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Marlene H. Dortch, Secretary
Federal Communications Commission
445 12th Street, S.W.
Washington, DC 20554

Re: **GN Docket No. 17-183,** ***Expanding Flexible Use in Mid-Band Spectrum Between 3.7 and 24 GHz***
Ex Parte **Communication**

Dear Ms. Dortch:

On behalf of the Fixed Wireless Communications Coalition, Inc. (FWCC),[1] I am electronically filing this communication in the above-referenced docket.

This responds to two *ex parte* submissions from the group of companies filing as Apple Inc., *et al.* ("RLAN Group").[2]

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[1] The FWCC is a coalition of companies, associations, and individuals interested in the fixed service – i.e., in 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, cable TV providers, backhaul providers, and/or their respective associations, communications carriers, and telecommunications attorneys and engineers. Our members build, install, and use both licensed and unlicensed point-to-point, point-to-multipoint, and other fixed wireless systems. For more information, see www.fwcc.us.

[2] Letter from Apple Inc., *et al*. to Marlene H. Dortch, Secretary, FCC (filed May 14, 2018) ("RLAN Group May 14 Ex Parte"); *FS-RLAN Coexistence in the 6 GHz Band* (slide deck), attached to Letter from Paul Margie, Counsel for Apple Inc., *et al*. to Marlene H. Dortch, Secretary, FCC (filed April 12, 2018) ("RLAN Group April 12 slide deck").

A. SUMMARY

RLAN Group seeks to deploy a billion unlicensed RLAN devices in the 5.925-7.125 GHz bands at power levels ranging up to +35.3 dBm (3.4 watts) EIRP. The FWCC has shown these will cause widespread harmful interference to the 95,000 licensed 6 GHz links in the Fixed Service ("FS"), which must operate at extremely high levels of reliability. RLAN Group concedes there will be interference, but claims it will be rare and can be controlled through mitigation. We show below that the interference will not be rare, but pervasive and consistent, and that the proposed mitigation methods cannot work.

Even the degree of interference that RLAN Group admits to would decimate FS reliability. The actual interference would be orders of magnitude worse, affecting virtually every FS receiver studied.

RLAN Group does not dispute that most 6 GHz FS links operate at reliability levels of 99.999% or 99.9999%, nor does it dispute that RLAN deployment must leave these numbers largely unchanged. By careful manipulation of its numbers—in ways that we question below—RLAN Group manages to push the interference estimates down to 0.2%, which it calls "extremely low."[3] To the contrary, in a service that limits outages to 0.001% or 0.0001%, an interference rate of 0.2% would still degrade FS performance by several orders of magnitude.

The extraordinarily high reliability of FS operations calls for extraordinary interference protection. Six-nines and five-nines reliability allow for total annual outages of thirty seconds or five minutes, respectively. High enough levels of interference will cause link outage at any time of day. Even low levels can cause outages at night, when FS systems are under stress from multipath fading. It takes just one brief interference event to one FS receiver to disable an entire network of links for several minutes while it resynchronizes, using up years' worth of outage allowance.[4]

To avoid significant impairment to FS reliability, RLAN Group would have to show that RLAN-caused receiver outages over the course of a year are well below the permitted levels from other causes—*i.e.*, on the order of 3 seconds or 30 seconds. This requires making nighttime interference in excess of 1 dB extremely improbable. It can be done; frequency coordination among FS facilities and with FSS earth stations routinely maintains near-zero interference levels. But RLAN Group has not shown it can meet the same standard.

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[3] RKF Study at 54.

[4] RLAN Group makes the startling claim that "[f]or short periods an FS link with no excess margin can tolerate an I/N of +36.8 dB." RLAN Group April 12 slide deck at 6. It cites in support NTIA Report 05-432, *Interference Protection Criteria, Phase 1 - Compilation from Existing Sources*. We have studied that report and see no basis for the claim, which defies long-accepted principles of interference analysis.

Instead, RLAN Group posits mitigation measures,[5] but nowhere does it provide a quantitative explanation of how any would work. To be sure, some of these measures have been shown to protect other services in other bands. But most will not work to protect 6 GHz FS. We explain in Part F below why only one of the measures would be useful, and that one has limited applicability.

RLAN Group has withheld an explanation of its analysis sufficiently detailed to permit replication. It effectively asks the Commission to take its word on the results. Given the importance of the issue, and our very different and fully documented findings, the Commission should not accept RLAN Group's conclusions without full engineering backup. Part E identifies some of their assumptions as being overly optimistic, but those explain only part of the discrepancy between their results and ours. We want to account for the rest.

The FWCC's analysis, presented in full, shows far more pervasive interference:[6] RLAN Group's criterion of 1 dB interference into virtually every link, not just 0.2%. RLAN Group's criticisms of our study are ineffective. We respond to each below.

We thought one criticism in particular—on the distribution of RLAN power levels—might have some merit, so we reran our analysis using RLAN Group's numbers. (See Part C, below.) The incidence of interference came down somewhat, but not nearly enough: our results still show 1 dB or more interference into almost every FS receiver. The results also show interference strong enough (40 dB or more) to disable a link at any time of day for almost 2% of FS systems.

Lacking RLAN Group's full analysis, we are concerned that they count on FS systems' fade margin to absorb interference. See Part D. RLAN Group denies doing this, but it also makes statements that suggest the opposite. Likewise, RLAN Group continues to insist that multipath fading does not begin until midnight, after a hypothetical RLAN "busy hour" has concluded, where in fact fading begins at sundown. The difference could matter only if RLAN Group planned to improperly encroach on FS receivers' fade margin.

The likelihood of interference is not a matter of opinion, but turns on engineering analysis—on which group's calculations better reflect reality. To justify the RLAN deployment, RLAN Group must both establish that the devices will not cause harmful interference to FS receivers, and also quantitatively counter the FWCC's showing that widespread interference in fact will occur. It has failed at both.

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5 *E.g.*, RLAN Group May 14 Ex Parte at iii, 14.

6 *See* George Kizer, *Studies Regarding RKF's Frequency Sharing for Radio Local Area Networks in the 6 GHz Band Proposal*, attached to Letter from Cheng-yi Liu and Mitchell Lazarus to Marlene H. Dortch, Secretary, FCC (filed March 13, 2018) ("Kizer Analysis").

B. THE MISSING RLAN INTERFERENCE ANALYSIS

RLAN Group rests its claims of noninterference on a study prepared by its contractor RKF.[7] The report of that study filed with the Commission states assumptions and results, but the analysis in between is missing. That should disqualify it from serious consideration.

Unlicensed devices (like the RLANs) must protect licensed services (such as the FS) from harmful interference.[8] RLAN Group projects deploying almost a billion of them.[9] Once they are in consumers' hands, there is no way to call them back or turn them off. RLAN Group has to establish before the fact that the devices will be incapable of causing harmful interference to FS receivers. The RKF Study fails in this because there is no way to tell whether the claimed results follow from the assumptions. But even if RKF's claimed results are correct, they still show unacceptable interference to the FS.

The Commission should require RLAN Group to set out its analysis in enough technical detail that a competent radio engineer can replicate the calculations. (Both the FWCC and the National Spectrum Management Association did this.) Having the burden of proof as to non-interference, RLAN Group must show its proof. We particularly want to find the explanation for RLAN Group's interference predictions being so different from ours. By withholding a presentation of its analysis that permits technical review, RLAN Group is saying, "trust us"—not enough to warrant a decision in its favor.

The lack of a comprehensive technical report from RLAN Group also contributes to apparent ambiguities and internal inconsistencies in its filings. What RLAN Group calls FWCC's misreadings may result in part from our efforts to make sense of an incomplete write-up. If RLAN Group believes its analysis is correct, then instead of challenging our critique piecemeal, it should simply lay out its work in detail.

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7 *Frequency Sharing for Radio Local Area Networks in the 6 GHz Band (January 2018),* prepared by RKF Engineering Services, LLC on behalf of Apple Inc. et al., (filed Jan. 26, 2018) ("RKF Study").

8 47 C.F.R. § 15.5.

9 RKF Study at 11, 13.

C. RESULTS OF THE FWCC STUDY

RLAN Group wrongly states that the FWCC study predicts 5.6 interfering RLAN devices over an entire urban market.[10] We found something much worse: 5.6 RLAN devices ***interfering with every fixed microwave receiver we studied.***[11]

These numbers reflect interference at the 1 dB level, which RLAN Group took as its own criterion.[12]

RLAN Group specified outdoor devices at three different powers, the highest being 35.3 dBm EIRP. The initial FWCC simulation put all RLANs at 35 dBm. If the Commission certifies RLANs at this power, RLAN Group will have no way to enforce its distribution, so the FWCC is entitled to consider a worst-case condition.

RLAN Group objected,[13] noting that its own study assumed 35 dBm outdoor RLANs would be in the minority (Table 1):[14]

Type	Power (dBm EIRP)	Distribution
Outdoor high power access point	35.3	20%
Outdoor low power access point	24.1	30%
Indoor/outdoor client	18.5	50%

Table 1
RLAN power distributions
per RLAN Group

We redid our simulation to use this distribution. Unlike RKF, which used a weighted average of the three device powers,[15] we ran a more exact simulation by populating the study

10 RLAN Group May 14 Ex Parte at 16.

11 Kizer Analysis at 3 Table 1 (captioned "Average Number of Interference Cases per Receiver"), reproduced in Table B, attached.

12 RKF Study at 5, 6, 11 (citing a criterion of I/N = -6 db, equivalent to 1 dB fade margin degradation).

13 RLAN Group April 12 slide deck at 15.

14 *Id.* (powers); *Id.* at 22, Table 3-6 (distribution).

15 RKF Study at 22.

areas with devices at random locations and having random powers in accord with RLAN Group's percentage distributions. The simulation procedure was otherwise unchanged.[16]

Table 2 shows the new results (in boldface) side by side with our initial results.

Fade Margin Reduction Due to RLANs	Fraction of FS Receivers Affected		Likely Consequence
	RLAN powers per Table 1	RLAN powers at 35 dBm	
over 1 dB	**nearly all**	nearly all	exceeds RKF criterion
over 10 dB	**over half**	over half	vulnerable to ordinary fades
over 20 dB	**1/4**	1/3	
over 30 dB	**1/14**	1/9	bit errors occur
over 40 dB	**1/59**	1/33	link fails

Table 2
Fractions of FS receivers that experience interference from RLANs

(More detailed summaries of results for both sets of RLAN powers are attached.)

There is no significant change to the fractions of FS receivers experiencing interference in the range 1-20 dB. **All FS receivers still see unacceptable levels of interference.** The fraction of FS receivers experiencing the very worst interference—enough to shut down a link in broad daylight—is approximately halved, but that is still orders of magnitude too high. Our simulation study area in Houston, Texas, for example, includes 838 FS receivers, many serving the petroleum industry, some in safety-critical applications. Fourteen Houston FS receivers are subject to night-or-day failure from RLAN interference in excess of 40 dB.

D. RLANs and FS Fade Margin

Fade margin is an extra reserve of signal power built into an FS link to compensate for the loss of received power caused by atmospheric fading. At 6 GHz, all fading is multipath fading caused by layers in the atmosphere that form at night. FS fade margins are typically in the range 25-40 dB, depending on the reliability needed. Interference that does not cause an immediate outage will still cut into the fade margin and leave the system more vulnerable to outage from fades it could otherwise withstand. If the system is already in a fade condition, even a small degree of interference may be enough to bring it down.

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16 For details on the procedure, *see* Kizer Analysis, summarized at Letter from Cheng-yi Liu and Mitchell Lazarus to Marlene H. Dortch, Secretary, FCC at 6-8 (filed March 13, 2018).

Typically, interference that uses up 1-20 dB of fade margin leaves the system vulnerable to loss of communication from natural fade; 30 dB of interference causes errors in transmission; and 40 dB shuts down the link.

(The interference path from an RLAN to an FS receiver is not subject to multipath fading because the path is too short. The RLAN signal reaches the FS receiver at full force.)

We questioned earlier whether RLAN Group's non-interference claims rely on having FS fade margin soak up the interfering signal.[17] That would be improper, because at night FS systems need all of their designed-in fade margin, leaving no excess to counter interfering signals from RLANs.

RLAN Group has since answered the question—but answered it both ways. On the one hand, it stated, in italics:

> RKF's study *did not* apply unused multipath fade margin, which would have reduced a link's susceptibility to interference.[18]

Yet the same slide also says the contrary (our italics): "multipath fade margin *can be used* to reduce IPC between 8:00 am and midnight."[19] Another slide in the same presentation similarly says:

> A link with excess fade margin can tolerate higher levels of interference. For any given link, if excess fade margin is available, the IPC [interference protection criterion] may be relaxed dB-for-dB.[20]

And again, a more recent RLAN Group filing says:

> RLAN devices are very unlikely to cause harmful interference to FS … because of, among other things, the significant fade margin designed into FS systems.[21]

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17 Letter from Cheng-yi Liu and Mitchell Lazarus to Marlene H. Dortch, Secretary, FCC at 11 (filed March 13, 2018.

18 RLAN Group April 12 slide deck at 12 (emphasis in original).

19 *Id*. at 9 (emphasis added).

20 *Id*. at 6.

21 RLAN Group May 14 Ex Parte at iv.

We need clarity on this point—in plain, unambiguous language with engineering backup. If RLAN Group's interference calculations did include the use of FS fade margin, they must be redone and corrected results submitted.

RLAN Group's possible reliance on fade margin would be consistent with its continuing (and incorrect) insistence that multipath fading—and hence the need for FS fade margin—does not begin until midnight.[22] Multipath fading begins at sundown. This is a fact of atmospheric physics and not subject to lawyerly dispute.[23] And even if RLAN Group were right on this point, it still does not propose to shut down RLAN usage after midnight.

RLAN Group questions the FWCC's "bare assertion" that FS fade margins are 10 dB less than RKF claims, adding that RKF based its data on link characteristics in the Commission's ULS database.[24] It is not clear where RKF got its data, as ULS does not record the receiver thresholds, receiver filter losses, and feeder (waveguide) losses needed to compute fade margin. The FWCC presented the actual data derived from a much more complete proprietary database.[25]

RLAN Group's continuing argument over typical fade margin, and its tenacity on the time of day when multipath fading begins, could matter only if RLAN Group improperly relied on unused FS fade margin—which it claims not to do.

E. DISPUTES OVER SIMULATION METHODS

The FWCC and RLAN Group have each criticized the other's simulations. We address those points here. One of RLAN Group's objections, relating to RLAN power, prompted us to rerun our simulation using their numbers, but the results did not change enough to matter. (Part C, above.) Here we show why RLAN Group's other objections to our approach are either unfounded or would have only small effects on the outcome.

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22 Most recently, RLAN Group May 14 Ex Parte at 12-13.

23 RLAN Group misreads a source: RLAN Group April 12 slide deck at 9, *citing* George Kizer, *Abnormal Propagation*," TIA TR45 Working Group on Microwave Systems, Doc. No. TR45.WGMS-170112-377 at 11. Kizer titled his paper "Abnormal Propagation" because it concerns a rare form of propagation called "obstruction fading" seen only in specific areas of the country. The paper says nothing about the run-of-the-mill, nightly multipath that threatens most FS links.

24 RLAN Group May 14 Ex Parte at 13, perhaps referring to RKF Study at 49 (fade margin calculations included "[v]irtually all links from ULS").

25 Kizer Analysis at 22-23.

1. Line of sight.

Most interference paths have two components: one from the RLAN through buildings, trees, and other such clutter to a breakpoint, with high attenuation per distance, and then a line-of-sight component from the breakpoint to the FS receive antenna, having much lower (free space) attenuation. The "combined" curves in RKF's models lack breakpoints and so apparently lack a line-of-sight component.[26] We concluded from this that RLAN Group had ignored the line-of-sight propagation described in the WINNER II algorithm. RLAN Group disputes our interpretation;[27] it now tells us—for the first time—that the model it actually applied was a particular WINNER II scenario that does have a breakpoint.[28]

(This shows again the importance of RLAN Group submitting its full analysis. The Commission should not permit a party to withhold elements critical to its conclusions, only to whip them out as needed to counter opponents' objections.)

A much smaller number of interference paths have no obstruction at all between the RLAN and the FS receive antenna. They are line-of-sight all the way. These occur along streets, in unbuilt areas, and in flat, low-rise cites having FS facilities on nearby elevated ground. We showed several examples of such paths.[29]

Line-of-sight interference into FS receivers has been well studied. An ITU Recommendation—the most authoritative ITU document short of a Radio Rule—concludes that RLANs "may be difficult to deploy" in an FS environment unless separated from the FS systems by a distance greater than the line-of-sight limit: 40-50 km from the city center.[30]

A 10-foot FS antenna having line of sight with a 35 dBm RLAN in the main beam will receive 40 dB of interference from an RLAN 15 km away**. Every FS receiver having line-of-**

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26 RKF Study at 34-35, Figures 4-2 and 4-3

27 RLAN Group May 14 Ex Parte at 11-12.

28 Specifically, Scenario C1 from WINNER II Final Report at 44-45, Table 4-4. https://cept.org/files/8339/winner2%20-%20final%20report.pdf

29 Letter from Cheng-yi Liu and Mitchell Lazarus, counsel to FWCC, to Marlene H. Dortch, Secretary, FCC (March 30, 2018) (attachment) (photographs marked with free-space paths serving public safety applications in ten major U.S. cities).

30 Recommendation ITU-R 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* at 15 (2005), available at https://www.itu.int/dms_pubrec/itu-r/rec/f/R-REC-F.1706-0-200501-I!!PDF-E.pdf. *See also* Kizer Analysis at 26-28 ("Overview of ITU-R Recommendation F.1706").

sight with a co-channel RLAN in the main beam will fail.[31] RLAN Group disputes this,[32] but its reasons make no sense to us:

- clutter blocking line of sight (we did not include those cases);
- antenna discrimination (absent by definition in main-beam cases);
- polarization mismatch (expressly disclaimed in RLAN Group's calculations[33]);
- a claim that an FS link with no excess margin can tolerate an I/N of +36.8 dB (no evidence for this; see footnote 4 above); and
- a claim that an FS link with excess fade margin can tolerate higher levels of interference (but RLAN Group says it does not use excess fade margin).

Experience shows that most FS interference comes from these relatively uncommon but still significant line-of-sight cases. RLAN Group dismisses them as "corner-case geometries [that] are extremely rare"[34]and that can be cured with mitigation solutions. By "extremely rare" RKF means "on the order of two-tenths of one percent,"[35] which we showed above is far too high to protect the FS. Part F below explains why the proposed mitigation techniques are inadequate.

2. Statistical modeling

The FWCC does not reject statistical modeling as a method of analysis.[36] We do disagree with how RKF applied it.

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31 *See also* Letter from Dave Meyer, National Spectrum Management Association, to Marlene H. Dortch, Secretary, FCC (filed March 27, 2018).

32 RLAN Group April 12 slide deck at 6.

33 RKF Study at 28, 30 Table 3-12 ("RLAN Interference Reduction Factors Not Considered in this Report").

34 Letter from Paul Margie, Counsel for Apple Inc., *et al*. to Marlene H. Dortch, Secretary, FCC at 2 (filed Jan. 25, 2018) (cover letter for RKF Study).

35 RKF Study at 7.

36 RLAN Group May 14 Ex Parte at 1-2.

RKF cites a probability of 0.209% of an RLAN causing 1 dB of interference to an FS receiver.[37] But the probability of interference is not an important consideration, unless it is several orders of magnitude lower than RKF's. It takes just one brief interference incident to shut down multiple links in a network for several minutes, enough to violate RLAN Group's obligation not to cause harmful interference. Predicting 0.209% probability of interference into 95,000 FS links is tantamount to saying that interference is certain.

RLAN Group asserts that a time-sensitive, statistical approach is appropriate because RLAN traffic is bursty.[38] But even a short burst of interference into one receiver can leave behind many minutes of outage across the whole network. RLAN Group's statistics overlook this.

Without the complete analysis we cannot be sure, but it appears that RKF's 0.209% estimate reflects a 50% confidence criterion. RLAN Group denies this, and in something of a *non sequitur*, expands its denial to add that it considered the full distribution of possible propagation scenarios, not just median propagation conditions.[39] RLAN Group does not explain how this relates to statistical confidence in the results, or even say what the level of confidence is.

Our own, very different results are easily confirmed: they follow directly from the numbers of RLAN emitters impacting each FS receiver at specified interference levels.[40] We show that virtually all FS receivers will receive more than 1 dB of interference.

3. Duty cycle

RLAN Group accuses the FWCC of assuming RLANs have a 100% duty cycle.[41] We did not. We assumed only that any RLAN may turn on at any time and potentially cause interference to an FS receiver that is always on. Even a bursty RLAN signal at a high enough level is 100% certain to cause interference; and even short-lived interference to one receiver can take a network down for several minutes while it resynchronizes. Moreover, an RLAN in a communications session is likely to transmit repeatedly on the same frequency. An FS receiver hit with a burst of interference can expect many more over minutes or hours.

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37 RKF Study at 45-46. More precisely, RKF specified this probability of I/N exceeding -6 dB, equivalent to 1 dB impairment of fade margin.

38 RLAN Group April 12 slide deck at 7.

39 RLAN Group May 14 Ex Parte at 2.

40 *E.g.*, Kizer Analysis at 3 Table 1.

41 RLAN Group May 14 Ex Parte at 2-5; RLAN Group April 12 slide deck at 14.

RLAN Group's duty cycle calculations show anther misuse of probabilities.[42] FS operators measure intervals between outages in years. Whether RLANs induce outages once a day or once a month, whether the outages last seconds or minutes, the interference is still unacceptably destructive to FS operations (and violates the RLAN providers' Part 15 obligations). Because everyday FS reliability is so high, adequate protection requires near-100% certainty that total RLAN-caused outages into every FS receiver will not exceed a few seconds per year—without averaging over receivers. Multiplying down with duty cycle numbers cannot achieve this.[43]

4. *Channelization*

RLAN Group is correct: FWCC assumes a microwave receiver is subject to interference from an RLAN regardless of channelization.[44] Any RLAN can operate on any frequency without regard to the frequencies in use by nearby FS receivers, making every receiver potentially subject to interference from any RLAN.

RLAN Group attempts to use channelization in the same way it does duty cycle, to bring down an irrelevant probability of interference. But its calculations overlook key realities.

RLAN Group seems to assume that taking channelization into account reduces the likelihood of interference by a factor of 60.[45] This is a considerable overstatement. A weighted average of RLAN Group's projected bandwidths is 94 MHz.[46] The entire band is 1200 MHz wide, so a single average RLAN will take up fully one thirteenth of it. The non-zero FS channel bandwidth—30 MHz is the most common—further increases the chances of collision.

But the reality is much worse. A microwave receiver (like all others) is sensitive to interference in the channels adjacent to the channel it is tuned to, and for strong interference, in second-adjacent channels as well. This further broadens the interference threat into frequencies well beyond RLAN Group's estimates.

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[42] RLAN Group May 14 Ex Parte at 2-5.

[43] RKF does make claims of low annual outage times, but with no backup whatsoever. RKF Study at 53-54. The numbers are particularly suspect because they are much too low to square with RKF's claims of 0.2% interference.

[44] RLAN Group May 14 Ex Parte at 18-19; RLAN Group April 12 slide deck at 14.

[45] Calculation: RLAN Group says that taking into account both duty cycle and channelization would reduce the effective number of instantaneously transmitting, co-channel RLANs from 15 per km^2 to 0.0011 per km^2; and it puts the duty cycle at 0.44%. RLAN Group April 12 slide deck at 14. Its overall reduction factor is 15/0.0011 = 13,636. The factor owing to duty cycle is 1/0.0044 = 227. The remaining factor due to channelization must be 13,636/227 = 60. We show in text why this number is far too high.

[46] RKF Study at 24, Table 3-9.

In addition, RLAN Group does its calculations as though only one RLAN might interfere with each microwave receiver. The actual risk is much greater: an average of four RLANs will affect each receiver at the 1 dB level.[47] Typically each of these will operate in different parts of the band, expanding the risk to additional FS receiver channels.

Conversely, an RLAN at a given location may threaten more than one FS receiver. The average FS receiver site has 2.7 receive antennas;[48] some have more. Many of these serve systems that use multiple receivers on the same path, tuned to different frequency channels spaced across the band so as to increase transmission capacity—another increase in risk of exposure to RLANs.

Wider RLAN bandwidths raise the odds of coinciding or overlapping with an FS receiver bandwidth. RLAN Group tries to offset this by arguing that a wide bandwidth dilutes the RLAN's transmitted power.[49] But that considers only half the equation. Doubling the RLAN bandwidth reduces the power per MHz only by a modest 3 dB, but it doubles the chances of encroaching on an FS receiver passband.

5. RLAN antenna attenuation

RLAN Group incorrectly suggests that lower RLAN antenna gain above the horizontal will significantly reduce the interference potential.[50] Consider a 100 foot tower carrying a Category B FS antenna—the worst-case antenna for our argument. An unobstructed RLAN comes within the main beam at a distance of 2,974 feet.[51] With the RLAN at ground level (also our worst case), the interference path makes an angle of 2 degrees above the horizontal. The RLAN antenna provides no significant attenuation at that angle, and less when the RLAN is farther from the FS tower. Even the case of a microwave receiver on a mountaintop, overlooking a city on flat terrain, does not produce a high enough look angle for significant RLAN antenna attenuation.

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47 *See* Table A, attached.

48 Approximately 95,000 receivers occupy 35,263 unique sites. Data courtesy of Comsearch.

49 RLAN Group May 14 Ex Parte at 18.

50 RLAN Group May 14 Ex Parte at 17-18.

51 Comments of the Fixed Wireless Communications Coalition at 9, Figure 1 (filed Oct. 2, 2017).

6. *Barren areas*

RLAN Group discounts barren areas because few people live there.[52] But those areas have disproportionate numbers of microwave facilities, relative to population. The sparseness of buildings makes the FS facilities there disproportionately susceptible to line-of-sight interference.

7. *Busy-hour usage*

FWCC did not overestimate busy-hour usage, as RLAN Group claims,[53] because we made no assumptions about busy hour. We assumed only one RLAN operating at a time, using RLAN Group's geographical distribution. RLAN Group speculates that RLAN usage moves indoors after dark.[54] But even here in Washington's unwelcoming climate, we see plenty of people using wireless devices outdoors during the dark hours of the evening. And again, if the RLANs do not rely on unused fade margin, the time of day of RLAN usage should not affect the interference potential.

8. *Barnett-Vigants vs. P.530*

RLAN Group criticizes the FWCC's use of the Barnett-Vigants prediction model in place of RLAN Group's preferred ITU-R P.530.[55] RLAN Group might favor P.530 because it predicts less interference, although the difference is small. But where P.530 better suits primarily European terrain at relatively high latitudes, Barnett-Vigants was developed for low-latitude terrain with typical North American climate and weather. Barnett-Vigants is the *de facto* North American path design standard, used by the majority of US operators and frequency coordinators.[56]

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52 RLAN Group May 14 Ex Parte at 14.

53 RLAN Group May 14 Ex Parte at 18.

54 RLAN Group May 14 Ex Parte at 18.

55 RLAN Group May 14 Ex Parte at 13.

56 The two models reflect real geographic differences in propagation. One study shows that a 65 km link in Western Europe has the same statistical distribution as a 42 km link in the United States, underscoring that P.530 is less appropriate for U.S. calculations. Boithias, L., *Radio Wave Propagation* at 1-49, New York: McGraw-Hill (1987).

F. MITIGATION

Each time RLAN Group concedes that interference may occur, it proposes mitigation as a catch-all remedy.[57]

Mitigation techniques work best at higher frequencies, where they can exploit limited propagation and high directionality to keep unwanted signals away from victim receivers. Unfortunately, the same excellent propagation characteristics and lack of directivity with small antennas that make 6 GHz attractive to RLAN Group also rule out most of the mitigation methods it suggests.

RLAN Group recommends specifically the "established RLAN mitigation techniques" used in the 5 GHz U-NII band,[58] and cites a list of proposed methods filed earlier in the docket.[59] RKF also provides an overlapping list of methods.[60]

The U-NII methods are almost completely ineffective for protecting 6 GHz FS. Although the frequencies are similar, the tasks are very different. U-NII systems must protect only about 45 Terminal Doppler Weather Radars ("TDWRs") at major airports around the country. The 6 GHz fixed link receivers are 2,000 times more numerous than TDWRs and have very different technical characteristics.

RKF proposes Dynamic Frequency Selection, by which a U-NII device detects a TDWR signal and avoids operating on the same frequency.[61] This works at 5 GHz because each TDWR emits a strong signal on the same frequency that requires protection, making them relatively easy to find and avoid. (Even then, it took the Commission, NTIA, and the industry several years to work out an effective solution.) In contrast, an FS signal at the receiver is so weak that detecting it requires an antenna several feet in diameter; an inches-long RLAN antenna would most often miss the signal entirely. Detection of an FS signal from the paired transmitter at the receive site might be easier, but would not tell the RLAN what frequencies to avoid. Nearly all 6 GHz FS systems uses different transmit and receive frequencies, and the pairings are not always uniform.

RLAN Group classifies its mitigation methods according to the type of RLAN device.

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57 RLAN Group May 14 Ex Parte at iii, 13, 14 (twice), 15, 16-17, 17, 20; RLAN Group April 12 slide deck at 18.

58 RLAN Group May 14 Ex Parte at iii.

59 Reply Comment of Apple Inc., *et al*. at 16-21 (filed Nov. 15, 2017) ("RLAN Group Reply"), *cited by* RLAN Group May 14 Ex Parte at iv n.7.

60 RKF Study at 26-27.

61 RKF Study at 27.

Low-power fixed outdoor devices would have limits on antenna height, power, and antenna gain.[62] Because we assumed all emitters are at ground level, restricting antenna height will not reduce the interference we found. Limits on power and antenna gain can help only if there is some way to keep RLANs away from locations having line of sight with an FS receiver; otherwise the EIRP limit would have to be about 2 microwatts, too low to be useful.[63]

Higher-powered fixed devices would be sited at locations chosen to avoid interference to FS receivers.[64] We would not object to this proposal if (1) device locations and frequencies are subject to bilateral frequency coordination that gives protection comparable to the procedures that FS operators use for siting new facilities;[65] (2) coordinated devices cannot change their locations or frequencies without re-coordinating, and (3) coordinated devices must change frequency and/or location to accommodate a newly coordinated FS link that would otherwise receive interference.

Non-fixed higher-powered units would check frequency and location using the ULS database before transmitting, transmit ID information, and keep logs for checking interference reports.[66] Such a system could work satisfactorily only if it:

- used adequately conservative interference criteria;
- always assumed line-of-sight propagation (because there is no reliable way to rule it out for mobile devices);
- used a complete and accurate FS receiver database (which ULS does not provide); and
- protected adjacent and (where necessary) second-adjacent channels.

After-the-fact remedies are of no use. An FS operator has no way to detect interference until after a link fails, and even then cannot identify the source of the interference, nor can the FS receiver decode an RLAN's ID information. In the case of a mobile interferor, successfully identifying the unit would be of no help in protecting against future interference. The Commission must insist that RLANs prevent interference from the start, and not rely on fixing it afterward.

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62 RLAN Group Reply at 18-19.

63 Letter from Dave Meyer, National Spectrum Management Association, to Marlene H. Dortch, Secretary, FCC at 4-6 (filed March 27, 2018).

64 RLAN Group Reply at 19.

65 *See* 47 C.F.R. § 101.103(d).

66 RLAN Group Reply at 19-20.

Indoor operation. RLAN Group suggests that fixed indoor devices can operate at power levels higher than corresponding outdoor devices.[67] It offers no specifics, but RKF mentions indoor +35.3 dBm gaming routers.[68] The degree of attenuation through building walls increases with frequency. At 6 GHz the attenuation is relatively low, 10-20 dB at most, and near zero through windows. Keeping 6 GHz RLANs indoors would provide only modest interference protection at best. (The Commission dropped the indoor-only limitation on the 5.15-5.25 GHz U-NII band in 2014.[69])

Uncontrolled client devices. RLAN Group proposes uncontrolled client devices across the entire 6 GHz band at power levels similar to those for client devices in U-NII-1 band: 30 dBm EIRP.[70] That is far too high for uncontrolled devices—6 dB ***higher*** than the weighted average of the outdoor emitters in Table 1 that we showed will cause widespread interference. There is nothing to stop these client devices from wandering into an FS receiver main beam, an event that will certainly shut down the link.

NPRM. RLAN Group's call for an NPRM to consider mitigation issues is premature.[71] Simply proposing again the same ineffective measures in an NPRM would be pointless; and an NPRM in itself is unlikely to produce new mitigation approaches that RLAN Group, with its collective technical expertise, has not already advanced. Before the Commission commits its own further resources, and asks the public to expend resources as well, it should demand a technically supported showing that interference-free 6 GHz RLAN operation is at least feasible.

CONCLUSION

As the proponent of an unlicensed technology, RLAN Group has the burden of establishing that it can prevent harmful interference to incumbent licensed users. This means preserving the currently high levels of 6 GHz FS reliability.

Designed-for (and routinely achieved) outage levels for most FS links are either 30 seconds or five minutes per year, per receiver, with the most critical applications allowed the least outage. RLAN Group must show that RLAN interference events will be rare enough not to cause outages significantly above these levels.

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67 RLAN Group Reply at 20-21.

68 RKF Study at 18, Table 3-4.

69 *Unlicensed National Information Infrastructure (U-NII) Devices in the 5 GHz Band*, First Report and Order, 29 FCC Rcd 4127 at ¶ 44 (2014).

70 RLAN Group Reply at 21. Devices in the U-NII-1 band (5.15-5.25 GHz) have an output power limit of 250 mW plus 6 dB antenna gain, for 30 dBm (1 watt) EIRP. 47 C.F.R. § 15.407(a)(1)(iv).

71 RLAN Group April 12 slide deck at 2, 4, 18, 19; RLAN Group May 14 Ex Parte at iii, iv, 20.

RLAN Group has not met this burden. Unless it can do better, the Commission should close out this part of the proceeding.

Respectfully submitted,

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cc (via email): Paul Margie, Counsel for Apple Inc. *et al*.

ATTACHMENT: Summary of Simulation Results

City	Number of Paths	Fade Margin Reduction > 1 dB	Fade Margin Reduction ≥ 10 dB	Fade Margin Reduction ≥ 20 dB	Fade Margin Reduction ≥ 25 dB	Fade Margin Reduction ≥ 30 dB	Fade Margin Reduction≥ 40 dB
Chicago	**492**	4.055	0.921	0.254	0.142	0.073	0.014
Houston	**838**	4.115	0.968	0.247	0.129	0.072	0.025
Los Angeles	**513**	4.004	0.906	0.271	0.144	0.078	0.018
New York City	**452**	4.126	0.951	0.283	0.159	0.077	0.018
Phoenix	**231**	4.130	1.039	0.264	0.134	0.065	0.017
San Francisco	**301**	4.120	0.947	0.262	0.136	0.086	0.013
Seattle	**266**	4.162	0.966	0.237	0.135	0.075	0.008
Washington DC	**705**	4.051	0.957	0.255	0.142	0.067	0.020
Average	**475**	4.095	0.957	0.259	0.140	0.074	0.017

Table A

Average Number of Interference Cases per Receiver
(Revised Simulation—RLAN Power Levels per Table 1 in Text)

City	Number of Paths	Fade Margin Reduction > 1 dB	Fade Margin Reduction ≥ 10 dB	Fade Margin Reduction ≥ 20 dB	Fade Margin Reduction ≥ 25 dB	Fade Margin Reduction ≥ 30 dB	Fade Margin Reduction≥ 40 dB
Chicago	**492**	5.601	1.253	0.380	0.206	0.115	0.030
Houston	**838**	5.621	1.257	0.357	0.200	0.121	0.033
Los Angeles	**513**	5.474	1.225	0.370	0.197	0.121	0.029
New York City	**452**	5.585	1.273	0.389	0.217	0.119	0.032
Phoenix	**231**	5.647	1.305	0.377	0.223	0.130	0.041
San Francisco	**301**	5.543	1.241	0.354	0.199	0.121	0.037
Seattle	**266**	5.671	1.242	0.359	0.203	0.120	0.030
Washington DC	**705**	5.558	1.226	0.369	0.214	0.114	0.031
Average	**475**	5.587	1.253	0.369	0.207	0.120	0.033

Table B

Average Number of Interference Cases per Receiver
(Original Simulation—All RLAN Power Levels 35 dBm)