



September 3, 2021

VIA ELECTRONIC FILING

Ms. Marlene H. Dortch, Secretary
Federal Communications Commission
45 L Street, NE
Washington, DC 20554

Re: *Ex Parte* Presentation, *Expanding Flexible Use of the 3.7-4.2 GHz Band*, GN Docket No. 18-122

Dear Ms. Dortch:

C-Band spectrum presents the most immediate and critical opportunity to help propel 5G deployment in the United States and enable our country to reap the resulting benefits of innovation, enhanced consumer welfare, and economic growth. The record-breaking C-Band auction represents the largest investment in a spectrum auction to date and brings the total to more than \$200 billion in payments to the government for the spectrum needed to power wireless networks, over and above the more than \$600 billion of capital investment made over the life of the wireless industry.¹ CTIA's members are making substantial investments today to implement C-Band operations, which will help close the spectrum gap as nations across the globe have already deployed these frequencies and are set to have on average 210 more megahertz of licensed mid-band spectrum available by the end of next year to support 5G connectivity.

Throughout this proceeding, several aviation organizations ("Organizations") have argued that 5G operations in the C-Band will cause interference to radio altimeters that operate 220 megahertz or more away—but they ignore that real-world deployments in the C-Band and other nearby bands, both in the U.S. and abroad, operate today without any evidence of harmful interference to altimeters. Moreover, aviation has declined to make available underlying data that would allow all stakeholders to fully evaluate those assertions. Any reasoned review of aviation's analysis exposes significant faults, as CTIA has demonstrated. The attached Technical Annex further underscores these failings. With no transparency into test results and indefensible testing parameters, the Organizations' calls to upend 5G deployments in the C-Band must be rejected.

¹ See *CTIA 2021 Annual Survey Highlights*, attached to Letter from CTIA to Marlene H. Dortch, FCC, GN Docket No. 18-122, et al. (filed July 30, 2021).



For nearly a year, CTIA has submitted filings that identify significant failings with aviation stakeholders' analysis of C-Band 5G/radio altimeter coexistence.² CTIA has highlighted, for instance, that the aviation stakeholders' report used a standard that was untethered to existing altimeter performance requirements to assess 5G coexistence; failed to show test results by altimeter model and instead presented an analysis using an amalgamation of worst-case performance that does not reflect any real-world circumstance; applied a worst-case landing scenario with unrealistic and contradictory settings and assumptions; and incorporated multiple unwarranted and unprecedented margins to the analysis.

The Organizations' claims are further belied by existing services near the radio altimeter band both domestically and internationally that operate without any evidence of causing harmful interference. In other words, if aviation's claims were true, interference would be occurring today from existing operations; it is not. In the U.S., for example, very high powered federal radars below 3.65 GHz and federal ground-to-air systems in 4.4 GHz (immediately adjacent to altimeters) have operated for years. Europe harmonized 3.4-3.8 GHz for 5G (which includes the U.S. Phase 1 band segment), and at least 11 providers have launched in nine countries since 2018. And Japan has some 90,000 5G base stations deployed with just a 100-megahertz guard band on either side of the altimeter band, without claims of interference caused by 5G.

Despite these real-world deployments and record evidence submitted by CTIA demonstrating that the aviation study is unverifiable and technically flawed, the Organizations continue to make claims that the Commission's technical rules mandated in the C-Band Report and Order are insufficient to ensure coexistence between 5G operations in the 3.7-3.98 GHz band and aviation altimeters operating at least 220 megahertz away. The attached CTIA Technical Annex goes further to reiterate fundamental mistakes in their analysis and to critique their most recent filings. The Technical Annex shows:

- *Transparency is paramount for a fact-based engineering analysis, but to this day aviation stakeholders have not identified the altimeters that were tested, let alone submitted into the record individual altimeter performance data.* Without such basic information, neither the wireless stakeholders nor the Commission can reproduce the tests, nor can they independently verify whether the altimeters tested were operating consistent with manufacturer specifications, or if they are representative of installed equipment on aircraft, for example. What's more, by providing only aggregated performance results, aviation supplies an amalgam of worst-performing data from multiple radio altimeters chosen rather than data likely to match the performance of any individual device. The Commission has a process for

² For a detailed analysis of the flaws identified by CTIA, see Letters from CTIA to Marlene H. Dortch, Secretary, FCC, GN Docket No. 18-122 (filed Aug. 26, 2020; Oct. 27, 2020; Oct. 30, 2020; Nov. 17, 2020; Dec. 7, 2020; and Mar. 4, 2021).



confidential filings, but aviation has not provided Commission staff with access to the test data. Absent such access, the RTCA Report must be dismissed. Any discussion of interference mitigation strategies absent such evidentiary data and analysis is unwarranted.

- ***Spurious emissions from 5G operations in the 3.7-3.98 GHz band do not pose a risk to radio altimeter performance in the 4.2-4.4 GHz band.*** The Organizations' spurious emissions analysis has the same shortcomings as its fundamental emissions analysis—including the same faulty landing scenario, improper protection criteria, and addition of multiple unnecessary testing margins (including claims for an unprecedented separate aeronautical safety margin that the aviation industry did not use in its own testing for an aviation wireless service that would operate in the altimeter band). The same adjustments CTIA identified as necessary to bring reality to RTCA's analysis for fundamental emissions apply equally for 5G spurious emissions.
- ***The Organizations' worst case landing scenario ("WCLS") remains inconsistent and faulty.*** As but one example, aviation used a perfectly reflecting surface when calculating ground-based altimeter interference from aircraft on the ground (better reflection results in a stronger altimeter signal), but used rough terrain when calculating the landing plane's altimeter (poorer reflection results in a weaker altimeter signal), even though the signals would be reflecting *from the same runway environment*.
- ***Claims that harmful interference may occur due to handsets carried onboard aircraft are faulty.*** Putting aside that the Commission's rules for C-Band operations do not permit user equipment operation in flight, the Organizations' technical assessment of user equipment onboard aircraft is incorrect, as it ignores that transmit power control will further reduce the EIRP and depends on a scenario that assumes multiple worse-than-worst case assumptions.

As demonstrated in the Technical Annex and CTIA's prior filings, all nine altimeters tested by AVSI would have sufficient margin if the technical errors in the RTCA Report and AVSI testing were corrected.³

* * *

Given the aviation industry's failure to make test data available or identify altimeters that were tested, its inconsistent testing parameters as applied to 5G, and the lack of real-world evidence of interference where 5G and other systems have been deployed both domestically and internationally, CTIA urges the Commission to rebuff aviation's arguments and the RTCA Report.

³ Letter from CTIA to Marlene H. Dortch, Secretary, FCC, GN Docket No. 18-122, at 19 (filed Mar. 4, 2021).



Pursuant to Section 1.1206(b) of the Commission's rules, a copy of this letter is being electronically submitted into the record of this proceeding. Please do not hesitate to contact the undersigned with any questions.

Sincerely,

/s/ Kara Graves

Kara Graves

Assistant Vice President, Regulatory Affairs

Doug Hyslop

Vice President, Technology and Spectrum Planning

Attachment

Technical Annex: Radio Altimeters



September 3, 2021

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1. Executive Summary

After years of consideration of the public record, the Federal Communications Commission—as the expert agency with a deep understanding and interest in ensuring services can coexist—determined in the 2020 C-Band Order that the 3.7 GHz technical rules and the spectral separation of at least 220 megahertz from radio altimeter operations “are sufficient to protect aeronautical services in the 4.2-4.4 GHz band.”¹ Aviation stakeholders, led by the Aerospace Vehicle Systems Institute (“AVSI”), engaged in subsequent testing that was submitted as the RTCA Report, relying on faulty parameters to make unverifiable claims.² CTIA has filed numerous technical analyses that highlight these deficiencies and make clear that, if corrected, all of the altimeter models tested would not present a risk of harmful interference.

Several aviation organizations (“Organizations”) filed a document in May 2021 making numerous incorrect claims regarding CTIA’s showings on C-Band 5G / radio altimeter coexistence and the faults CTIA identified with the RTCA Report and the AVSI testing.³ This Technical Annex underscores the faults identified in the Organizations Letter and aviation’s prior analyses and responds to further mischaracterizations and faulty technical claims made by aviation interests. As demonstrated herein and in CTIA’s prior studies, all nine altimeters tested by AVSI would have sufficient margin if the technical errors in the RTCA Report and AVSI testing were corrected.

1.1 Recap of Key Issues in the Record

In multiple filings, CTIA has discussed at length numerous technical defects with the unrealistic inputs and conditions used in the AVSI testing and RTCA Report.⁴ Of note, aviation stakeholders have applied:

- ***A made-up standard only to assess 5G.*** To test C-Band 5G/radio altimeter coexistence, aviation devised a new testing standard that is more conservative than the Federal Aviation Administration (“FAA”)’s existing altimeter performance requirements, TSO C87a, which references the European Organisation for Civil Aviation Equipment (“EUROCAE”) ED-30

¹ *Expanding Flexible Use in the 3.7-4.2 GHz Band*, Report and Order and Order Proposing Modification, 35 FCC Rcd 2343 ¶ 395 (2020) (“C-Band Order”).

² RTCA, *Assessment of C-Band Mobile Telecommunications Interference on Low Range Radar Altimeter Operations*, RTCA Paper No. 258-20/SC239-006 (rel. Sept. 18, 2020) (“RTCA Report”).

³ Letter from Aerospace Industries Association, et al., to FCC, GN Docket No. 18-122, at 3 (filed May 12, 2021) (“Organizations Letter” or “Letter”).

⁴ For a detailed analysis of the flaws identified by CTIA, see Letters from CTIA to Marlene H. Dortch, Secretary, FCC, GN Docket No. 18-122 (filed Aug. 26, 2020; Oct. 27, 2020; Oct. 30, 2020; Nov. 17, 2020; Dec. 7, 2020; and Mar. 4, 2021).

requirements.⁵ As a result of aviation’s contrived testing parameters, altimeters operating to manufacturer specifications that match or come near to existing altimeter standards could fail *even with no C-Band 5G operations present*.⁶

- ***An amalgamation of worst-case performance that does not reflect any real-world circumstance.*** Aviation’s analysis was assembled by extracting the worst-performing data points from up to nine different altimeter types into a combined performance envelope (one for each of three altimeter categories: commercial, other fixed wing aircraft, and helicopters). This worst-case performance data represents a combined data set of altimeter models of unknown age, design, penetration, and condition.⁷ As CTIA previously noted, one poorly performing altimeter—which appears to have shown erratic behavior during testing and could be a faulty unit—may be driving aviation stakeholder claims.⁸
- ***Unrealistic landing scenarios.*** Aviation applies a worst-case landing scenario (“WCLS”) with settings and assumptions that are contradictory and do not match real-world situations. As but one example, aviation used a perfectly reflecting surface when calculating altimeter interference from aircraft on the ground (better reflection results in a stronger altimeter signal), but used a rough terrain when calculating the landing plane’s altimeter (poorer reflection results in a weaker altimeter signal), even though the signals would be reflecting from the same runway environment. In the real world, radio propagation obeys the laws of physics, and the aviation industry’s contrived and inconsistent environment does not exist in an actual landing scenario.⁹ The AVSI test data underlying the RTCA Report employed incorrect inputs and conditions, making all conclusions based on AVSI data unreliable.
- ***Unwarranted margins.*** Aviation applies multiple unwarranted margins to its analysis that it did not apply when performing coexistence tests to assess an aviation wireless service that would operate in the altimeter band. For example, aviation applies a 6 dB aeronautical safety margin to the 4.2-4.4 GHz band, even though the Commission has never before incorporated an aeronautical safety margin in any interference protection analysis for spectrum that is so far removed in frequency from an aeronautical band. If the Commission were to apply an aeronautical safety margin to all spectrum incumbents at a distance of 220 to 500 megahertz from the edge of an aeronautical band, it would impact all spectrum below 2 GHz and 68 percent of spectrum below 10 GHz.¹⁰ Further, aviation applies margins attributed to

⁵ See, e.g., Letter from Andrew Roy, Aviation Spectrum Resources, Inc., et al., to Marlene H. Dortch, Secretary, FCC, GN Docket No. 18-122, at 2 (filed June 17, 2021) (“Organizations June 17 Letter”).

⁶ CTIA October 27, 2020 Analysis at 9-13; CTIA October 30, 2020 Analysis at 5; CTIA November 17, 2020 Analysis at 5; CTIA March 4, 2021 Analysis at 1.

⁷ CTIA August 26, 2020 Analysis at 6; CTIA October 27, 2020 Analysis at 5, 6; CTIA October 30, 2020 Analysis at 6.

⁸ CTIA March 4, 2021 Analysis, Presentation at 26.

⁹ CTIA October 27, 2020 Analysis at 11, 12; CTIA October 30, 2020 Analysis at 8; CTIA November 17, 2020 Analysis at 8, 9, 15, 17; CTIA March 4, 2021 Analysis at 6, 9, 13, 14, 19, 27, 35.

¹⁰ CTIA October 27, 2020 Analysis at 13; CTIA October 30, 2020 Analysis at 7.

measurement uncertainty (1 dB), and for manufacturing tolerances and environmental conditions (4 dB),¹¹ which have triggered questions regarding empirical evidence to support such margins.¹²

These are but a handful of the failings in the aviation industry's overall analysis on C-Band 5G/aviation coexistence. And the Organizations' recent filings do not overcome CTIA's showings that aviation's interference analysis is faulty and should be disregarded.

1.2 Issues Expanded on in the Technical Annex

This CTIA Technical Annex goes further to address the Organizations' latest refusal to provide underlying data, reiterate fundamental mistakes in their analysis, and critique their most recent filings in defense of their flawed showings. Notably, as detailed in this Technical Annex:

- **Transparency is paramount for a fact-based engineering analysis, but to this day aviation stakeholders have refused even to identify the altimeters that were tested, let alone submit into the record individual altimeter performance data.** Without such basic information, neither the wireless stakeholders nor the Commission can reproduce the tests, nor can they independently verify whether the altimeters tested were operating consistent with manufacturer specifications, or if they are representative of installed equipment on aircraft, for example. The Commission has a process for confidential filings, but aviation has not provided Commission staff with access to the individualized test data.
- **Spurious emissions from 5G operations in the 3.7-3.98 GHz band do not pose a risk to altimeter performance in the 4.2-4.4 GHz band.** Aviation's spurious emissions analysis is plagued by the same shortcomings as its fundamental emissions analysis, including the same faulty landing scenario, improper protection criteria, addition of multiple unnecessary testing margins, and a separate aeronautical safety margin.¹³ Further, aviation stakeholders have applied criteria from ITU-R Recommendation M.2059 which, as explained below, only provides guidance on altimeter performance at maximum reporting altitude and thus is not appropriate for analyzing interference at the lower altitudes used in the RTCA Report.
- **Claims that harmful interference may occur due to handsets carried onboard aircraft are faulty.** Aviation claims that harmful interference may occur due to handsets carried on board aircraft,¹⁴ but the analysis is faulty for several reasons. First, handheld cellular devices must be in airplane mode when in flight. Second, in any event, end user devices

¹¹ Aviation also backed off the power threshold by 1 dB, for a total "test margin" of 6 dB.

¹² Organizations June 17 Letter at 9.

¹³ *Id.* at B-2.

¹⁴ *Id.* at B-3.

cannot attach to a network unless they receive a downlink signal with sufficient signal quality, and an end user device that is not connected to the system will not transmit (and thus will not risk causing interference). Third, transmit power control will further reduce the EIRP. Fourth, RTCA assumes five handsets transmitting simultaneously, all at maximum power, and all located at exactly the same worst-case location within the aircraft.¹⁵ This scenario depends on multiple worse-than-worst case assumptions.

- ***The WCLS analysis remains inconsistent and faulty.*** Aviation’s missed approach scenarios continue to mis-apply fundamental elements.¹⁶ Namely, any landing scenario—whether a successful landing or a missed approach—must account for the smooth terrain that exists on a runway. Smooth terrain better reflects the altimeter signal and provides a stronger altimeter signal at the aircraft receiver, as opposed to rough terrain, which tends to scatter the altimeter signal. But aviation’s WCLS analysis incorporates rough terrain over the runway when assessing the received altimeter signal levels (but not in its assessment of altimeter interference levels from aircraft on the ground), and this is not a real-world scenario, even for missed approaches. Beyond the runway, an aircraft experiencing a missed approach may encounter rough terrain but would not be subject to the aggregate interference from ground-based altimeters. Again, the Organizations’ filing ignores real-world operations. Aviation has recently claimed that CTIA piles “best case upon best case,” a misleading claim to disguise the completely unrealistic scenarios used by the Organizations.
- ***CTIA’s analyses apply to all three categories of radio altimeters.*** The Organizations incorrectly claim that CTIA’s critique of worst case landing analysis is limited solely to the case for Category 1 (large commercial transport aircraft), and not Category 2 (other fixed wing) or Category 3 (helicopter).¹⁷ But AVSI applied WCLS to both Category 1 and 2 aircraft with the same aerodrome configuration for both, and CTIA’s analyses apply equally to AVSI’s Category 2 WCLS testing, as noted in CTIA’s March 4 letter.¹⁸ Additionally, CTIA previously submitted a ten-page response to aviation’s helicopter (air ambulance) study that focused on Category 3 altimeters.¹⁹ And CTIA’s March 4 filing expressly stated that Category 3 altimeters “would also have a positive margin,” or no interference, and observed that the Category 3 testing would be identical to the Category 2 testing, with the exception of the interference from the ground-based altimeters.²⁰

¹⁵ RTCA Report at 30.

¹⁶ Organizations Letter at B-6.

¹⁷ *Id.* at B-8.

¹⁸ CTIA March 4, 2021 Analysis at 19.

¹⁹ CTIA August 26, 2020 Analysis.

²⁰ CTIA March 4, 2021 Analysis at 19.

- **Aviation fails to adequately address different treatment afforded to Wireless Avionics Intra-Communication (“WAIC”) as compared to 5G.** CTIA has pointed out the difference in the way that aviation has treated interference analysis for WAIC, a desired aviation improvement operating within the 4.2-4.4 GHz band, as compared to 5G in the C-Band. For example, AVSI applied cable loss values to the 5G analysis that were considered at length and determined *not to apply* in the WAIC context as part of the International Civil Aviation Organization (“ICAO”). Further, for WAIC, AVSI tested each power level setting for 10 minutes, while for 5G the test time for each power level was 7 seconds. Aviation claims that in either case, the 2% relative accuracy threshold criterion allows for the exclusion of occasional outliers, if they occur.²¹ However, because of the differing test durations, for 5G operations AVSI would consider four “outliers” to be harmful interference, whereas the WAIC testing would permit up to 360 “outliers” before being considered harmful interference. The Organizations attempt to dismiss CTIA’s concerns by asserting that the WAIC study is preliminary and interim in nature,²² but it was not, as AVSI shared test results with ICAO over the course of a two-and-a-half year period,²³ and as recently as August 2019. If the WAIC analysis was wrong, aviation should withdraw its earlier analysis and stay any efforts to pursue an allocation for WAIC.

For all these reasons, aviation’s filings cannot be deemed valid evidence that stakeholders and the Commission can rely on.

2. Ongoing Obscurity of Aviation’s Altimeter Test Data

A fundamental concern exists with aviation’s advocacy on C-Band 5G / altimeter coexistence: the lack of visibility into the altimeter testing data collected by AVSI.

Transparency is paramount for a fact-based engineering analysis, but to this day aviation has not identified the altimeters that were tested, let alone submitted into the record any individual altimeter performance data. Without such basic information, neither the wireless stakeholders nor the Commission can reproduce the tests, nor can they independently verify whether the altimeters tested were operating consistent with manufacturer specifications, if the altimeters tested were certified by either the FAA or the Commission for operation in the 4.2-4.4 GHz band, or if they are representative of installed equipment on aircraft. The RTCA Report would likely not stand up to a fair peer review because of the lack of data necessary to repeat the analyses.

²¹ Organizations June 17 Letter at 5.

²² Organizations Letter at 4.

²³ See WAIC Radio Altimeter Interference Susceptibility Testing, ICAO FSMP WG4, ICAO APAC, March 29-April 7, 2017; Radio Altimeter-WAIC Interference Susceptibility Testing Status Update, FSMP WG9, ICAO Montreal, Canada, 22-30 August 2019.

The Organizations Letter continues to misinform the Commission and all stakeholders by stating that “[n]o data has been withheld” and that “[a]ll data received from AVSI in preparation of the [RTCA] Report was publicly disclosed in the [RTCA] Report itself.”²⁴ This cleverly crafted statement shrouds the facts. The RTCA Report relies entirely on data that RTCA received from AVSI, but AVSI only provided summary, aggregated data to RTCA.²⁵ While RTCA may have provided “[a]ll data” it received from AVSI, it is at best misleading to claim that “[n]o data has been withheld.”²⁶ Commission staff must have access to the data underlying the RTCA Report, as the aviation industry’s findings cannot be relied on without adequate transparency and review. The Commission has a process for confidential filings, but aviation has not provided Commission staff with access to the test data. Absent access, the RTCA Report must be dismissed.

The aviation industry’s concerns about flight safety are undercut by its unwillingness to share the underlying individualized test data, which was collected in a “black box” testing process. The testing process applied external stimuli to a closed system and observed the resulting behavior—a process that does not reveal manufacturer proprietary information. Aviation stakeholders have no valid reason for withholding individual altimeter black box test data. As previously noted by CTIA, there may be one poorly performing altimeter—which may be a faulty unit—driving all of aviation stakeholder claims.²⁷

While the lack of transparency has hindered the ability for any party to derive meaningful information from the Report, the obscured test data has a further fault. As CTIA has noted in previous studies, the AVSI test inputs, conditions, and pass/fail criteria deviated from aviation performance requirements, and reflected unrealistic flight scenarios. The AVSI test data underpinning the RTCA Report is flawed,

²⁴ Organizations Letter at 3. Even more perplexing, the Organizations Letter responds to concerns of transparency only in the context of the RTCA Report, but oddly, RTCA is not a signatory to the letter; AVSI is, and it has the individual altimeter test data that could provide the FCC and interested parties with greater insight into altimeter performance, but it uses the RTCA Report as cover.

²⁵ RTCA Report at 152, *attached to* Letter from Terry McVenes, RTCA, Inc., to Marlene Dortch, Secretary, FCC, GN Docket No. 18-122 (filed Oct. 20, 2020) (“RTCA SC-239 received summary data from AVSI and is not able to provide individual altimeter performance data.”).

²⁶ The Organizations reference RTCA as a multi-stakeholder group, but RTCA is an aviation organization, and RTCA’s Special Committee 239 (SC-239)—which formed a 5G Task Force to study 5G/aviation coexistence—itsself stated “[t]he 5G interference report is envisioned to provide *an aviation industry technical position* for spectrum regulators.” SC-239, Terms of Reference, Rev. 1, at 3 (Dec. 17, 2020), <https://www.rtca.org/wp-content/uploads/2020/12/SC-239-TOR-Rev-1-Approved-12-17-2020.pdf> (emphasis added). In contrast, the C-Band Multi-Stakeholder Group constituted a cross-industry Technical Working Group-3 (“TWG-3”) to address 5G/altimeter coexistence. TWG-3 was co-chaired by aviation and wireless industry representatives and was comprised of 29 different companies and associations across the aviation industry, wireless service providers and manufacturers, cable providers, Wireless Internet Service Providers, and others, with membership evenly split across aviation and wireless interests. Within TWG-3, the RTCA Report was not a consensus document. See Letter from C-Band Technical Working Group 3 - 5G / Aviation Coexistence to FCC, GN Docket No. 18-122 (filed Nov 16, 2020).

²⁷ CTIA March 4, 2021 Analysis, Presentation at 26.

and claims based on the flawed data are unfounded. Further discussion of the CTIA analyses, the errors in the aviation filing, and correction to the Organizations' false claims are provided below.

3. 5G Spurious Emissions Will Not Cause Harmful Interference

Spurious emissions from 5G operations in the 3.7-3.98 GHz band do not pose a risk to altimeter performance in the 4.2-4.4 GHz band, contrary to claims in the Organizations Letter. CTIA's filings with the Commission note deficiencies in the test setup, modeling, and conclusions of the RTCA Report. These deficiencies apply equally to the overload (fundamental emissions) and desensitization (spurious emissions) cases. CTIA's March 4, 2021 filing provides the math for the overload case because the claimed overload exceedance was higher; since the same corrections apply to the desensitization case, the same analysis shows that 5G spurious emissions will not affect altimeter performance.

3.1 Inapplicability of ITU-R Recommendation M.2059

The Organizations Letter reiterated RTCA's flawed analysis,²⁸ relying on the International Telecommunication Union – Radiocommunication ("ITU-R") Recommendation M.2059 ("ITU-R Rec. M.2059"),²⁹ which provides protection criteria and RF performance characteristics for representative analog and digital radio altimeters. The Organizations Letter summarized RTCA's conclusions regarding 5G user equipment ("UE") fundamental and spurious emissions relative to the protection criteria in ITU-R Rec. M.2059.³⁰

RTCA's analysis was critically flawed, both for the 5G base station analysis and for the UE³¹ analysis: ITU-R Rec. M.2059 only provides guidance of altimeter performance at maximum reporting altitude,³² but the 5G conditions assessed by RTCA were at much lower heights. While 5G signal levels are stronger at lower altitude, so are reflected radio altimeter signals. As the RTCA Report recognized, altimeter

²⁸ Organizations Letter at B-3.

²⁹ Recommendation ITU-R M.2059, Operational and Technical Characteristics and Protection Criteria of Radio Altimeters Utilizing the Band 4200-4400 MHz (02/2014).

³⁰ Organizations Letter at B-3, Table 1.

³¹ User equipment onboard an aircraft will be inoperable at the maximum reporting altitude. The UE must be attached to a ground network in order to transmit, and ground networks do not provide a sufficient signal to permit a UE to connect at several thousand feet above the ground.

³² ITU-R Rec.M.2059 defined the overload threshold as the 1 dB compression point of the receiver front end. A 1 dB compression means external energy entering the receiver front end is sufficient to raise the minimum detectable desired signal by 1 dB. Thus, by definition, the overload thresholds in ITU-R Rec.M.2059 apply to the maximum reporting altitude of the altimeter. The same reasoning applies to the spurious emissions threshold derivation.

performance is significantly improved at the lower altitudes where 5G is strongest.³³ As a result, the RTCA calculations relying on M.2059 significantly overestimated interference to radio altimeters.

3.2 WAIC and 5G Spurious Emissions

The Organizations Letter misunderstands CTIA’s comparison of WAIC and 5G spurious emissions.³⁴ CTIA observed that results that logically should have been the same were not. AVSI’s WAIC test placed an orthogonal frequency-division multiplexing (“OFDM”) transmission within the altimeter passband, and increased the power until desensitization occurred. AVSI’s 5G testing for spurious emissions followed the exact same procedure—placing an OFDM transmission within the altimeter passband, and increasing the power until desensitization occurred. The test approaches were identical, and in an unbiased testing environment, should have yielded identical results. But the results were not identical—a clear red flag—due to AVSI’s unjustified use of more strict inputs for 5G and extraneous margins.

3.3 AVSI Spurious Emissions ITMs

AVSI measured the spurious emissions resilience of nine altimeters. Rather than providing the underlying data that would enable third-party evaluation of aviation’s claims, AVSI instead selected the worst data point of all altimeters, conditions, and altitudes and provided RTCA with a sanitized Interference Tolerance Mask (“ITM”) for each of three altimeter categories. The ITMs included 6 dB of margin added on top of test conditions more harsh than prior aviation testing, as noted in CTIA’s March 4, 2021 study.³⁵ AVSI’s claimed spurious emissions ITMs are invalid due to the numerous flaws in the test methodology and test conditions. A summary of the technical flaws in AVSI’s spurious emissions testing is provided in Table 3-1 for the landing scenario.

Attribute	Error (dB)	Explanation
Test Margin	6	EUROCAE ED-30 does not require test margin.
Safety Margin	6	Inappropriate for transmissions >200 MHz away.
Loop Loss	6	Adjusted per ED-30 guidance.
Landing Height	16	Corrected height has lower loop loss.
Runway Surface	20	Runway surface reflectivity is better.
Other RA Interference	24	Per 5G Americas analysis.
Total Error	78	

Table 3-1: AVSI Technical Errors in Landing Scenario³⁶

³³ RTCA Report at 50, Section 9.1.1 (“As expected, the ITM decreases with increasing altitude as the altimeters become more sensitive.”). Restating this sentence, the altimeter overload and spurious emissions performance improves at lower altitudes as the altimeters become less sensitive.

³⁴ Organizations Letter at B-11.

³⁵ CTIA March 4, 2021 Analysis, Presentation at 5.

³⁶ “Other RA Interference” at realistic landing heights as derived in *Mid-band Spectrum & the Coexistence with Radio Altimeters*, 5G AMERICAS, at 22 (July 21, 2021), <https://www.5gamericas.org/wp->

AVSI’s testing errors significantly exaggerated the altimeter’s susceptibility to spurious emissions in landing scenarios. With the corrections provided in Table 3-1, tens of dBs of margin would be available instead, for low-altitude cases of 5G base station and UE spurious emissions.

At higher altitudes where the radio altimeter’s receiver is more sensitive, the 5G base station signal level is weaker. Corrections to AVSI’s flawed setup are provided in Table 3-2 for this situation of base station spurious emissions at high altitudes.

Attribute	Error (dB)	Explanation
Test Margin	6	EUROCAE ED-30 does not require test margin.
Safety Margin	6	Inappropriate for transmissions >200 MHz away.
Loop Loss	6	Adjusted per ED-30 guidance.
5G Base Station	14	Per March 4, 2021 CTIA study.
Total Error	32	

Table 3-2: AVSI Testing Errors for High Altitude 5G BS Spurious Emissions

At higher altitudes, the RTCA Report claimed at most a 2 dB exceedance for base station spurious emissions.³⁷ After adjusting per the AVSI testing errors in Table 3-2, 30 dB of margin would be available.

3.4 Safeguards Prevent UE C-Band Operation Onboard Aircraft

Finally, in the case of 5G UE spurious emissions at high altitude, there are multiple safeguards in place, which CTIA explained to RTCA prior to RTCA’s adoption of the RTCA Report. First and foremost, the C-Band allocation in the FCC Table of Allocations is designated as “Mobile, except aeronautical mobile.”³⁸

Second, handheld cellular devices must be in airplane mode when in flight, per FCC Title 47, Part 22.925, which includes this notice: “The use of cellular telephones while this aircraft is airborne is prohibited by FCC rules, and the violation of this rule could result in suspension of service and/or a fine. The use of cellular telephones while this aircraft is on the ground is subject to FAA regulations.”³⁹ While the FAA has expanded the use of personal electronic devices to all phases of flight, passengers must “use

[content/uploads/2021/07/Presentation-Mid-Band-Spectrum-and-the-Co-Existence-with-Radio-Altimeters.pdf](#) (“5G Americas White Paper”).

³⁷ RTCA Report, Figures 10-24 and 10-28.

³⁸ 47 C.F.R. § 2.106.

³⁹ 47 C.F.R. § 22.925.

electronic devices in airplane mode or with the cellular connection disabled.”⁴⁰ Should devices be left turned “on” in luggage, such devices would remain in idle mode and would not transmit.⁴¹

A final safeguard is provided by the base station antenna pointing direction, beamwidth, and wireless network design constraints as part of normal operation. Base stations direct energy near or below horizon, targeting terrestrial users. UEs onboard an aircraft at a height of a few thousand feet would not have a sufficient base station signal to enable the UE to establish service. UEs must be connected to a wireless network in order to transmit. The UE will not connect due to the lack of a suitable ground network signal at higher altitudes, and therefore will not transmit. At lower altitudes, CTIA has already demonstrated, both above and in prior filings, that the landing scenarios used by AVSI and RTCA include multiple exaggerations, and heavily overestimated predicted interference levels.⁴²

3.5 Flawed Aircraft Interference Path Loss Assumptions for UEs In-Flight

Putting aside the safeguards noted above and in prior filings and engagement with the aviation stakeholders, the RTCA Report’s technical assessment of UEs onboard aircraft is incorrect. The RTCA Report’s scenario of 5G UE spurious emissions onboard an aircraft relied heavily on interference path loss (“IPL”) measurements between locations in the cabin and the aircraft system antennas. RTCA cited six sources for the IPL employed in its study; a closer examination of each source is warranted.

⁴⁰ FAA, Flying with Portable Electronic Devices (PEDs), https://www.faa.gov/travelers/fly_safe/ped/ (last visited Aug. 31, 2021).

⁴¹ Brief network messages related to device location may be transmitted over control channels while in idle mode if a network is visible to the device. Such transmissions would generally take place over lower spectrum bands with better RF propagation than the C-Band.

⁴² CTIA August 26, 2020 Analysis; CTIA October 27, 2020 Analysis; CTIA October 30, 2020 Analysis; CTIA November 17, 2020 Analysis; CTIA March 4, 2021 Analysis.

Source	4 GHz Measurements?	In-Flight Measurements?	Nearby Buildings?
UWB on Airbus A319 ⁴³	Yes	No	Not Stated
UWB on Four Aircraft ⁴⁴	Yes	No	No
2020 WAIC on Beechcraft B300 ⁴⁵	Yes	No	No
2014 WAIC on Airbus A320 ⁴⁶	Yes	No	With & Without
ATR Analysis ⁴⁷	Analysis only	N/A	N/A
Airbus Helicopter ⁴⁸	Yes, Door Open	No	Yes (picture)

Table 3-3: Aviation Sources for Aircraft Interference Path Loss

An error present in a few of the studies was testing an aircraft near surrounding buildings. Reflections from the buildings provide a propagation path to the altimeter antenna that is not present in flight at altitude. The test signals reflected off of the nearby building structures, resulting in a stronger signal at the altimeter antenna. The strong reflected signal reduced the IPL relative to the level that would have been present without the reflections. As noted in the 2014 Airbus A320 measurements, the IPL was largely driven by reflections.⁴⁹ When the aircraft is in flight, the in-cabin transmissions would not reflect off of nearby structures, and the IPL would be larger.

A larger issue present in all of the sources was the aircraft test location—on the ground, not in the air. The studies were largely focused on ultra-wideband (“UWB”) or personal electronic devices (“PEDs”) potentially impacting aircraft systems while parked or taxiing. This environment is different from the in-flight environment due to ground reflections. Transmitted signals inside the cabin emit through the aircraft windows, with some leakage along the aircraft skin. The IPL is heavily influenced by ground reflections, and IPL increases with increasing height above the ground.⁵⁰ None of these sources

⁴³ I. Schmidt et al., *UWB aircraft transfer function measurements in the frequency range from 2 to 8 GHz*, 2008 International Symposium on Electromagnetic Compatibility - EMC Europe, Hamburg (2008).

⁴⁴ J. Schüür and R. R. Nunes, *Determination of the path loss from passenger electronic devices to radio altimeter with additional EMI test*, 2012 ESA Workshop on Aerospace EMC, Venice (2012).

⁴⁵ S. Futatsumori (ENRI), *Interference Path Loss Measurement at Wireless Avionics Intra-Communication Band using Beechcraft B300 Aircraft*, ICAO FSMP Working Group 10, 10th Working Group Meeting (Aug. 2020).

⁴⁶ J. Engelbrecht, T. Fuss, U. Schwark and O. Michler, *Measurement of Interference Path Loss between Wireless Avionics Intra-Communications system and aircraft systems at 4.2-4.4 GHz band*, 2014 Loughborough Antennas and Propagation Conference (LAPC), Loughborough (2014).

⁴⁷ ATR: Radio Coupling (IPL) between Portable Electronic Devices (PEDs) and Radio Altimeter (RA) - FOR-1-D-73-00-EN - A.7 (May 24, 2019).

⁴⁸ Ponçon, Marc. Airbus ETGEE report 96/2020, *Measurement of typical IPL to RA antenna on Airbus Helicopter* (Nov. 11, 2020).

⁴⁹ Engelbrecht et al., *supra* note 46, Section II (“The signal propagation paths between RA antenna and measurement antenna are mostly realized via reflections or multiple reflections.”).

⁵⁰ *Ibid*, in section III, “In the analyzed setup the IPL is expected to increase with increasing height above ground,” and “Interference outside the RA main beam is only significant on ground.”

measured IPL for aircraft in flight, which is the scenario that must be assessed for any 5G UEs transmission onboard an aircraft in flight. The RTCA Report's assessment of UEs onboard aircraft is incorrect because the assumed IPL was measured on the ground, and does not reflect the IPL for aircraft in flight. CTIA disputes all aviation claims that 5G base station or UE spurious or unwanted emissions may impact altimeter performance.

4. Aviation Standards Applicability to AVSI Parameters

4.1 Cable Loss

The Organizations Letter claimed that DO-155's description of external loop loss implied a requirement to include cable loss in the test setup,⁵¹ but that is not so. DO-155 does not state that the manufacturer's recommended cable loss is to be added to the lab test setup.

AVSI said as much as recently as 2019. AVSI's August 2019 WAIC test update presented to ICAO clearly stated that under DO-155, cable loss should not be included in the altimeter lab test setup.⁵² Notably, just two months later, on October 22, 2019, AVSI's filing on 5G/radio altimeter coexistence incorporated more stringent assumptions, including cable loss, in its 5G testing.

4.2 Loop Loss Parameters Used by AVSI are Not Supported by Aviation Requirements

The Organizations Letter's stated loop loss is incorrect, and its claims of a CTIA error are also incorrect.

The FAA requirements for altimeters are described in Technical Standard Order ("TSO") C87a. TSO C87a defines the "minimum performance standards (MPS) your airborne low-range radio altimeter must first meet for approval and identification with the applicable TSO marking."⁵³ C87a defines the functional, environmental, software, and electronic hardware qualification requirements in order for an altimeter to be certified. Regarding altimeter performance and accuracy requirements, C87a references the requirements document prepared by EUROCAE, ED-30.⁵⁴

⁵¹ Organizations Letter at B-9.

⁵² Frequency Spectrum Management Panel (FSMP), Ninth Meeting of the Working Group, Montreal, Canada, 22-30 August 2019, RADIO ALTIMETER-WAIC INTERFERENCE SUSCEPTIBILITY TESTING STATUS UPDATE, at 2 ("In addition, the previously used cable loss assumption of 4 dB in transmit and receive path of all RAs was eliminated for consistency with the reference plane defined in DO-155 to make the test results applicable to all RA installations. The findings presented herein reflect corrections to the test setup to address those issues.").

⁵³ FAA TSO-C87a at 1 (May 31, 2012).

⁵⁴ EUROCAE ED-30, 1980 Edition, June 1980 – Minimum Performance Specification for Airborne Low Range Radio (RADAR) Altimeter Equipment.

ED-30 requires the altimeter accuracy to be measured in a laboratory environment “over the range of variation of the radar back reflexion (sic) coefficient of 0.01 to 1.0.”⁵⁵ In other words, ED-30 specifies the worst reflection coefficient in laboratory testing to be 0.01. Reflection coefficient defines the amount of the altimeter’s radio energy reflecting from the terrain and returning toward the altimeter antenna. The altimeter measures the time delay between the transmitted and reflected signals to calculate the aircraft height above terrain. A low reflection coefficient, such as 0.01, means that most of the energy is scattered, and only 1% of the energy returns toward the aircraft. Such a low reflection coefficient might be seen over very rough terrain.

The amount of the radio altimeter signal lost between the transmitting and receiving antennas is termed the loop loss. TSO C87a references RTCA/DO-155⁵⁶ Appendix B for external loop loss. DO-155 Appendix B provides curves of external loop loss as a function of height above ground for representative antenna gains. However, the DO-155 loop loss curves were developed assuming a more stringent reflection coefficient of 0.006.⁵⁷ In order to comply with ED-30, the DO-155 Appendix B loop loss curves must be adjusted to the specified reflection coefficient of 0.01. The signal strength difference between the coefficients of 0.006 and 0.01 can be calculated as $10 \cdot \log((0.01/0.006)) = 2.2$ dB. Therefore, 2.2 dB must be removed from the loop loss curves in DO-155, to adjust for the ED-30 guidance. In other words, ED-30 requires 2.2 dB less loss in the laboratory test setup compared with the assumptions in the DO-155 Appendix B curves.

The Organizations Letter’s derivation of loop loss contains a gross deviation from ED-30 guidance; the Letter cites DO-155 loop loss curves for a “10.8 dB” antenna gain assumption as being 92 dB.⁵⁸ Here, the Letter ignores the explicit guidance in ED-30 to employ a minimum reflection coefficient σ of 0.01, requiring a 2.2 dB correction to be applied to the DO-155 loop loss curves, which were developed using a σ of 0.006.

The Organizations Letter contains a second error regarding loop loss, by assuming an altimeter antenna pattern with a 60 degree beamwidth. Nearly all commercial altimeter antennas have a beamwidth of 45 degrees or less, as noted in Table 4-1, sourced from manufacturer specification data publicly available on their respective web sites.

⁵⁵ ED-30, Section 5.4.2.

⁵⁶ RTCA DO-155, Minimum Performance Standards Airborne Low-Range Radar Altimeters (Nov. 1, 1974) (“RTCA DO-155”).

⁵⁷ *Id.* at Section 6.0.

⁵⁸ Organizations Letter at B-9 (“Further, CTIA misrepresents the external loop loss for a 200-foot height, claiming it is 90 dB when in fact the external loop loss defined by DO-155 for a 10.8 dB antenna gain assumption is 92 dB at 200 feet.”).

Manufacturer	Model #	Roll Plane BW (Degrees)	Pitch Plane BW (Degrees)
Sensor Systems	S67-2018	+/- 30	+/- 25
Sensor Systems	S67-2002-45	+/- 22.5	+/- 20
Sensor Systems	S67-2002-29	+/- 22.5	+/- 20
Sensor Systems	S67-2002-28	+/- 22.5	+/- 20
Sensor Systems	S67-2002-19	+/- 22.5	+/- 20
Sensor Systems	S67-2002-18	+/- 22.5	+/- 20
Sensor Systems	S67-2002-14	+/- 22.5	+/- 20
Sensor Systems	S67-2002-12	+/- 22.5	+/- 20
Sensor Systems	S67-2002	+/- 22.5	+/- 20
Rami	AV-601	+/- 22.5	+/- 20
Cobham	20-21	+/- 22.5	+/- 20
Antenna Associates	LG81AT01	+/- 17.5	+/- 20
Antenna Associates	LG81K1	+/- 25	+/- 25
Antenna Associates	LG81N1	+/- 25	+/- 25
AeroAntenna	AT4300	+/- 22.5	+/- 20
UB Corp	AD43011	+/- 22.5	+/- 20

Table 4-1: Altimeter Antenna Manufacturers and Antenna Pattern Width⁵⁹

To match the antenna pattern predominating Table 4-1, the appropriate loop loss curve is DO-155's Figure 4,⁶⁰ not Figure 5 as used by the Organizations. Using the correct figure, the appropriate loop loss for a height of 200 feet, as adjusted for a σ of 0.01, is 88 dB. The Letter's suggested value of 92 dB is 4 dB worse than the appropriate worst case loop loss of 88 dB.

4.3 Worst Case Landing Scenario

Much of the Organizations Letter seeks to bolster aviation's WCLS analysis in light of inconsistencies that CTIA's filings have already demonstrated, but the Organizations Letter does not undo the faulty analysis aviation has put forward. As CTIA's March 4 filing observed, aviation set out an "impossible landing scenario" to assess the impact of 5G operations, where the landing aircraft "is coming in over the runway at a height that exceeds what is allowed by the FAA, rolling at a 20 degree angle, landing on a runway covered in sand or plowed land, with 14 other radio altimeters transmitting on the taxiway with perfect ground reflections, and the 5G base station's entire power pointing in a single beam directly at the aircraft from a structure located such that it would violate FAA rules regarding obstructions to air navigation."⁶¹ The Organizations Letter does not dispute this scenario, but asserts

⁵⁹ The only antenna in Table 4-1 with a beamwidth of 60 degrees is the Sensor Systems S67-2018, which is described as having an "integrated band-pass filter." Altimeter S67-2018, Sensor Systems, Inc. (dated Apr. 14, 2014), <https://www.sensorantennas.com/wp-content/uploads/2015/02/DS-S67-2018f.pdf>.

⁶⁰ DO-155, Appendix B at 8, Figure 4.

⁶¹ CTIA March 4, 2021 Analysis at 3.

that its analysis “presents a worst-case condition in which radio altimeters are still required to meet their minimum performance criteria.”⁶² The problem is, this is not worst-case, but rather is an implausible, conjured-up scenario.

Aviation’s claim that the scenario is a missed approach continues to mis-apply fundamental elements.⁶³ Namely, any landing scenario—whether a successful landing or a missed approach—must account for the smooth terrain that exists on a runway. Smooth terrain better reflects the altimeter signal and provides a stronger altimeter signal at the aircraft receiver, as opposed to rough terrain which tends to scatter the altimeter signal. But aviation’s WCLS analysis incorporates rough terrain over the runway without explanation—and this is not a real-world scenario, even for missed approaches. Beyond the runway, an aircraft experiencing a missed approach may encounter rough terrain but would not be subject to the aggregate interference from ground-based altimeters.

Further, as CTIA noted in the March 4 and earlier filings, AVSI’s WCLS does not reflect a realistic landing situation. AVSI improperly identified: the threshold crossing height (“TCH”) for a landing aircraft; the amplitude of other radio altimeter interference in the test setup; and different reflection coefficients for the same surface.

When evaluating a landing situation where automated landing systems may be in use, real-world TCH height, or height over the runway, is a critical factor in modeling the correct conditions. AVSI applied a TCH of 200 feet first, which CTIA contended was unrealistic. Aviation now criticizes CTIA’s use of the TCH of 60 feet, identifying one airport TCH of 80 feet.⁶⁴ A height of 80 feet is much closer to 60 feet than 200 feet. AVSI’s use of a landing height that does not reflect the reality of landing aircraft is not “worst case,” but rather “unrealistic.”

The lower height of a real landing aircraft contributes several critical improvements over AVSI’s test conditions: 1) the lower height increases the altimeter’s reflected signal strength due to a lower loop loss, simulating a shorter round-trip distance traveled by the altimeter signal;⁶⁵ 2) the interference from ground-based altimeters is much lower;⁶⁶ and 3) the runway surface has a much better reflection coefficient.⁶⁷ Aviation stakeholders have failed to address these significant flaws in AVSI’s test conditions.

⁶² Organizations Letter at B-5.

⁶³ *Id.* at B-6.

⁶⁴ Organizations Letter at B-6, n.18 (“Further, TCH values above 75 feet exist; for example, the Duluth International Airport (KDLH) ILS or LOC RWY 27 approach chart shows a TCH of 80 feet.”).

⁶⁵ CTIA March 4, 2021 Analysis at 13.

⁶⁶ 5G Americas White Paper at 22.

⁶⁷ RTCA DO-155 at A-5 (“With the equipment installed in an aircraft, operate the equipment in flight over a runway or other smooth surface.”).

The Organizations Letter attempts to cover AVSI's mistake by claiming that the 200 feet height represents a go-around, or missed approach, scenario. However, a go-around scenario involves different conditions. In order for the aircraft to be at 200 feet over the runway threshold, the go-around decision would have been previously made; any automated landing systems would be disengaged. The go-around aircraft, flying above the runway by AVSI's WCLS definition, would experience a much better reflection coefficient than that used in AVSI's testing, as runways are smooth terrain and AVSI applied a rough terrain coefficient that reflects more poorly. Thus, AVSI's 200 feet ITMs are flawed regardless of whether they are claimed to represent a landing aircraft or an aircraft executing a go-around.

The Organizations Letter claims that CTIA's March 4 filing is limited solely to User Category 1;⁶⁸ this is incorrect. AVSI applied WCLS test conditions to all three classes of altimeter; the only difference between Category 2 and Category 3 was the removal of Other RA interference for Category 3. CTIA's critique of the WCLS conditions applied accordingly to all classes of aircraft. AVSI applied the same WCLS analysis to both Category 1 and Category 2 aircraft with the same aerodrome configuration for both, and CTIA's analyses apply equally to AVSI's Category 2 WCLS testing, as noted in the March 4 filing.⁶⁹ Additionally, CTIA previously submitted a ten-page response to aviation's helicopter (air ambulance) study that focused on Category 3 altimeters.⁷⁰ And CTIA's March 4 filing expressly stated that Category 3 altimeters "would also have a positive margin," or no interference, and observed that the same corrections to the test conditions for Category 2 (other than Other RA interference) would also apply to the Category 3 testing.⁷¹

4.4 Equipment Regulation

The Organizations Letter confirmed that an altimeter designed more than 40 years ago—likely before the advent of solid state electronics—is still manufactured and deployed today.⁷² The continuing sale of antiquated technology by altimeter manufacturers is only part of CTIA's concern here. CTIA also noted that the one poorly performing altimeter driving RTCA's Category 2 and Category 3 claims was not behaving in a similar manner as the other altimeters tested.⁷³ Since AVSI only tested one unit for that model, and that one unit showed erratic behavior differing from all other altimeters and ITU-R Rec. M.2059 guidance by tens of dBs, its results cannot be relied upon. As a result, CTIA continues to dispute the RTCA Category 2 and Category 3 claims, which solely rest on this potentially malfunctioning altimeter.

⁶⁸ Organizations Letter at B-8.

⁶⁹ CTIA March 4, 2021 Analysis at 19.

⁷⁰ CTIA August 26, 2020 Analysis.

⁷¹ CTIA March 4, 2021 Analysis at 19.

⁷² Organizations Letter at B-10.

⁷³ CTIA March 4, 2021 Analysis at 26.

4.5 WAIC Status

The Organizations Letter portrayed the August 2019 and earlier WAIC test reports presented at ICAO's Frequency Spectrum Management Panel ("FSMP") as preliminary, yet the International Coordinating Council of Aerospace Industries Associations ("ICCAIA") pointed to a 2018 AVSI WAIC report as justifying power levels for WAIC SARPs.⁷⁴ According to the August 2019 FSMP session report, there did not appear to be disagreement of the AVSI testing inputs.⁷⁵

4.6 Domestic and International 5G Operations and Aviation Altimeters

As CTIA has highlighted previously, there is a disconnect between aviation's claims and existing nearby services that operate without any evidence of causing harmful interference. If aviation's analysis were accurate, existing services operating in nearby bands would already be causing harmful interference to altimeters. For example, Federal fixed and mobile services in the 4.4-4.94 GHz band operate with similar EIRP as 5G but without 220 megahertz of separation, and include ground transmitters pointing skyward towards the aircraft. And the Navy's AN/SPN-43 radar operates at much higher radiated power levels just below 3.65 GHz. The lack of widespread altimeter interference today reinforces that aviation's claims are without basis.⁷⁶

CTIA's prior studies also documented the large number of countries in which 5G systems have been operating in spectrum up through at least 3800 MHz for as much as three years. Japan has some 90,000 base stations deployed using spectrum up to 4100 MHz and above 4500 MHz.⁷⁷ If the RTCA Report reflected reality, then aircraft with altimeters in Categories 2 and 3, with their claimed exceedance of 40+ dB, would be regularly experiencing performance issues in these countries. The Organizations Letter's main defense here is to complain that CTIA did not "cite sources,"⁷⁸ but a non-interference event is by definition a non-event and is not reported, and therefore cannot be cited.

⁷⁴ FSMP August 2019, RA-WAIC Update, at 1 ("Based on that study, the eight meeting of FSMP-WG accepted that power limit as a valid requirement for WAIC SARPs.").

⁷⁵ FSMP-WG/9, Montreal, Canada, 22-30 August 2019, Report, Section 3.1.5 ("It was further assumed that there was no attenuation between WAIC transmissions, represented as transmissions from an equivalent e.i.r.p. point source at the geometric center of an aircraft, of one aircraft and an altimeter on another aircraft except for path loss and altimeter antenna discrimination. This results in WAIC interference levels that do not meet the protection criteria in ITU-R Rec.M.2059.").

⁷⁶ CTIA October 27, 2020 Analysis at 16-18; CTIA October 30, 2020 Analysis at 9; CTIA March 4, 2021 Analysis at 4.

⁷⁷ Japan has certain restrictions for deployment in the 100 megahertz band segments at 4000-4100 MHz and 4500-4600 MHz—which, notably, are not being utilized for 5G in the U.S. There are no special restrictions on operations below 4000 MHz.

⁷⁸ Organizations Letter at B-12.

5. Response to Organizations Letter Attachment C

In Attachment C of the Organizations Letter, the Organizations described FAA obstruction rules and derived theoretical tower heights for two types of approaches: an instrument landing system (“ILS”) and a localizer performance with vertical guidance (“LPV”). While the Letter indicated possible tower heights and locations, the Organizations did not derive the 5G signal levels corresponding to these hypothetical tower locations. Without this math, the Organizations cannot claim to have refuted CTIA’s assertion that 5G signals as strong as those claimed by RTCA would require exceedance of the FAA structural height limitations. CTIA provides the engineering analyses for these hypothetical locations below, demonstrating that the RTCA Report significantly over-estimated the 5G base station signal levels.

5.1 ILS Approach Path

The Organizations Letter first derived base station locations along the ILS approach path. The Letter concluded that a base station tower 75 feet above ground level (“AGL”) could be located 3,950 feet from the runway threshold, and a base station tower 100 feet AGL could be located 5,200 feet from the runway threshold.⁷⁹ The Letter stated that this situation was similar to the Chicago O’Hare example; the original RTCA O’Hare figure is reproduced in Figure 5-1 below.

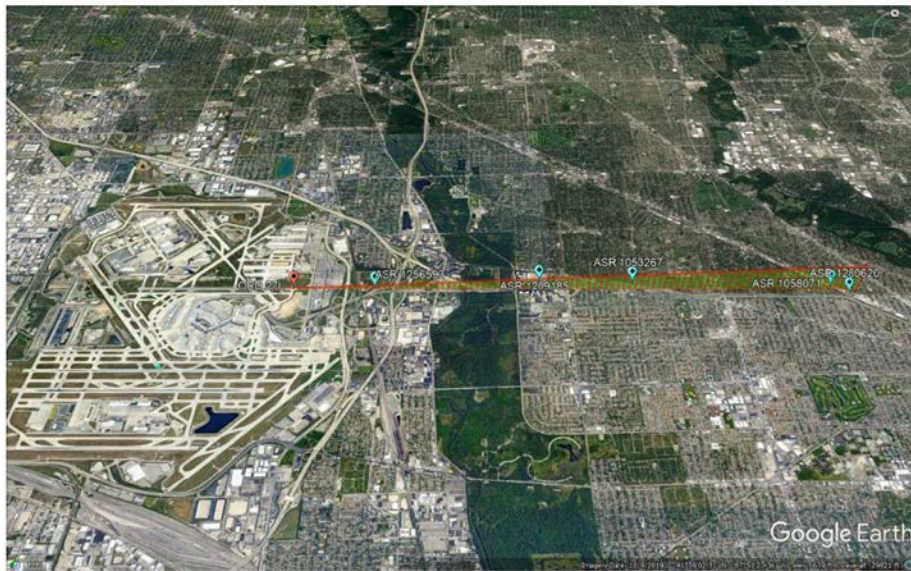


Figure 5-1: RTCA Study Chicago O’Hare Example

⁷⁹ Organizations Letter at C-3.

The tower closest to the O'Hare runway is shown in Figure 5-2, with a tower height of 78 feet AGL.⁸⁰



Figure 5-2: Tower Closest to O'Hare Airport (41 59 02 N, 87 52 25 W)

This tower is located 4,332 feet from the runway threshold as shown in Figure 5-3:

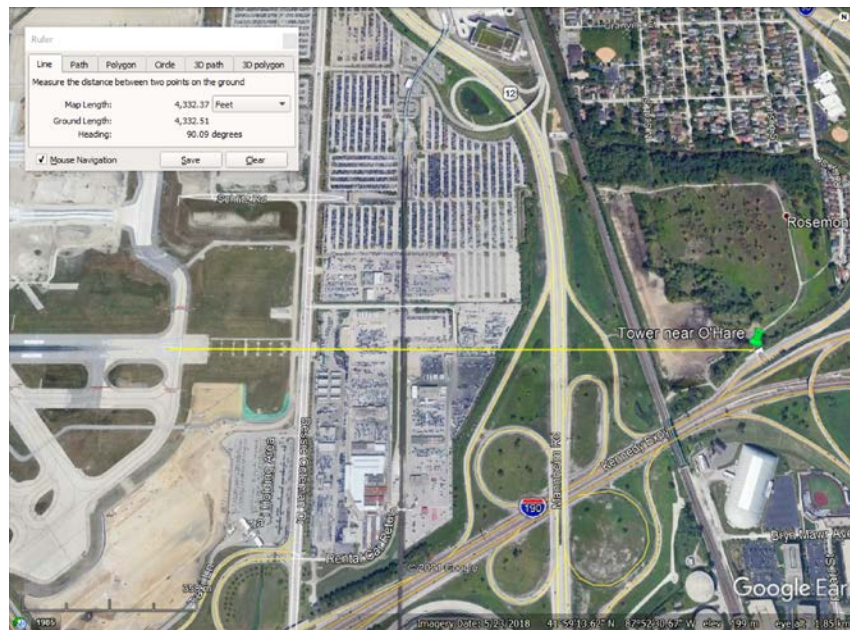


Figure 5-3: Distance of Tower to Chicago O'Hare Runway Threshold

The RTCA Report used the P.528 ground to air propagation model, with a highly pessimistic time percentage of 1%, meaning that 99% of the time the predicted signal is less strong than this level. This model results in predicted interfering signals stronger than a free space line-of-sight prediction, an extremely unlikely scenario. Of further note, P.528 is only applicable when the aircraft is above the tower height; when the aircraft height is similar to or lower than the tower height, P.528 cannot be used.

⁸⁰ The longitude coordinates listed in the RTCA Report were incorrect; the correct coordinates are shown herein.

The 5G base station antenna pattern used in the RTCA Report is provided in Figure 5-4 below, with a note added by CTIA identifying an erroneous grating lobe.

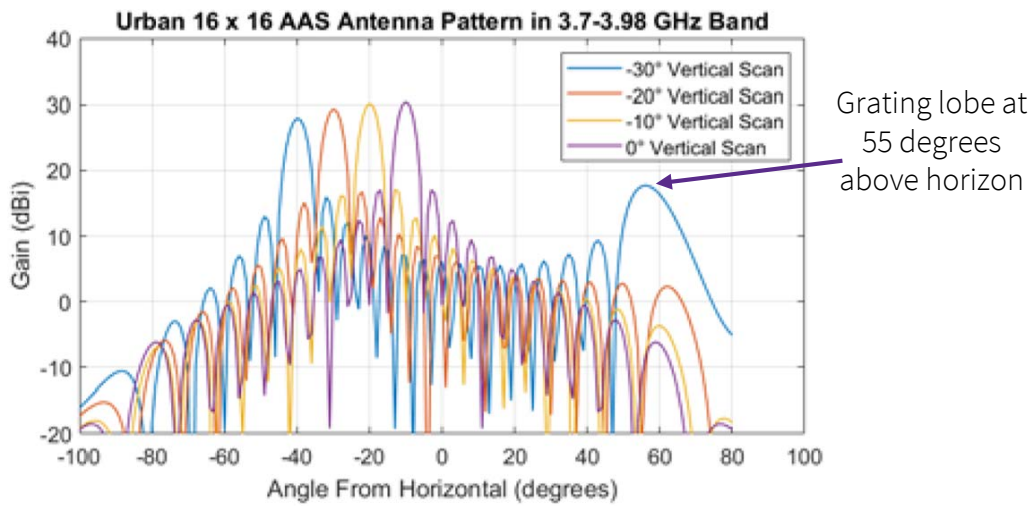


Figure 5-4: RTCA Figure 6-4, Urban 16x16 AAS Antenna Pattern

RTCA’s evaluation of the Chicago O’Hare approach used this flawed antenna pattern and assumed the full base station power was applied within a single beam,⁸¹ which resulted in the peak 5G signal levels above each base station depicted in RTCA Figure 10-33, provided below.

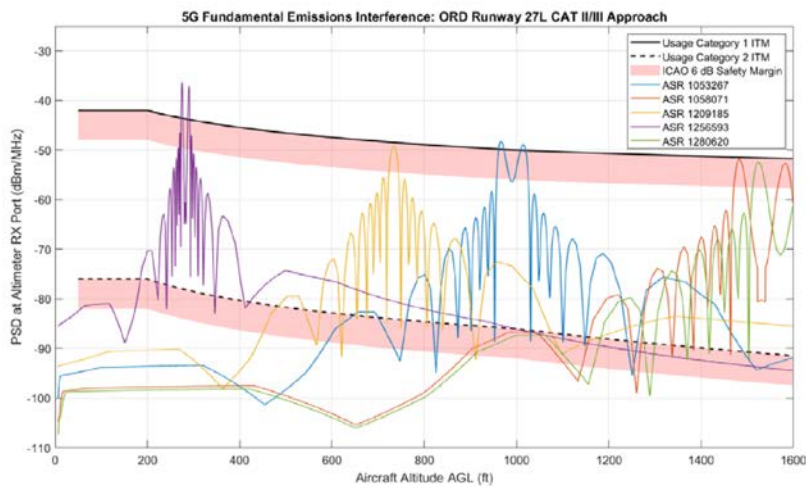


Figure 5-5: RTCA Figure 10-33, Chicago O’Hare Approach Path

⁸¹ Generally, the full base station power is shared among multiple traffic beams pointing in different directions. This reduces the power transmitted within the indicated grating lobe. Also, base station power is less when only a portion of the channel is in use.

In this figure, each color-coded curve shows the 5G signal strength at an aircraft following the ILS approach path, from each of five base stations. The left side of the graph is closest to the runway threshold. The nearest base station to O'Hare, with the signal level denoted in purple, produced the strongest signal in Figure 5-5 because the aircraft was at its lowest height relative to the base station locations. The peak signal level appears to be -36 dBm/MHz. For a 100 megahertz transmission, this becomes -16 dBm/100 MHz.

This purple peak occurs above the base station due to the grating lobe in the base station antenna pattern used by RTCA. Importantly, the grating lobe—which would not exist in a real base station implementation—creates a spike in signal strength at an angle of 55 degrees above horizon. At this sharp angle, the aircraft is relatively close to the base station. The signal falls off in strength as the aircraft moves farther away from that location—as illustrated by the peak, and signal roll off, visible with the purple line from Figure 5-5 above. The purple line actually shows two peaks, corresponding to the two points where the aircraft encounters a 55 degree angle to the base station (as the aircraft is approaching and departing the tower location), with a null when directly above the base station.

Figure 5-6 provides an illustrative view of the relative location of the aircraft and base station when the grating lobe is encountered (not to scale). The aircraft height is calculated from the glide path to Chicago O'Hare and the distance from the runway threshold. The slant distance from the base station to the aircraft is 255 feet, for the peak grating lobe at 55 degrees above horizon.

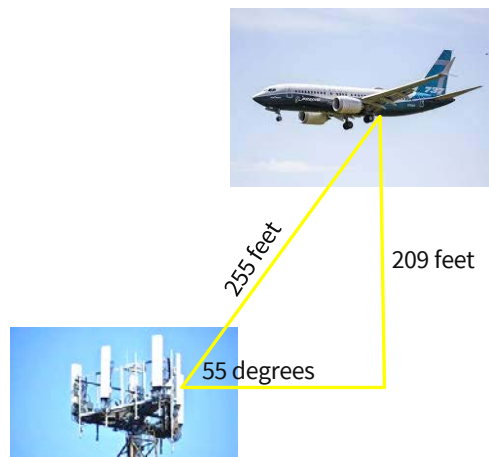


Figure 5-6: Aircraft Above a Base Station Near an Airport

The purple peaks in Figure 5-5 would be much lower in amplitude when using the corrected base station antenna pattern. Table 5-1 provides calculations for both the grating lobe case and for the corrected antenna pattern, when the aircraft is close above the base station at the 55 degree angle, reflecting a similar situation as the peak purple signal appearing in Figure 5-5 above.

Parameter	Grating Lobe	Corrected Pattern	Units
5G tower height	78	78	ft AGL
Angle to aircraft	55	55	degrees
Aircraft height	287	287	ft AGL
Slant distance to aircraft	255	255	ft
BS antenna gain toward aircraft	16	-2	dBi
Net EIRP toward aircraft	67.5	49.5	dBm/100 MHz
Free Space Path Loss	82.0	82.0	dB
Altimeter antenna gain	0	0	dBi
5G BS signal at aircraft	-14	-32	dBm/100 MHz

Table 5-1: 5G Signal at Aircraft Above a Base Station

The 5G signal level in Table 5-1 is 18 dB lower with the corrected antenna pattern. Note that a number of worst-case assumptions are included in the Table 5-1 calculations such that real-world signal levels will be less than that shown:

- The maximum base station power is applied within just one traffic beam. In operation, multiple traffic beams are in use at a given time and the base station power is spread among all beams, lessening the side lobe peak power.
- The RF propagation path is assumed to be free space path loss.
- The altimeter antenna pattern uses the maximum value for signals in the C-Band.
- No polarization mismatch is assumed, despite the differing antenna pointing directions.
- All resource blocks are in use in the full 100 megahertz channel, despite normal operations resulting in base station duty cycles ranging from 10% to 70%.

Next, we will evaluate the situation of an aircraft located above the runway threshold and within the peak antenna beam for the same tower location (at maximum EIRP). Table 5-2 calculates the nearest base station's power level to an aircraft over the runway threshold.

Parameter	FSPL	Units
5G tower height	78	ft AGL
Angle to aircraft	-0.3	degrees
Aircraft distance to threshold	0	ft
Aircraft height	53	ft AGL
Slant distance to aircraft	4322	ft
Relative BS antenna gain	30.5	dBi
Net EIRP toward aircraft	82	dBm/100 MHz
Path Loss (Free Space)	106.6	dB
Altimeter antenna gain	-10	dBi
Aircraft blockage	10	dB
5G BS signal at aircraft	-45	dBm/100 MHz

Table 5-2: 5G Base Station Signal to Aircraft Over the Runway Threshold

The altimeter antennas, mounted underneath the aircraft, do not have a line-of-sight path to the base station antennas. To remain worst case, the calculations assume free space path loss as though a line-of-sight condition exists, with a modest aircraft fuselage attenuation of 10 dB. RF signal attenuation through a metallic frame is typically tens of dB higher. In this unrealistic case in which the full base station power is directed in a single beam at the aircraft, the signal level is a further 13 dB lower than that of Table 5-1, and 31 dB lower than RTCA's claim.

5.2 ILS Transitional Surface

The Organizations Letter also derived the maximum possible tower height and closest location in the airport transitional surface, 200 feet offset from the runway threshold. The two examples defined in the Letter were:

- A tower 75 feet tall may be located 1,025 feet from the runway centerline.
- A tower 150 feet tall may be located 1,550 feet from the runway centerline.⁸²

The hypothetical tower locations relative to an exemplary runway threshold are shown in the figure below.



Figure 5-7: ILS Transitional Surface Hypothetical Tower Geometry

An aircraft 200 feet before the runway threshold would be at a height of 70 feet. Table 5-3 calculates the 5G base station signal at the altimeter receiver for the two ILS transition surface examples. The RF propagation equation used is free space path loss, even though the aircraft antennas are not in line-of-sight to the 5G tower, given the lower aircraft height. Modest aircraft blockage of 10 dB is again assumed. Notably, the calculations assume the maximum regulatory base station power is directed entirely at the aircraft, which will not occur in practice.

⁸² Organizations Letter at C-4.

	Tower A	Tower B
Tower Height (ft)	75	150
Horizontal Distance (ft)	1025	1550
Aircraft Height (ft)	70	70
Slant Distance to Aircraft (ft)	1025	1550
Path Loss (FSPL) (dB)	93.9	97.5
BS EIRP (dBm)	82	82
Altimeter Ant Angle (deg)	90	93
Altimeter Ant Gain (dBi)	-10	-10
Aircraft Blockage	10	10
5G Signal at Altimeter	-32	-36

Table 5-3: 5G Base Station Signals from Closest Possible Transition Surface Towers

As shown in Table 5-3, the closest hypothetical tower locations—which are likely closer to the runway than towers in practice—result in 5G signal levels that are much lower than RTCA’s claim, even with the worst case assumptions employed above. As CTIA stated in its March 4 Letter, a base station would need to exceed the FAA structural height limitations to present a 5G signal as strong as that claimed in the RTCA Report.

5.3 LPV Approach

The Organizations Letter also derived the closest locations and tower heights in the transitional surface for a non-precision approach termed LPV. LPV is an Area Navigation (“RNAV”) approach using guidance from the Global Navigation Satellite System (“GNSS”).⁸³ The GNSS signal is refined by the Wide Area Augmentation System (“WAAS”), which consists of ground-based reference stations providing corrections to the Global Positioning System accuracy.⁸⁴ FAA guidance for an LPV approach specifies the Decision Altitude is determined solely with reference to barometric altimeter and reference to “mean sea level,”⁸⁵ and in fact prohibits reliance upon a radio altimeter when performing an LPV approach.⁸⁶

⁸³ GNSS consists of the collection of satellite-based positioning systems, including the Global Positioning System (GPS) (United States), COMPASS/Beidou (China), GLObal Navigation Satellite System (GLONASS) (Russia), Galileo (Europe), India’s Regional Navigational Satellite System (IRNSS), and Quazi-Zenith Satellite System (QZSS) (Japan). See, e.g., United Nations Office of Outer Space Affairs, Global Navigation Satellite Systems (GNSS), <https://www.unoosa.org/oosa/en/ourwork/psa/gnss/gnss.html> (last visited Aug. 26, 2021).

⁸⁴ See, FAA, Satellite Navigation - Wide Area Augmentation System (WAAS), https://www.faa.gov/about/office_org/headquarters_offices/ato/service_units/techops/navservices/gnss/waas/#:~:text=WAAS%20is%20an%20extremely%20accurate%20navigation%20system%20developed%20for%20civil%20aviation.&text=WAAS%20provides%20service%20for%20all,airport%20departures%2C%20and%20airport%20arrivals (last visited Aug. 26, 2021).

⁸⁵ 14 C.F.R. § 1.1.

⁸⁶ FAA, RNAV (GPS) Approaches (dated June 12, 2012), https://www.faa.gov/about/office_org/headquarters_offices/ato/service_units/techops/navservices/gnss/library/factsheets/media/RNAV_QFacts_final_06122012.pdf (“Pilots must use the barometric altimeter as the primary altitude reference to meet all altitude restrictions.”).

Since the LPV approach relies on GNSS, WAAS, and the barometric altimeter, but does not appear to make use of the radio altimeter, no further analysis is needed.

6. Conclusions

CTIA has discussed at length numerous technical defects with the unrealistic inputs and conditions used in the RTCA Report. The test inputs, setup, and pass/fail criteria employed by AVSI in its laboratory testing did not adhere to aviation's radio altimeter performance requirements, rendering the output from such lab tests invalid. These invalid AVSI test results were employed in the RTCA Report to claim significant exceedances by 5G equipment transmitting more than 220 megahertz away from the altimeter band. Thus, aviation's claims regarding 5G fundamental and spurious emissions are invalid because the test data underpinning the analyses are invalid.

Further, aviation's claims regarding 5G exceedances relative to ITU-R M.2059 are mistaken because the M.2059 guidelines were designed for the maximum operating altitude of the altimeter. The heights assessed in the RTCA Report were lower than the maximum reporting altitude for the altimeters under test, resulting in incorrect conclusions regarding comparison to M.2059.

Given the significant errors in the AVSI testing and the subsequent RTCA claims based on AVSI's invalid ITMs, the FCC must reject aviation's claims.