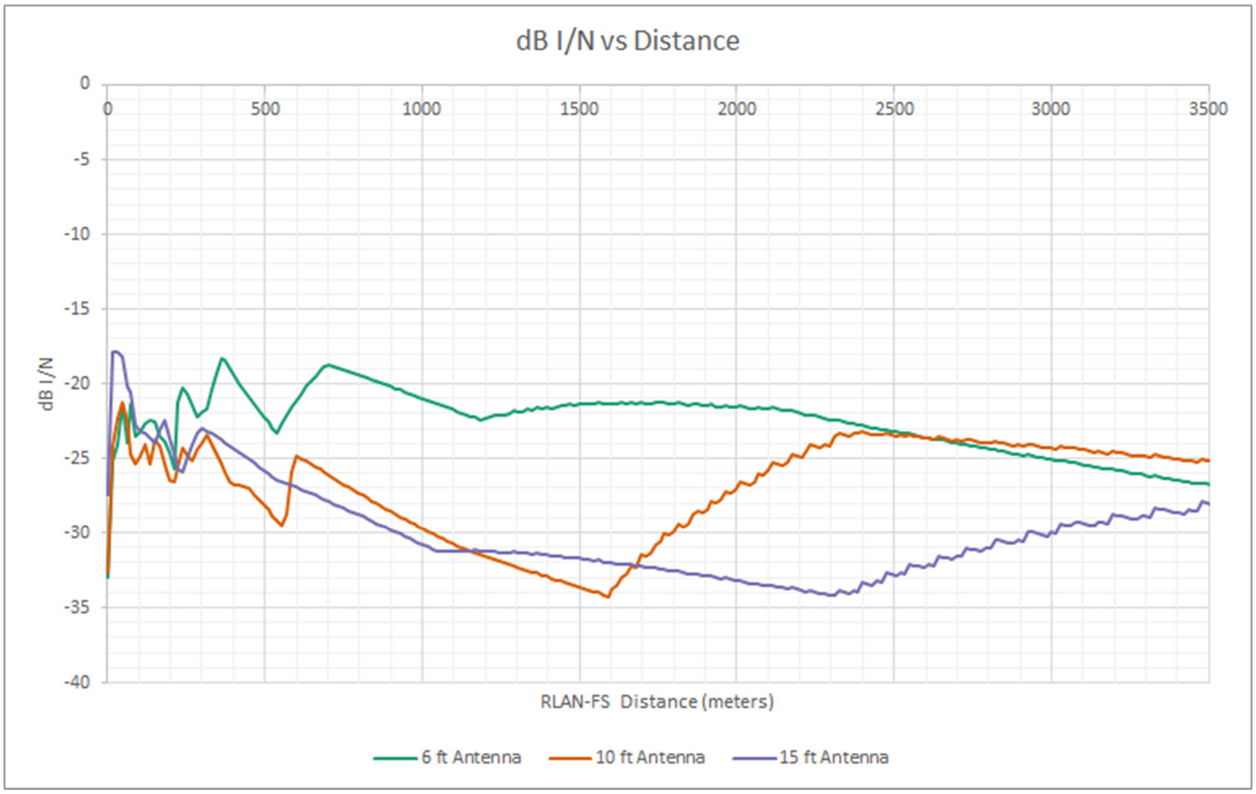
Applying the WINNER II model to a typical sharing scenario, which combines the assumptions described above, demonstrates that sharing under those conditions will not risk harmful interference. In this analysis, the worst-case interference, which occurred only at a very short distance for one type of antenna, is less than -38 dB I/N. That is far below levels that could cause harmful interference.

Figure 7: NON-LOS WINNER II Results with Real-World Assumptions



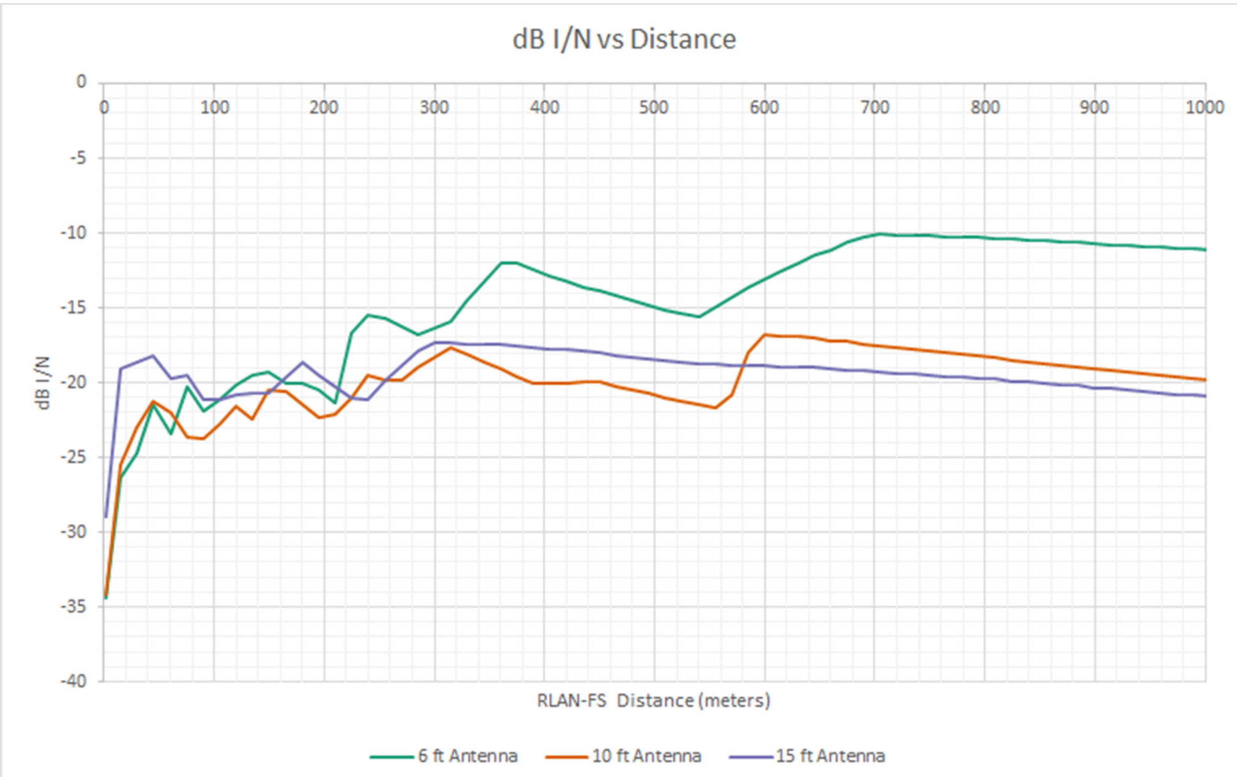
Sharing can even work when the unlicensed device is operating next to an open window. To illustrate that scenario, we changed the RLAN building entry loss assumption to 0 dB. Even without attenuation from building entry loss, the worst-case interference was -18 dB I/N. At that level, sharing the 6 GHz band remains safe.

Figure 8: WINNER II Results with Open Window



In fact, sharing is possible even assuming the unlikely scenario line-of-sight path loss for the first kilometer. Even the worst-performing antenna never reaches -6 dB I/N, and it only approaches -10 dB I/N at distances of approximately 700 meters.

Figure 9: WINNER II LOS Results



Low Probability of Worst-Case Positioning. Assessments of potential sharing between RLANs and FS operations of the 6 GHz band in other countries confirm that harmful interference to FS is extremely unlikely. For example, an analysis prepared for the European Conference of Postal and Telecommunications Administrations ("CEPT") examined the sharing and compatibility of indoor and outdoor RLANs (operating at total peak EIRP of 29.9 dBm using omnidirectional antennas) and information available at the time of the study about fixed point-to-point links in the United Kingdom in the 5.925–

6.425 GHz band.[27] In 250,000 simulations, the study assessed more than 300 trillion instantaneously transmitting RLAN-FS pairs for which RLAN transmit power was aggregated at the FS receiver, a model that corresponds with all the RLANs within 150 kilometer of each of the 505 FS receivers in the United Kingdom where the RLAN has non-zero spectral overlap with the FS. That study showed that there is only a 1 in 100 million probability that an unconstrained RLAN would meet or exceed -10 I/N at an FS receiver 2 percent of the time in the UK—10 times less than the long-term interference protection criteria requirement assumed for that study.[28]

FWCC Analysis. Contrary assertions from the Fixed Wireless Communications Coalition ("FWCC") about low-power indoor operations are unjustified. FWCC ignores all typical RLAN/FS interactions and instead asks the Commission to create rules based on a single unlikely scenario where there is only free space loss—no clutter, no system loss, and no polarization mismatch loss—and where the RLAN is operating at the same height above surrounding terrain at the FS link.[29] FWCC must assume that all of these unrealistic factors occur together to find its single corner-case sharing scenario:

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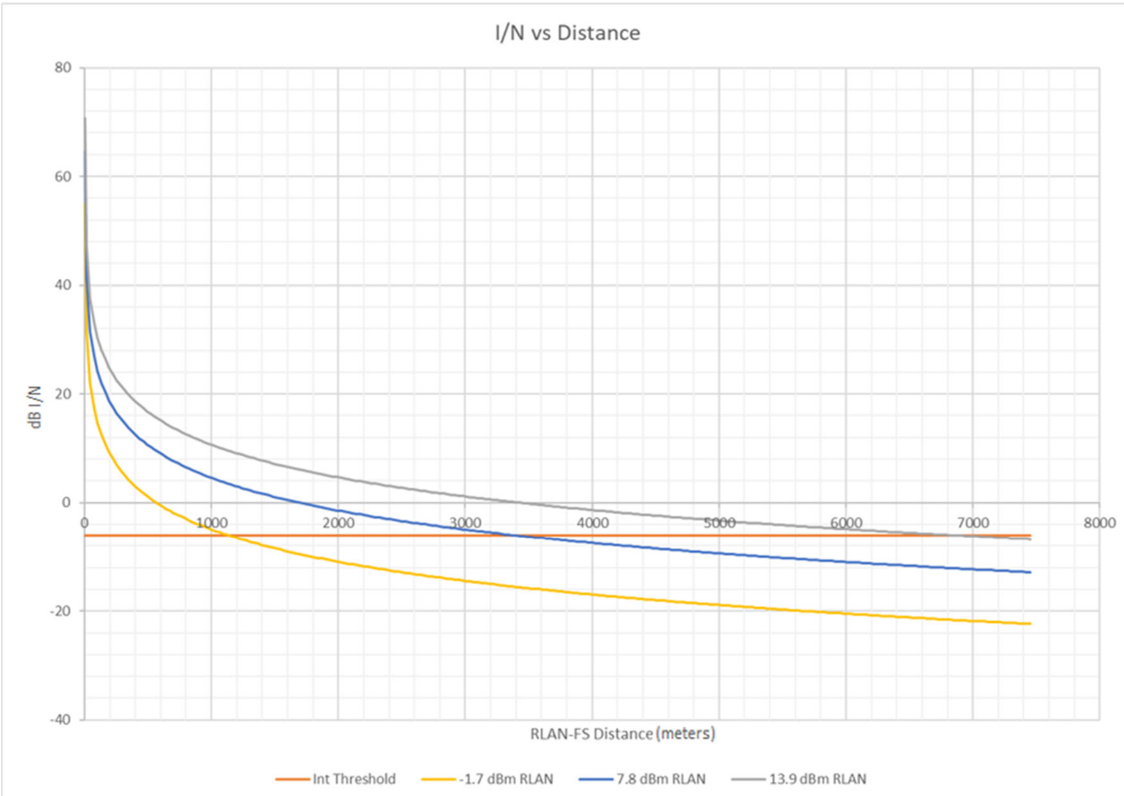
[27] Draft ECC Report No. 302, *Sharing and Compatibility Studies Related to Wireless Access Systems including Radio Local Area Networks (WAS/RLAN) in the frequency band 5 925–6 425 MHz*, https://cept.org/files/9522/Draft%20ECC%20Report%20302.docx. Although this data includes indoor and outdoor operations, the overwhelming majority of the RLAN operations modeled were indoors. Using historical and projected shipment data, the report assumes that 98 percent of RLANs will operate indoors as of 2025. This draft report is currently under public consultation. It is anticipated that no significant changes to the results would be proposed during the public consultation period.

[28] *Id.* at 79.

[29] *See* Letter from Cheng-yi Liu & Mitchell Lazarus, Counsel, Fixed Wireless Communications Coalition to Marlene H. Dortch, Secretary, Federal Communications Commission, GN Docket No. 17-183, ET Docket No. 18-295, at Attachment p. 5 (filed Aug. 28, 2018).

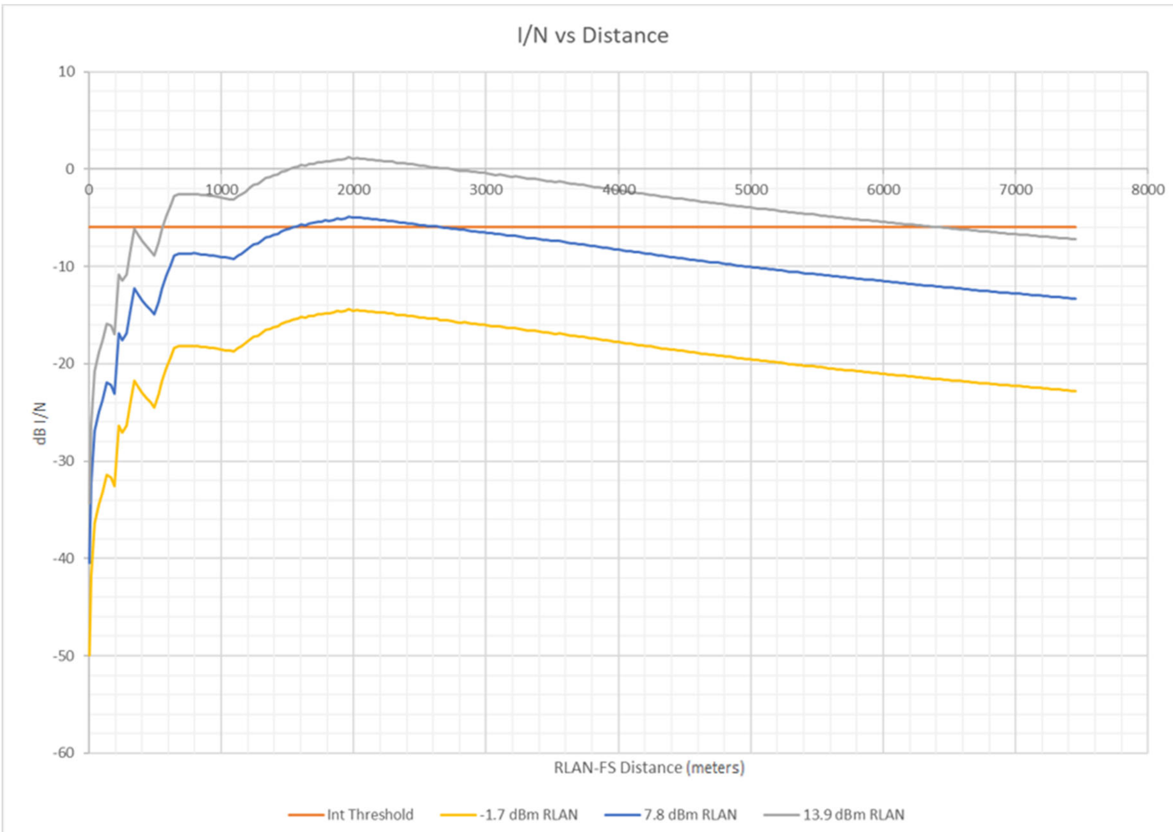
Figure 10: FWCC Interference Analysis Based on Unrealistic Assumptions



For the reasons described above, those assumptions are extremely unlikely to be observed in the real world, and they certainly should not form the basis for a rule of general applicability. Furthermore, even if an RLAN were in the unrealistic corner-case within a corner-case position to exceed an interference threshold of -6 dB I/N, based on the short burst duty cycles, this would only occur too briefly to cause harmful interference. It is highly unlikely that such interference would occur even 2 percent of the time as found in the CEPT study referenced above. In fact, Figure 11 below shows that if we correct even one of the errors in FWCC's unrealistic analysis to take into account *only* the difference between typical FS receiver height above terrain and the height of typical RLAN operations in a two-story home, FWCC's sharing analysis falls apart—even if we continue to make the extremely conservative assumptions of free space loss, no system loss, no polarization

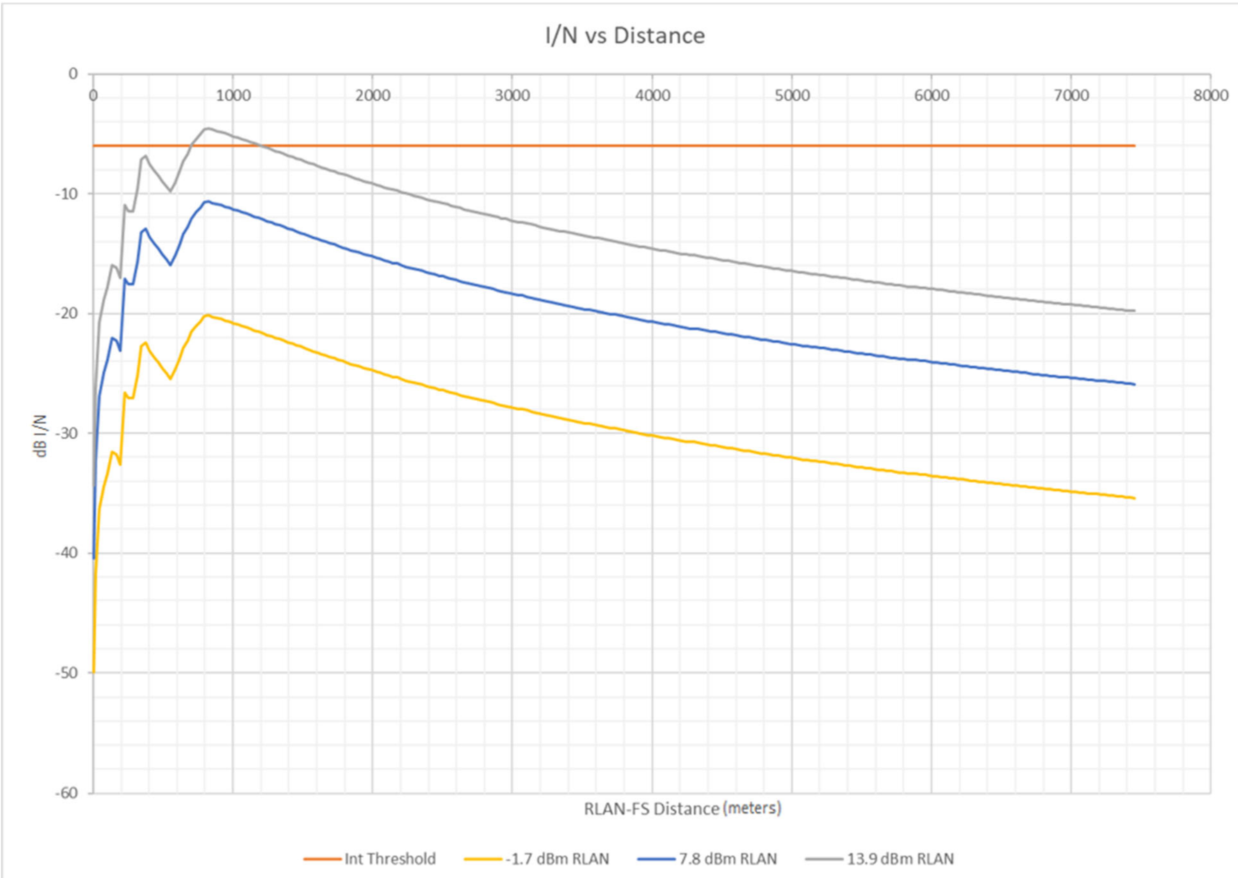
loss, and we assume that the unlicensed signal passes directly under the main beam of the receiver.

Figure 11: FWCC Interference Analysis with Modified Height Assumptions



Furthermore, if an RLAN device is only slightly outside of the main beam—just 2 degrees Azimuth angle—the interference risk is further limited as shown in Figure 12, even assuming free space path-loss and no clutter.

Figure 12: FWCC Interference Analysis with Modified Height Assumptions and Azimuth Angle



Taken together, these analyses show that the interference predictions offered by some FS providers are overstated and unreliable.[30] The Commission can confidently allow low-power indoor operations throughout the 6 GHz band.

30 *See* FS Response at 16–19 (describing flaws in FWCC's analysis, including unreasonable channelization assumptions and RLAN duty cycle and power level assumptions).

B. Indoor low-power operations across the 6 GHz band are essential to the band's economic success.

Today's unlicensed bands—which have driven investment, innovation, and economic development—have become crowded. As the NPRM recognizes, Congress recently addressed the "pressing need" for more unlicensed spectrum and required the Commission, working with other federal agencies, to identify new unlicensed spectrum resources.[31] Consistent with that congressional direction, and in response to studies that show that there is a significant need for more unlicensed spectrum right now, the Commission should take immediate action to designate new bands of unlicensed uses and to identify the operating rules that facilitate the most efficient use of that spectrum.[32]

Next-generation Internet data rates will require even more spectrum. Today, more than half of Americans have access to gigabit speeds,[33] and the cable industry has announced plans to deliver 10 gigabit-per-second data rates.[34] Those new capabilities will support revolutionary advances in streaming, virtual and augmented realities, smart cities, and other applications. With new capabilities comes more traffic. Cisco's latest Visual Networking Index demonstrates that Americans increasingly consume data wirelessly, and

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[31] NPRM ¶ 18 (citing Consolidated Appropriations Act, 2018, P.L. 115-141, Division P, the Repack Airwaves Yielding Better Access for Users of Modern Services (RAY BAUM'S) Act).

[32] *See* Steve Methley & William Webb, Quotient Assocs. Ltd., Wi-Fi Spectrum Needs Study 26 (2017) (finding that between 788 megahertz and 1.6 gigahertz of new mid-band spectrum will be needed by 2025 to meet demand for Wi-Fi).

[33] Amy Maclean, *Tech Minds Gather to Dissect DAA at Expo*, Cablefax (Oct. 23, 2018),http://www.cablefax.com/regulation/tech-minds-gather-to-dissect-daa-at-expo.

[34] Press Release, NCTA – The Internet & Television Association, Introducing 10G: The Next Great Leap for Broadband (Jan. 7, 2019), https://www.ncta.com/media/media-room/introducing-10g.

that Wi-Fi handles the lion's share of wireless traffic.[35] Similarly, 5G, the next generation of mobile technology, will continue to offload large amounts of traffic onto Wi-Fi and will require significant Wi-Fi capacity that can support ultra-high quality voice and video services.[36] Next-generation Internet data-rate advances will, therefore, only be fully realized if Americans can experience them through Wi-Fi.

The latest Wi-Fi standards can deliver that experience, but they need access to contiguous 160-megahertz channels, and devices that can put those channels to work, to do so. The latest Wi-Fi standard, Wi-Fi 6, leverages various channel sizes ranging from 20 to 160 megahertz wide. The wide channels facilitate higher data rates. But manufacturers will only invest in putting this technology into consumer devices if there is a sufficient number of 160-megahertz channels. As illustrated in Figure 13 below, the Commission's current proposal to authorize low-power indoor operations in 6.425–6.525 GHz and 6.875–7.125 GHz would only allow for one additional 160-megahertz channel for indoor low-power operations that falls fully inside the U-NII-6 and U-NII-8 bands.[37] All of the other 160-megahertz channels include at least a portion of the U-NII-5 and U-NII-7 bands.

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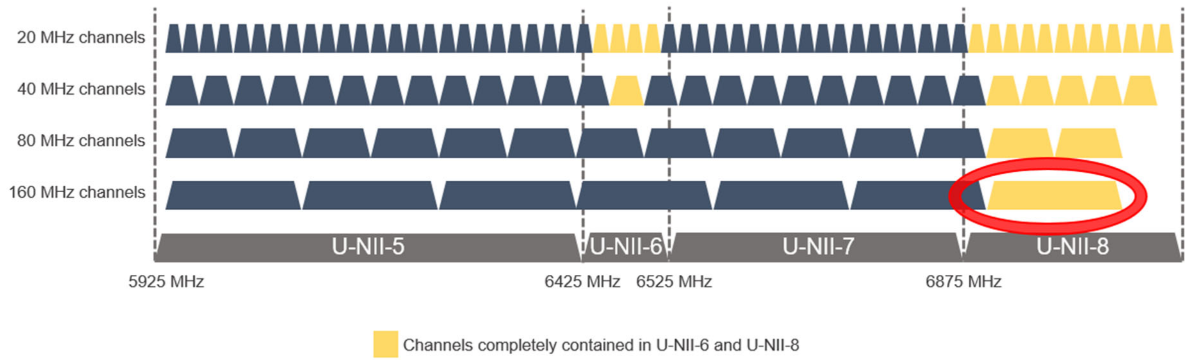
35 *See VNI Forecast Highlights Tool*, Cisco Systems Inc., https://www.cisco.com/c/m/en_us/solutions/service-provider/vni-forecast-highlights.html# (last visited Feb. 13, 2019) (projecting that North America's Fixed/Wi-Fi Internet traffic will be 1.5 times greater than Fixed/Wired Internet traffic in 2022); *see also* Wi-Fi Alliance, Next Generation Wi-Fi: The Future of Connectivity 5 (2018), https://www.wi-fi.org/downloads-registered-guest/Next_generation_Wi-Fi_White_Paper_20181218.pdf/35810.

36 Cisco Systems, Inc., IEEE 802.11ax: The Sixth Generation of Wi-Fi 2 (2018), https://www.cisco.com/c/dam/en/us/products/collateral/wireless/white-paper-c11-740788.pdf ("Cisco Report").

37 NPRM ¶ 59.

Figure 13: Single 160-Megahertz Channel in U-NII-6 and U-NII-8
Under the NPRM Proposal



Allowing low-power indoor operations throughout all four 6 GHz sub-bands, by contrast, would create many more 160-megahertz channels to deliver gigabit speeds over Wi-Fi, both by freeing more spectrum for indoor low-power use and by facilitating straddling sub-band channels. Thus, authorizing low-power indoor operations across the band would significantly increase the amount of spectrum available for Wi-Fi, making substantial progress in the effort to keep up with continually increasing demand for this keystone service. Because indoor low-power operations do not require AFC systems, which will take some time to deploy, those benefits will become available as soon as the FCC adopts new rules.

II. The FCC Should Permit Very-Low-Power Portable Devices to Operate in U-NII-5, U-NII-7, and the Bottom 100 Megahertz of U-NII-8 Without AFC.

Broadcom urges the Commission to create a very-low-power category of devices that are permitted to operate indoors and outdoors at power levels of up to 14 dBm EIRP. To ensure that this important use case creates very limited risk of harmful interference to incumbents, Broadcom recommends that PSD be limited to 1 dBm/MHz for very-low-power portable APs and any associated client devices.[38] This action would open up a host of new

[38] *See* RLAN Group Comments at 68–69.

innovative short-range, peer-to-peer, and connectivity-sharing use cases—helping to maximize the 6 GHz band's value.

Ensuring that portable devices can take full advantage of U-NII-5, U-NII-7, and the lower 100 megahertz of U-NII-8 is critical to the success of the band.[39] Broadcom believes that the 6 GHz band will be essential to unlocking the immersive potential of portable augmented and virtual reality ("AR" and "VR") devices. Among its many benefits, 5G will bring to widely available mobile devices the low-latency and high-speed capabilities that AR and VR require, making these technologies increasingly ubiquitous.[40] Handheld mobile devices are, however, only part of the AR and VR ecosystem. To fully experience the learning, entertainment, and communications benefits that AR and VR offer, consumers will also use peripheral devices like gloves and goggles. Many, if not most, of these peripheral devices will connect to a 5G device through unlicensed technologies, leveraging capabilities in 802.11ax that can deliver sub-one-millisecond latency and gigabit data rates using contiguous 160-megahertz channels.[41] But this disruptive use case is only feasible if 6 GHz devices have reliable access to a clear channel. Opening the full five 160-megahertz channels across U-NII-5, U-NII-7, and the lower 100 megahertz of U-NII-8 to portable unlicensed operations will help ensure that a clear channel is reliably available. Just like the original U-NII rulemaking fueled the development of the Wi-Fi industry, the creation of a very-low-power category will lead to AR and VR going mobile.

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[39] Here again, the Commission should also authorize operations at higher U-NII-8 frequencies in places where there is no authorized BAS TV pickup licensee.

[40] *See* Pablo Iacopino et al., GSM Association, The 5G Era in the US 10 (2018), https://www.gsmaintelligence.com/research/?file=4cbbdb475f24b3c5f5a93a2796a4aa28&download.

[41] *See* Cisco Report at 4.

Very-low-power 14 dBm portable, battery operated devices would operate in geometries and at sufficiently low powers to pose no real-world risk of harmful interference to FS operations. For example, a portable device operating in a 160-megahertz channel at 14 dBm EIRP would have a transmitted PSD of only -8 dBm/MHz (157 uW/MHz). Even a 20-megahertz transmission would amount to a meager 1 dBm/MHz. To reduce the risk of harmful interference, Broadcom suggests that the Commission cap the maximum transmitted PSD to 1 dBm/MHz for this device class (*e.g.*, 14 dBm radiated energy scales to 1 dBm/MHz radiated PSD). Such very-low-powered operations in typical usage scenarios would not cause harmful interference into FS links. FS links have very high link margins (typically 37 dB according to the National Telecommunications and Information Administration), which would keep links operating in the presence of these faint RLAN signals.[42] The Commission should permit such devices to operate in the U-NII-5 and U-NII-7 bands, and in the lower 100 megahertz of the U-NII-8 band.

Power Levels. Battery-operated mobile devices that are typically used on a portable basis are capable of operating at conducted power levels around 18.5 dBm (and to meet the specific absorption rate ("SAR") limits mandated by the Commission to limit RF energy into the human body).[43] These handsets typically have negative gain antennas, and will typically emit EIRP less than 14 dBm. For example, filings in the FCC's equipment

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[42] National Telecommunications and Information Administration, NTIA Report 05-432, Interference Protection Criteria, Phase 1 – Compilation from Existing Sources Table 4-1 (FS DMS Default Values in Appendix 7 of ITU-R Radio Regulations), https://www.ntia.doc.gov/files/ntia/publications/ipc_phase_1_report.pdf.

[43] *RF Safety FAQ*, Federal Communications Commission, https://www.fcc.gov/engineering-technology/electromagnetic-compatibility-division/radio-frequency-safety/faq/rf-safety#Q5 (last visited Feb. 13, 2019).

certification database show that 5 GHz Wi-Fi in a handset will typically operate with an antenna gain of -6 to -8 dBi per antenna.[44] While the peak gain for both antennas will be typically a few dB higher (-4 to -6 dBi), this assumes a near perfect correlation for both antennas, which has a very small probability of occurring in the real world. As Broadcom's measurements of a 2017 smartphone show, the EIRP of the entire system is typically well below 14 dBm EIRP in any single direction.

Figure 14: Radiated Power Measurements from 2017 Smartphone

This is because such devices typically have two antennas, and the antenna polarization and peak power will not be perfectly correlated as indicated in the antenna analysis for low power indoor devices above.[45] For a portable device, 10 dBm EIRP or less would be a

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44 *See, e.g.*, Samsung Electronics Co., Ltd., FCC ID A3LSMG960U, UNII Test Report 1 (submitted to Office of Engineering and Technology, Federal Communications Commission, Dec. 22, 2017), available at https://apps.fcc.gov/oetcf/eas/reports/ViewExhibitReport.cfm?mode=Exhibits&%20RequestTimeout=500&calledFromFrame=N&application_id=%2BZTZhonvwc6u0ndFKcTALw%3D%3D&fcc_id=A3LSMG960U; Samsung Electronics Co., Ltd., FCC ID A3LSMG965U, UNII Test Report 1 (submitted to Office of Engineering and Technology, Federal Communications Commission, Dec. 22, 2017), available at https://apps.fcc.gov/oetcf/eas/reports/ViewExhibitReport.cfm?mode=Exhibits&RequestTimeout=500&calledFromFrame=N&application_id=e8S9YVFhRlzYBcndtf0jSg%3D%3D&fcc_id=A3LSMG965U.

45 *See supra* at 14–16.

conservative assumption for energy emitted in any single direction.[46] We can, based on ITU Report M. 2292-0, conservatively expect client devices operating between 3 GHz and 6 GHz to experience 4 dB of body loss.[47]

Network Geometry. Very-low-power portable devices present no real-world risk of harmful interference to FS operations. Portable network geometries typically position unlicensed devices, including those in moving vehicles, well outside the boresight of an FS receiver or well away from the receiver. As discussed above, the average FS receiver is 43 meters high. For reasons similar to our analysis of network geometry for low-power indoor devices, a portable device operating at a height of 1.5 meters—at or above upper body height for most standing and sitting adults outdoors or in a moving vehicle—will either be off-axis (and subject to the rejection properties described above) or a significant distance away. Here again, a portable device operating at an elevation angle of 2 degrees or less from the center of the main beam will be more than a kilometer from the receiver and would still be over 1 degree outside of the main beam.

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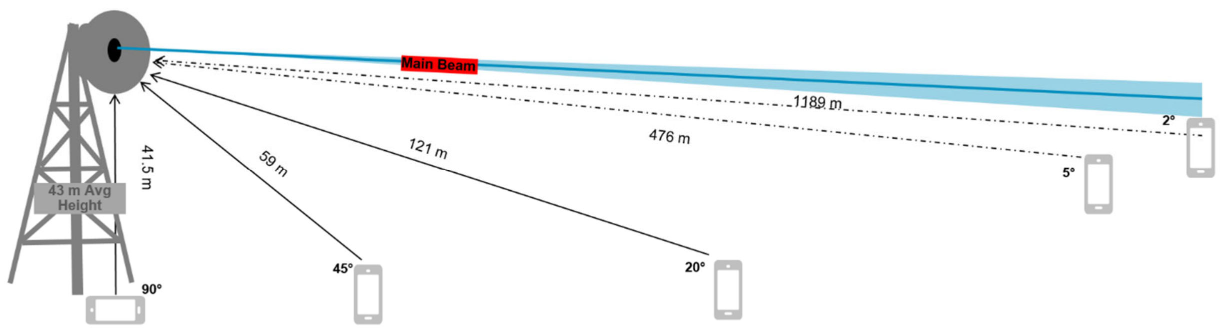
46 To support this conclusion, we conducted over-the-air measurements of EIRP in an anechoic chamber using a popular mobile phone model transmitting in test mode in the 5 GHz band. To account for positioning effects, we took measurements with the phone oriented in different positions: flat on the table, back side pointing up, back side rotated 90 degrees, front side up, and front side rotated 90 degrees.

47 International Telecommunication Union, Report ITU-R M.2292-0, Characteristics of Terrestrial IMT-Advanced Systems for Frequency Sharing/Interference Analyses 7–8 tbl.2 (2013).

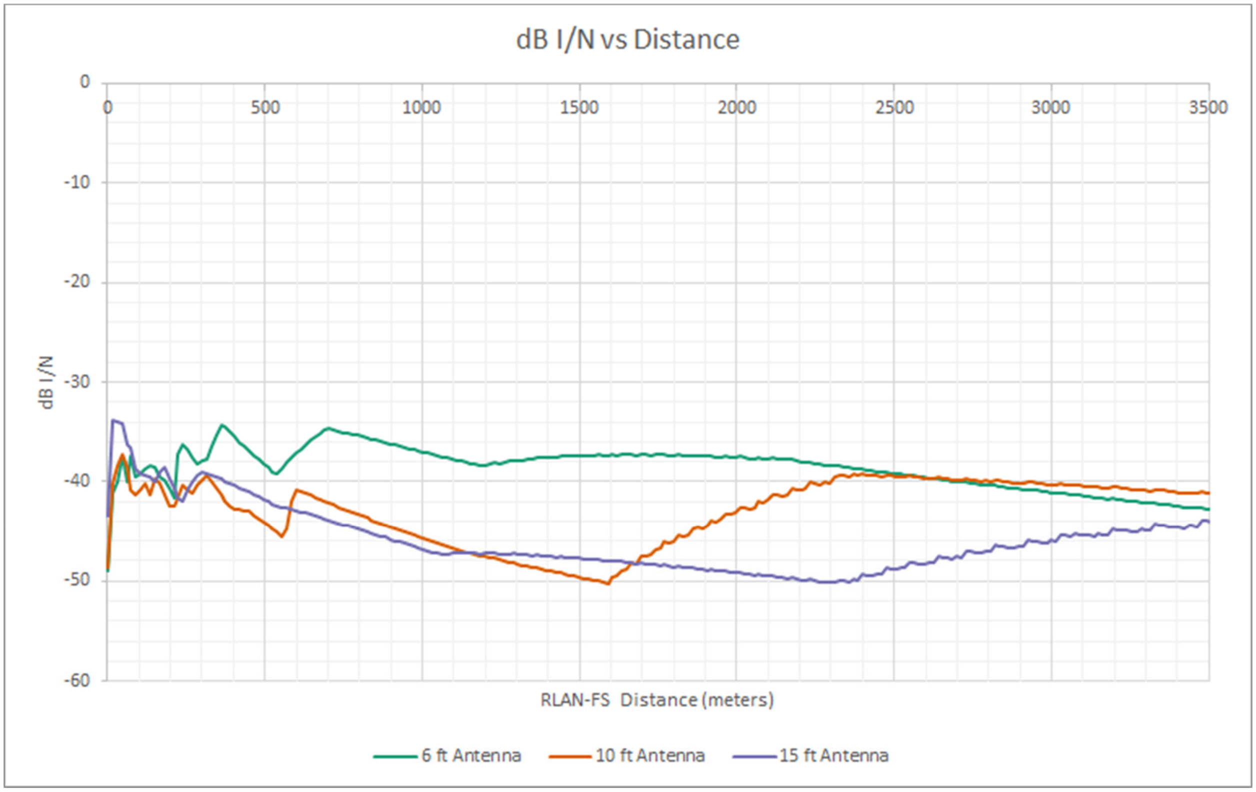
Figure 15: Network Geometry of FS Receiver (43 meters) and Portable Outdoor RLAN (1.5 meters)



The WINNER II Non-LOS and LOS path loss models confirm that sharing is feasible in these typical scenarios.[48] For non-rural scenarios, the WINNER II Non-LOS path model clearly demonstrates that sharing works when a very-low-power portable device is operating outdoors. Applying the power limits and additional sources of attenuation discussed above, for a device transmitting on a 160-megahertz channel at a total of 14 dBm radiated power, the WINNER II model shows that interference at the FS receiver would not exceed -32 dB I/N, far below any reasonable threshold for harmful interference.

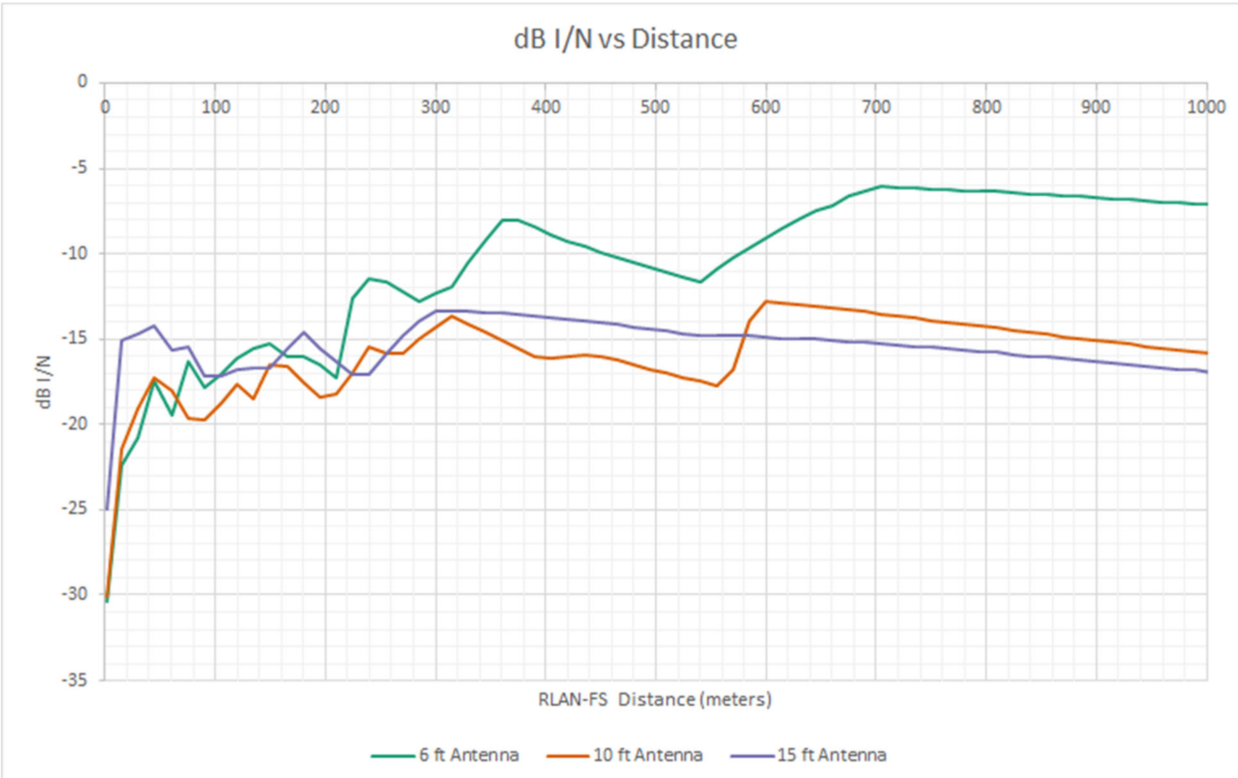
[48] *See supra* at 17–18 (explaining why these are the preferred propagation models).

Figure 16: WINNER II Non-LOS Results for a Device Transmitting on a 160-Megahertz Channel



Even when we assume a clear line-of-sight between the RLAN and the FS receiver, sharing is still safe. Applying the WINNER II LOS model, as illustrated in Figure 17 below, none of the three antennas modeled never exceeds -6 dB I/N. One antenna begins to approach -6 dB I/N when the RLAN and FS receiver are approximately 700 meters apart and does not cross that interference threshold.

Figure 17: WINNER II LOS Results



III. The Commission Should Adopt Power Spectral Density Limits that Allow Devices to Take Advantage of OFDMA Techniques.

While the Commission has proposed reasonable access point power levels, the NPRM's proposals related to PSD limits are more restrictive than necessary to protect incumbents in the band. To facilitate the modulation scheme used in OFDMA, and to unlock its efficiency and quality of service benefits, the Commission should align total power with PSD over 2-megahertz channels: 27 dBm/MHz for RLANs controlled by the AFC and 21 dBm/MHz for low-power indoor devices.[49] These rules will allow operators to take advantage of the efficiencies in OFDMA.

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[49] Note that for very-low-power portable APs we recommend the Commission limit operations to 1 dBm/MHz PSD to ensure that such devices do not create harmful interference in the event the device is operating outdoors in a worst-case geometry.

In 802.11ax, OFDMA uses transmissions between an AP and a client device (and vice versa) on bandwidths as small as 2 megahertz. The Commission should ensure that devices can exploit advantages of OFDMA, especially on the uplink direction where each user may transmit in a narrow bandwidth (*e.g.*, 2 megahertz) with higher PSD limits. This is very important to address downlink/uplink power imbalance and close the communication link, which significantly increases the range of the communication system.[50]

In Uplink OFDMA ("UL-OFDMA"), the AP specifies the transmit power used by each station in order to meet target receiver signal-to-interference-plus-noise ratio for the selected rate; hence Transmit Power Control ("TPC") is built in to UL-OFDMA. This provides significant reduction in total transmit power compared to legacy uplink transmissions without TPC (or with loose TPC rules). Most of this traffic is driven by residential video where the number of stations simultaneously sending uplink traffic to the same AP is small, hence most of the time an uplink packet containing data will only be sent by one user—but OFDMA is still needed in this case because it allows stations to "make the link" by focusing the same amount of energy into a narrower bandwidth. Rules, like those the NPRM proposes, that restrict a client device from being able to reach the allowed EIRP limit even when only transmitting in a 2-megahertz narrowband resource unit, would significantly impinge on those operations.

The changes described above to facilitate OFDMA are feasible, and they would be a great improvement over the NPRM's proposed PSD limit, which is not well aligned with the needs of the 6 GHz band and its incumbents. The Commission's proposal of 17 dBm/MHz

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[50] In most cases, downlink transmit power is 10 dB or greater than the user device's uplink power.

is similar to the existing U-NII-1 rules, which were designed to protect a different type of incumbent operation.[51] In selected PSD limits for U-NII-1, the Commission's goal was to protect Globalstar's Mobile Satellite Service feeder uplinks in the 5096–5250 MHz band.[52] Those satellites operate at approximately 1200 kilometer altitude. The geostationary satellites operating in the Fixed Satellite Service in the 6 GHz band are positioned about 30 times higher, at approximately 36,000 kilometers altitude. A single unlicensed device would experience 30 dB more in path loss before interfering with a geostationary satellite. As explained in the RLAN Group Comments, adjusting the NPRM's proposal to 27 dBm/MHz for RLANs controlled by the AFC would not increase the risk of harmful interference from standard-power RLANs because it would be accounted for in the AFC.[53]

IV. The Commission Should Allow Client Devices to Operate at the Same Power Level as the Access Point with which They Are Associated.

To facilitate innovative uses of Wi-Fi, the Commission should also allow all client devices operating in the 6 GHz band to transmit at the same power and PSD as the AP with which they are associated. In the NPRM, the Commission proposes to limit client devices' maximum conducted output power to 63 milliwatts and a maximum PSD of 5 dBm per megahertz.[54] Those proposed limits are much lower than the Commission's proposals for standard-power and low-power APs, and that difference will result in unbalanced links that allow client devices to send signals over distances much shorter than they can receive signals. For certain use cases, that imbalance could create debilitating limits on two-way

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[51] *See* NPRM ¶ 78; *see* 47 C.F.R. § 15.407(a)(1).

[52] *See generally* Globalstar, Inc. Petition for Notice of Inquiry Regarding the Operation of Outdoor U-NII-1 Devices in the 5 GHz Band, Docket No. RM-11808 (filed May 21, 2018).

[53] *See* RLAN Group Comments at 68–69.

[54] NPRM ¶ 78.

communication. For example, virtual reality user equipment creates massive amounts of uplink data that must be transmitted back to the AP. If client-device power levels are too low, the range of the AP is effectively limited because the AP needs communication back from the client device to determine that data has been received and decoded. Because the interference analysis above applies to client devices (with the exception of the fixed downward tilt of common ceiling-mounted access points), as reflected in the RLAN Group Comments, the Commission can increase client-device power limits without increasing risk to FS links and other band users.[55]

V. The Commission Should Allow Standard-Power Operations in the Bottom 100 Megahertz of the U-NII-8 Band.

Standard-power RLANs should be allowed to operate in unused frequencies or outside of BAS coverage areas, similar to how the Commission has enabled FS to share those bands today. As the Commission has correctly recognized, standard-power outdoor RLANs can coexist with existing licensees in U-NII-5 and U-NII-7 using AFC.[56] For the reasons described above, and documented in the RLAN Group Comments, RLANs pose little threat to FS operations in those bands—and in the lower 100 megahertz of the U-NII-8 band and at higher frequencies in locations where there is no authorized BAS TV pickup licensee.[57] While sharing in the U-NII-8 band also requires RLANs to protect mobile operations, the Commission can confidently extend standard-power RLAN operations into the bottom 100 megahertz of U-NII-8, where there has not been significant investment in

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55 *See* RLAN Group Comments at 49.

56 NPRM ¶¶ 22–23.

57 *See* RLAN Group Comments at 46–47.

Mobile BAS infrastructure. Adjusting the NPRM's proposal in this way will increase investment in the band by opening up an additional 160-megahertz channel that straddles the U-NII-7 and U-NII-8 bands.[58]

VI. The Commission Should Support the Use of the 6 GHz Band for Wireless Broadband Service in the Standard-Power Bands Under Part 15.

As the Commission has repeatedly recognized, mid-band spectrum is a scarce and valuable commodity that should be used as efficiently as possible. Because FS incumbents are clustered in certain parts of the country, the 6 GHz band presents expansive opportunities for unlicensed uses in rural areas, where FS links are relatively rare. WISPs, many of whom are also point-to-point FS users in the 6 GHz band, are well positioned to take advantage of this opportunity.[59] The Commission should make minor modifications to its proposed power limits for outdoor devices operating in U-NII-5, U-NII-7, and the bottom 100 megahertz of U-NII-8 to facilitate WISPs' Part 15 operations.[60]

Authorizing outdoor point-to-point and point-to-multipoint operations in the 6 GHz band is in the public interest because it will support the efficient, low-cost expansion of broadband services to rural and underserved communities. As Chairman Pai has explained, "deployment in sparsely populated rural areas" is critical to "extend[ing] digital

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58 *See supra* Figure 13 at 28.

59 Letter from Stephen E. Coran, Counsel, Wireless Internet Service Providers Association, to Marlene H. Dortch, Secretary, Federal Communications Commission, at 3, GN Docket Nos. 17-258 & 17-183, ET Docket No. 18-295 (filed Oct. 17. 2018).

60 The Commission should also permit operations at higher frequencies in the 6 GHz band in locations where no BAS TV pickup licensee is authorized.

opportunity to all Americans."[61] Because WISPs already extensively use Part 15 operations in the neighboring (and congested) 5 GHz band, they will be able to quickly take advantage of the 6 GHz opportunity by modifying their 5 GHz equipment and leveraging their knowledge of FS operations to design systems that maximize their Part 15 operations while still protecting fixed links.

The Commission can maximize the 6 GHz band's benefit to fixed wireless broadband consumers by making minor changes to the NPRM's proposed power limits.[62] Client-device power levels higher than those proposed in the NPRM would permit better coverage in hard-to-serve areas. Specifically, the Commission should allow APs and clients to operate up to +18 dBm EIRP antennas, for a maximum of 36 dBm EIRP. These rules would allow coverage to extend 6 or more miles in sparsely populated areas where there are few incumbent FS operations. This proposal would also harmonize with the highly successful existing rules for the 5 GHz band, facilitating consistent operations across nearby channels.

Such changes pose no meaningful risk to licensees because an AFC is more than capable of enabling this important use case while protecting incumbent operations. As explained in the RLAN Group Comments, the Commission has correctly concluded that AFC systems will provide incumbent FS operations adequate protection from harmful interference by ensuring that no single unlicensed device causes an unacceptable noise increase at an FS receiver.[63] In nearly every respect, AFC systems that work for

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[61] Chairman Pai Proposes Over $500 Million In Funding To Promote Rural Broadband Deployment (Jan. 16, 2018), https://www.fcc.gov/document/chairman-pai-proposes-500-million-boost-rural-broadband.

[62] *See* NPRM ¶ 78.

[63] *See* RLAN Group Comments at 40–45.

conventional unlicensed operations will work in the same way for the outdoor point-to-point and point-to-multipoint operations WISPs require. As described below, the AFC rules should, while requiring strict performance criteria, be sufficiently flexible to facilitate a number of engineering and operational choices, which may vary across AFCs. An AFC specifically designed for point-to-point or point-to-multipoint operations might, using that flexibility, be designed to account for the narrow beamwidth of each RLAN link as it determines channel availability. Given the low risk such operations pose to existing 6 GHz users, the Commission should seize this opportunity to expand broadband access and take a significant step toward closing the digital divide.

VII. The Commission Should Ensure that the Rules Governing AFC Systems Are Simple and Facilitate Different Kinds of Uses.

The Commission's proposed AFC framework will protect incumbent FS operators and can be implemented in a cost-effective manner that will promote the adoption of unlicensed 6 GHz services.[64] The AFC systems will do so by allowing APs to "obtain a list of permissible frequencies from an AFC system prior to transmitting or a list of prohibited frequencies in which it cannot transmit."[65] Consistent with its goal that the AFC be "simple" and "easy to implement," the Commission should allow the market to develop many options rather than engaging in command-and-control regulation of engineering details.[66]

The only essential requirement should be that the AFC prevent unlicensed devices from operating in locations and on channels that risk causing harmful interference to licensed incumbent operations. To facilitate a variety of solutions, however, the

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64 *See id.* (explaining that an AFC system will prevent interference by ensuring that no single interferer will increase the noise at the FS receiver beyond a certain acceptable level).

65 NPRM ¶ 25.

66 *See id.*

Commission should give engineers as much freedom as possible to make engineering and design decisions regarding AFC systems—as long as they can provide the protection the FCC determines that FS systems require. The rules should authorize centralized and decentralized systems; cloud-based and device-based systems; open and proprietary systems; and profit and non-profit systems. The Commission's goal should be to adopt rules that authorize many types of AFC implementations that are simple, flexible, and customizable to meet the needs of many kinds of customers. Those rules will foster higher competition and lower costs, leading to more efficient use of the 6 GHz band.

Device Registration. Consistent with this approach, the Commission should not adopt a requirement that every device must register with every AFC, which would be unnecessary and burdensome.[67] Such an extreme registration rule would only be useful for databases that need to exchange information with each other about a specific device in order to manage aggregate interference by limiting the number of devices operating in any given channel in a given area. However, as the Commission recognized, aggregate interference to FS systems is not a concern in the 6 GHz band, so AFC operators need not exchange data between systems.[68] Here, where the goal is to limit the maximum interference from a single device, there is no need for cross-AFC communication and therefore no need for individual device registration.[69]

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[67] *Id.* ¶¶ 27–28.

[68] RLAN Group Comments at 41 (explaining that "any measurable interference to an FS receiver, if it occurs, will be caused by a single RLAN transmitter, not aggregate interference from multiple devices").

[69] For similar reasons, the AFC rules should not require AFC systems to record the frequencies used by each access point under AFC control.

Nor is device registration likely to be useful in the event of harmful interference. The only way such registration could be useful in resolving interference issues is via a unique transmit identifier for each RLAN user, combined with the ability of an incumbent licensee to contact the RLAN in the event of suspected interference. However, both incumbent FS operators and prospective RLAN operators have considered transmit identifiers but have dismissed the concept as unworkable.[70] Transmit identifiers would create additional costs and burdens for licensees, because licensees would first have to receive the identifier in the event of suspected interference, and then send a request to the RLAN device to cease operation. Receiving the identifier would not be trivial; the Commission would have to mandate the use of a particular technology for modulating the identifier signal, and licensees would need to acquire the new device (potentially including invasive use of a sniffer on the receiver antenna). The best way to prevent interference *ex ante* is through appropriate power limits, other technical rules, and device certification. The low utility of individual device registration is not worth the costs of such a requirement.

Indeed, such costs would be significant—a device registration requirement would not only impose additional burdens on licensed FS operators but would also impose costs on RLAN networks that would make operating in the 6 GHz band difficult or infeasible. Registering individual RLAN devices would require the collection, verification, protection, and synchronization of data on millions of individual consumers' devices, which would lead to far greater complexity than the uncomplicated AFC the NPRM proposed. Additionally,

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70 NPRM ¶ 87.

the collection and maintenance of such data would reduce the consumer appeal of RLAN devices by creating privacy concerns.

Proprietary Access. Broadcom supports the Commission's proposal to certify multiple AFC implementations and urges the Commission to adopt rules allowing any or all of the AFC system configurations it proposes.[71] If the Commission adopts sufficiently flexible rules, the market is likely to create opportunities for AFC systems that offer service to the entire span of unlicensed users, as well as more specialized AFCs serving a sub-set of those users, or proprietary AFCs for their own customers or that interoperate only with a particular manufacturer's devices. For example, an operator of a cloud-based AFC implementation might make its system available to multiple companies, while an equipment manufacturer might offer service on its own AFC only to users of its devices. Figure 18 demonstrates another possible configuration whereby the AFC system and AFC-controlled device are integrated, which is, as explained in additional detail in the RLAN Group Comments, one of many potential AFC system configurations.[72]

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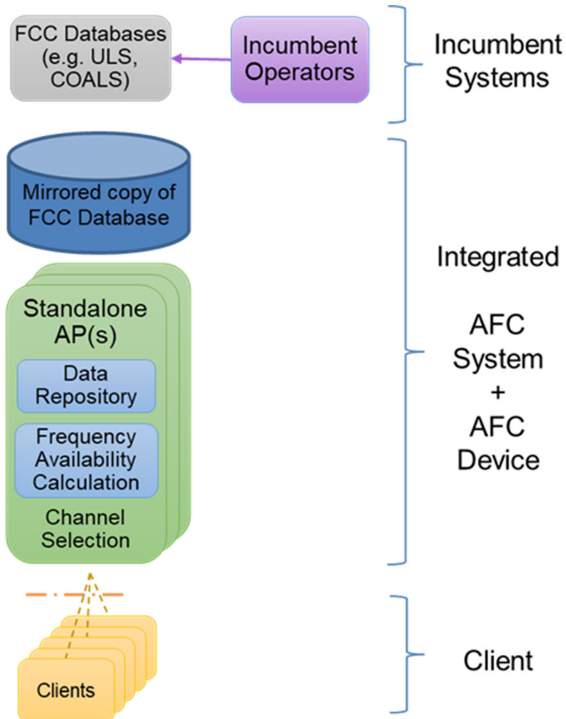
[71] *See id.* ¶ 33.

[72] *See* RLAN Group Comments at 59–63 (explaining several potential, and not mutually exclusive, AFC system architectures).

Figure 18: Standalone Access Point with Integrated AFC



AFC systems using various configurations can operate concurrently, meeting the needs of different kinds of users and creating multiple options that will ensure that the 6 GHz band is efficiently used by unlicensed services. The FCC should not prevent companies from adopting any number of possible business plans. The proprietary business model requires that AFC operators have the ability to restrict access to their systems and to enforce different requirements under their own AFC rules. Not every AFC must be open to all devices, and there is no non-arbitrary reason why every AFC system must be available to all. Unlike database systems in other bands that must exchange information, AFC systems will operate independently of each other. The function and value of AFC control in the 6 GHz band is to prevent harmful interference ahead of time by determining when and where any given RLAN device may operate without causing interference to the licensees.

VIII. The Commission Should Permit Standard-Power Portable Devices in the U-NII-5 and U-NII-7 Bands and in the Lower 100 Megahertz of the U-NII-8 Band.

The Commission should permit standard-power, portable APs to operate both indoors and outdoors, including in vehicles, throughout U-NII-5 and U-NII-7, and in U-NII-8 in the lower portion of the band and outside of licensed BAS coverage areas. As discussed fully in the RLAN Group Comments, standard-power operations are appropriate in the 6 GHz band because an AFC framework can use specific information from FS receivers and a robust propagation model to ensure that no single unlicensed device creates harmful interference to an FS receiver. Because the AFC can also protect incumbents from harmful interference from portable devices and those in vehicles, standard-power portable devices should be permitted to operate in the same bands used by non-portable standard-power RLANs.[73] The AFC can ensure that portable APs operate only in allowed frequencies through methods such as geofencing. Using geofencing, an AFC could determine allowed frequencies in a defined operating area. When a user leaves that area, the device would stop operating until the AFC provides new allowable frequencies for operations.

For even more efficient operation, AFC systems could develop protocols that allow standard-power portable APs to establish favorite locations (*i.e.*, home and office) or regular routes (*i.e.*, a commuter train line or bus route) that are pre-set through the AFC to ensure that they only operate in permissible frequencies and cannot cause harmful interference into an FS receiver. If the device moves outside of the locations for which the master device has received the permissible frequencies from the AFC, it would be unable to operate

[73] These devices would also be limited to 30 dBm (1 watt) conducted power and 36 dBm (4 watts) radiated power, and 27 dBm/MHz PSD.

unless and until the AFC provides new frequencies for the new location. The Commission adopted a similar protocol for 600 MHz unlicensed devices, which can pre-load information on channel availability for multiple locations and use that data to define a safe region where it can operate.[74] This feature could help provide efficient 6 GHz service for millions of Americans who, for example, regularly commute using public transportation that operates on a standard route.

Finally, the Commission should allow portable devices to operate in moving vehicles. Modern dual-frequency GPS technology allows for extremely high location precision because the algorithms for moving vehicles, especially those moving at higher speeds, account for the fact that the vehicle is constrained to a roadway or parking lot. AFC systems can effectively govern portable device operation in vehicles, provided that AFC master devices have received allowed frequencies from an AFC for all the areas in which they are operating. If an AFC master device cannot do so, the FCC equipment certification program should not certify it for mobile operation.

CONCLUSION

The 6 GHz band offers the Commission a perfect opportunity to secure the future growth of Wi-Fi and other unlicensed services. The NPRM's proposal lays out a framework that offers the promise of a vibrant and efficiently used band. To realize this promise, the Commission should adopt its proposed framework and make these important improvements:

1. Authorize low-power indoor unlicensed operations throughout the entire 6 GHz band;
2. Permit very-low-power portable devices to operate in U-NII-5, U-NII-7, and the bottom 100 megahertz of U-NII-8 without AFC.

[74] 47 C.F.R. § 96.39(a)(3).

3. Set PSD rules to facilitate OFDMA use;

4. Allow client devices to operate at the same power level as the access point with which they are associated;

5. Permit standard power access points to operate using AFC in the bottom 100 megahertz of the U-NII-8 band;

6. Set power limits for standard-power outdoor operations that promote broadband deployment;

7. Create simple, flexible, and customizable AFC rules; and

8. Permit standard-power portable devices to operate under AFC control and very-low-power portable devices to operate without AFC.

These changes will promote innovation, rapid rollout of devices, and avoid imposing detailed and over-regulatory strictures that could undermine innovation.

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