Before the
Federal Communications Commission
Washington DC 20554

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

REPLY COMMENTS OF THE FIXED WIRELESS COMMUNICATIONS COALITION

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The Fixed Wireless Communications Coalition, Inc. (FWCC)[1] files these reply comments in response to the Notice of Proposed Rulemaking in the above-captioned proceeding.[2]

A. INTRODUCTION AND SUMMARY

The FWCC does not oppose the use of unlicensed RLANs in 6 GHz Fixed Service (FS) spectrum, so long as RLAN operation does not increase the incidence of FS outages—which are rare to begin with. We show that this requires all RLANs to be under the control of an Automated Frequency Coordination system that is designed, constructed, and operated to maintain the very high levels of reliability that are routine for the FS.

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1 The FWCC is a coalition of companies, associations, and individuals actively involved in the fixed services—*i.e.*, terrestrial fixed microwave communications. Our membership includes manufacturers of microwave equipment, fixed microwave engineering firms, licensees of terrestrial fixed microwave systems and their associations, and communications service providers and their associations. The membership also includes railroads, public utilities, petroleum and pipeline entities, public safety agencies, backhaul providers, and/or their respective associations, communications carriers, and telecommunications attorneys and engineers. Our members build, install, and use both licensed and unlicensed fixed wireless systems. For more information, see www.fwcc.us.

2 *Unlicensed Use of the 6 GHz Band*,33 FCC Rcd 10496 (2018) (Notice).

Terminology:

- "FS" includes the Part 101 Common Carrier and Private Operational Fixed Services, but not the Part 74 Broadcast Auxiliary Service.
- A "link" is a licensed FS channel on a physical path. There may be multiple links on a single FS license.
- "AFC" refers to an Automated Frequency Coordination system intended to prevent RLANs from causing interference to FS operations.

This is the FS usage of the bands at issue:[3]

Band Name	Frequencies (MHz)	FS Usage (links)
U-NII-5	5925-6425	66,324
U-NII-7	6525-6875	30,280
TOTAL		**96,604**

None of the RLAN proponents promises to fully protect these FS operations. Some fail to grasp the legal principle that unlicensed devices must protect licensed, critical services.[4] The more responsible RLAN interests offer only to limit interference, not to prevent all RLAN-caused failures. Their approach, repeated through several pleadings, consists of concatenating unlikelihoods:

1. An indoor RLAN is probably not near a window.[5]
2. Even if it is, the RLAN is probably not in an FS receiver antenna main beam.[6]

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3 Link data courtesy of Comsearch, current as of January 21, 2019.

4 *E.g.*, Open Technology Institute at New America, *et al*. at 18 (Commission should balance even demonstrated FS interference against opportunity loss); Midcontinent Communications at 18 (Commission should restrict fade margins and use propagation models that allow the most unlicensed device use in the 6 GHz band).

5 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 (collectively, RLAN Group) at 23.

6 RLAN Group at 20-21.

3. If the RLAN is in the antenna main beam, it is probably far enough away not to cause interference.[7]

4. If the RLAN does cause interference, it probably won't use up all of the receiver's available fade margin.[8]

5. Even if it does use up the fade margin, it may just cause a slowdown, not a complete outage.[9]

These chains of assertions have intuitive appeal, but do not stand up to examination. Most of the individual assertions have no quantitative support, and when they do, it often rests on overly optimistic assumptions. This reply comment seeks to supplant the RLAN proponents' guesswork with mathematical and technical analysis.

The RLAN companies project deploying 958,062,017 RLAN devices,[10] some transmitting multiple gigabytes per hour,[11] distributed among tens of thousands of FS receivers. Both the RLANs and the FS facilities will be concentrated into urban and suburban areas. The numbers of potential RLAN/FS encounters will be astronomical.

We agree with the proponents that any one RLAN is unlikely to cause interference, for all the reasons they advance: wall attenuation, FS antenna discrimination, and so on. But there will be almost a billion RLANs in operation, not just one. Given those very large numbers, it will sometimes happen that an RLAN turns up in an FS antenna main beam with no intervening clutter. We show that even a low-power RLAN under these conditions, even indoors, will cause disabling interference from kilometers away.

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[7] *Id*. at 21.

[8] *Id*. at 15.

[9] *Id*.

[10] *Frequency Sharing for Radio Local Area Networks in the 6 GHz Band January 2018, attached to* Letter from Paul Margie, Counsel to Apple Inc., *et al*. to Marlene Dortch, Secretary, FCC, in GN Docket No. 17-183 at 12, Table 3-1 (filed Jan. 26, 2018) (RKF Study).

[11] RKF Study at 15.

RLAN proponents dismiss these as "corner cases,"[12] as if the name justifies ignoring them. FS engineers know better. In the real world of microwave communications, interference is rare, but when it happens, the cause is most often a single emitter at an unlikely location with atypical path loss: a corner case. The risk is low, per RLAN, but the proponents invoke a fallacy in trying to show it is low for multiple RLANs as well. They take an *average* attenuation from clutter, building walls, and such, and assume it will be there in every case. This approach gives very wrong results over a large number of RLANs. If a single unit has an interference risk of only one in a trillion, a population of 958,062,017 units presents an unacceptably high overall risk of 0.1%[13]—a number that suggests interference into about 100 FS receivers.

Just as most drivers don't often need their vehicles' airbags, many indoor and low-power RLANs won't often need AFC coordination. Like the airbags, though, the AFC is essential for those infrequent situations that would otherwise cause serious harm. A careful driver might go a lifetime without having an airbag deploy. Yet the 250 million cars and trucks on U.S. roads make it a mathematical certainty that hundreds of airbags deploy every day, saving lives and preventing serious injuries. It is likewise a mathematical certainty (see Part D.2) that AFC control is needed for all RLANs, to prevent FS outages that would otherwise occur.

It does not take many such outages to seriously degrade FS performance. Most 6 GHz links operate at 99.9999% or 99.999% reliability. These numbers allow for total outages of only thirty seconds or five minutes per year. A networked FS system—most are—may need fifteen minutes to resynchronize after a short interruption, so that even a transitory interference event

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12 *E.g.*, Broadcom at 6-7; RLAN Group at 37; Hewlett Packard at 13.

13 We show the calculation in Part D.2.

can eat up years' worth of outage allowance. The Commission must ensure that RLAN operation leaves FS reliability unchanged.

Most people think of Murphy's Law as a mildly ironic joke. FS engineers take it as a design criterion. When specifying a link to operate flawlessly for years at a time, designers work to account for every realistically possible combination of contingencies—including those that are individually improbable. They take extensive (and expensive) measures to maintain uninterrupted, full-speed communications in the face of unlikely circumstances.

The spread of uncontrolled (or inadequately controlled) RLANs would undo this careful planning, opening the likelihood of outages on a scale that FS end users cannot accept. Users who require (and pay for) five-nines and six-nines reliability will see intolerable interruptions. Some of the links that fail will be carrying safety-critical communications: controlling railroad trains; keeping electric voltage steady; providing reliable water supplies and waste-water management; maintaining safe pressures and flow rates in gas and oil pipelines; communicating lifesaving calls to ambulances, fire fighters, and police.

The proposals laid out in our first-round comments will fully protect FS operations while still fostering widespread RLAN use. RLAN proponents seek less effective controls on some devices, and no controls at all on others. No doubt their weakened version of frequency coordination will make more frequencies available at some locations. It will also make RLAN devices less expensive so as to "stimulate investment"[14]—a euphemism for increasing proponents' revenues. But the costs they seek to avoid will shift to the utilities and industries and public safety agencies in the form of increased FS outages. Requiring FS users to subsidize RLANs through service failures would be bad policy all around.

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[14] RLAN Group at 16.

The Commission's choice is not whether to allow RLAN operation. It can do that while fully maintaining FS reliability. The choice is whether to prioritize incremental improvements in Internet access over the integrity of a licensed, ultra-reliable service whose applications include safety-critical services.

The Commission can best serve the public interest by authorizing RLAN deployment under rules that fully protect the FS.

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Part B below looks at the law relevant to RLAN/FS interference.

Part C summarizes some of the many filings from electric utilities, water utilities, public safety agencies, telephone companies, and others who are concerned that RLAN interference will cause grave harm to the public they serve.

Part D addresses the fallacies and errors of fact that appear in several of the pro-RLAN comments, including some from technically sophisticated parties:

- mistaken reliance on average propagation characteristics, antenna heights, etc.;
- mistaken reliance on low interference probabilities per RLAN device;
- the mistaken assumption that every RLAN will be either outside an FS antenna main beam or too far away to cause interference;
- the mistaken assumption that keeping lower-powered RLANs indoors will prevent interference;
- mistaken reliance on FS fade margin to absorb interference; and
- the mistaken idea that FS operators take 30 days or more to get on the air after filing an application.

Part E takes up specific issues relating to RLAN and AFC operation. Our aim is to substitute verifiable facts and technical analysis for RLAN proponents' unsupported assertions.

Finally, in Part F, we explain why the notion of relocating FS users out of the 6 GHz band is both impracticable and unnecessary.

B. THE COMMISSION CANNOT LAWFULLY AUTHORIZE RLANS THAT CAUSE HARMFUL INTERFERENCE TO THE FS.

Ever since the Commission first authorized unlicensed operation in 1938,[15] it has held to the principle that all unlicensed devices must protect all licensed services. The Commission has emphasized that unlicensed devices (such as RLANs) may not

> transmit energy in a way that has a significant detrimental effect on the operation or development of the nation's communications network.[16]

For decades this requirement has been codified at Section 15.5.[17]

A 2008 U.S. Court of Appeals decision on unlicensed use construed Section 301 of the Communications Act, which on its face prohibits any radio transmission without a Commission license.[18] The court held the Commission can overlook the licensing requirement, and thereby authorize unlicensed devices, only where it has determined the devices will not cause harmful interference to licensed services.[19] Harmful interference is defined to include interference that "seriously degrades, obstructs, or repeatedly interrupts" licensed operation.[20] We show below, in detail, that inadequately coordinated RLANs will seriously degrade and repeatedly interrupt FS

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15 FCC press release No. 30678 (1938) (adopting rules for "low power radiofrequency electrical devices").

16 *Ultra-Wideband Transmission Systems*, Second Report and Order and Second Memorandum Opinion and Order, 19 FCC Rcd 24558 at ¶ 69 (2004).

17 "Operation of an [unlicensed device] is subject to the conditions that no harmful interference is caused … [to] the operation of an authorized radio station …." 47 C.F.R. § 15.5(b).

18 "No person shall use or operate any apparatus for the transmission of energy or communications or signals by radio … except under and in accordance with this chapter and with a license in that behalf granted under the provisions of this chapter." 47 U.S.C. § 301.

19 *American Radio Relay League, Inc. v. FCC,* 524 F.3d 227, 234-35 (D.C. Cir. 2008).

20 47 C.F.R. § 2.1.

communications. It follows that RLAN operation can be lawful only when coordinated in such a way as to fully maintain FS reliability. For the Commission to approve a deficient coordination scheme would violate Section 301.

Improperly coordinated RLANs would also raise questions under Section 333:

> No person shall willfully or maliciously interfere with or cause interference to any radio communications of any station licensed or authorized by or under this chapter ….[21]

A manufacturer or distributor that knowingly markets a poorly coordinated (or non-coordinated) RLAN whose use impairs FS communications might reasonably be said to have "cause[d] interference" as prohibited by Section 333.[22]

RLAN coordination adequate to fully protect the FS is required as a matter of law.

C. FS OPERATIONS ARE CRITICAL TO THE SAFETY OF LIFE AND PROPERTY AND TO U.S. ECONOMIC ACTIVITY.

Much of this pleading focuses on how an AFC system can maintain FS reliability at its currently high levels. Here, we explain why this is important.

The record shows broad agreement that 6 GHz band FS services are vital to Americans' well-being. More than twenty public safety agencies in at least 13 states filed comments cautioning that RLAN interference can "cause safety concerns for not only our public safety users, but to the public they serve."[23] In addition to numerous individual public safety agencies,

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[21] 47 U.S.C. § 333.

[22] The Commission has frequently invoked Section 333 against unlicensed devices that cause interference. *E.g.*, *CMARR, Inc.*, Notice of Apparent Liability for Forfeiture, 29 FCC Rcd. 7499 (Enforcement Bur. 2014); *Towerstream Corporation*, Notice of Apparent Liability for Forfeiture and Order, 28 FCC Rcd 11604 (2013); *Utah Broadband*, Notice of Apparent Liability for Forfeiture and Order, 26 FCC Rcd. 1419 (Enforcement Bur. 2011).

[23] Sheboygan County Sheriff's Department at 1; *see also*, *e.g.*, City of Madison Traffic Engineering Division – Radio Shop at 1; City of Los Angeles at 5-6; City of New York at 2; City of Austin at 1; City of Portland at 1; Lucas County Sheriff's Office at 1; Washington County

APCO International[24] and the National Public Safety Telecommunications Council[25] both filed comments emphasizing that, if the Commission fails to prevent interference in the 6 GHz band, "public safety agencies and the communities they serve will face irreparable harm."[26]

More than thirty utilities and other critical infrastructure industry ("CII") entities noted the threats that RLAN interference poses to "the safe, reliable and secure delivery of essential energy and water services."[27] Railroads and telecommunications providers explain the critical nature of 6 GHz FS operations from the standpoints of both safety and economic infrastructure.[28] Countless financial transactions, from gas station credit card swipes to high-frequency stock trades, depend on 6 GHz FS communications.

"Literally, lives depend on the proper operation and functioning of this [public safety FS] system,"[29] said one public safety worker. "The stakes are too high to allow consumer devices to

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Sheriff's Office at 1; St. Croix County Emergency Support Services at 1; Regional Wireless Cooperative at 6-7.

[24] A non-profit association with over 31,000 members, primarily consisting of state and local government employees who manage and operate public safety communications systems.

[25] Membership includes, among others, the National Sheriff's Association, National Emergency Number Association, National Association of State Emergency Medical Services Officials, International Association of Fire Chiefs, International Association of Emergency Managers, International Association of Chiefs of Police, and American Association of State Highway and Transportation Officials.

[26] APCO International at 4; *see also* National Public Safety Telecommunications Council at 12.

[27] Utilities Technology Counsel at 3; *see also, e.g.*, Idaho Power Company; Xcel Energy Services, Inc.; Texas New Mexico Power Company; Imperial Irrigation District; El Paso Electric Company; American Electric Power; Southern California Public Power Authority.

[28] *See, e.g.*, Association of American Railroads at 3-5; NE Colorado Cellular, Inc., dba Viaero Wireless at 1-3; AT&T Services, Inc. at 6-9.

[29] Peter M. Stallone at 1.

jeopardize licensed communications facilities on which public safety agencies and critical infrastructure industries rely."[30]

While RLAN proponents pay repeated lip service to the critical nature of 6 GHz band use, they fail to grapple with the need to adequately protect FS networks that, day in day out, must meet the exacting reliability needs of critical infrastructure, public safety, and other users.

1. Electric and water utilities

"Critical infrastructure organizations … provide services that are vital to the health and safety of the public, as well as the nation's economy."[31] Most Americans take for granted the power when they flip a switch, and the water when they reach for a faucet. These systems depend on the integrity of 6 GHz band FS operations.[32] In turn, the U.S. economy relies on our ability to take these services for granted.

Critical Infrastructure Coalition members

> use 6 GHz licensed spectrum to transport data and voice communications such as Supervisory Control and Data Acquisition (SCADA) system data, land mobile voice communications, grid network monitoring systems for electric utilities, distribution automation systems for electric and water providers, and substation security surveillance systems…[33]

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[30] Southern Company Services, Inc. at 4-5. *See also* AT&T Services, Inc. at 15-16 ("The [record] is clear that licensed 6 GHz operations for public safety, critical infrastructure, and commercial uses are vital and vulnerable components of our Nation's telecommunications infrastructure that must be protected from harmful interference.")

[31] El Paso Electric Company at 8.

[32] "Every citizen, organization, and business in the country profoundly relies on [CIIs] being able to communicate without interruption or harmful interference – a fact the Commission explicitly highlights as it pertains to electric utilities in its concurrent docket." Tucson Electric Power Company and UNS Electric, Inc. at 4.

[33] Critical Infrastructure Coalition at 4; *see also* Southern Company Services, Inc. at 6-9.

Interference to any of these systems can damage the electric grid or trigger faults that "may quickly spread, potentially causing damaging domino effects and electrical outages."[34] If a power company's communications systems are disrupted, the safety of the company's field crews is at risk.[35] During emergency situations, when minutes matter most, "communications loss could result in delayed restoration efforts, increasing the likelihood of widespread outages."[36]

These SCADA and other systems need at least 99.999% FS reliability, due to

> the extremely low latency with which teleprotection systems must respond to isolate an outage. If interference prevents these teleprotection systems from operating **within milliseconds**, it could result in a widespread outage.[37]

These reliability standards are not just industry best practices; they are the law. Modesto Irrigation District points out that "MID and other electric utilities must meet stringent federal standards set by the North American Electric Reliability Corporation that address issues of reliability, cybersecurity, and physical security."[38] Failure to comply with these standards "could result in civil penalties of up to $1 million per day per violation for non-compliance."[39]

Utilities Technology Council summarizes:

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34 Tucson Electric Power Company and UNS Electric, Inc. at 8.

35 *Id.*

36 *Id. See also* American Electric Power at 1 ("The main points of concern are with the safety of our employees and the risks of both the disruption of reliable electric service and the prolonged restoration of electric service outages for our customers caused by the interference to [our] private telecommunications network.")

37 Utilities Technology Counsel at 5-6 (emphasis added).

38 Modesto Irrigation District at 1; *see also* The City of Los Angeles at 7-8 (similar).

39 Southern California Public Power Authority at 1; *see also* The City of Los Angeles at 7-8 (similar).

> The public interest in Wi-Fi and mobile services cannot outweigh the critical importance of maintaining safe, reliable and affordable electric and oil & gas services.[40]

This is particularly true where FS interference cannot be easily remedied after the fact.[41] "[G]iven the importance of the essential services that depend on these microwave systems and the sensitivity of these microwave systems and the underlying utility application they help to support,"[42] the Commission's primary responsibility is to ensure full FS interference protection before permitting unlicensed operations in the 6 GHz band.[43]

Water utilities likewise use 6 GHz FS for mission-critical command-and-control communications. The Chelan County Public Utility District in Washington depends on the 6 GHz band for reliable operation of hydroelectric plants, transmission and distribution systems, water and waste water facilities, parks, fisheries, and broadband transport infrastructure.[44] Beyond simply providing water to consumers' homes, the Chelan County PUD is responsible for power generation, dam maintenance, water distribution, waste water treatment, and the management of public lands. FS failures at its hydroelectric plants could cause power outages and risk dam failure. Problems with the water distribution system could leave consumers without

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[40] Utilities Technology Counsel at 7; *see also* Southern California Public Power Authority at 1 ("Whatever benefit that may be accrued by expanding the use of the 6 GHz band for unlicensed use will be outweighed by the risks to our critical communication networks needed for emergency response, storm restoration and situational awareness of the electric grid infrastructure.").

[41] Utilities Technology Counsel at 11.

[42] Portland General Electric at 1.

[43] For an account of why 6 GHz links are so important to utilities, *see* M. Douglas Mcginnis, *Spectrum and Utility Communications Networks: How Interference Threatens Reliability*, included in The Utilities Technology Council, the Edison Electric Institute, the American Public Power Association, the National Rural Electric Cooperative Association, the American Petroleum Institute, and the American Water Works Association at 21 *et seq*.

[44] Chelan County Public Utility District at 1.

access to clean, safe drinking water, cause contamination with waste water, and cause environmental damage.[45]

Water companies across the country rely on FS-based SCADA systems to monitor, maintain, and control water systems, including "control [of] flow and pressure, [and] pipeline leak detection, as well as water gathering peer-to-peer communications used to automate the water pipeline gathering system, down hole temperature, and pressure used in subsurface reservoir analysis."[46] The same systems also help utilities manage scarce resources more prudently, saving ratepayers and taxpayers money, which further enhances local economies. Finally, SCADA systems are critical to the water utilities' environmental management. One utility puts it succinctly: "[T]here are no other communications alternatives or options available that adequately meet" these needs.[47]

2. Oil & Gas Pipelines

FS operations in the 6 GHz band play a vital role in supporting oil and gas pipelines necessary for everything from electric generation to the distribution of gasoline. The Critical Infrastructure Coalition's oil and gas member companies

> use SCADA systems to support telemetry and pipeline measurement data systems, which include remotely monitoring tank levels, pipeline pressures, alarms and other various aspects of controlling and monitoring operational facilities.[48]

These systems also "support oil and gas pipeline valve, pump, and compressor controls at compressor stations, crude pump stations, and along the entirety of the pipelines themselves."[49]

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45 *Id.*

46 Critical Infrastructure Coalition at 5.

47 Chelan County Public Utility District at 1.

48 Critical Infrastructure Coalition at 5.

49 *Id.*

,All of these functions "rely on constant, seamless communications networks supported by fixed 6 GHz microwave links."[50]

Information from SCADA systems "includes data for well site safety and event notification which ensures quick response to environmental and life critical events."[51] By responding to emergencies quickly, or better, anticipating problems before they become emergencies, pipeline providers and oil and gas companies can greatly mitigate the risks associated with their operations. This keeps their employees and the public safer and the environment cleaner. Protecting public and environmental safety also mitigates the economic damage done by pipeline and oil and gas emergencies, and promotes economic efficiencies, which in turn lead to more reliable service at lower prices.

3. Public Safety

Communities of every size rely on 6 GHz FS operations to support police, firefighters, EMTs, and other first responders. These links primarily support the mission-critical land mobile radio systems used for dispatch and tactical communications.[52] Public safety networks are also needed to "activat[e] severe weather sirens for tornadoes" and other emergency systems where seconds matter and reliability makes a difference in people's lives.[53]

In Cook County, Illinois, "the sheriff's Radio Systems serve over 11,000 licensed portable, mobile and control station subscribers units; and those units transmit over 80,000 messages a day …"[54] Overall, 6 GHz public safety networks transmit millions of messages in a

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50 *Id.*

51 *Id.* at 5.

52 The City of New York at 3; The City of Los Angeles at 5.

53 Washington County Sheriff's Office at 1.

54 Cook County Sheriff's Police Department at 1. These systems reach far beyond the Cook County Sheriff's Police Department to cover police, courts, corrections, community based corrections, federal agencies operating in the Chicago area (including the FBI, DEA, ICE, and

year. New York City "receives approximately ten million E-911 requests for service annually,"[55] and the Los Angeles Fire Department alone responds to more than 400,000 calls a year.[56] Many of these reach first responders over 6 GHz FS links.

Not only big cities depend on public safety networks backhauled by FS. Lincoln County, Oregon is a rural county, on the Oregon Coast with a population of only 46,000—though it triples during the summer months.[57] Its Sheriff's Office's radio system services three dispatch centers and is the primary source for seven fire districts, four law enforcement agencies, and the county public roads department.[58] This kind of shared use is common. The Lucas County [Ohio] Emergency Medical Service (EMS) Countywide Communications System (CCS) links nine different Lucas County emergency departments to first responders, paramedics, air ambulances, and mobile physicians in Lucas, Wood, Fulton, and Henry Counties.[59] The record shows many other communities using 6 GHz FS links to support their public safety networks,[60] along with many state emergency management and public safety departments.[61]

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the U.S. Marshals), public health agencies, local highway departments, the Chicago Office of Emergency Management, and over 50 suburban police and fire agencies. *Id*.

[55] The City of New York at 1.

[56] The City of Lost Angeles at 5.

[57] Lincoln County Sheriff's Office at 1.

[58] *Id.*

[59] Lucas County Emergency Medical Services at 1; *see also, e.g.,* Washington County Sheriff's Office at 1.

[60] *See, e.g.,* Sheboygan County Sheriff's Department at 1 (serving approximately 115,300 residents of Sheboygan City and County); Dakota County Board of Commissioners at 1 (serving over 422,00 residents); Baltimore County at 1 (serving approximately 832,000 residents); Nassau County Police Department at 1 (population approximately 1.36 million); Regional Wireless Cooperative at 1-4.

[61] *See, e.g.,* State of Florida Department of Management Services, Division of Telecommunications, Bureau of Public Safety.

Because public safety agencies are responsible for the lives of the public and first responders,[62] public safety fixed service operations are designed for availability times of 99.9999%.[63] Wireless microwave has proven to be the best network connectivity solution for public safety communications "because of its reliability, cost effectiveness and it is not as susceptible to outages during disasters as wireline alternatives."[64] Interference from unlicensed devices likely "will not be identified until after a communications failure, putting safety of life and property at risk."[65]

FirstNet—a major Commission priority[66]—likewise depends on FS operations in the 6 GHz band. AT&T plans to utilize 6 GHz microwave links in its roll-out of FirstNet.[67] In part because of its FirstNet obligations, AT&T's comments urged the Commissions to take a cautious approach to this proceeding, so AT&T can "meet a robust reliability standard to assure that the public safety community can depend on FirstNet for its mission critical communications."[68]

APCO International, drawing on its members' unparalleled expertise and experience in public safety radio communications, pus forward this cautionary note:

> APCO takes issue with the suggestion that proposals for unlicensed operations should be evaluated based on whether they pose a "material risk" of harmful interference to incumbent link. This standard is unacceptable. Levels of interference that are tolerated for commercial uses

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62 *See, e.g.*, Bastrop County Wireless Radio System Manager at 1; Lucas County Sheriff's Office at 1; City of Portland at 1.

63 APCO International at 4; *see also* National Public Safety Telecommunications Council at 8.

64 City of Austin at 1.

65 APCO International at 4.

66 Ajit Pai, *Supporting our Public Safety Heroes* (FCC Blog June 1, 2017) (FCC committed to working with FirstNet and state and local partners so first responders have tools they need to communicate seamlessly during emergencies). Available at https://www.fcc.gov/news-events/blog/2017/06/01/supporting-our-public-safety-heroes

67 AT&T Services, Inc. at 7; *see also* Cook County Sheriff's Police Department at 3.

68 *Id.* at 13-14.

> of spectrum do not translate to public safety, where the lives of responders and their communities may be impacted by interference to communications.[69]

The National Safety Telecommunications Council, whose members include a broad federation of public safety organizations, agrees:

> From a technical perspective, a five 9's and in some cases six 9's level of reliability is needed for critical public safety links. Maintaining these levels of reliability is accomplished through link designs with requisite levels of fade margin. Contrary to the Commission's proposal, such fade margins must not be eroded through the deployment of unlicensed devices.[70]

4. Railroads

The Association of American Railroads' freight members rely on the 6 GHz FS bands to provide mission-critical railway safety operations.[71] These links support vital railroad communications links, including dispatch radio traffic, centralized train control systems, positive train control, phone systems, and crew train orders. FS operations also relay data regarding train signals, remote switching of tracks, train routing, and information from trackside telemetry, which detects, among other things, damaged rails, overheated wheel bearings, dragging equipment, and rock slides.[72]

Railroads depend on FS integrity to preserve life and property, including property shipped by freight rail and property adjacent to railroad rights-of-way.

> Consequently, these railroad communications systems need to be extremely reliable and are typically designed to ensure availability greater than 99.999%, which equals less than five minutes of downtime per year.[73]

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69 APCO International at 16.

70 National Safety Telecommunications Council at 12.

71 Association of American Railroads at 1.

72 *Id.* at 3-4.

73 *Id.* at 4.

Given the statutory deadline to implement positive train control industry-wide by December 2020, "railroads continue to invest heavily in improving railway safety and are becoming reliant on microwave links for their critical operations."[74]

5. Telecommunications

Telecommunications providers depend on the 6 GHz band for backhaul and backup resiliency in the nation's telecommunications infrastructure. Ironically, despite RLAN proponents' suggestion that unlicensed use in the 6 GHz band could be used to bridge the digital divide,[75] telecommunications providers currently use the 6 GHz band to provide service in underserved areas. NE Colorado Cellular, Inc., dba Viaero Wireless, serves primarily rural markets in Colorado, Nebraska, Kansas, Wyoming, and South Dakota,[76] where its facilities support customers' "health, safety, and well-being."[77] Given the critical nature of the traffic, it designs its microwave links to a 99.9999% criterion.[78]

Larger providers also rely on the dependability of FS operations in the 6 GHz band. "AT&T alone holds 8,138 licenses in [the 6 GHz band] used to operate thousands of microwave links."[79] It uses these links on both a standalone basis and as backup, often preferring FS links to other options because "6 GHz is not susceptible, like fiber, to cable cuts, which makes it a uniquely resilient asset for critical communications."[80] AT&T also uses 6 GHz FS links to backhaul traffic to and from cell sites, making these links "essential parts of the United States'

74 *Id.* at 4-5.

75 *See, e.g.*, NCTA at 2; Wi-Fi Alliance at 33; Midcontinent Communications at 3-7.

76 NE Colorado Cellular, Inc., dba Viaero Wireless at 1.

77 *Id.*

78 *Id.* at 3.

79 AT&T Services, Inc. at 7. Each license can authorize multiple links.

80 *Id.* at 8.

emergency 9-1-1 system."[81] It notes that "6 GHz systems are also some of the fastest to be brought back on-line in any post-disaster restoration effort."[82]

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FS operations fill an irreplaceable role in the complex, interconnected systems that protect Americans' lives, property, economic activity, and daily communications. The experts responsible for operating those diverse systems find the 6 GHz band invaluable because of its unique propagation characteristics. No other non-Government band in the spectrum can reliably span the distances that 6 GHz makes easy.[83] "[T]here is simply too much at risk to safety, the economy, and the nation's infrastructure if unlicensed devices are released into the wild without first taking every possible engineering precaution to eliminate the potential for interference."[84]

D. RLAN COMMENTS SHOW DEEP MISUNDERSTANDINGS OF FS PHYSICS AND OPERATION.

Some of the RLAN filings contain surprising, sometimes naive, errors of fact and analysis. Not surprisingly, these consistently underestimate RLAN interference. For the Commission to act on these claims as if they were true would badly distort regulatory outcomes.

We address a few of the more consistent factual errors here, and take up others in their specific contexts.

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81 *Id.*

82 *Id.*

83 The Utilities Technology Council, the Edison Electric Institute, the American Public Power Association, the National Rural Electric Cooperative Association, the American Petroleum Institute, and the American Water Works Association at 6-7.

84 Southern Company Services, Inc. at 1-2.

1. Calculations based on "typical" propagation, antenna height, etc. will lead to FS interference.

RLAN proponents predict low likelihoods of interference by averaging critical factors like propagation losses, FS antenna height, and building wall attenuation. They use propagation models that show "average" or "typical" path attenuation. Necessarily, many of the actual paths will have lower losses and better propagation than the model predicts, and hence will be more likely to cause interference. Likewise, nearly half of FS antenna heights are lower than average. Where building walls of a particular construction attenuate signals by *X* dB on average, that number will drop for an RLAN near a window. Combining several of these average or typical factors, as RLAN proponents do, yields what appears to be convincingly unlikely interference. But given the large numbers of expected RLANs, inevitably some will defy the averages: an RLAN near a window having line-of-sight to a lower-than-average FS antenna. These are the "corner cases" missed by analyses that rely on average conditions—but are the cases most likely to cause interference in practice.

Broadcom criticizes the FWCC for ignoring "typical" RLAN/FS interactions, and for requesting rules based on an "unlikely scenario" in which "unrealistic factors" occur together.[85] Broadcom overlooks the virtual certainty that 958,062,017 RLANs operating among tens of thousands of FS receivers will sometimes bring unrealistic factors together. Those will threaten serious harm if not anticipated and protected against. Given that today the FS operates 24/7/365 with near-perfect reliability, even relatively rare combinations of factors will degrade FS service to unacceptable levels.

Hewlett Packard clearly frames the policy choice, albeit backwards:

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85 Broadcom at 21.

> It would be unwise for the Commission to adopt rules for the entire band based on assumptions built on cherry-picked FS links that do not represent the bulk of real-world deployments, *especially when those rules could unnecessarily undermine investment and innovation in the 6 GHz band*.[86]

It does not matter if the bulk of real-world RLAN deployments are unlikely to cause interference. What Hewlett Packard dismisses as "cherry-picking" are the very RLAN/FS combinations that, when they do inevitably occur, will cause disabling interference. The rules we request are needed to prevent those from occurring.

We do not dispute that protecting the FS might make RLAN service more expensive, mostly due to the need to put all RLANs under AFC control. We doubt that an honest, long-term estimate would show the additional costs are so great as to "undermine investment and innovation."[87] But that is a secondary consideration. The Commission's first responsibility is to protect the public's reliance on the services that flow through licensed FS facilities.

RLAN providers understandably relish the prospect of access to a full 1200 MHz of unlicensed spectrum. Unlike the bands at 900 MHz, 2.4 GHz, and 5.8 GHz, where unlicensed devices can operate freely without causing harm, this band is dense with nationwide facilities that carry critical services. Fully protecting those from interference is the cost of access to the band.

2. Even very low interference probabilities predict near-certain interference when applied to large numbers of RLANs.

RLAN proponents argue that indoor and outdoor RLANs below certain power levels do not need AFC control because combinations of factors will reduce their risk of interference to

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[86] Hewlett Packard at 17-18 (emphasis added). Similarly, Broadcom at 21 (asserting FWCC ignores typical RLAN/FS interactions and asks for rules based on unlikely scenario).

[87] Hewlett Packard at 18.

"negligible" levels.[88] Hewlett Packard describes an "interference lottery" of four separate conditions that together are needed to cause interference, a combination whose likelihood it calls "vanishingly small."[89]

None of the RLAN proponents attempts to quantify "negligible" or "vanishingly small." Instead, their argument is entirely intuitive. A list of mitigation factors is framed so as to strike the reader as unlikely; therefore their combination must be even more unlikely; and so (the argument goes) any residual risk of interference can safely be ignored.

We question elsewhere the reliability of the various mitigation factors. Here, we address a more fundamental error in the approach: overlooking the very large number of RLANs involved.

Suppose some combination of factors were to yield a truly small probability of a given RLAN impairing an FS link: say, 1 chance in 10 million. Is this negligible? A much-cited study in the record puts the number of RLANs to be deployed at 958,062,017.[90] It follows mathematically: *at least one of those RLANs is dead certain to impair an FS link.*[91] Worse: the probability is greater than 99% that well over 100 FS receivers will receive interference.[92]

We do not present the above numbers as realistic estimates, but only to demonstrate that non-quantitative guesses about interference can give misleading results. This number, though, can be relied upon: reducing the overall FS interference probability to 0.1%—still far too high—

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88 *E.g.*, RLAN Group at 35, 49.

89 Hewlett Packard at 12-16 (proximity to an FS receiver main beam, propagation through building walls, co-channel operation, and operation during a deep FS fade). *See also* Microsoft at 9-11 (similar); Broadcom at 6-7 (net risk is "extremely low").

90 RKF Study at 12, Table 3-1.

91 The probability of an RLAN causing interference is $[1-(1-10^{-7})^{958,062,017}]$ = 99.999999999 99999999999999999999999999999998 percent.

92 This uses a normal approximation to the binomial distribution with μ=95.8 and σ=9.788.

requires reducing each RLAN's probability of causing interference to 1 in a trillion.[93] These kinds of numbers might be achievable using an AFC system for all RLANs—but not otherwise.

The Commission should require every claim of non-interference to rest on quantitatively supported estimates, and to account for the projected numbers of RLANs. Claims that lack this rudimentary backup are not worth consideration.

3. RLANs will come within FS receiver antennas' main beams.

Several RLAN interests make the specious argument that an FS antenna "will virtually always be located high above where any RLAN devices, especially outdoor devices, are used."[94] Elsewhere, and equally wrong: "[T]he only devices operating in or near the main beam of an FS link in any reasonable proximity to the FS receiver will be located within high-rise buildings."[95]

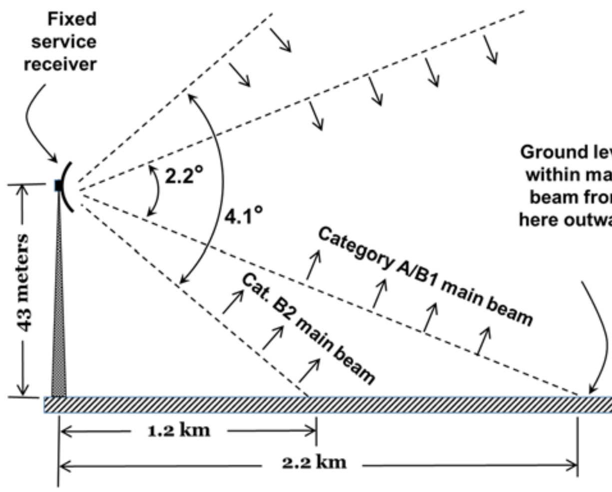

Figure 1: FS main beam geometry
(drawn to scale with horizontal compressed)

Geometry says otherwise. See Figure 1. With an FS antenna 43 meters high— an average antenna height used in some of the proponents' calculations[96]— and an antenna meeting the Commission's

93 Here the probability of any one or more deployed RLANs causing interference is $[1-(1-x)^{958,062,017}] = 0.001$, where x is the probability of one individual RLAN causing interference. Solving for x gives 1.04×10^{-12}. All of these calculations make the reasonable assumption that the probabilities of RLANs causing interference are independent of one another.

94 RLAN Group at 17. Similarly, Wi-Fi Alliance at 12; Qualcomm at 10; Microsoft at 10-11.

95 RLAN Group at 24.

96 *E.g.*, Apple at 9; Broadcom at 7-8.

most stringent 6 GHz standard,[97] an RLAN at ground level in front of the antenna falls in the main beam at all distances greater than 2.2 km. At that 2.2 km distance, an RLAN at 14 dBm—the power level proponents say is safe without AFC control—will cause 22.95 dB of fade margin degradation, enough to take down many links.[98]

In attempting to defend uncontrolled indoor operation, RLAN interests claim—incorrectly—that FS engineers clear most or all of the main beam out to several miles from each end of a link.[99] Some say this is needed to keep structures from intruding into the "first Fresnel zone" between the transmit and receive antennas, which would impair operation of the link. The implication is that no indoor RLANs, even in tall buildings, can be in the antenna main beam.

The argument is factually wrong. Obviously from Figure 1, there can be indoor RLANs in small buildings within the main beam, beyond 2.2 km. (The exact distance will vary with the antenna size.) But the same is also true for tall buildings. The first Fresnel zone, which indeed must be kept clear, is far narrower than the receive antenna main beam. See Figure 2, based on the same numbers that RLAN Group uses in its example.[100] RLAN Group correctly notes the need to keep structures out of the first Fresnel zone, but from there wrongly implies there can be no buildings in the main beam.[101] Figure 2 shows there are enormous volumes of space outside the first Fresnel zone, yet within the main beam, providing many square kilometers of room for buildings of any height that can host interference-causing RLANs. The main beam has the shape of a horizontal cone that is far larger than the first Fresnel zone. We show in Part E.3 that

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97 47 C.F.R. § 101.115(b) (table) (Category A or B1).

98 For details on the calculation, see Part D.4 and Appendix A.

99 *E.g.*, RLAN Group at 21; Hewlett Packard at 18-19 and Appendix 2 at 2; Broadcom at 8-9.

100 RLAN Group at B-6.

101 *Id*. at B-6-7. Similarly, Hewlett Packard, Appendix 2 at 7-8; Broadcom at 8-9.

uncontrolled indoor RLANs anywhere in this region, even many kilometers from an FS receiver, present a serious interference threat.

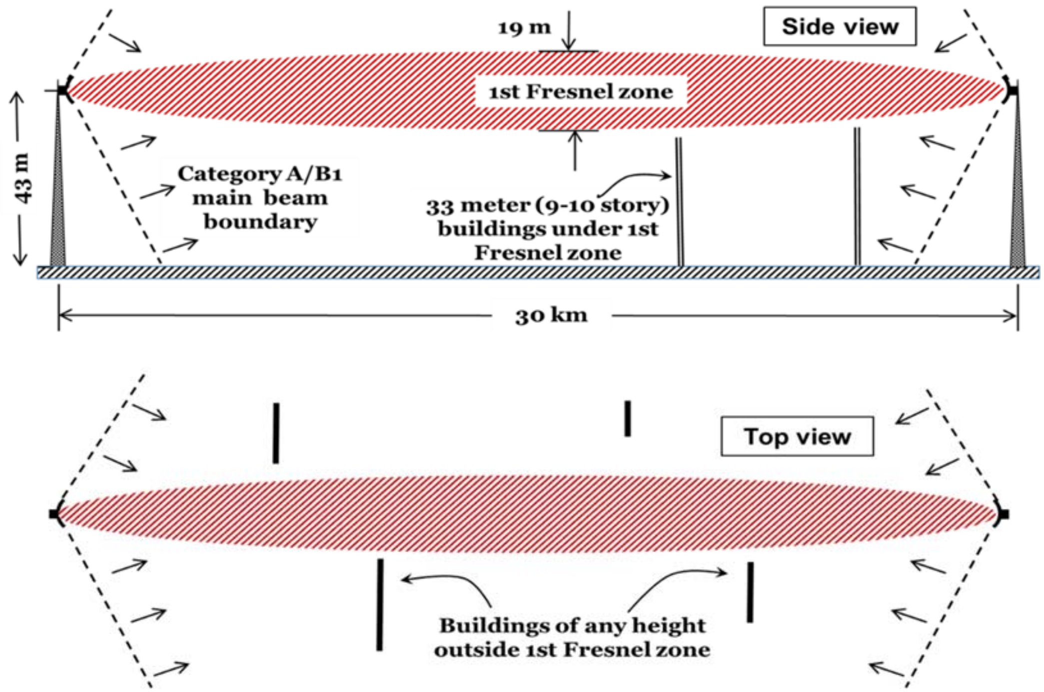

Figure 2: Limited effect of first Fresnel zone (drawn to scale with horizontal compressed)

4. FS fade margin is not available to compensate for RLAN interference.

FS links are subject to usually nighttime (sundown to sunup) atmospheric conditions of "multipath fading" that intermittently and unpredictably reduce the signal strength at the receiver, by anywhere from a few dB to a few tens of dB.[102] Multipath fades are the single greatest threat to 6 GHz FS reliability. FS designers use multiple techniques to maintain communications through fades, including space diversity (two physically separated antennas on

[102] Multipath is caused by changes in temperature or humidity at different elevations that cause an upward-traveling component of the transmitted signal to refract (bend) back toward the receive antenna, just as a lens bends light rays. Because the refracted signal takes a longer path than the direct signal, it can arrive at the receiver out of phase with the direct signal, and partially cancel out the direct signal. This reduces the signal strength at the receiver.

the same tower serving the same link), automatic transmit power control (temporary boosts in transmitter power), and adaptive modulation (downshifting to slower and more robust modulations). But those are backups. The first line of defense is fade margin: an extra reserve of power built into every link to deliver adequate power to the receiver despite a fade.

RLAN interests write as though they can use FS fade margin to soak up RLAN interference.[103] But fade margin is not a shared resource. It is an expensive form of protection needed to ensure fully reliable FS communications. As indicated in Part E.1, we are willing to give up 1 dB of fade margin to accommodate RLANs (from an I/N = -6 dB interference criterion), but not more. The industry needs the rest to maintain its very high level of reliability. Any calculation that purports to show a lack of RLAN interference by taking fade margin into account is invalid.

5. Most 6 GHz FS links start operation very soon after filing a license application.

RLAN Group seeks to update the AFC database only every 30 days because, it says, an FS link almost never enters operation less than 30 days after Commission receipt of the license application.[104] Wi-Fi Alliance thinks 30 days is often enough because FS links take months to construct and deploy.[105] Both are wrong.

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103 *E.g.*, RLAN Group at 45 (high-reliability FS links designed with sufficient fade margin will let communications continue despite transient RLAN interference); Wi-Fi Alliance at 14 (interference potential reduced even further when FS links' excess fade is considered); Hewlett Packard Appendix 2 at 10 (only interference during extreme signal fade conditions could affect FS receivers).

104 RLAN Group at 42.

105 Wi-Fi Alliance at 23.

The rules on conditional authorization permit an FS operator to turn on a 6 GHz link immediately upon filing the application.[106] The large majority of 6 GHz applications qualify. Most operators put the link into service on the same day that they file. But there is no public record of the system being in use until the operator files a construction certificate. That is not due until 15 days after the close of the construction period,[107] which comes 18 months after the license grant,[108] which in turn comes several weeks after operation can lawfully begin.

Because most 6 GHz FS links start up quickly, the AFC database will need updates at least every day. An FS link is entitled to protection from the moment it is authorized to operate—not 30 days later.

For the same reasons, each RLAN will have to refresh its permissions at least once every 24 hours. An RLAN that cannot do so must be presumed to have lost contact with the database, and must cease operation until contact is restored.

E. MEASURES NEEDED TO ENSURE FS COMMUNICATIONS INTEGRITY

1. Interference criterion

The appropriate interference criterion is I/N = -6 dB, equivalent to 1 dB fade margin degradation. This value is widely accepted for national and international frequency coordination procedures, standards, and recommendations.[109] The FWCC has consented to accept that level of interference.

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106 47 C.F.R. § 101.31(b). Frequency coordination must be complete before the application can be filed. The exceptions to conditional authorization rarely apply at 6 GHz.

107 47 C.F.R. § 1.946(d).

108 47 C.F.R. § 101.63(a).

109 TIA/EIA, *Interference Criteria for Microwave Systems*, Telecommunications Systems Bulletin TSB10-F at B-1, Annex B, Section B-2 (June 1994); ITU-R Recommendation F.758-6, *System Parameters and Considerations in the Development of Criteria for Sharing or Compatibility Between Digital Fixed Wireless Systems in the Fixed Service and Systems in Other*

RLAN interests seek instead to use I/N = 0 dB,[110] with no documented justification. This value will increase the fade margin degradation to 3 dB, which roughly doubles the risk of outage for an FS receiver combatting a deep fade. The Commission should conform to widespread usage by setting the interference criterion at I/N = -6 dB.

2. Propagation models

RLAN proponents favor various combinations of propagation models.[111] These are valid only on a statistical basis, when averaged over many possible interference paths. They convey no information about any actual path. Because they are averages, they are mathematically certain to underestimate attenuation for a substantial fraction of paths, and are certain to allow operation on interfering frequencies.

We agree that attenuation can be included in the propagation calculation when it is known to exist along a particular path—*e.g.*, as a mapped building or mapped terrain feature. Otherwise the AFC must assume free-space propagation. It would be foolhardy to assume attenuation on a particular path just because the models says it appears on an average path.

This one point explains much of the discrepancy between the RLAN proponents' low interference assessments and our much more alarming predictions. The RLAN proponents assume high clutter losses.[112] We look to the statistically inevitable cases having zero clutter loss.

Services and Other Sources of Interference, Geneva: International Telecommunication Union, Radiocommunication Sector at 9, Table 2 (Sept. 2015).

110 RLAN Group at 15; Wi-Fi Alliance at 24; Hewlett Packard at 27-28.

111 RLAN Group at 43-45 and Appendix A; Wi-Fi Alliance at 25; Wireless Internet Service Providers Ass'n at 18-19; Broadcom at 18-20.

112 See Part D.4 for a specific example.

3. Uncontrolled indoor use

RLAN interests propose uncontrolled indoor operation in all of the 6 GHz bands at 30 dBm (1 watt) radiated power.[113] They point to factors that reduce the probability of interference: elevation mismatch, building attenuation, FS antenna rejection, and so on.[114] Each of these can sometimes (not always) *reduce* the likelihood of interference, but none of them, even in combination, promises to eliminate all interference. Each of the factors varies widely from one RLAN location to another, over ranges of tens of dB. There is always a nonzero probability that a particular RLAN will see low attenuation from all of them. Even where that probability is low for an individual RLAN, it becomes a serious risk when multiplied by hundreds of millions of devices.[115]

Disturbingly, in a tacit concession that its plans will cause interference notwithstanding these mitigation factors, RLAN Group proposes to rely on the expensive safeguards that FS operators install to protect against atmospheric fades: spatial diversity, cross-polarization, adaptive modulation, and forward error correction.[116] Those safeguards must be left intact. Every dB of protection that RLAN interference consumes is one more dB of vulnerability to natural fades.

RLAN Group concedes the worst case of a building "located within the main beam of an FS receiver, unshielded by terrain or other buildings between the FS transmitter and receiver."[117] It calls this "highly unusual."[118] But FS systems are reliable because they are engineered to

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[113] RLAN Group at 3 (table); Broadcom at 5-6; Boeing at 6-7; Hewlett Packard at 7.

[114] RLAN Group at 20-21.

[115] See Part C.2 for examples.

[116] RLAN Group at 19. *See also* Hewlett Packard at 18 (similar).

[117] RLAN Group at 21.

[118] *Id*.

protect against all of the more usual threats to communication. Unusual threats can multiply FS outages many-fold. With a large number of RLANs, even unusual events become certainties.

RLAN proponents try to argue that a 30 dBm RLAN does not need coordination indoors because (they say) an indoor device is unlikely to be in an FS main beam, and the building walls will attenuate the signal enough to prevent interference.

We showed in Part D.3, above, that the first argument is wrong: an RLAN in either a short building or a tall building can easily come within an antenna main beam. Many will.

The argument on building walls is also wrong. RLAN Group asserts that a typical building wall near the same elevation as an FS link will necessarily be of high-rise construction, and so will attenuate 6 GHz signals by at least 30 dB.[119] But the RLAN elevation is almost irrelevant. We also showed in Part D.3, above, that even a single-story wood-frame residence, offering far less attenuation, can equally well be in the antenna's main beam, a very few kilometers from the tower. Although any single number for wall attenuation is certain to be wrong for a large number of cases, a better typical value for 6 GHz is in the neighborhood of 20 dB.[120]

But even the proponents' 30 dB wall still leaves a major interference threat. A 30 dBm RLAN in an FS antenna main beam behind a 30 dB wall will degrade the fade margin by the agreed-upon 1 dB criterion from a distance of 12.1 km. At 1 km, the degradation is fully 15.9 dB.

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119 *Id*. at 23. Leading Builders of America (at 7) suggests basing building loss on the kinds of construction required under contemporary building codes—as if older buildings do not exist.

120 Loew, L. H., Lo, Y., Laflin, M. G. and Pol, E. E., *Building Penetration Measurements from Low-height Base Stations At 912, 1920, and 5990 MHz*; NTIA Report 95-325 at 108, Table D-6 (Inst. for Telecom. Sciences, NTIA Sept. 1995) (measurements at 5.99 GHz).

(Even the 18.5 dBm indoor RLAN proposed earlier in the proceeding[121] still causes 1 dB of interference through a 30 dB wall from 3.2 km. Through a 15 dB residential wall, that 18.5 dBm device causes interference from 18 km away.)[122]

The conclusion is clear: even indoor RLANs at any useful power will cause unacceptable interference to the FS, unless under AFC coordination.

4. Uncontrolled outdoor use

RLAN interests seek authority for devices at 14 dBm with no AFC control, even outdoors,[123] claiming the interference risk is "vanishingly small."[124] We strongly disagree.

At the outset, we raise the procedural question whether the Commission can lawfully adopt a rule authorizing uncontrolled outdoor devices, where the Notice made no mention of this possibility, and where the request is not reasonably a "logical outgrowth" of the Notice.[125]

As a substantive matter, an outdoor 14 dBm device that falls in an FS receiver main beam will degrade the fade margin by 1 dB or more from a distance of 61 kilometers (in practice limited by curvature of the Earth). The same device from a more realistic 10 km will degrade the FS fade margin by 10.2 dB.

RLAN Group predicts zero FS interference from this device.[126] The discrepancy between their results and ours arises from their use of a propagation model that assumes a very high

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121 RKF Study at 18, Table 3-4.

122 Methodology for the calculations is in Appendix A.

123 RLAN Group at 35-39; Wi-Fi Alliance at 10-15; Hewlett Packard at 7; Broadcom at 27-29.

124 RLAN Group at 36.

125 *Council Tree Communications, Inc. v. FCC*, 619 F.3d 235, 249-50 (3d Cir. 2010) (final rule adopted must be "a logical outgrowth" of the rule proposed), *cert. denied*, 563 U.S. 903 (2011).

126 RLAN Group at 36 & n.66.

degree of clutter loss of over 150 dB.[127] This again raises an issue we have stressed throughout. The conditions in our analyses—an RLAN in the FS antenna main beam with no intervening clutter—are unlikely for any one RLAN. But with hundreds of millions of devices in operation, the probability of this configuration rises by hundreds of millions. The likelihood of severe FS interference from uncontrolled outdoor RLANs, even at 14 dBm, becomes a statistical certainty.

5. Guard bands required

The Wireless Internet Service Providers Association sees no need to protect adjacent FS channels because, it says, RLAN devices will respect Commission-imposed out-of-band emissions limits.[128]

We explained in our first-round comments why this misunderstands the problem. We provide a brief summary here.[129]

Any radio receiver, including an FS receiver, is sensitive to frequencies outside but close to the channel it is tuned to. Figure 3 shows a typical plot of FS receiver sensitivity as a function of frequency, for a 30 MHz FS channel bandwidth.[130] The triangular shaded areas represent receiver sensitivity outside the nominal channel being received—*i.e.*, in the adjacent channels. These frequencies will see attenuation as low as 12 dB, so that RLAN signals there may be

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[127] A less important factor is RLAN Group's (at 36 n.66) also assuming 7 dB of feeder loss and body loss.

[128] Wireless Internet Service Providers Ass'n at 21.

[129] For details, *see* Fixed Wireless Communications Coalition at 25-28 and Attachments B and C.

[130] The plot is redrawn for a 30 MHz FS channel from TIA Committee TR-45 Working Group for Microwave Systems (George Kizer, Chairman), *Engineering Considerations for Fixed Point-to-Point Microwave Systems, Draft Standard ANSI/TIA-10*, Arlington: Telecommunications Industry Association, at 63, Figure 13 (C-6) (publication pending, expected May 2019).

strong enough to cause severe interference. Note that the receiver will pick up interference from an RLAN on nearby frequencies even if the RLAN has no out-of-band emissions at all.

This necessitates a guard band on either side of the FS channel receiver bandwidth, from which RLANs must be excluded. A guard band equal to half the nominal FS channel will offer adequate interference protection in most cases.[131] A wider guard band (or reduced RLAN power) will likely be needed for an RLAN within about a kilometer of the FS receiver and within a few degrees of its antenna main beam. Conversely, a narrower guard band may suffice for an RLAN situated toward the outer edges of an exclusion zone. A variable-width guard band might best protect the FS while maximizing the spectrum for RLAN operations.

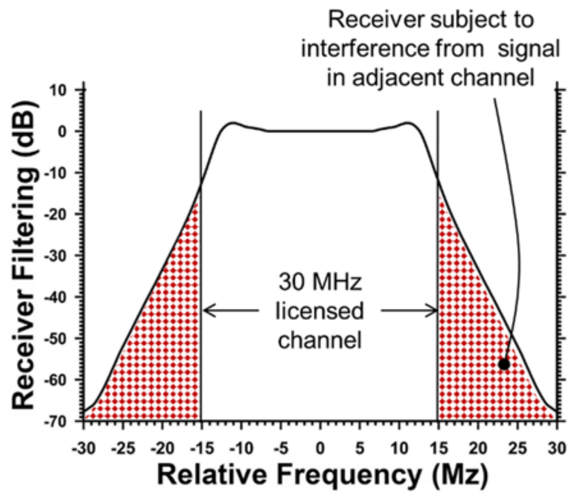

Figure 3: 30 MHz FS victim receiver passband response

The Association of American Railroads suggests a promising alternative: the use of exclusion zones for adjacent and second-adjacent channels that are smaller than the main-channel exclusion zone.[132] Pending more detailed study, we think this approach should work as well to protect the FS. The choice may come down to which option is easier to implement in an AFC system, and which frees up more spectrum for RLANs.

131 *See* Fixed Wireless Communications Coalition at Attachment C.

132 Association of American Railroads at 11.

6. AFC database

RLAN Group wants the AFC system to use FS receiver data in ULS, on the mistaken assumption that ULS contains the same data that private frequency coordinators use in siting a new FS link.[133] In fact the receiver data in ULS is error-prone and unreliable. Comsearch, an industry leader in FS frequency coordination, calls ULS primarily an administrative, rather than a technical, database.[134] Comsearch reports that ULS is of limited utility in informing interference analysis, and notes that many of the errors in ULS are outside FS licensees' control.[135]

More complete and accurate FS receiver databases do exist. We ask the Commission to explore ways to use these in the AFC system. Assuming no great difference in cost, the burden on RLAN operators should be the same whether the AFC is protecting actual FS receivers or phantom receivers inferred from bad ULS data.

Some RLAN interests, in favoring the use of ULS, support an amnesty that would allow FS licensees to update their ULS information without penalties, fees, or coordination requirements.[136] Our first-round comments noted that one obstacle to ULS updates is the mandated filing fees for license modifications.[137] These are statutory, and so would require relief from Congress.

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133 RLAN Group at 41.

134 Comsearch at 16-17.

135 *Id*. *See also* National Spectrum Management Association at 4 (ULS plagued with inaccuracies and lacks critical data).

136 RLAN Group at 43; Hewlett Packard at 28.

137 All FS licenses must pay a filing fee of $305 per call sign for major modifications. *Wireless Telecommunications Bureau Fee Filing Guide* at 27-28 (effective Sept. 4, 2018). Non-common-carrier licenses pay the fee even for minor modifications. *Id*. For details, *see* Fixed Wireless Communications Coalition at 28-29.

7. RLAN location accuracy—in general

We concur with the RLAN interests' proposal that RLAN devices be permitted to use location methods of varying precision,[138] so long as the level of uncertainty is properly reported to the AFC, which then coordinates the device as though it were in the worst-case position(s) within the range of uncertainty. We support this approach for both horizontal and vertical positioning.

Wi-Fi Alliance proposes locating RLANs with a 95% confidence level.[139] This is irresponsible: equivalent to permitting 5% of RLANs to be wrongly located, thereby to be incorrectly coordinated, and consequently to become interference threats. Each RLAN must be coordinated over its entire range of uncertainty.

8. RLAN location accuracy—vertical

We concur with the RLAN interests that favor three-dimensional coordination, taking the elevations of the RLAN transmitters and FS receivers into account.[140]

We also agree that professional installation can be optional,[141] if subject to this condition: where the RLAN is not professionally installed, and also cannot reliably determine its own elevation via GPS—as will sometimes happen with indoor units[142]—then its vertical position is unknown, and the device must be coordinated for the worst case among all possible elevations,

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138 *See* RLAN Group at 55.

139 Wi-Fi Alliance at 25.

140 RLAN Group at 6; Wi-Fi Alliance at 26; Sony at 1; Microsoft at 16.

141 RLAN Group at 54; Microsoft at 19.

142 Indoor GPS is so unreliable that the Commission has proposed using the receipt of a GPS signal as a trigger to automatically shut down indoor-only devices. Notice at ¶ 71.

over its range of possible horizontal positions. This will allow the inexpensive deployment of consumer devices while still protecting FS receivers.[143]

9. Client devices and probe requests

RLAN interests seek to operate client devices at the same power as the associated access point.[144] We have no objection, so long as the client device is coordinated at that higher power over the full volume of its maximum possible operating range around the access point, also taking into account the uncertainties of the access point's location.

Some parties want authority for client devices to send non-coordinated "probe" requests to join a network, before the client device comes under the control of a coordinated device.[145] Some cite irrelevant precedents to TV White Space operations and to U-NII-2.[146] Others say that because the probe requests last only milliseconds, they would produce a "negligible" probability of FS interference.[147]

Physics disagrees. As a rough guide, a receiver is sensitive to interference lasting any longer than the reciprocal of its passband. This means a 30 MHz FS receiver will detect events whose duration exceeds about 33 nanoseconds. Wi-Fi Alliance's milliseconds-long event is several orders of magnitude longer than that, and potentially highly interfering.

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143 *See* RLAN Group at 54 (seeking to avoid professional installation so as to promote a consumer market).

144 RLAN Group at 49; Wi-Fi Alliance at 17; Microsoft at 11-12; Cambium Networks at 4; Qualcomm at 16; Broadcom at 36-37.

145 Wi-Fi Alliance at 28; Wireless Internet Service Providers Ass'n at 16; Hewlett Packard at 30-31.

146 Wireless Internet Service Providers Ass'n at 16; Hewlett Packard at 30. The precedents have no bearing here because the services being protected have technical characteristics very different from the FS.

147 Wi-Fi Alliance at 28; Hewlett Packard at 30-31.

10. Interference reporting and resolution

Some parties oppose having the AFC register individual RLAN devices and the frequencies they use.[148] That would make it impossible to identify and disable an RLAN that causes actual interference—for example, due to device malfunction. The Commission should require device registration so as to swiftly shut down a unit that fails to conform to AFC guidance or causes FS interference for any other reason, on receipt of an FS interference report.

Hewlett Packard contemplates multiple, independently operating AFCs, each controlling its own fleet of RLANs, such that each AFC "does not need to know where devices under the control of another AFC are operating."[149] We are generally neutral on the specifics of AFC administration, and have no opinion on independent AFCs, with one important proviso: there must be a central point to which an FS operator can report interference, and which has the capability to immediately shut down an offending RLAN device. The Commission's authority for Higher Ground to provide licensed mobile satellite service in the 6 GHz band included such a requirement.[150] It is needed here as well.[151]

Apple is concerned that AFC registration of a device would tie a hardware identifier to its location and thereby violate the end user's privacy.[152] But there is no need to relate the hardware identifier to a particular end user. In order to resolve an interference issue, the AFC needs only to

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148 Wi-Fi Alliance at 30; Apple at 14-15; Broadcom at 41-43.

149 Hewlett Packard at 25. *See also* Apple at 12 (disfavoring requirement that AFC systems coordinate); Microsoft at 18 (supporting "decentralized" AFCs).

150 *Higher Ground LLC*, Order and Authorization, 32 FCC Rcd 728 at ¶¶ 38, 40(c) (Internat'l Bur., Wireless Telecom. Bur., Office of Engineering and Technology 2017).

151 Some RLAN interests agree with us on the need for close coordination among AFCs and registration of devices. Wireless Internet Service Providers Ass'n at 19; Sony at 5; Midcontinent Communications at 14-15.

152 Apple at 14-15.

know that at time *A* it assigned frequencies *B* to device *C* in exclusion zone *D*. It does not need to know anything about the identity of the person using the device, or even the device's location within the exclusion zone.

11. Mobile operation

RLAN interests propose mobile operation, including in vehicles, by pre-checking all possible locations of the RLAN in advance, as computed from its present position.[153]

A capability along these lines will be necessary for hand-carried RLANs. An RLAN whose GPS detects that the device is in motion will have to re-check frequently with the AFC.

We oppose operation in vehicles, at least at the outset. This would require far more frequent re-checks and the capability of changing frequencies on the fly—functions that would greatly complicate the demands on a system whose basic feasibility is still hypothetical. We are open to rethinking the question after the AFC system is up and operating reliably. In the meantime, the Commission's rules must require an RLAN whose GPS detects motion faster than walking speed to automatically shut down.

Exception: we do not oppose operation while in motion, even in vehicles, within a geofenced facility whose every internal location is re-checked at least once every 24 hours.[154] This presumes the geofencing capability has been shown to be extremely reliable and impossible for the end user to defeat, and that the device *continuously* confirms its location within the geofenced area.

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153 RLAN Group at 51-52; Hewlett Packard at 25-26; Apple at 4-5; Qualcomm at 15-16.

154 *See* RLAN Group at 52.

12. Operation in aircraft

We oppose operation in aircraft.[155] We are concerned about inadvertent emissions during takeoff and landing, as the aircraft passes through an FS antenna main beam. If airline personnel neglected to turn off the RLAN system at low altitudes—just when the crew is busiest—the result could be catastrophic.

Boeing seeks a rule that allows operation in aircraft parked at airport facilities.[156] We have no objection so long as the operation is AFC coordinated. We explained in Part D.3 above why all indoor operation needs coordination. Boeing puts the fuselage attenuation at about 20 dB,[157] comparable to a building wall. Operation inside the aircraft needs coordination just as other indoor RLANs do.

13. Power spectral density

We support the Commission's proposed limit for a maximum power spectral density (PSD) of 17 dBm/MHz,[158] similar to U-NII-1. We oppose the requested increase to 27 dBm/MHz.[159] The only ground offered for the increase is that U-NII-3, which allows the higher level, is "spectrally much closer" to 6 GHz than to U-NII-1, at the proposed lower level.[160]

This argument makes no sense. U-NII-3 is an ISM band, and for that reason has no incumbents that carry critical services. U-NII-2, which has radar operations that need protection

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155 RLAN Group at 53; Hewlett Packard at 26-27; Apple at 10-11; Boeing at 7-11.

156 Boeing at 11-12.

157 Boeing at 8.

158 Notice at ¶ 78.

159 RLAN Group at 68-69; Qualcomm at 16-17. Wireless Internet Service Providers Ass'n (at 13) seeks a higher effective PSD of 23 dBm/360 kHz, equivalent to 27.4 dBm/MHz. It takes this number from the CBRS rules, which will use far narrower bandwidths and have no application here.

160 RLAN Group at 69.

from unlicensed devices, has an even lower maximum PSD than U-NII-1, at 11 dBm/MHz.[161] The Commission's proposed 17 dBm/MHz PSD limit for the 6 GHz bands is the highest that is appropriate.

Moreover, RLAN interests plan to use much higher bandwidths than at 5 GHz, with 80% of units projected to have bandwidths of 80 MHz or higher.[162] Even at 17 dBm/MHz, these will deliver adequate power.

14. Antenna gain

RLAN interests seek to carry over the 5 GHz U-NII rules on antenna gain to 6 GHz, so as to implement point-to-point and point-to-multipoint operation. They seek either unlimited antenna gain with no output power penalty, as at U-NII-3, or a penalty of 1 dB for every dB of antenna gain over 6 dBi.[163]

As we explained in our first-round comments, both types of operation would greatly complicate AFC coordination.[164] The AFC database would have to take into account not only an RLAN's location and elevation, but also its antenna gain, azimuth and elevation angle. (Directional antennas for client devices as well would multiply these complications.[165]) We oppose point-to-point unlicensed operation in the initial roll-out, but are open to considering it after the AFC setup is running smoothly.

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161 47 C.F.R. § 15.407(a)(2).

162 RKF Study at 24, Table 3-9.

163 RLAN Group at 69-72. *See also* Wi-Fi Alliance at 32; Wireless Internet Service Providers Ass'n a 10, 14; Open Technology Institute at New America, *et al*. at 21; Hewlett Packard at 29-30; Cambium Networks at 3; Broadcom at 38-40. Ubiquiti (at 1) seeks unlimited EIRP.

164 FWCC Comments at 33-34.

165 Wireless Internet Service Providers Ass'n at 15.

We doubt that point-to-multipoint RLAN systems using directional antenna can be coordinated reliably. These would have the same problems as point-to-point RLANs, but more of them, and in addition are likely to add and change remote locations on a frequent basis. The Commission has proposed point-to-multipoint in part of the 4 GHz band.[166] The FWCC does not oppose this, so long as existing 4 GHz FS links remain protected.[167] We think the best solution is to move forward with point-to-multipoint in part of the 4 GHz band and exclude it from 6 GHz.

15. Integrated antennas

The Internet offers noncompliant, easily installed Wi-Fi antennas that boost EIRP far above lawful levels. We have no doubt that similar attachments for 6 GHz RLANs would quickly be marketed to consumers and business owners who wish to extend the range of their devices. Unlike antennas for the ISM bands, the after-market installation of excessive-gain antennas at 6 GHz, being unknown to the AFC system, would threaten severe interference to the FS. For this reason we ask the Commission to require that each RLAN be shipped in a factory-sealed case with integrated antennas that the end user cannot easily bypass or replace.

One party wants to allow an operator to attach any antenna to any device.[168] This is obviously unacceptable. Even the "unique coupling" option in Section 15.203 is unsuitable for a band that carries critical services, as it can be defeated much too easily.

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166 *Expanding Flexible Use of the 3.7 GHz to 4.2 GHz Band*, 33 FCC Rcd 6915 (2018) (4 GHz Order & NPRM).

167 Comments of the Fixed Wireless Communications Coalition in GN Docket No, 18-122 (filed Oct. 29, 2018).

168 Midcontinent Communications at 12-13.

F. Proposals to Reallocate Over Half the 6 GHz Band for Mobile Use are Not Feasible.

Two parties propose reallocating the 6.425-7.125 GHz segment for licensed mobile use and relocating the incumbents.[169] The incumbents include 30,280 fixed links in the 6.525-6.875 GHz (U-NII-7) band.

1. Infeasibility of FS relocation

Both parties agree that relocated incumbents must be "made whole" with "comparable facilities" at the new licensees' expense,[170] but have no firm plans on how to accomplish that. Ericsson refers to "other FS band and fiber."[171] But there are no other FS bands suitable for 6 GHz users. The Commission has closed 4 GHz to new applications,[172] and plans to sunset the present licensees.[173] Many U-NII-7 FS users are there due to lack of room at U-NII-5, meaning they cannot relocate to U-NII-5.[174] The other FS bands are all above 10 GHz, where they are subject to rain fade, and so cannot carry links as long as at 6 GHz; and the lowest of those bands, at 11 GHz, is heavily congested. If fiber were a feasible substitute for a given FS link, it might already be in use, as the engineers who built the link could have opted instead for fiber's greater capacity. But both overhead and buried fiber are easily cut or broken, and breaks take hours to repair. This makes fiber too unreliable for critical applications at some kinds of locations. And

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169 CTIA at 9-13; Ericsson at 13-16.

170 CTIA at 10; see also Ericsson at 14 (similar).

171 Ericsson at 15.

172 *Temporary Freeze on Applications for New or Modified Fixed Satellite Service Earth Stations and Fixed Microwave Stations in the 3.7-4.2 GHz Band*, GN Docket Nos. 17-183, 18-122, Public Notice, DA 18-398 (released April 19, 2018).

173 4 GHz Order & NPRM at ¶ 48.

174 The rules permit 30 MHz links in U-NII-7 only if they cannot be accommodated in U-NII-5. 47 C.F.R. § 101.147(a) note 33. There are thousands of 30 MHz links in U-NII-7.

fiber is prohibitively expensive in high-density urban areas and rugged terrain, where only FS is workable.

That leaves only one relocation option: the dubious prospect of reallocating part of the 7.125-8.4 GHz federal FS band for shared non-federal use, and moving current U-NII-7 FS users there.[175]

CTIA tries to make the relocation sound easy, saying the process has "stood the test of time"—referring to the two FS relocations out of the 2 GHz bands.[176] There, incoming licensees were required to provide FS systems "at least equivalent" to the existing systems as to throughput, reliability, and operating costs.[177] The first of those relocations was disruptive and acrimonious, and in some cases took many years—a poor basis for future planning.[178] When the second 2 GHz relocation came around, some FS operators took cash settlements rather than go through the process.

Moreover, availability of the 7.125-8.4 GHz federal band for private FS use is very much in doubt. The FWCC has had a rulemaking petition on this issue pending since 2010 without action.[179] An NPRM on relocation out of U-NII-7 is premature unless and until the Commission has in hand and has made public:

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175 CTIA at 13-16; Ericsson at 13-16.

176 CTIA at 11.

177 47 C.F.R. §§ 10.173(d), 101.75(b).

178 One example of the difficulties: Much of the original 2 GHz FS equipment, although still having years of useful life, was no longer manufactured. The current models had features the old ones lacked. Incoming licenses objected to paying for equipment with the new features, on the ground it was not comparable to the old. The FS incumbents did not need the new features and also did not want to pay for them, but equipment without those features was not available.

179 *Federal and Non-Federal Sharing in the 7125-8500 MHz Band*, RM-11605, Public Notice (released June 4, 2010).

- a clear statement from NTIA agreeing to reallocate enough of the 7.125-8.4 GHz to accommodate the U-NII-7 users among existing federal users, with adequate room for the future expansion of both;

- detailed information on the density of federal use, by location, adequate for an independent assessment of available spectrum;[180]

- information on federal users' channelization (as we understand that older links are channelized haphazardly); and

- NTIA's commitment to make full federal link data available to non-federal frequency coordinators, for the purpose of coordinating non-federal users.

Unless NTIA can be forthcoming on these points, the Commission should not further consider relocating U-NII-7 FS users. To start a relocation proceeding without first confirming that relocation is even possible would be a waste of everyone's time.

2. A better option: 4 GHz

The Commission has opened a rulemaking on repurposing the 3.7-4.2 GHz band for point-to-multipoint and/or mobile use.[181] We urge it to keep the 6 GHz band intact, and to address any immediate need for additional mobile spectrum at 4 GHz. While that has less total spectrum than the 700 MHz CTIA and Ericsson seek at 6.425-7.125 GHz, the transition to mobile use at 4 GHz would be far simpler and less disruptive.

CONCLUSION

The FWCC does not oppose unlicensed RLANs in the 6 GHz FS bands, so long as FS operations are fully protected at their current levels of reliability.

Adequate protection requires preventing interference events that may be unlikely for an individual RLAN, but become statistical certainties over the projected large numbers. RLAN

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180 We understand the 7.125-8.4 GHz band is used by the Defense Communication System, which our members report has been unwilling in the past to share coordination details in other bands.

181 4 GHz Order & NPRM.

interests oppose some of the needed measures, which include AFC control for all RLANs outdoor and indoors, on the ground that they will allow fewer RLAN frequencies at some locations and may raise costs. Such considerations are secondary to the obligation to protect FS operations.

The policy choice, simply put, is between marginal improvement in Internet access *versus* a licensed, ultra-reliable service that carries applications critical to the safety of life and property. The Commission can allow RLAN operation, while fully maintaining FS reliability, by requiring AFC control for all RLANs as set out above.

This is the Commission's first attempt at introducing hundreds of millions of unlicensed devices into a critical-service band with tens of thousands of receivers that need protection. We urge the Commission to proceed cautiously, and to resolve reasonable doubts in favor of the essential services on licensed fixed links.

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Appendix A

Calculating Interference from an RLAN in the Main beam of a Category A or B1 FS Antenna

George Kizer

If we assume the transmitter and victim receiver bandwidths completely overlap, interference I from an RLAN transmitter may be calculated using the following formula:

Victim Receiver Interference (dBm) = RLAN EIRP - Path Loss
- Building Loss + Receiver Antenna Gain
- Side Lobe Rejection - Near Field Loss
- Bandwidth Mismatch Loss - Polarization Decoupling Loss (1)

RLAN EIRP (dBm) is the RLAN transmitter power (dBm) plus antenna gain (dBi).

Path Loss (dB) is the propagation loss between the RLAN transmitter and victim receiver antennas. In the absence of specific path knowledge, Path Loss is free space loss[1,2]:

$$\text{Path Loss (dB)} = 92.5 + 20\ \text{Log}_{10}[\text{Frequency (GHz)}] + 20\ \text{Log}_{10}[\text{Path Distance (kilometers)}] \quad (2)$$

At the center of the lower 6 GHz band, Path Loss (dB) = $92.5 + 20\ \text{Log}_{10}[6.175] + 20\ \text{Log}_{10}$ [Path Distance (kilometers)]

$= 20\ \text{Log}_{10}$ [Path Distance (kilometers)] + 108.3

[1] ITU-R P.452-16, Prediction Procedure for the Evaluation of Interference Between Station on the Surface of the Earth at Frequencies above about 0.1 GHz, July 2015, page 18, "Where there are doubts as to the certainty of the clutter environment this additional [clutter] loss should not be included."

ITU-R Recommendation F.1706, Protection Criteria for Point-to-Point Fixed Wireless Systems Sharing the Same Frequency Band with Nomadic Wireless Access Systems in the 4 to 6 GHz Range. Geneva: International Telecommunication Union, Radiocommunication Sector, January 2005, page 1, “the maximum aggregate interference from the NWAS including base station and terminal stations should be such that the degradation to an FWS receiver threshold does not exceed 0.5 dB under free space propagation conditions”.

[2] Kizer, page 669, formula (A.28).

Building Loss (dB) is the additional loss that the transmitted signal encounters due to its location. Typically this is only significant for indoor transmitters.

Receiver Antenna Gain (dBi) is the antenna gain. For these applications we shall use the FCC specification for a Category A/B1 antenna:[3] 38 dBi.

Side Lobe Rejection (dB) is the loss of antenna gain when the interfering path is off azimuth from the main beam. For main beam interference this value is zero.

Near Field Loss (dB) is the loss of antenna gain when the transmitter is in the near field of the receiver antenna. For the examples in text, near field loss is zero.

Bandwidth Mismatch Loss (dB) is the loss of interference power if the interfering signal is wider than the victim receiver. We will use the RLAN channel bandwidths and their estimated probability of use[4]. We will assume the RLAN channel bandwidth is wider than, and completely overlaps, a 30 MHz FS channel bandwidth.

Weighted Average RLAN Transmitter Bandwidth = (160 MHz x 30%)
+ (80 MHz x 50%) + (40 MHz x 10%) + (20 MHz x 10%) = 94 MHz (3)

Bandwidth Mismatch Loss (dB) = 10 Log_{10} [Expected RLAN transmitter bandwidth / victim receiver bandwidth (MHz)]
= 10 Log_{10} [94 MHz / 30 MHz]
= 5.0 (4)

Polarization Mismatch Loss (dB) is the loss introduced when the transmitter antenna polarization is not aligned with the receiver antenna polarization. We will assume the RLAN transmit antenna can assume any polarization[5]. Since the receiver antenna will be either vertical or horizontal polarization, on average we would expect a 3 dB antenna to antenna polarization mismatch loss.

Substituting into Equation (1): Victim Receiver Interference (I) (dBm)
= RLAN EIRP - [20 Log_{10} [Path Distance (kilometers) +108.3] - Building Loss
+ 38 - 0 - 0 - 5 - 3

= RLAN EIRP - 20 Log10 [Path Distance (kilometers)] - Building Loss - 78.3 (5)

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[3] 47 C.F.R. § 101.115.

[4] RKF Study, page 24, Table 3-9.

[5] RKF Study, page 17, Paragraph 3.2.1, “In each installation, the orientation of the RLAN antenna is in general not fixed. Therefore, in the analysis we assumed an equal weight assigned to all values in the E-plane pattern.”

Threshold Degradation: Receiver path performance is a direct function of path fade margin. Fade margin is limited by the combined power level of receiver front end noise and external interference, given by the following formula:

$$RFM = \{10 \log_{10} [10^{N/10} + 10^{I/10}] \} - N \qquad (6)$$

RFM = Reduction in Fade Margin (dB)
N = Receiver Front End Noise (dBm)
I = External Interference (dBm) (from equation (5))

Receiver front end noise N is given by the following:[6]

$$N(dBm) = -114 + NF + 10 \, Log_{10}(B) \qquad (7)$$

NF = receiver noise figure (dB)
B = receiver bandwidth (MHz)

RLAN Group suggests the typical receiver noise figure in these bands is about 5 dB.[7] We assume a 30 MHz FS bandwidth.

$$N(dBm) = -114 + 5 + 10 \, Log_{10} (30) = -94.2 \qquad (8)$$

Substituting in equation (8) gives $RFM = \{10 \log_{10} [10^{-9.42} + 10^{I/10}] \} + 94.2$ (9)

[6] Kizer, G., *Digital Microwave Communication*, Hoboken: Wiley and Sons, 2013 (Kizer), page 674, formula (A.54).

[7] Paul Margie, *Expanding Flexible Use in Mid-Band Spectrum between 3.7 and 24 GHz*, GN Docket No. 17-183, Harris, Wiltshire & Grannis, filed January 26, 2018, (RKF Study) page 29.