November 22, 2019

<u>Via Electronic Filing</u>

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

Re: Expanding Flexible Use of the 3.7 to 4.2 GHz Band (GN Docket No. 18-122)

Dear Ms. Dortch:

We submit for the Commission's consideration an analysis of the compatibility between radio altimeters (RAs) operating in the 4200-4400 MHz band and point-to-multipoint (P2MP) systems operating in adjacent 3700-4200 MHz band spectrum. Combining the results of laboratory measurements from the Aeronautical Vehicle Systems Institute (AVSI)[1] with realistic (but conservative) operating and deployment characteristics of P2MP systems, the analysis concludes that aside from entirely unrealistic scenarios—either a P2MP system is constructed on or at the end of an airport runway, or more than 300 P2MP base stations are constructed within approximately 2 km of a single airport—the interference level into RAs will not exceed even the *minimum* interference power studied by AVSI. Consistent with statements by the aeronautical industry in this proceeding,[2] these new results confirm that fixed systems in the adjacent band pose no significant risk to the operation of radio altimeters.

Please contact the undersigned with any questions.

Respectfully submitted,

/s/ Louis Peraertz

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[1] *See* AVSI: AFE 76s2 Project Members, *Preliminary Report: Behavior of Radio Altimeters Subject to Out-of-Band Interference* (dated Oct 22, 2019) (attachment to Letter from Dr. David Redman, AVSI, to Marlene H. Dortch, Sec'y, FCC, in GN Docket No. 18-122 (filed Oct. 22, 2019)).
[2] *See id.* at 5.

Point-to-Multipoint Operations in the Upper Portion of the 3700-4200 MHz Band Will Have No Effect on Radio Altimeter Operations in the Adjacent Band

November 22, 2019

Summary

The interference analysis submitted by the Aerospace Vehicle Systems Institute (AVSI)[1] has been combined with simulations using realistic characteristics and deployment scenarios for point-to-multipoint (P2MP) systems to study the potential for interference from P2MP into radio altimeters (RAs). A P2MP system would either have to be installed directly on an airport runway, or 300-1,000 P2MP base stations would have to be deployed within about 2 km of an airport, for P2MP systems to produce power levels that meet even the minimum simulated interference power in the AVSI Study.

Because P2MP systems in the C-band would be licensed systems and their operating parameters approved by an automated system prior to commencement of transmissions, their locations with respect to airports can be taken into account, and extreme situations, such as siting a P2MP system close to an airport runway, could be easily avoided.

Therefore, under all reasonable and plausible scenarios, P2MP systems will not interfere with RAs operating in the 4200-4400 MHz band. This is consistent with the AVSI assertion that fixed systems pose little threat to RAs.

1. Introduction

AVSI has submitted an extensive study of the potential impact to airborne RAs that could result from interference from adjacent-band signals in the 3700-4200 MHz band. In that study, AVSI conducted laboratory simulations of signals of various bandwidth and received signal strength in the 3700-4200 MHz band and examined the impact of those signals on the accuracy and availability of altitude determinations produced by seven different models of RA commonly used in commercial and private aviation.

AVSI rightfully points out that “proposed changes to frequency allocations now must be carefully examined to understand the potential impact to RA operation and by extension to the safety of commercial and private aviation operations.”[2] The P2MP community is committed to protecting RA operation in the adjacent 4200-4400 MHz band from interference caused by P2MP systems in any part of 3700-4200 MHz. The P2MP systems will be virtually identical in nature to the fixed systems already in the band (and in the upper adjacent 4400-4940 MHz federal fixed service

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[1] *See* AVSI: AFE 76s2 Project Members, *Preliminary Report: Behavior of Radio Altimeters Subject to Out-of-Band Interference* (dated Oct 22, 2019) (attachment to Letter from Dr. David Redman, AVSI, to Marlene H. Dortch, Sec’y, FCC, in GN Docket No. 18-122 (filed Oct. 22, 2019)) (AVSI Study).

[2] *See id.* at 1.

band), which AVSI acknowledges pose little threat to RAs.[3] That conclusion is supported by the analysis below.

2. Analysis Inputs

2.1 Relevant Characteristics of the Radio Altimeter

AVSI assumes an RA antenna with 10.8 dBi gain and 60 deg beamwidth, and a receive cable loss of 3 dB.[4] For this analysis, the RA antenna pattern is conservatively assumed to have a flat gain equal to the max gain (10.8 dBi) inside the -3 dB beamwidth, in accordance with ITU-R Recommendation M.2059,[5] which also recommends allowing for as much as 45 deg pitch and roll of the plane, causing the bore sight of the main beam to point as much 45 deg from directly below the plane, which we refer to as zenith. Given that the edge of the main beam extends 60/2 = 30 deg from the zenith in level flight, and with 45 deg of pitch or roll, the edge could be as much as 75 deg off the zenith, the main beam is conservatively assumed to have the maximum gain of 10.8 dBi at all angles for the purpose of this analysis.

The summary of RA characteristics is:

- RA antenna gain: 10.8 dBi (all angles)
- RA receive cable loss: 3 dB

As in the AVSI Study, the plane is assumed to be flying at an altitude of 200, 1000, or 2000 ft (61, 305, or 610 m).

2.2 Relevant Characteristics of the P2MP System

The following P2MP system parameters are assumed in this analysis:

- Max EIRP of base station: 50 dBm
- Max EIRP of Customer Premise Equipment (CPE): 47 dBm
- Max antenna gain: 19.9 dBi (from actual antenna pattern)
- Antenna Pattern: A typical 3650-3700 MHz (Part 90) P2MP system antenna pattern, as shown in Figure 1.
- Base station conducted power: 50 dBm - 19.9 dB = 30.1 dBm
- CPE conducted power: 47 dBm - 19.9 dB = 27.1 dBm
- System bandwidth: 20 - 100 MHz[6]
- Base station antenna height: 50 m
- CPE antenna height: 5 m

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[3] *See id.* at 5.
[4] *See id.* at 7.
[5] *See* Int'l Telecomm. Union, *Operational and Technical Characteristics and Protection Criteria of Radio Altimeters Utilizing the Band 4200-4400 MHz*, ITU-R Recommendation M.2059-0 at Annex 2 (Feb. 2014), *available at* https://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.2059-0-201402-I!!PDF-E.pdf.
[6] *See* discussion in Section 4. The bandwidth does not directly enter into the calculation.

- Distance between base station and CPE: 2 km (2000 m)
- Base station antenna downtilt: arctan[(50 m - 5 m)/2000 m] =1.3 deg
- CPE antenna uptilt = base station antenna downtilt = 1.3 deg

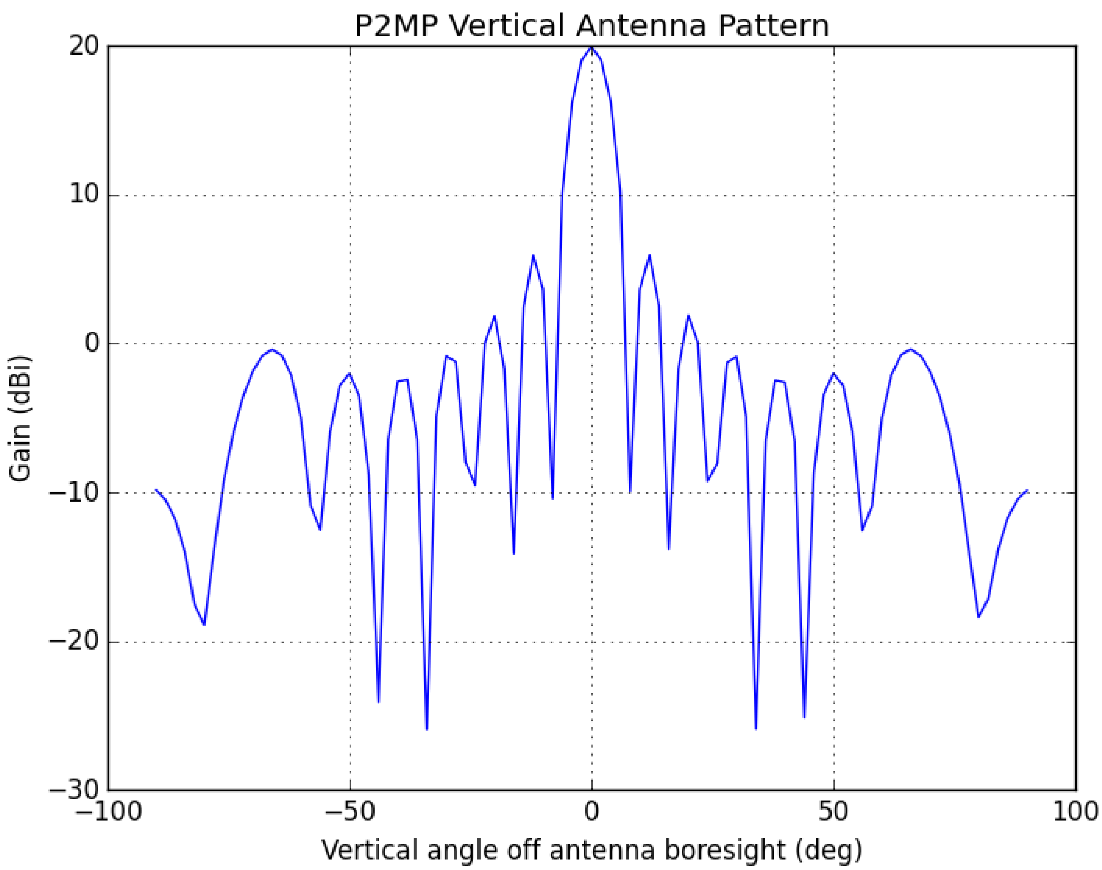

Figure 1: Gain pattern of the P2MP antenna (base and CPE).This is the gain pattern of a 3650-3700 MHz (Part 90) P2MP antenna.

2.3 Geometry

A plane is assumed to fly directly over both a P2MP base station and an associated CPE. The geometry is shown in Figure 2. It is conservatively assumed that the plane flies directly along an azimuth corresponding to the direction to which the base and CPE antennas are pointed. For this reason, the vertical pattern of the base and CPE antenna is used without adding any additional discrimination from the horizontal pattern of the antenna. If, for example, the plane flies over the base or CPE along an azimuth that is offset from the pointing direction of the antennas, or if the plane flies near but not directly over a base station or CPE, an additional attenuation factor would apply, because the plane is generally not flying along the direction toward which the antennas are pointed. Such a factor was not applied for the purpose of this analysis, but would further reduce predicted interference if it were.

2.4 Propagation Model

Free space loss is assumed.

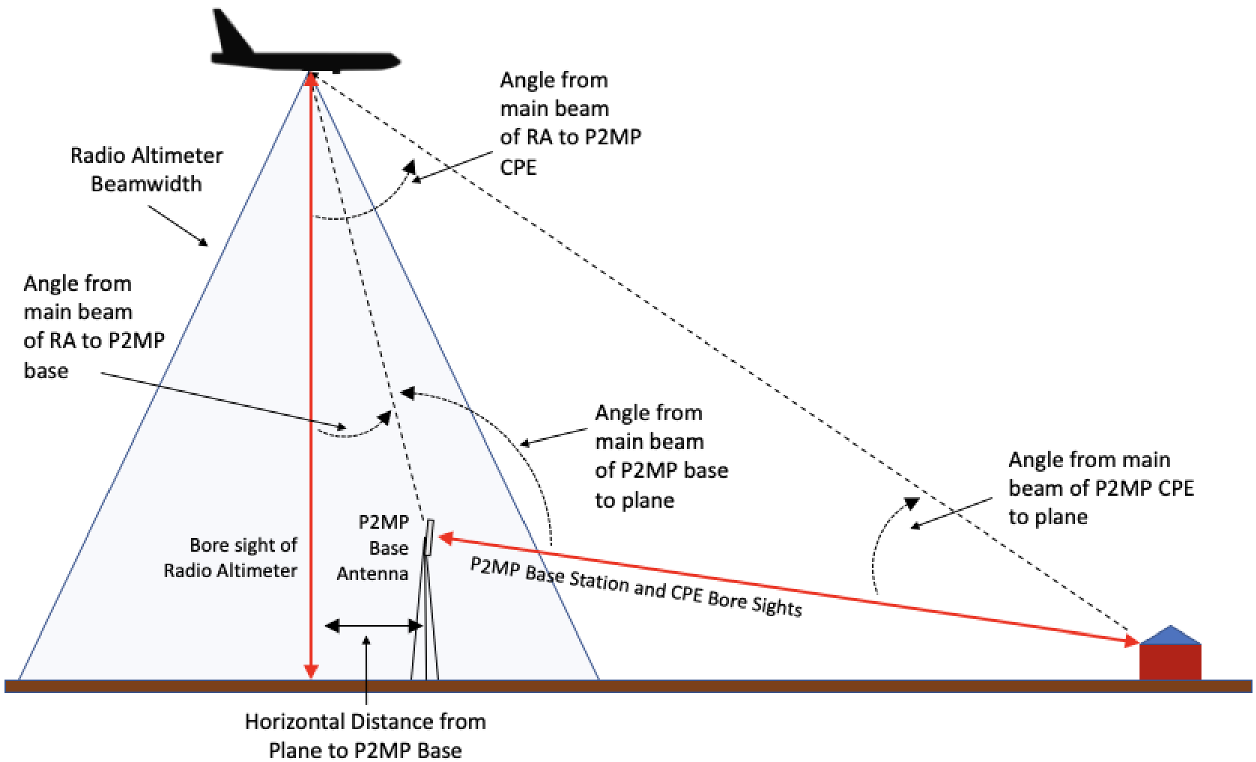

Figure 2: Geometry of plane flying directly over a P2MP base station and CPE.

3. Analysis Results

The total out-of-band power received by the RA as the plane flies directly over the base station and CPE, for plane heights of 200, 1000, or 2000 ft (61, 305, or 610 m), was computed. Before giving the complete results, the result of a single component of the analysis, in this case, the received power from the base station only for a plane at 2000 ft (610 m), is shown below for the purpose of explaining the qualitative features of the results. To simplify the description, no downtilt is applied to the P2MP antenna for this example.

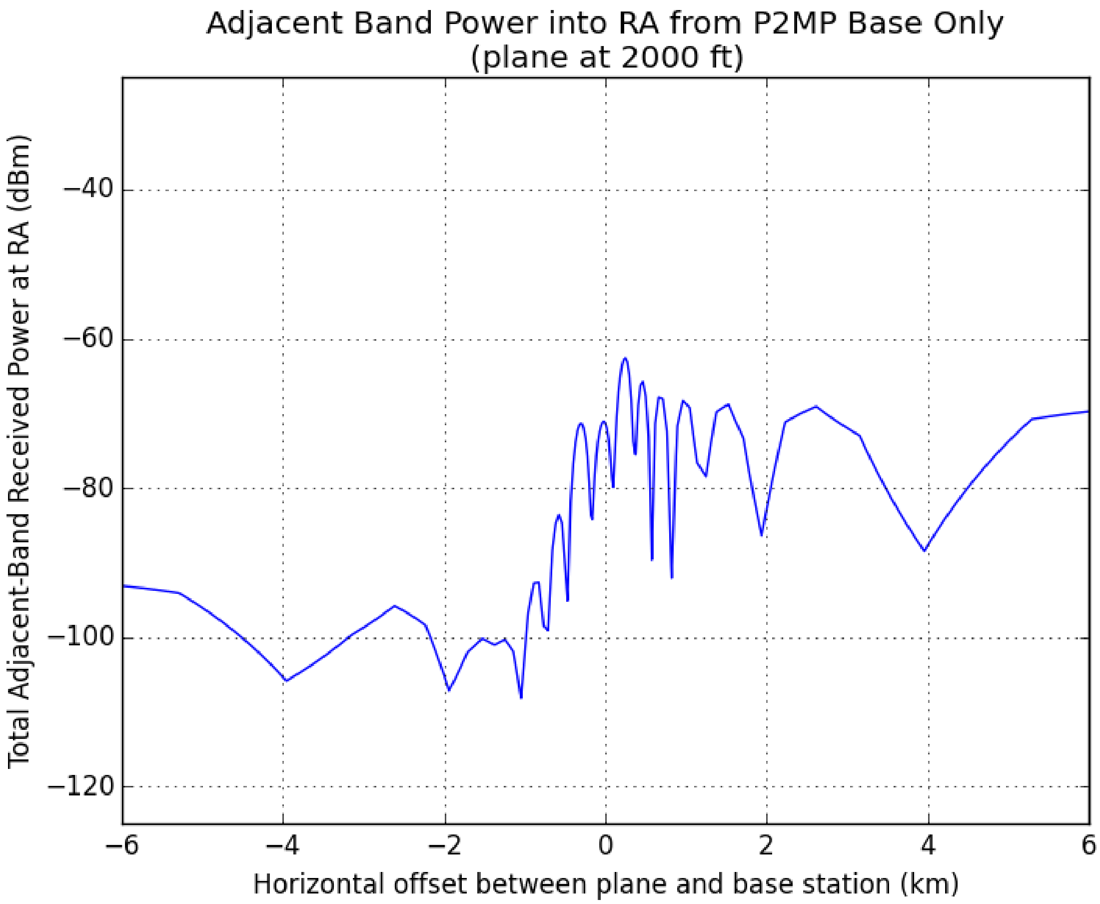

Figure 3: Adjacent band power into an RA from the P2MP base station, for a plane at 2000 ft (610 m). The base station is located at x = 0, and its antenna is pointed toward positive x.

The qualitative structure of the results in Figure 3 is explained here:

- At large negative horizontal offset, the plane is approaching the tower from behind the antenna. At large range, the relative vertical angular offset of the RA and P2MP antennas is changing only very slowly as the plane approaches, so the relative total gain caused by the base station antenna pattern also changes relatively slowly.
- As the plane gets closer to directly over the P2MP system (x=0), the relative angles change increasingly rapidly, and the received power shows rapid oscillations as the plane rapidly passes in and out of the vertical pattern sidelobes of the P2MP base antenna.
- At an offset of 0 km, the plane is directly overhead of the P2MP base station.
- At positive offsets, the plane is now in the general direction at which the P2MP base station is pointing (although it is still in the vertical sidelobes of the base station beam),

so the received power is typically higher for positive offsets compared to negative offsets.

- As the plane reaches greater positive offsets, it is coming closer to the main beam of the base antenna, but in reality it never reaches the main beam. The plane only approaches the main beam of the base station at very large distances (hundreds of km), but propagation loss overcomes any antenna gains at that distance. For example, Figure 4 shows the simulation run out to a distance of over 300 km.

Note that throughout this simulation, it is assumed that the plane is flying at a constant altitude directly along the principal vertical plane of the antenna pattern, so only the vertical pattern is applied; no additional loss to account for the horizontal pattern of the antenna is considered.

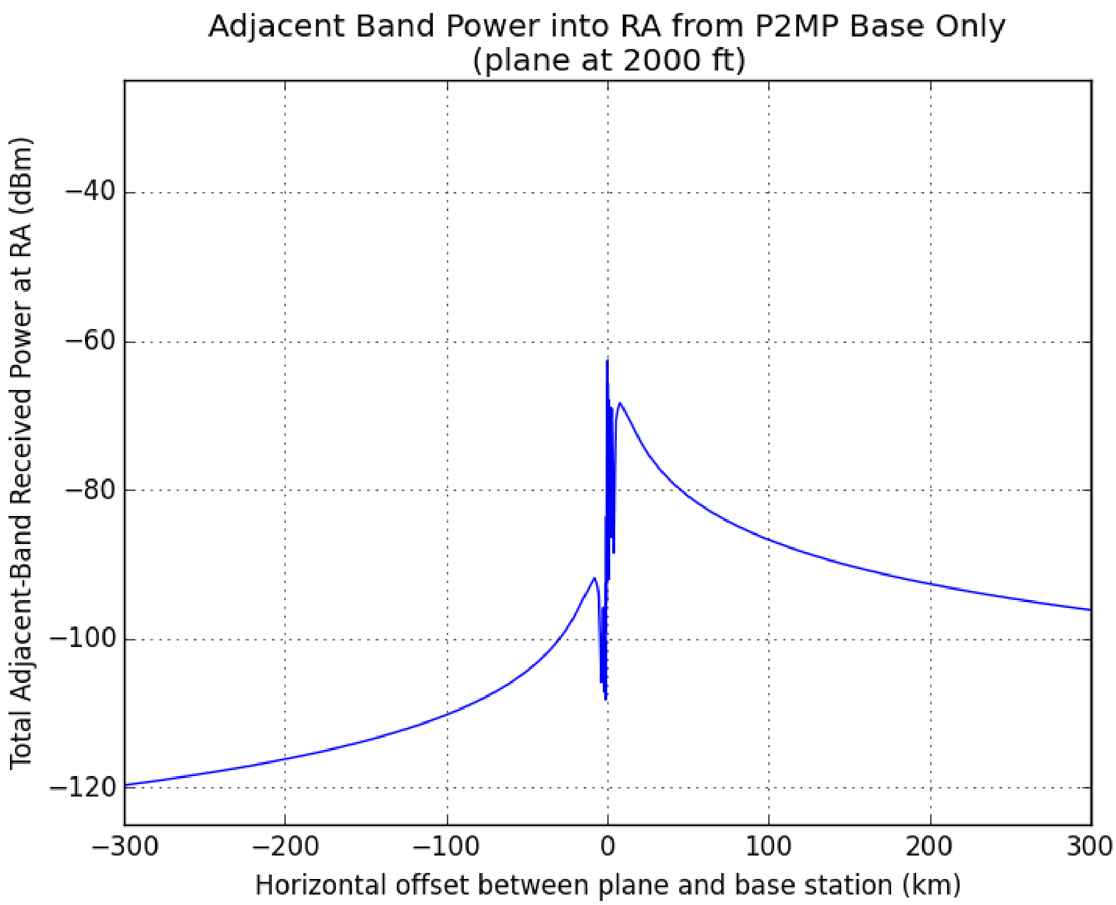

Figure 4: Same simulation as Figure 3, displayed to a larger distance.
At large distances the smooth decline in signal strength is due to 1/R^2 free space loss.

A “sanity check” on the results in Figure 3 can be made by calculating the expected signal strength when the plane is directly overhead of the P2MP base station:

- The distance between the base antenna and the plane is the difference between the 50 m height of the antenna and the 2000 ft (610 m) elevation of the plane. The difference is 560 m.
- The free space loss over 560 m at 3950 MHz (the mid-point of C-band) is 99.3 dB.
- The conducted power of the base station is 30.1 dBm (Section 2.2).
- The gain of the P2MP antenna in a direction of 90 deg (straight up) is approximately -9.9 dBi, based on Figure 1.
- The EIRP of the base station towards overhead is 30.1 dBm - 9.9 dB = 20.2 dBm.
- The gain of the RA antenna is 10.8 dBi.
- The RA system has a 3 dB receive cable loss.
- Combining all of the factors, the approximate expected received signal strength at $x = 0$ is: 20.2 dBm EIRP - 99.3 dB free space loss + 10.8 dBi RA antenna gain - 3 dB RA cable loss = -71.3 dBm, which is consistent with Figure 3 as evaluated at x=0.

For comparison, the interference contribution received by the RA from the CPE device (only) is shown in Figure 5:

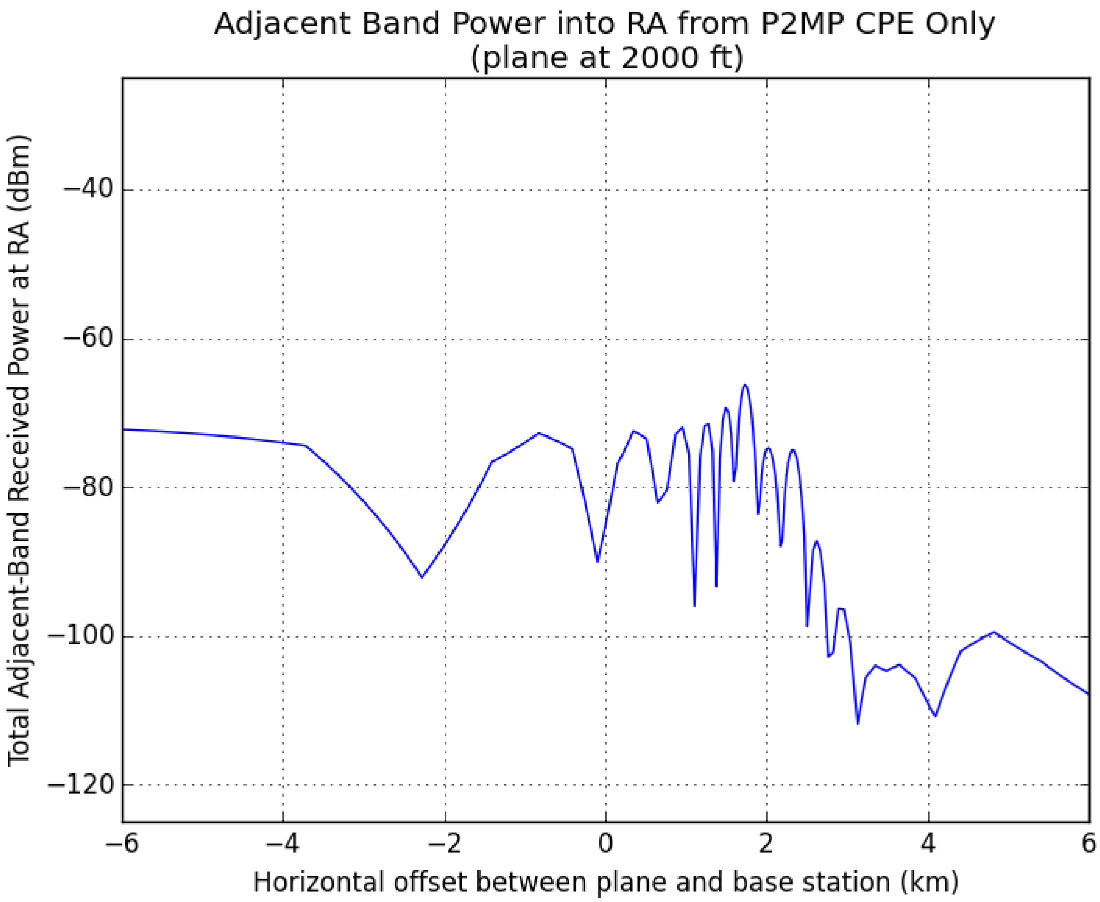

Figure 5: Adjacent band power into an RA from the P2MP CPE only, for a plane at 2000 ft (610 m). The CPE is located at x = +2 km, and its antenna is pointed back toward the base station located at x = 0.

The analysis is completed by adding in the contributions of both the base and CPE and adding the 1.8 deg base antenna downtilt and the corresponding 1.8 deg CPE antenna uptilt.

The results are in Figure 6 for a plane at constant elevations of 200 ft (61 m), 1000 ft (305 m), and 2000 ft (610 m):

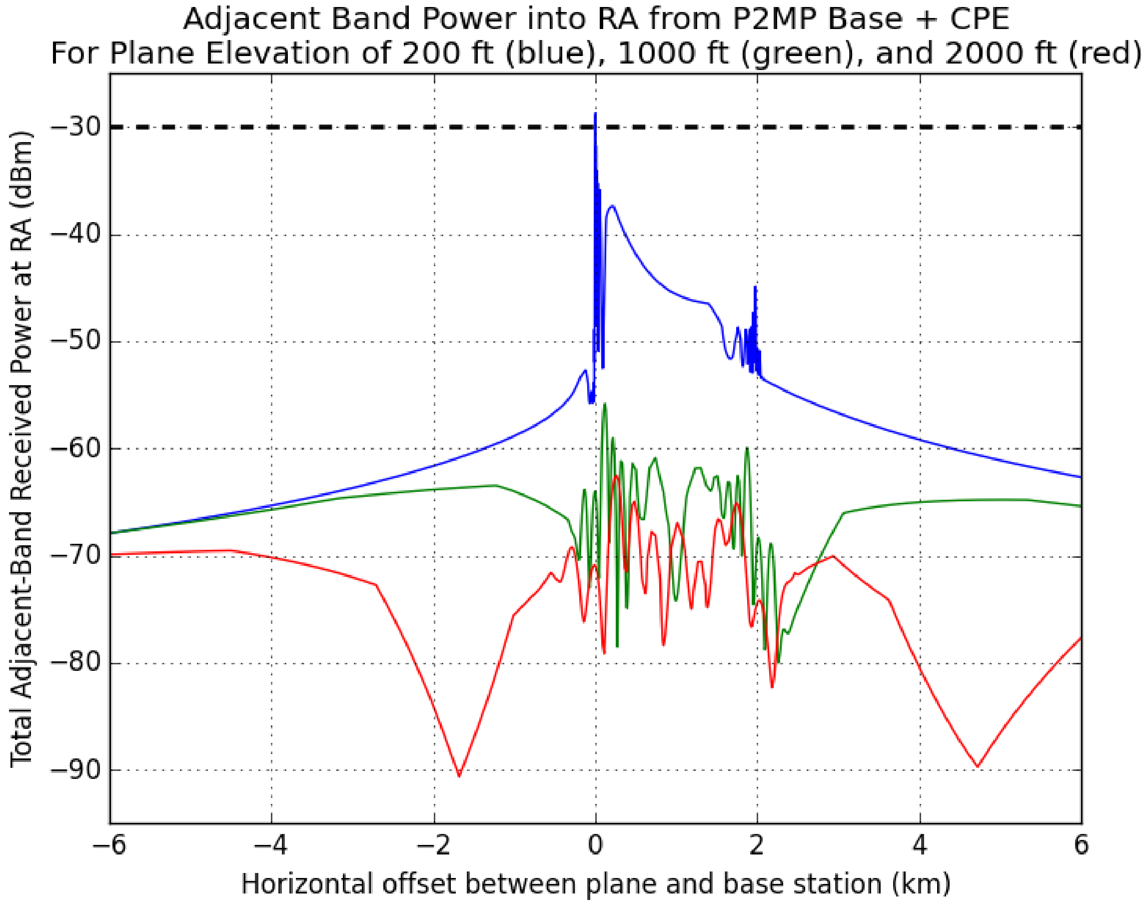

Figure 6: Total adjacent band power into an RA flying directly over a P2MP base station (*x*=0 km) with a downtilt of 1.8 deg pointed toward an associated CPE (*x*=2 km) with an uptilt of 1.8 deg pointed back to the base station, for a plane at elevations of 200 ft / 61 m (blue), 1000 ft / 305 m (green), and 2000 ft / 610 m (red). The dashed line at -30 dBm is the *minimum* interference power simulated in the AVSI Study.

While the results shown are for planes at constant elevation, the impact of a plane ascending or descending while passing over the base station and CPE will fall generally somewhere between the curves. For example, a plane approaching from the left at -6 km starting at 2000 ft (610 m) and descending to 1000 ft (305 m) by $x = +6$ will have received interference characteristics starting off with the 2000 ft (610 m) curve at $x = -6$ and becoming the 1000 ft (305 m) curve at $x = +6$, and generally in between the two at other values of x. In no case will it have interference power that exceeds the envelope of either curve.

4. Discussion

In the AVSI Study, the *minimum* total interference power studied was -30 dBm. In the simulations described here, only one scenario resulted in a received interference power that exceeded (by 1.2 dB) even the minimum power in the AVSI Study, and that was the case of a plane flying at an elevation of 200 ft (61 m). This scenario is unrealistic in the context of

interference from P2MP systems, because a plane at an elevation of 200 ft (61 m) will almost certainly be on final approach, and, as mentioned by the AVSI Study, such a plane is likely located on the threshold of the runway. Simply put, there is no plausible scenario in which a P2MP tower will be placed directly at the end of (or even on) a runway and, in fact, FAA rules would likely prevent such an occurrence. When designing P2MP systems, it is easy to avoid placing them on the short final approach paths of airports.

In the other scenarios (i.e., the plane at 1000 ft (305 m) and 2000 ft (610 m) elevation), the results here show that predicted maximum interference is some 25 - 30 dB below the *minimum* interference power simulated in the AVSI Study.

While a plane could be exposed to multiple P2MP base stations and CPE, most of the impact is from the base station, and most of that impact is only within about 2 km of the tower. Given the 25-30 dB margin before the received power even gets to the minimum power used in the AVSI Study, there would need to be roughly 300-1000 P2MP base stations within about 2 km of one another for the aggregate interference to exceed even the *minimum* power studied by AVSI. This is extremely unlikely to occur, especially in rural areas where P2MP systems are likely to be deployed.

And despite this discussion comparing the predicted interference power to the *minimum* studied received power in the AVSI Study, there's no conclusion in that report that adverse effects even occur at the minimum studied power. For example, in Figure 6 of the AVSI Study, in their "typical statistical plot,"[7] significant disruption of RA operation does not occur until the interference power exceeds approximately -6 dBm, which is tens of dB higher still than any of our predicted levels of P2MP interference.

In Section 4 of the AVSI Study, they present plots showing the PSD at which adjacent band signals of increasingly wide bandwidth impact all seven models of tested RAs, as the upper edge of the interference gets closer to 4200 MHz (the lower edge is fixed at 3700 MHz), assuming constant power spectral density. It's difficult to compare those results with the simulations here, because those results have two factors occurring simultaneously: the total signal power is increasing due to increasing signal bandwidth, and the upper edge of the signal is simultaneously coming closer to the 4200 MHz band edge. It is not possible to determine which factor is more important with regard to the demonstrated interference. A more realistic scenario would be to use various signal bandwidths (for example, 20, 40, and 100 MHz), and vary the center frequency while keeping their total power constant. Regardless, given the interference margin demonstrated here, it is unlikely that a P2MP signal of any power spectral density, no matter how close to 4200 MHz, would cause any disruption to RA operations.

Finally, even though the demonstrated interference margins are very high, the conservative assumptions used in this analysis are reiterated:

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[7] *See* AVSI Study at 13.

- The RA antenna gain toward the P2MP system is assumed to be maximum at all times. In reality, the P2MP system will often be outside the main beam of the RA. For example, assuming an RA beamwidth of 60 deg, a P2MP transmitter will be outside of the main beam of the RA when the plane's horizontal distance is more than approximately 0.2 or 0.4 km away from the transmitter for the plane at an elevation of 1000 or 2000 ft (305 or 610 m), respectively, assuming the plane is level. Beyond these distances, the RA antenna gain can be significantly less than the main beam gain of 10.8 dBi. This effect was not taken into account.

- The plane is assumed to fly directly over the P2MP base station and an associated CPE. In most cases, a plane will not fly directly over a base station or CPE, and additional P2MP antenna discrimination will apply. Additional propagation loss will also apply in this case.

- The base station and CPE are both assumed to be operating with 100% duty cycle. This cannot be the case for TDD systems, but is assumed for the purpose of this conservative analysis.

- No mitigation techniques have been considered. For example, a conducting shield could be placed directly above a P2MP antenna to reduce the sidelobe levels in the upward direction.

- The predicted interference levels are referenced to the -30 dBm *minimum* level analyzed by AVSI. Their results with respect to total adjacent band power do not indicate any negative impact until the adjacent band power exceeds about -5 dBm. If this is used as the criterion, an additional 25 dB or margin should be added to the results here. In that case, even if the plane is at 200 ft (61 m) altitude, no harmful interference will be received by the RA.

5. Out-of-Band Emissions from P2MP into RA Band

Although not addressed in the AVSI Study, for completeness the predicted impact of out-of-band emissions from P2MP systems in the 3700-4200 MHz into the 4200-4400 MHz RA band are considered. The same out-of-band emissions limits are presumed to apply to C-band P2MP systems that currently apply to Citizens Broadband Radio Service (CBRS) operations.[8] Assuming a 20 MHz guard band, the out-of-band emissions into RAs would not exceed -40 dBm/MHz.

The thermal noise limit of the RA devices depends on their noise figure: N = -111 dBm/MHz for a 3 dB noise figure, and N = -109 dBm/MHz for a 5 dB noise figure. Assuming a reasonable interference criterion for the RAs of -6 dB I/N, the resulting interference limits would be I = -117 dBm/MHz and I = -115 dBm/MHz, respectively.

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[8] *See* 47 C.F.R. §96.41(e)(2).

Figure 7 shows a simulation similar to that conducted in Section 3, but applied to the out-of-band interference power spectral density. The figure shows the interference objectives for the two noise figure scenarios as well.

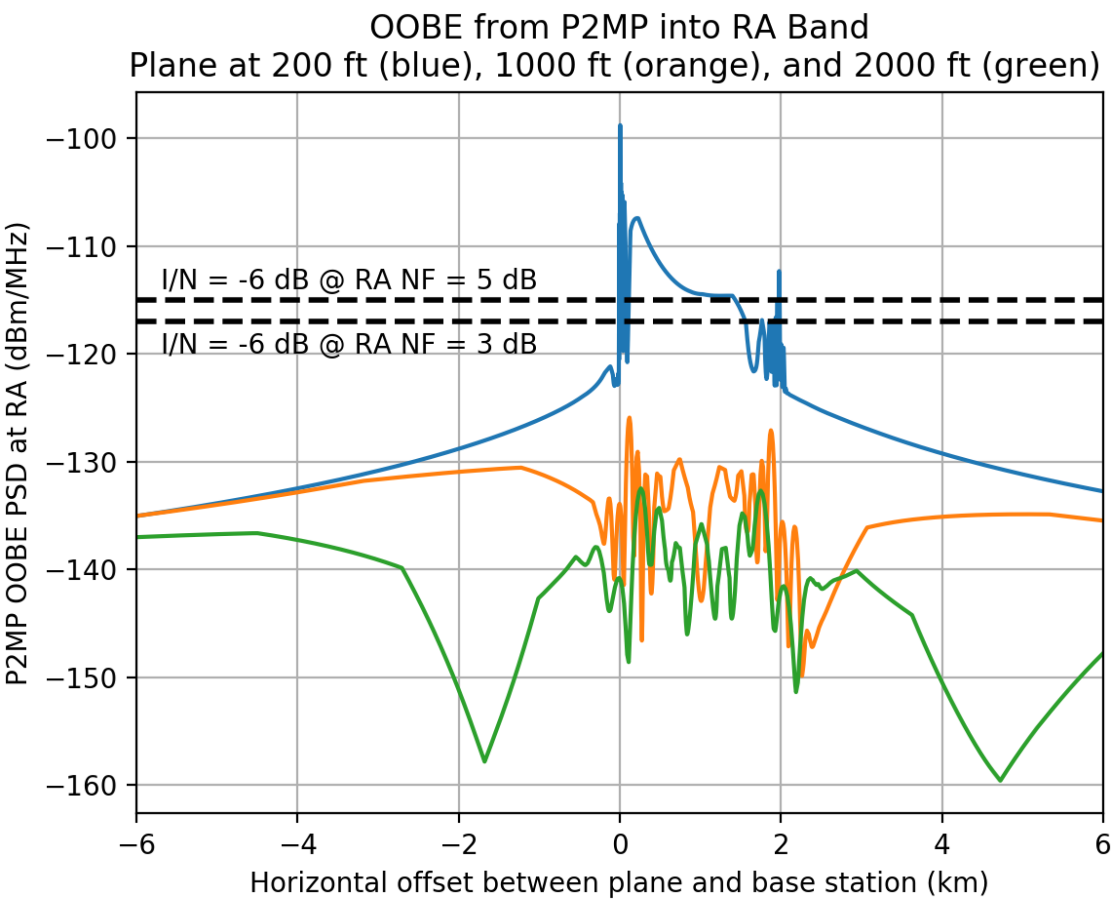

Figure 7: Total out-of-band power spectral density from P2MP system into the 4200-4400 MHz band for a plane at 200, 1000, or 2000 ft (61, 305, or 610 m) altitude. The interference objectives for a criterion of I/N = -6 dB for an RA receiver with a noise figure of 3 and 5 dB are shown.

As evident from Figure 7, and consistent with the analysis of adjacent-band interference in section 4, the only concern would be a P2MP system located at the threshold of (or even on) an airport runway. Realistic scenarios involving a plane not at elevations typically encountered only in an airport environment show that out-of-band emissions will not be a factor. Note that the same conservative assumptions listed at the end of section 4 apply.

6. Conclusion

The interference analysis submitted by AVSI has been combined with simulations using realistic characteristics and deployment scenarios for P2MP systems to study the potential for

interference from P2MP into RAs. A P2MP system would either have to be installed directly on an airport runway, or 300-1,000 P2MP base stations would have to be deployed within about 2 km of an airport, for P2MP systems to produce power levels that meet even the minimum simulated interference power in the AVSI Study.

Because P2MP systems in the C-band would be licensed systems and their operating parameters approved by an automated system prior to commencement of transmissions, their locations with respect to airports can be taken into account, and extreme situations, such as siting a P2MP system close to an airport runway, could be easily avoided.

Therefore, under all reasonable and plausible scenarios, P2MP systems will not interfere with RAs operating in the 4200-4400 MHz band. This is consistent with the AVSI assertion that fixed systems pose little threat to RAs.