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January 22, 2020

Via ECFS

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

Re: ***Written Ex Parte Communication***

GN Docket No. 18-122, *Expanding Flexible Use of the 3.7 GHz to 4.2 GHz Band*

Dear Ms. Dortch:

T-Mobile USA, Inc. ("T-Mobile")[1/] hereby responds to the analysis submitted by the Aerospace Vehicle Systems Institute ("AVSI") regarding protection requirements for radio altimeters ("RAs") operating in the 4200-4400 MHz band from the planned adjacent-band terrestrial operations in the 3700-4200 MHz spectrum (the "C-band").[2/] The AVSI Report contains numerous technical and analytical errors that lead to inaccurate conclusions and thereby greatly overstates the potential protection required.

The above-referenced proceeding represents a unique opportunity for the Commission to make valuable mid-band spectrum available for terrestrial broadband networks so that the United States can continue to lead in the race to Fifth Generation ("5G") wireless networks and technology. Throughout this proceeding, AVSI and others representing aviation sector interests have urged the Commission to protect RAs from terrestrial C-band use.[3/] T-Mobile recognizes

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1/ T-Mobile USA, Inc. is a wholly owned subsidiary of T-Mobile US, Inc., a publicly-traded company.

2/ Letter from Dr. David Redman, Aerospace Vehicle Systems Institute, to Ms. Marlene H. Dortch, Secretary, FCC, GN Docket No. 18-122, Attachment, *Preliminary Report: Behavior of Radio Altimeters Subject to Out-Of-Band Interference*, Aerospace Vehicle Systems Institute (filed Oct. 22, 2019) (the "AVSI Report").

3/ *See, e.g.*, Letter from Edward A. Yorkgitis, Jr., Counsel, Aviation Spectrum Resources, Inc., to Ms. Marlene H. Dortch, Secretary, FCC, GN Docket No. 18-122 (filed Nov. 12, 2019); Letter from Andrew Roy, Executive Secretary, Aeronautical Frequency Committee, *et al.*, to Ms. Marlene H. Dortch, Secretary, FCC, GN Docket No. 18-122 (filed Sept. 6, 2019); Letter from Andrew Roy, Executive the important role that RA operations play in aviation safety and agrees that the Commission must ensure that RA systems can continue to operate reliably. However, the Commission must not overprotect RA use of the 4200-4400 MHz band at the potential cost of limiting full access to the C-band for terrestrial use. That is why T-Mobile questions – and the Commission must critically review – the tentative conclusions reached in the AVSI Report.

T-Mobile asked Alion Science and Technology Corporation ("Alion") to preliminarily assess the AVSI Report.[4/] Alion is a global industry leader in the design and delivery of complex engineering solutions for the defense and intelligence agencies. Alion has more than 55 locations across the United States and provides mission support to its customers across the globe. Alion also operates more than 25 research lab facilities. A copy of Alion's analysis (the "Alion Study") is attached.

As explained further in the attached, Alion questions the conclusions of the AVSI Report based on four primary failings –

- Questionable interference margin assumptions – RAs operate in the presence of other RAs. But the AVSI Report does not account for how much of the interference margin is consumed by RA-to-RA in-band interference, rather than adjacent-band operations. Moreover, the high level of interference assumed from in-band operations (leaving little margin for out-of-band interference) is unrealistic because it assumes that aircraft will be closer to one another than safety considerations would permit. Finally, the baseline interference margin is likely also inaccurate because the reflection coefficient is unnecessarily restrictive.
- Incorrect waveform assumptions – The terrestrial waveform used assumes that there is a flattened response 40 dB from the peak. However, roll-off will be more than 40 dB. The assumed waveforms would not exist in any base or fixed station authorized by the Commission.
- Unrealistic operational assumptions – The AVSI Report assumed an unrealistic emission level from terrestrial operations at the RA site. But, unless the RA receiver and terrestrial transmitter are collocated – a very unlikely scenario particularly for RA receivers – RAs will never experience those emissions. The AVSI Report assumed increasing levels of interference, but with no basis for assuming those levels would ever occur.
- Silence on interference mechanism – While interference typically occurs because of front-end overload or receiver desensitization, the AVSI Report fails to identify the cause on which its analysis is based. And reliance on either mechanism may be flawed for the reasons noted in the Alion Study.

Secretary, Aeronautical Frequency Committee, *et al.*, to Marlene H. Dortch, Secretary, FCC, GN Docket No. 18-122 (filed June 19, 2019); Reply Comments of Aviation Spectrum Resources, Inc., GN Docket No. 18-122, *et al.*, (filed Dec. 11, 2018); Comments of Aviation Spectrum Resources, Inc., GN Docket No. 18-122, *et al.*, (filed Oct. 29, 2018).

[4/] T-Mobile expects that Alion will conduct a further review of the AVSI Report. That further review will be added to the record when it is available.

T-Mobile is pleased to answer questions about the Alion Study and to assist in further analysis to determine an appropriate level of protection to RAs. Pursuant to Section 1.1206(b)(2) of the rules, a copy of this letter and the attachment have been submitted in the record of this proceeding. Should there be any questions regarding the foregoing or attached, the Commission is asked to contact the undersigned.

Respectfully submitted,

/s/ Steve B. Sharkey

Steve B. Sharkey
Vice President, Government Affairs
Technology and Engineering Policy

Attachment

ALION

ENGINEERING MISSION SUCCESS

Alion Review of AVSI Report, "Preliminary Report: Behavior of Radio Altimeters Subject to Out-Of-Band Interference"

January 21, 2020

RESED-20-007

Alion Conclusions Regarding the AVSI Report

- The operational scenario baseline assumptions appear to be unrealistic, potentially overstating the risk of interference from wireless broadband.
- The simulated waveform used to characterize the wireless broadband signals appears to exhibit spectral characteristics that are not consistent with the theoretical waveform for this type of signal. This would result in unrealistically high OoBI levels.
- The level of modeled emissions from the wireless broadband transmitter at the RA receiver at which interference was predicted to occur was very high. Whether these levels are possible in any reasonable scenario was not addressed and should be further investigated.
- The interference mechanism in the analysis was not identified and should also be further investigated.

Introduction

- Proposed changes to frequency allocations in the 3700 – 4200 MHz frequency band are a legitimate concern for the avionics world. The 3700 – 4200 MHz frequency band is adjacent to the band that Radio Altimeters (RAs) operate within (4200 – 4400 MHz). The 3700 – 4200 MHz band has previously been occupied by Fixed (FS), and Fixed-Satellite (space-to-Earth) (FSS) in the United States. RAs have operated in the presence of these services for decades without major issues, indicating existing designs have sufficient margin to tolerate radio emissions from these services. Any proposed changes to frequency allocations must be investigated to determine the potential impact to RA operation and, by extension, to the safety of commercial and private aviation operations.
- Experimental studies were undertaken by the Aerospace Vehicle Systems Institute (AVSI) to characterize the behavior of RAs while exposed to adjacent Radio Frequency (RF) emissions in the 3700 – 4200 MHz frequency band. The AVSI data was considered preliminary and was released ahead of schedule to ensure the Federal Communications Commission (FCC) had initial data to consider in its Notice of Proposed Rulemaking (NPRM) process.
- Alion reviewed the AVSI analysis approach and associated data to further understand the potential impact of 3700 – 4200 MHz band emissions to RA operations.

Baseline in-band interference effects

- Three operational scenarios were considered.
- First, a "worst-case landing scenario" (WCLS) was considered in which the victim aircraft was at an altitude of 200 ft. while crossing the runway threshold just prior to landing. A large number of other aircraft were operating nearby on the taxiway and apron of the airport. Each of the aircraft on the ground produces in-band interference from their RAs.
- The second and third operational scenarios considered the victim aircraft flying at altitudes of 1000 and 2000 ft., respectively. In both cases, due to the large path loss of the interference signals, the in-band interference from RAs aboard other aircraft was assumed negligible and was ignored.
- All three of the operational scenarios included interference from own-ship RAs for five of the seven RA types tested. Two RA types that are not typically installed in multiplex (multiple altimeter) configurations did not include interference from own-ship RAs.
- During testing of the 200 ft. altitude case, two of the RAs would not operate in the presence of baseline in-band RA interference. To restore operation, the loop loss was reduced by 2 to 3 dB. This indicates that the available interference margin of the RA under test was consumed by the in-band RAs before any adjacent-band interference was introduced. The 1000 and 2000 ft. cases did not exhibit this behavior. For those cases, the other aircraft interference was assumed negligible and not included. This suggests that for the 200 ft. case, the interference from the other aircraft may have caused the interference margin to be exceeded.

Baseline in-band interference effects (continued)

- As stated in the report, RAs have operated in the presence of other altimeters for many decades without major issues, indicating existing designs have sufficient margin to tolerate such interference. When there have been problems it was usually due to poor Electromagnetic Compatibility (EMC) on own aircraft. The baseline in-band interference testing should reflect this robust interference margin.
- The positions of the other aircraft in the scenario were based on the scenario geometry dictated by International Civil Aviation Organization (ICAO) aerodrome design guidelines, but not specifically described in the report.
- The high level of baseline in-band interference from the other aircraft should be further investigated. Received power levels from RAs on other aircraft near the runway, were as high as -56 dBm. A received power this high would likely require another aircraft to be within the mainbeam of the victim RA. For a 200 ft. altitude, the 60 degree RA beamwidth footprint would be 230 ft. in diameter. An aircraft within this area would likely lead to safety issues.
- It may also be beneficial to examine the use of a terrain reflection coefficient of 0.01. The reflection coefficient was used to determine the loop loss for the analysis. This coefficient may be too restrictive to provide a sufficient interference margin.

AVSI OFDM waveform

- For the AVSI analysis, a simulated Orthogonal Frequency-Division Multiplexing (OFDM) waveform was generated to characterize the 3700 – 4200 MHz wireless signals. The spectrum analyzer plot of the waveform shows a flattened response approximately 40 dB down from the peak. The OFDM spectrum should roll off more than 40 dB over this frequency range. Shown on the right is the spectrum of a theoretical OFDM waveform.

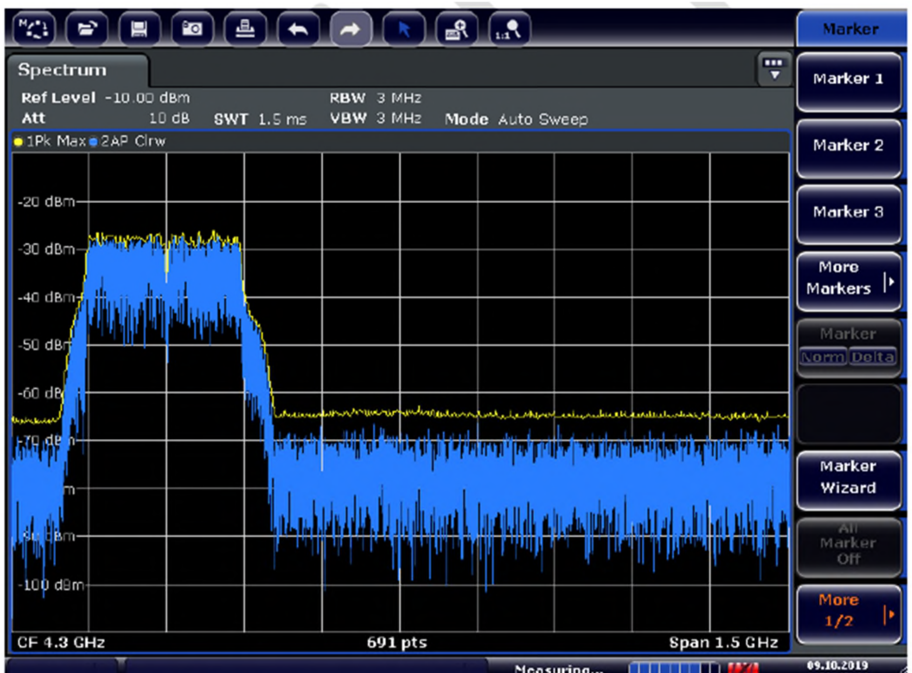
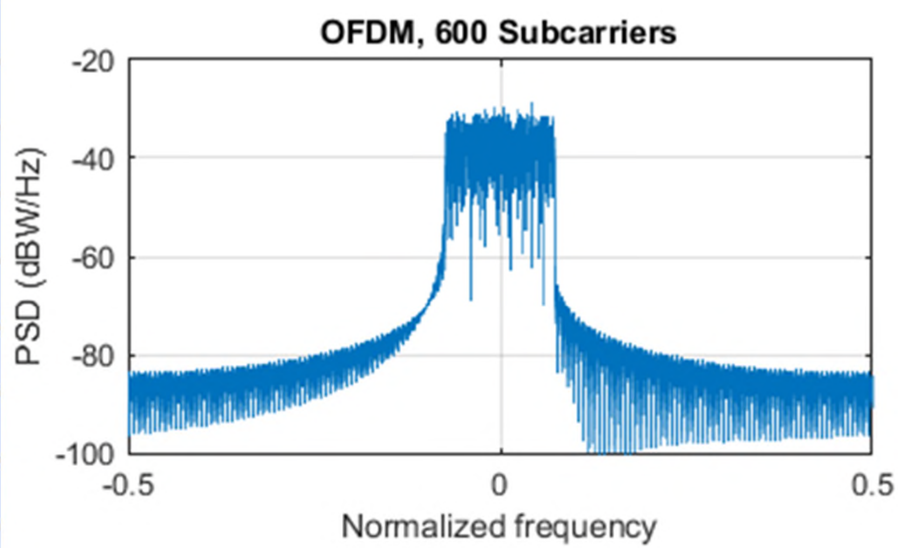


Figure 4: 300 MHz OoBI Waveform Centered at 3850 MHz Pictured on a Spectrum Analyzer.



AVSI OFDM waveform (continued)

- The Out-of-Band Interference (OoBI) levels in the analysis would not comply with the emission limits for virtually any services associated with a base station or fixed station governed by FCC rules: Part 27 services, Part 27.53 or Part 96 services, Part 96.41(e)(i). A follow on study should look at limits associated with these Code of Federal Regulations (CFR) guidelines (43 + 10log(P), 70 + 10log(P), and the Part 96 limits).
- It appears that the OoBI levels in the analysis were flat. Limits may be flat, but real systems tend to have a roll-off. Investigating the emission spectrum roll-off may be worthwhile.

Application of analysis results to real-world scenarios

- The analysis does not consider the operational interactions between aircraft and wireless base stations/user equipment. Further, the report recommends that worst-case flight and Fifth Generation (5G) deployment scenarios be studied to account for all possible RF interactions with RAs.
- The level of the modeled emissions from the wireless transmitter at the RA receiver ranged from -30 dBm to 0 dBm. These levels at which interference is predicted to occur are very high. It would be surprising to see interfering signals with the high levels seen here from a communication system that is not collocated with the victim receiver.
- It appears that the analysis applied increasing levels of interference until performance degradation occurred. Whether these levels were possible in any reasonable scenario was not investigated.

Interference mechanisms

- The interference mechanism in the analysis is unclear.
- The primary interference coupling mechanisms between RAs and interfering signals are receiver front-end overload and receiver desensitization.
- Receiver front-end overload occurs when received energy from the fundamental frequency of an interfering signal saturates the receiver front-end (e.g., low-noise amplifier, LNA) resulting in gain compression (reduction in output signal level) of the desired signal sufficient to degrade performance.
- Receiver desensitization occurs when spurious emissions outside of the communication system 3700-4200 MHz band cause degradation to the RA receiver performance.
- If the interference mechanism was receiver front-end overload, such interference wouldn't ordinarily be expected given the frequency separations in the analysis, unless the victim system had little or no RF selectivity. If this was the case, it would be expected that interference issues would have surfaced before with other adjacent-band incumbents. International Telecommunication Union Recommendation ITU-R M.2059 describes the RA front-end as generally having modest selectivity (gradual RF-filter roll-off). It describes a representative RF filter with 24 dB per octave roll-off below 4200 MHz to a maximum of 40 dB of signal attenuation.
- If the interference mechanism was receiver desensitization, then more investigation is necessary as the expected spurious levels from possible future systems would be governed by Part 27 or 96 and it is not clear that levels would ever be as high as those generated in the analysis.

Review of analysis data

- The following slides show some areas in which the analysis data presented was inconsistent or lacked explanation.
- This is included for completeness, knowing that AVSI considers the data very preliminary.

RA 7 data inconsistencies

- The 1000 ft. data (Fig. 8) was not consistent with Fig. 11 except for possibly the first and last points (50 and 480 MHz bandwidth).

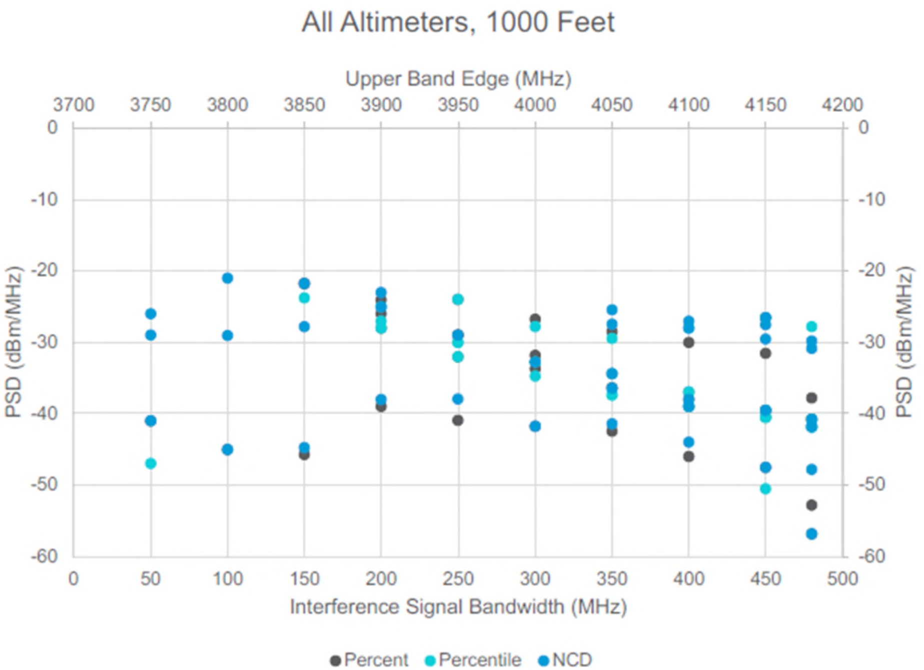


Figure 8: Aggregate Plot of Altimeter Break Points, 1000 Feet.

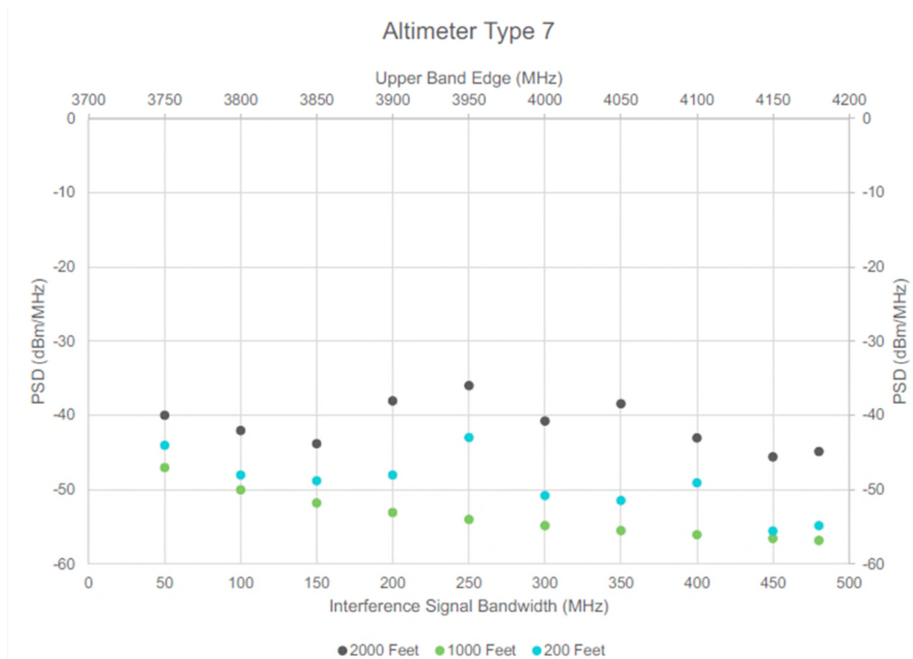


Figure 11: Minimum Break Points of Altimeter Type 7 for Each Altitude Tested.

RA 7 data inconsistencies (continued)

- The 200 ft. (Fig. 7) and 2000 ft. (Fig. 9) data was consistent with Fig. 11. However, the 2000 ft. case showed better performance than the 200 ft. case. It would be expected that the 200 ft. case would perform better due to a higher Signal-to-Noise (S/N). The reduced performance may have been due to in-band RA interference from other aircraft (which applied to only the 200 ft. case). However, this was not seen for RA types 1 through 6.

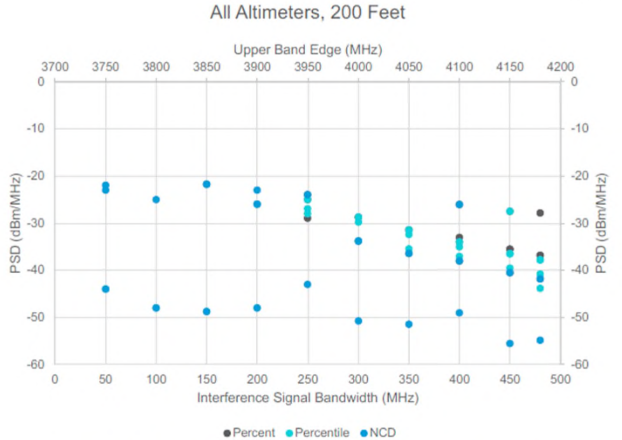


Figure 7: Aggregate Plot of Altimeter Break Points, 200 Feet.

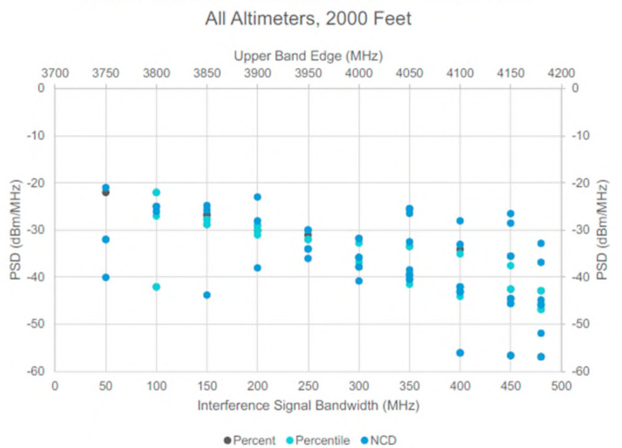


Figure 9: Aggregate Plot of Altimeter Break Points, 2000 Feet.

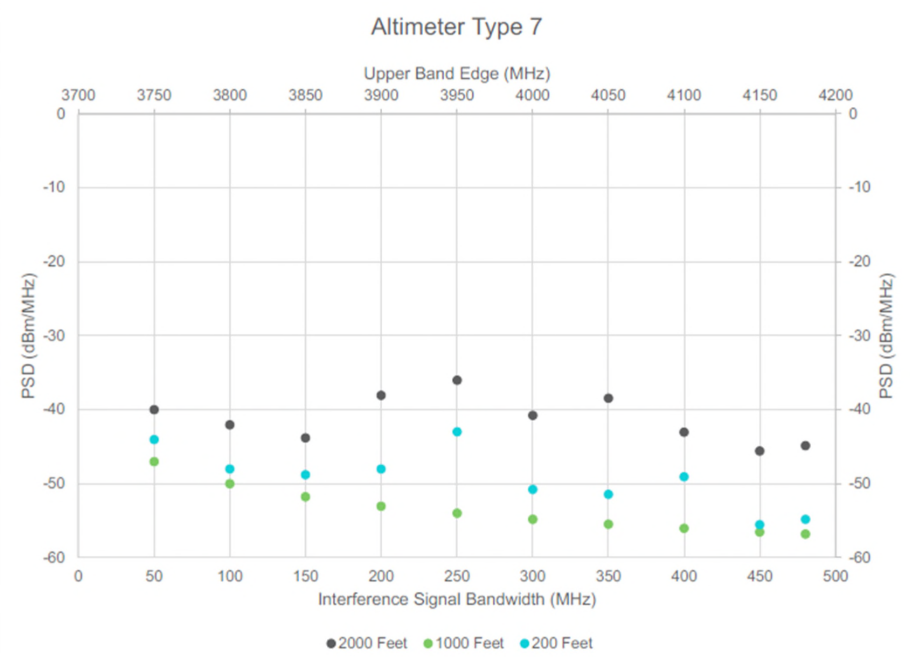


Figure 11: Minimum Break Points of Altimeter Type 7 for Each Altitude Tested.

Undocumented Measurements

- The analysis measurements reflected 7 types of altimeters. Figs. 8 and 9 showed measurements for up to 9 cases. These may have been repeated measurements for specific altimeters, but it was not mentioned in the text.

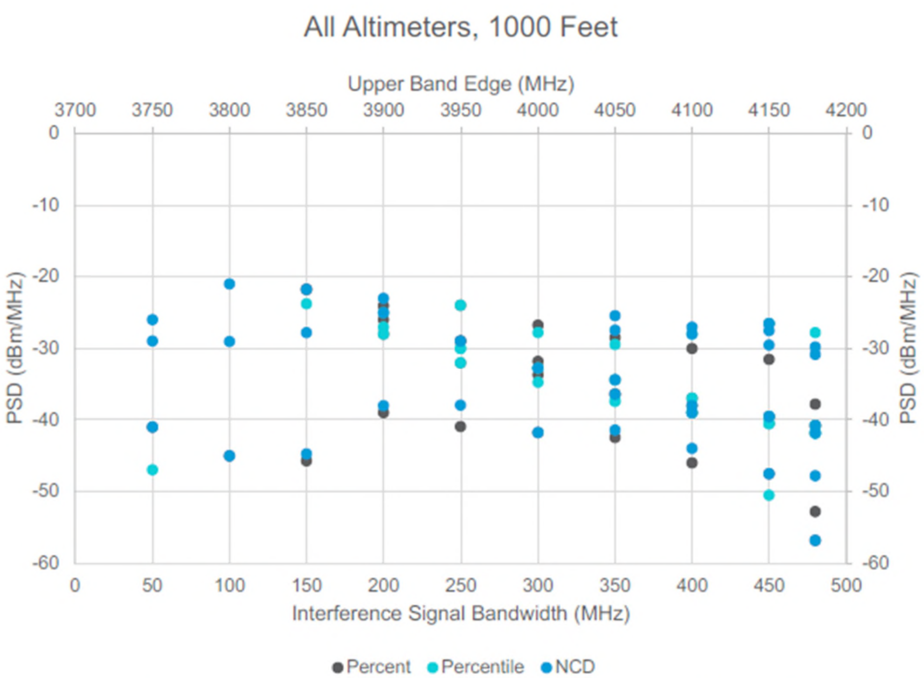


Figure 8: Aggregate Plot of Altimeter Break Points, 1000 Feet.

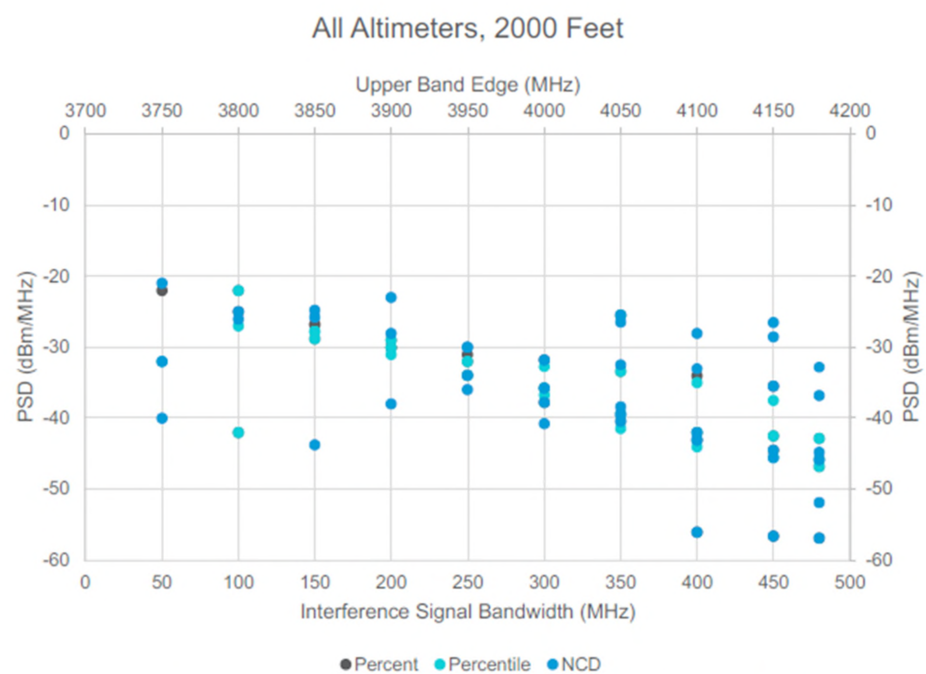


Figure 9: Aggregate Plot of Altimeter Break Points, 2000 Feet.

Summary of Observations

- The operational scenario assumptions require further investigation.
  - Two of the RAs would not operate in the presence of baseline in-band RA interference, which indicates that the available interference margin of the RA under test was consumed by the in-band RAs before any adjacent-band interference was introduced.
  - A high level of RA interference from other aircraft was assumed which may suggest an unlikely proximity of aircraft in the scenario.
  - The reflection coefficient, used to determine the loop loss for the analysis, may have been too restrictive to provide a realistic baseline interference margin.
- The simulated OFDM waveform used to characterize the 3700 – 4200 MHz wireless signals requires further investigation.
  - The spectrum of the waveform appears to exhibit a flattened response approximately 40 dB down from the peak. The OFDM spectrum should roll off more than 40 dB over this frequency range. As a result, the OoBI levels in the analysis would not comply with the emission limits for virtually any services associated with a base station or fixed station governed by FCC rules.

Summary of Observations (continued)

- The application of the analysis results to real-world scenarios should be addressed.
  - The analysis did not consider the operational interactions between aircraft and wireless base stations/user equipment. This should be further investigated with 5G deployment scenarios to determine the likelihood of interference.
  - The level of the modeled emissions from the wireless transmitter at the RA receiver at which interference was predicted to occur was very high. Interfering signals at levels this high would be unlikely unless the communication system was collocated with the victim receiver.
  - It appears that for the testing, increasing levels of interference were applied until performance degradation occurred. Whether these levels were possible in any reasonable scenario was not addressed.
- The interference mechanism in the analysis is unclear and should be further investigated.
  - The primary interference coupling mechanisms between RAs and interfering signals are receiver front-end overload and receiver desensitization.
  - Understanding the interference mechanism would be beneficial in evaluating the analysis assumptions and resolving the anomalies observed in the testing.