Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington DC 20554

In the Matter of	)	
	)	
Revision of Part 15 of the Commission's Rules	)	ET Docket No. 13-49
to Permit Unlicensed National Information	)	
Infrastructure (U-NII) Devices in the 5 GHz Band	)	

REPLY COMMENTS OF DR. ELI YABLONOVITCH

I, Dr. Eli Yablonovitch, respectfully submit these Reply Comments in the above-captioned proceeding in support of the Commission's proposals addressing interference concerns between consumer Wi-Fi devices and long-distance point-to-point links in the ISM Band while at the same time increasing spectrum available for U-NII operations.[1]

I. BACKGROUND

I am a Professor of Electrical Engineering and Computer Sciences at UC Berkeley, where I hold the James & Katherine Lau Chair in Engineering. I am also a Fellow of the IEEE, the Optical Society of America, and the American Physical Society and the Director of the National Science Foundation Center for Energy Efficient Electronics Science, a multi-University Center based at the University of California-Berkeley.

I have had the honor to be elected as Member of the National Academy of Engineering (NAE), the National Academy of Sciences (NAS), and the American Academy of Arts & Sciences (AAAS), as well as a Foreign Member of the Royal Society of London. I have been awarded the Harvey Prize (Israel), the IEEE Photonics Award, the IET Mountbatten Medal (UK), the Julius Springer Prize, the R.W. Wood Prize, the W. Streifer Scientific Achievement Award, and the Adolf Lomb Medal. I also have an honorary Ph.D. from the Royal Institute of Technology, Stockholm, and from the Hong Kong Univ. of Science & Technology.

I received my Ph.D. degree in Applied Physics from Harvard University. I worked for two years at Bell Telephone Laboratories, and then became a professor of Applied Physics at Harvard. I joined the University of California, Los Angeles, in 1992 as the Northrop-Grumman Chair Professor of Electrical Engineering.[2] As an entrepreneur, I am the Co-Founder of Ethertronics Inc., the world-wide leading independent supplier of cellphone antennas.

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[1] *Unlicensed National Information Infrastructure (U-NII) Devices in the 5 GHz Band*, Notice of Proposed Rulemaking, 28 FCC Rcd 1769 (Feb. 20, 2013) ("*Notice*").

[2] More information is available at the following site: http://www.eecs.berkeley.edu/Faculty/Homepages/yablonovitch.html.

II. SUMMARY

In the *Notice* in this proceeding, the Commission proposed making additional spectrum available in the U-NII-1 (5.15-5.25 GHz), U-NII-2B (5.35-5.47 GHz), and U-NII-4 (5.85-5.925 GHz) bands. The agency also proposed extending the upper edge of the U-NII-3 (5.725-5.825 GHz) band to 5.85 GHz. The *Notice* seeks comment on the technical rules that should apply to these new bands. As discussed in more detail below, the potential for interference to consumer Wi-Fi devices is prevalent in these bands. Accordingly, the Commission should apply the more stringent rules governing the U-NII-2A band to the U-NII-1, U-NII-2B, and U-NII-4 bands. This would minimize potential interference scenarios and likely permit the development of new broadband products capable of operating at higher data rates than is now possible.

In addition, the Commission is considering harmonizing its rules governing the operation of digital devices in the ISM Band (5.725-5.85 GHz) under Section 15.247[3] of its rules. The Commission proposed consolidating all equipment authorizations for digitally modulated devices under the same Section 15.407 U-NII rules.[4] This proposal is grounded in the public interest and should be adopted. It will increase the utility of the U-NII-3 band by standardizing equipment authorizations with other U-NII bands and eliminating various interference scenarios between consumer Wi-Fi devices and long-distance, point-to-point links currently operating in the ISM band.

III. REPLY COMMENTS

The Commission's rules governing devices in the ISM Band allow fixed point-to-point systems to utilize unlimited antenna gain.[5] In contrast, the Commission's rules governing U-NII-3 devices require a 1 dB reduction in power for every 1 dB the antenna gain exceeds 23 dBi for point-to-point links.[6]

The *Notice* proposed eliminating the distinction between the ISM and U-NII-3 bands to standardize operations, decrease the complexity associated with administration, maintenance, and enforcement of these rules, and reduce interference.[7] The Commission proposed to apply the more stringent antenna gain limitations currently required under Section 15.407 of its rules across both bands to "ensure that there is no increase in the potential for interference from unlicensed devices operating under the new combined rule parts."[8] At the same time, the *Notice* proposed increasing the amount of spectrum available for unlicensed operations in the 5 GHz band by authorizing an additional 195 MHz of bandwidth. Both proposals will increase the

[3] 47 C.F.R. §15.247.

[4] *Notice* ¶¶ 27-28.

[5] 47 C.F.R. §15.247.

[6] 47 C.F.R. §15.407.

[7] *Notice* at ¶26.

[8] *Id.* at ¶33.

functionality of these bands while maximizing use and should be adopted with appropriate technical requirements for the additional spectrum.

The disparity in antenna gain limitations between U-NII-3 and ISM bands should be eliminated to protect services currently authorized in the U-NII bands, simplify the equipment authorization process, and reduce certification costs for manufacturers.[9] Removing the disparity and adopting the more stringent antenna gain requirements proposed by the Commission in the *Notice* will facilitate multiple operations on these frequencies by minimizing the likelihood of various interference scenarios between long-distance, point-to-point links in the ISM band and consumer Wi-Fi networks using the U-NII-3 band.

A. The Commission Should Eliminate the Distinction in Antenna Gain Between the U-NII-3 and ISM Bands

The Wireless Internet Service Providers Association ("WISPA") urges the Commission to preserve the current rules for the ISM band, arguing that its members provide service to more than three million rural consumers using the more permissive antenna gain in the ISM Band for point-to-point long-haul links.[10] WISPA claims other unlicensed bands are not available for this purpose.[11] Though no alternative unlicensed bands afford users the relaxed antenna gain limitations of the ISM band, alternative spectrum in fact exists for WISPA's members to provide point-to-point long-haul links in rural areas.

i. Alternative Spectrum Exists for Wireless Internet Service to Rural Communities

If the Commission adopts its proposed rule changes, WISPA's members could still provide wireless Internet service via unlicensed frequencies by deploying additional antennas.[12] However, WISPA's members are not limited to providing wireless Internet service via unlicensed frequencies. Under Part 101 of the Commission's rules, service also may be provided through licensed microwave links in the 6 GHz or 11 GHz bands. The Commission's rules permit 60 MHz-wide channels for point-to-point operations in the 6 GHz band and 80 MHz-wide channels in the 11 GHz band.[13] Based on a limited review of the Commission's Universal Licensing System, it appears that sufficient spectrum exists for WISPA's members to provide these services in rural areas in both bands.[14] In addition, the emergence of new technologies like

[9] *Id.* at ¶26.

[10] WISPA Comments p. 2.

[11] Id. pp. 12-13.

[12] Id. p. 14.

[13] *Facilitating the Use of Microwave for Wireless Backhaul and Other Uses and Providing Additional Flexibility To Broadcast Auxiliary Service and Operational Fixed Microwave Licensees*, 77 Fed. Reg. 54426 ¶35 (Sept. 5, 2012); 47 C.F.R. §101.109(c).

[14] *See, e.g., In Re Deployment of 11 GHz, 18 GHz, and 23 GHz Microwave Bands – Report Pursuant to Section 6412 of the Middle Class Tax Relief and Job Creation Act of 2012*, Report to Congress, DA 12-1880, (Rel. Nov 20, 2012).

XPIC and MIMO techniques each double the bandwidth available through these licensed channels and higher modulations increase bandwidth as well.

WISPA argues that the Commission's current rules for the ISM Band promote the efficient deployment of equipment because operators need not wait for an FCC license to begin operating. However, the Commission's rules permit an expedited prior coordination notice period for the 6 and 11 GHz bands[15] while affording applicants the ability to operate under conditional temporary authority once an application has been filed with the Commission.[16] As a result, equipment may be deployed in the 6 GHz and 11 GHz licensed bands nearly as efficiently as on unlicensed frequencies if the operator initiates the licensing process at the same time it purchases equipment and negotiates a tower lease.

In addition, WISPA complains the proposed changes will require its members to upgrade existing equipment at substantial cost.[17] At the same time, however, WISPA urges the Commission to mandate equipment upgrades in the future if necessary to address the agency's interference concerns with Terminal Doppler Weather Radar ("TDWR") facilities.[18] While the Commission may wish to address WISPA's complaint by grandfathering existing ISM equipment while freezing future deployments inconsistent with the new requirements, the expense of transitioning to a licensed 6 GHz or 11 GHz system should not be substantially more than the cost associated with upgrading equipment once the equipment has reached end-of-life and is replaced.

ii. The Commission's Proposed Rules Will Reduce the Risk of Interference to TDWR and Consumer Wi-Fi Devices

WISPA claims higher gain antennas in the ISM band "could in no way contribute to interference to TDWR facilities."[19] The Commission's *Notice* succinctly detailed issues of interference to TDWR caused by U-NII devices.[20] There are only about 50 TDWRs in the United States, yet even with this small number the Commission is rightly concerned with interference to these facilities caused by unlicensed, point-to-point links.

While the potential for interference to TDWR facilities is important, the Commission should not overlook the significant potential for unlimited-gain antennas to interfere with much more widespread consumer Wi-Fi devices. Without adopting the proposed changes to its rules, the Commission could expect to see many more similar instances of interference to the countless Wi-Fi networks across the country.

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[15] 47 C.F.R. 101.103(d)(2)(vi).

[16] 47 C.F.R. §101.31.

[17] WISPA Comments, p iii.

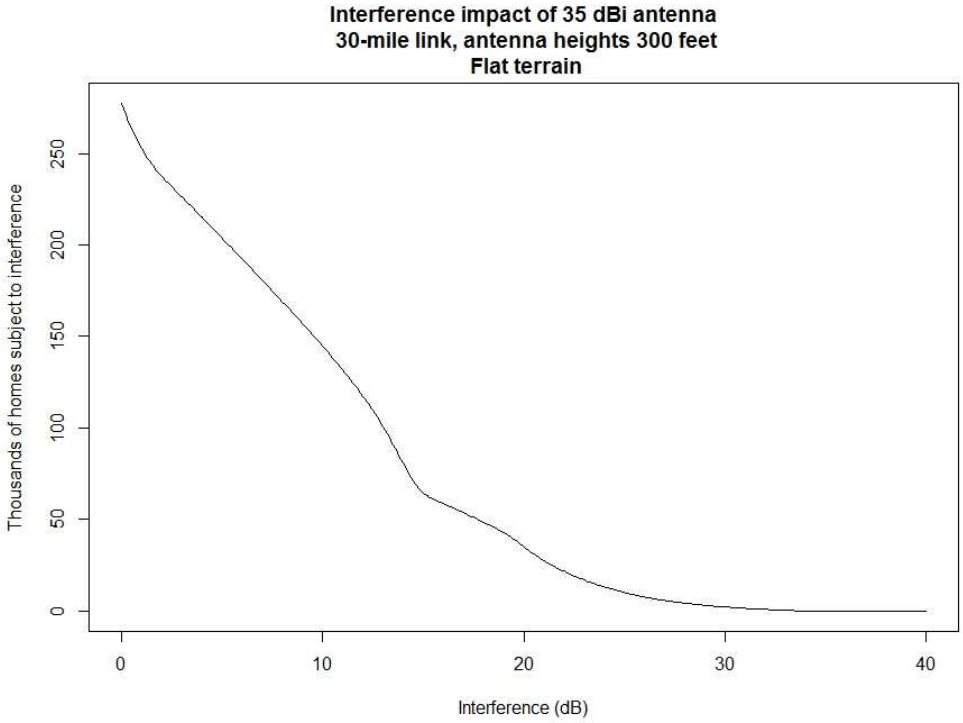
[18] Id. p. 15.

[19] Id. p. 13.

[20] *Notice* at ¶66. Unlicensed devices certified to operate in the ISM band were modified to operate at high power in other U-NII bands and, as a result, caused interference to TDWR facilities.

The Commission's current rules permitting unlimited gain and a stronger signal in the ISM band may allow WISPA's members to penetrate further in rural areas, but they also threaten to interfere with consumer Wi-Fi applications. Based on our calculations summarized in the graph below, a single point-to-point long-haul link operating under the Commission's current ISM band rules potentially threaten tens of thousands of consumer Wi-Fi devices to varying degrees. The chart estimates the cumulative number of homes potentially impacted by a typical high-gain, point-to-point link in a suburban area.[21]

A single unlicensed long-haul link may cause receive signal strength intensity ("RSSI") to hundreds of thousands of consumer Wi-Fi devices that significantly exceed the noise floor of those devices depending on the proximity of the Wi-Fi device to the unlicensed antenna. This interference means an increased RSSI is required for consumer Wi-Fi devices to achieve the required signal-to-noise ratio ("SNR") levels necessary to function properly. In some cases, the increase in RSSI necessary for the Wi-Fi device to achieve the required SNR level to function properly is significant. If the Commission retains its relaxed antenna gain rules for the ISM band or applies these liberal rules to other U-NII bands, it is possible that thousands of long-haul links may be constructed nationwide, each of which could interfere with thousands of consumer Wi-Fi devices.



[21] This is a challenge and does not factor in topographical elements (natural or man-made). In this estimate, interference (dB) is the difference between the RSSI and the noise floor. We used the following technical parameters: Tx Power (30 dBm), Tx Antenna Gain (35 dBi), Rx Antenna gain (-3 dBi), Frequency (5.8 GHz), Noise Floor (-93 dBm), antenna height (300 feet), link distance (30 miles), housing density (3,000 homes/mi^2).

This interference calculation was conducted over a typical suburban terrain. Less interference is predicted in rural areas where there are fewer households, but significantly more interference should be expected in urban areas where a single link could irradiate entire apartment buildings.

The potential for interference to consumer Wi-Fi devices is not only great in urban areas, but increases significantly along with antenna gain. The graph below plots the cumulative number of houses reasonably predicted to receive a given interference level (measured in dB) based on various antenna gains. The number of impacted houses is proportional to the square root of antenna gain. This graph makes it clear that as antenna gain increases, the potential for interference to consumer Wi-Fi devices also increases. Hundreds of thousands of homes and Wi-Fi devices are potentially impacted by a single long-haul link relying on an unlimited gain antennas.

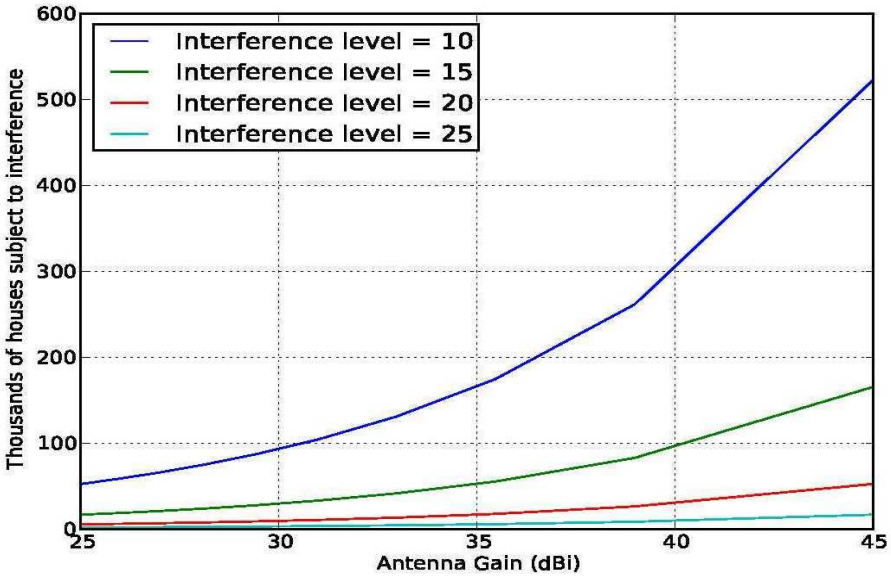


Figure 2: Number of impacted houses by different interference levels for a range of antenna gains.

The interference problem becomes clearer when considering a typical long-distance, point-to-point link in the ISM band with the same technical parameters used to create the chart above: Tx Power (30 dBm), Tx Antenna Gain (35 dBi), Frequency (5.8 GHz). In the 5 GHz U-NII bands, a Wi-Fi device may have an omnidirectional antenna gain of approximately -3 dBi.[22] Taking into account free space loss, the received signal strength intensity at *d* miles from the transmitting antenna is equal to:

Transmitter Power+Transmitter Antenna Gain+Receiver Antenna Gain-20log(d)-20log(Frequency)-96.6dBm

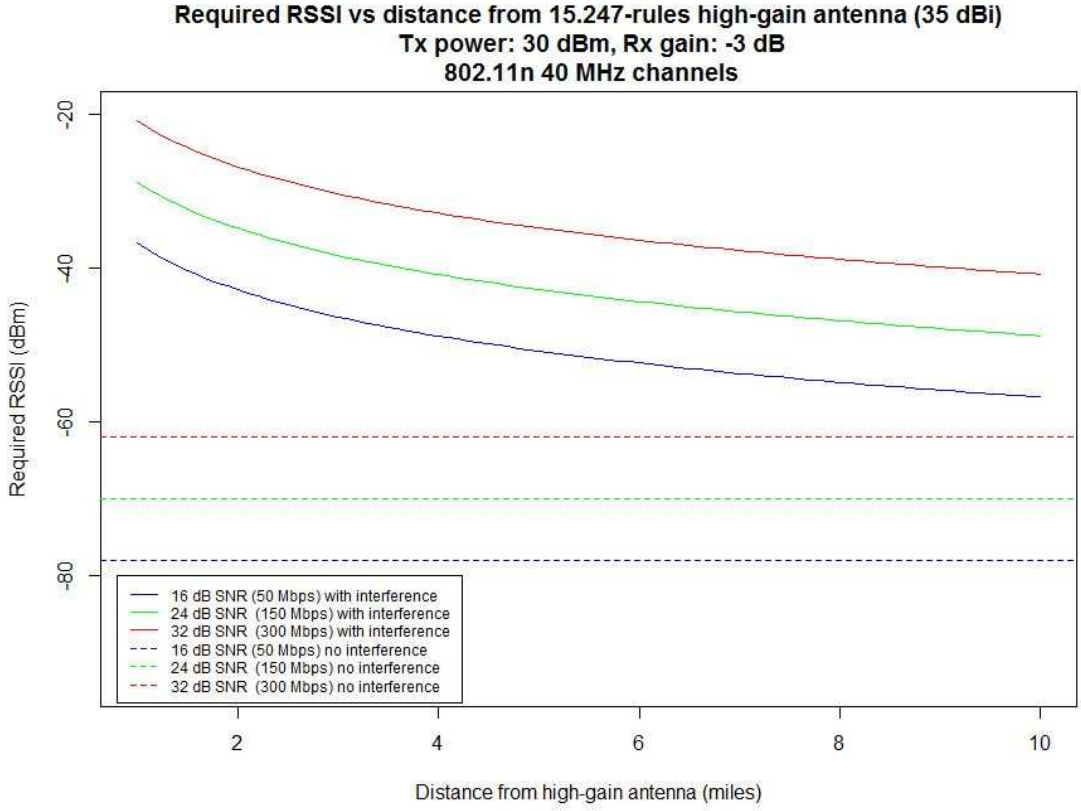
[22] This is the antenna gain value of an iPhone 5.

Even at distances of 10 miles, this translates into an RSSI of approximately -70 dBm, well above a typical noise floor value of -93 dBm.

The IEEE 802.11n standard is a wireless networking standard that uses multiple antennas to increase data rates. Under this standard, to properly demodulate a 40 MHz-wide channel at 5 GHz, the recommended SNR[23] ranges from 14 dB (for a data rate of 30 Mbps) to 32 dB (for a data rate of 300 Mbps). With an interference strength of $RSSI_{INT}$ dBm, the Wi-Fi RSSI would have to be:

$$RSSI_{Wi\text{-}FI} = RSSI_{INT} + SNR$$

The table below shows the required Wi-Fi RSSI versus the distance from the interfering transmitter for various data rates. The horizontal lines show the much lower required RSSI when no interference is present. As noted above, even at distances of 10 miles, a long-haul link in the ISM band creates significant interference to consumer Wi-Fi devices. The Commission's proposal will significantly reduce the interference risk to consumer devices.



The interfering signal is strong over long distances and many towns and neighborhoods are exposed to potential interference. Consequently, there are many opportunities for long-haul

[23] *See*, Cisco Unified Wireless Site Survey 2012, Table 3-1.

point-to-point links in the ISM band to interfere with widely available consumer Wi-Fi networks. These interference opportunities are greater in urban settings, where Wi-Fi users are concentrated, and will increase as Wi-Fi usage continues to expand rapidly into suburban and rural areas.

This potential interference reinforces the desirability of jettisoning the unlimited gain rules applicable to the ISM band or, even better, relocating WISPAs members' long-haul, point-to-point links from the unlicensed 5 GHz band to the licensed 6 GHz or 11 GHz bands. Spectrum is available in these bands in rural settings and, though these bands likely are more congested in urban areas, the risk of interference from the high-powered operations in the ISM band is more prevalent in urban settings as well.

One additional interference concern the Commission should consider is with the neighboring Dedicated Short Range Communication Service ("DSRC") in the 5.85-5.925 GHz band. The *Notice* points out that TDWR facilities could receive interference from unlicensed users that illegally modified their equipment to broadcast in the adjacent TDWR band.[24] Similarly, owners of unrestricted gain links could modify equipment to broadcast in the adjacent UNII-4 band, which is allocated for primary DRSC use. Many commenters urged the Commission to protect DSRC operations.[25] By instituting the proposed changes to the permitted antenna gain, these revisions will help reduce future public safety risks.

WISPA downplays the potential for interference in its comments by stating that "higher-gain antennas achieve their extra gain by narrowing their antenna beamwidth. This narrower antenna beamwidth actually *decreases* the likelihood of interference of all kinds. The narrower beamwidth is *less likely* to impinge upon any antenna other than the desired receiving antenna."[26] However, the potential interference is not resolved by increasing the power and narrowing the beamwidth. Such changes merely modify the area potentially impacted by the signal.[27]

WISPA noted that the stricter requirements on antenna gain could lead long distance links to stop using the ISM/U-NII-3 band. This would not be a negative development from the consumer perspective. Rather, it would protect consumer Wi-Fi devices by reducing the likelihood of interference, while promoting the public safety by protecting DSRC and TDWR facilities from potential interference.

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[24] *Notice* at ¶9.

[25] Several parties in this proceeding highlighted potential DSRC interference concerns, including the Alliance of Automobile Manufacturers, the Arizona and California Departments of Transportation, Ford Motor Company, Toyota Motor North America, and the National Transportation Safety Board ("NTSB"). Though the NTSB is not opposed to spectrum sharing, it urged the Commission to ensure that expanding access to the U-NII-4 band not result in interference to DSRC operations.

[26] WISPA Comments pp. 13-14 (emphasis in original).

[27] Increasing the power to broadcast longer links would narrow the beamwidth and change the area of potential interference from a circle or square near the antenna to a long rectangle that extends much further from the antenna in a narrower direction.

B. The Commission Should Make Additional Spectrum Available for Unlicensed Operations with Existing Technical Limitations of 15.247

A primary purpose of the *Notice* was to make additional spectrum available to increase wireless broadband access and investment.[28] One facet of this increased spectrum is to expand the upper edge of the U-NII-3 Band to 5.85 GHz. As the Commission noted, this extra 25 MHz of spectrum would provide an incentive for device manufacturers to certify devices under Section 15.247 of the Commission's rules rather than under Section 15.407.[29] This expansion also will "allow U-NII-3 devices to operate across the full range of spectrum that can currently be accessed by digitally modulated devices under Section 15.247."[30]

The Commission should expand the U-NII-3 Band and provide additional unlicensed spectrum for U-NII operations as proposed in the *Notice*. The interference concerns outlined above for consumer Wi-Fi devices, TDWR facilities, and DRSC devices are as great or greater in the other U-NII Bands. Accordingly, the Commission should apply the same technical limitations proposed in the *Notice* to any additional unlicensed spectrum allocations.

The Commission also has proposed to make additional spectrum available in the U-NII-1, U-NII-2B, and U-NII-4 bands. The *Notice* sought comment on whether the rules governing the U-NII-1 band should be harmonized with the rules governing the U-NII-2A band (5.25-5.35 GHz)[31] or the U-NII-3 band.[32] The potential for interference to consumer Wi-Fi devices is similar in the U-NII-1 band as in the ISM/U-NII-3 bands discussed above. Accordingly, the Commission should apply the rules governing the U-NII-2A band to the U-NII-1 band. The same rules should apply to the neighboring U-NII-2B band. This would minimize potential interference scenarios and as the Commission noted, "likely permit the introduction of a wide-range of new broadband products capable of operating at higher data rates than is now possible."[33]

Finally, the Commission has proposed additional unlicensed operation in the U-NII-4 band. As discussed above, many commenters urged the Commission to study this issue further and ensure that DSRC operations in the U-NII-4 band are protected from interference.[34] In addition, two other federal agencies urged the Commission to proceed with caution in the proposed expansion of unlicensed operations in the U-NII-4 band.[35]

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[28] *Notice* at ¶2.

[29] *Notice* at ¶29.

[30] *Id*.

[31] The U-NII-2A band permits 250 mW with a maximum EIRP of 30 dBm with 6 dBi antenna gain. *Notice* at ¶39.

[32] The U-NII-3 band permits 1 watt with a maximum EIRP of 36 dBm with 6 dBi antenna gain with no restriction on outdoor operation. *Notice* at ¶40.

[33] *Notice* at ¶ 39.

[34] *See, e.g.,* Comments of American Association of State Highway & Transportation Officials, pp 6-8.

[35] *See*, Letter of the Department of Transportation, p. 2, Comments of National Transportation Safety Board, p. 3-4.

IV. CONCLUSION

The potential for interference to consumer Wi-Fi devices is prevalent in the U-NII-1, U-NII-2B, and U-NII-4 bands. As discussed above, the Commission should permit unlicensed operations in these bands while taking a cautious approach by adopting appropriate technical limitations to ensure that consumer Wi-Fi devices are protected from harmful interference. The Commission's proposals for the U-NII-3 band are well balanced and address interference concerns between consumer Wi-Fi devices and long-distance, point-to-point links in the ISM Band while increasing spectrum available for U-NII operations. The Commission should apply the more stringent rules governing the U-NII-2A band to the other U-NII bands. Applying these technical limitations will ensure unlicensed devices do not cause harmful interference and thus can continue to operate in the 5 GHz band while the Commission provides additional spectrum for a wider range of broadband technologies.[36]

Respectfully submitted,

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[36] *Notice* at ¶1.