May 10, 2019

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VIA ECFS

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

Re: *Aeronet Global Communications Inc.'s Petition for Rulemaking to Amend the Commission's Allocation and Service Rules for the 71-76 GHz, 81-86 GHz, and 92-95 GHz Bands to Authorize Aviation Scheduled Dynamic Datalinks*, RM-11824

Aeronet Global Communications Inc.'s Petition for Rulemaking to Amend the Commission's Allocation and Service Rules for the 71-76 GHz, 81-86 GHz, and 92-95 GHz Bands to Authorize Maritime Scheduled Dynamic Datalinks, RM-11825

Dear Ms. Dortch:

Aeronet Global Communications Inc. submits this letter and the attached study by Comsearch (the "*Comsearch Study*") in support of its petitions for rulemaking.[1] These petitions seek minor amendments to the allocation and service rules for the 71-76 GHz, 81-86 GHz, and 92-95 GHz spectrum bands (collectively, the "E Band") to authorize use of this spectrum to provide Gigabit-per-second broadband to aircraft in flight and ships at sea. Aeronet's innovative datalink technology—scheduled dynamic datalinks ("SDDLs")—would deliver myriad public interest benefits for consumers, carriers, and others. And by acting quickly on these petitions, the Commission can achieve first-mover advantages, locking in U.S. technological leadership in these growing broadband markets.

While several commenters offered support for Aeronet's petitions,[2] a few expressed concerns about possible interference from Aeronet's operations.[3] As Aeronet explained, any interference concerns are fully addressed by the existing E-Band rules. Those rules require a nationwide licensee to register individual links with independent database managers before

[1] *See* Petition for Rulemaking of Aeronet Global Communications Inc., RM-11824 (Feb. 6, 2019); Petition for Rulemaking of Aeronet Global Communications Inc., RM-11825 (Feb. 6, 2019).

[2] *See* Comments of Loon LLC, RM-11824 & RM-11825 (Mar. 11, 2019); Comments of WorldVu Satellites Limited, RM-11824 & RM-11825 (Mar. 11, 2019).

[3] Reply Comments of Moog, RM-11824 & RM-11825 (Mar. 26, 2019); Opposition of T-Mobile USA, Inc., RM-11824 & RM-11825 (Mar. 11, 2019); Consolidated Comments of Elefante Group, Inc. on the Aeronet Petitions, RM-11824 & RM-11825 (Mar. 11, 2019).

commencing service; interference is then addressed on a link-by-link basis through coordination.[4] Like everyone else, Aeronet can and will follow these rules and procedures.

To demonstrate the adequacy of the current E-Band framework to address any interference concerns arising from Aeronet's operations, Aeronet asked Comsearch, an industry-leading spectrum coordinator with decades of experience and one of three FCC-designated E-Band Database Managers,[5] to evaluate how it would handle Aeronet's planned operations under existing procedures to prevent interference.[6] Comsearch "explore[d] the interference potential between Aeronet's systems and the incumbent fixed link service and whether the Aeronet systems are compatible with the existing link registration database" and concluded that all of Aeronet's SDDL configurations can be coordinated through a combination of existing systems and processes, "straightforward" new functionalities, and operational limitations which Aeronet is willing to accept.[7]

As a threshold matter, Comsearch agrees that numerous features of Aeronet's planned operations and the E Band "enhance compatibility between the Aeronet systems and" other users and uses in the E Band.[8] These features include Aeronet's "use of high gain and highly directional antennas"; its use of "automatic power control"; "absorption losses due to gases in the lower atmosphere"; the geometry of the system, which leads to "rain fading correlation of desired and interference signals"; and the narrow-beam nature of transmissions in the E Band, which prevents interference except where there is "geographic proximity" *and* "azimuth and elevation" alignment.[9] Comsearch also agrees that several SDDL configurations (ground-to-air links, shore-to-ship links, and shore-to-aerostat links) can be "recorded and analyzed using the existing link registration systems."[10] Comsearch likewise concludes that other configurations of SDDLs (air-to-air links, ship-to-ship links, and aerostat-to-ship links) need not be registered if Aeronet adopts

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[4] 47 C.F.R. § 101.1523; *In re Spectrum Horizons Battelle Memorial Institute Petition for Rulemaking To Adopt Fixed Service Rules in the 102-109.5 GHZ Band*, Notice of Proposed Rulemaking and Order, 33 FCC Rcd 2438, 2452 ¶ 29 (2018).

[5] *See Wireless Telecommunications Bureau Broadband Division Announces Second Renewal of Database Managers for Management of the 71-76 GHz, 81-86 GHz, and 92-95 GHz Bands*, Public Notice, 29 FCC Rcd 14773 (2014); *In re Allocations and Service Rules for the 71-76 GHz, 81-86 GHz, and 92-95 GHz Bands*, Order, 19 FCC Rcd 20524, 20527 ¶ 8 (WTB 2004) (describing Comsearch and two other designated databases as "uniquely qualified" given their "years of experience in database design, frequency coordination and spectrum management").

[6] *See* Att. A, Comsearch, *Aeronet Aviation and Maritime Communications Systems* (May 2, 2019) ("*Comsearch Study*").

[7] *Id.* at 3-5, 42-44.

[8] *Id.* at 3.

[9] *Id.* at 3; *see also id.* at 21.

[10] *Id.* at 4. While Comsearch describes that it may depict Aeronet's systems as "[w]ide-beam antennas . . . in the link database to cover the variable narrow-beam transmission directions," *id.* at 4, it is important to reemphasize that Aeronet will not actually be using wide-beam antennas in its systems.

operational limitations to mitigate exposure to other users.[11] And Comsearch concludes that while some configurations (air-to-ground and ship-to-shore links) will require coordination in some cases,[12] and while such coordination will require new database functionalities, implementing these functionalities will be "straightforward."[13]

With respect to Aeronet's planned aviation SDDLs, Comsearch concludes as follows:

- Ground stations will need to be registered in coordination databases, which will need to make minor adjustments to existing processes and calculations to account for potential interference from ground stations to fixed service links and from aircraft transmitting to ground stations.[14]
- Aeronet's "use of a minimum elevation angle of 5 degrees" for its ground-to-air links "mitigates much of the[] interference potential since fixed link antenna elevation angles are concentrated near zero."[15]
- Air to ground SDDLs can be handled through a new proximity trigger, and interference even within the trigger zones around ground stations can be avoided in "nearly all cases" due to azimuth or elevation angle offsets; the "few remaining cases" could be evaluated using a new coordination calculation.[16]
- Aeronet could adopt operational limitations for its aircraft-to-aircraft SDDLs, under which, there would be a "manageable number" of fixed service users that would be at risk of interference, and subject to coordination to be resolved.[17]

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[11] *Id.* at 5.

[12] *See id.* at 4 ("Off-axis antenna discrimination in azimuth or elevation would resolve *nearly all* exposures." (emphasis added)).

[13] *Id.*; *see also id.* at 44 ("The needed new data, analysis, and coordination functions involve recording coordination zones, implementing proximity triggers, applying antenna beam offsets, and calculating worst-case levels. Minor changes to the data rules of the existing link database would also be needed . . . . Comsearch anticipates that implementing this functionality would be straightforward . . . ."). Comsearch recommends that Aeronet "foster protection and growth of the incumbent fixed service by developing and providing [functionality] enhancements with transparency." *Id.* at 42. Aeronet has already signaled its commitments in this regard, and stated its willingness to work with the Commission and others to develop procedures and mechanisms to facilitate spectrum sharing in the E-Band. Reply to Comments and Opposition of Aeronet Global Communications Inc., at 11-12, RM-11824 & RM-11825 (Mar. 26, 2019).

[14] *Comsearch Study* at 42.

[15] *Id.* at 3-4.

[16] *Id.* at 42. As discussed above, Comsearch predicts that the development of the proximity trigger and new calculation would be straightforward.

[17] *Id.* at 42-43.

With respect to Aeronet's planned maritime SDDLs, Comsearch concludes as follows:

- Shore stations and aerostats will need to be registered in databases, and links between them can be analyzed using existing link registration processes.[18]

- Ship operation areas likewise would need to be registered, and potential interference from shore-to-ship SDDLs could be addressed using existing interference calculations.[19]

- Ship-to-shore SDDLs would require analysis under a proximity trigger, based on the location of existing links inland from shore stations. Within trigger zones, issues could be resolved in "nearly all cases" due to azimuth or elevation angle offsets; the "few remaining cases would need to be evaluated using a new calculation."[20]

- Ship-to-aerostat SDDLs "would not be harmful"; Aeronet could avoid even potential interference from aerostat-to-ship and ship-to-ship SDDLs through operational limits.[21]

Aeronet is committed to ensuring that its operations are consistent with existing and future innovative uses and users of the E Band. For this reason, Aeronet will continue to work constructively and transparently with Comsearch and other FCC-designated Database Managers to ensure they have the materials, information, and support needed to develop the new straightforward functionalities that may be necessary to coordinate Aeronet's SDDL configurations. Moreover, Aeronet is willing to accept Comsearch's proposed operational limitations as formal conditions by the Commission when it grants Aeronet's petitions.

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[18] *Id.* at 43.

[19] *Id.*

[20] *Id.* As noted, Comsearch predicts that the development of these functionalities would be straightforward.

[21] *Id.* at 43-44.

In light of the foregoing, the Commission should quickly grant the instant petitions.

Respectfully submitted,

/s/ Samuel L. Feder

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Attachment

ATTACHMENT A:

Comsearch, *Aeronet Aviation and Maritime Communications Systems* (May 2, 2019)

Aeronet Aviation and Maritime Communications Systems

COMPATIBILITY WITH INCUMBENT E-BAND FIXED

SERVICES AND LINK REGISTRATION SYSTEM

Table of Contents

Executive Summary

Aeronet proposes systems of Aviation and Maritime Scheduled Dynamic Datalinks in the E-band (71-76 GHz and 81-86 GHz). For Aviation, these links would be between ground stations and aircraft and between aircraft. For Maritime, these links would be between shore stations and ships, between shore stations and aerostats[1], between aerostats and ships, and between ships. The incumbent E-band service is fixed terrestrial point-to-point links that are authorized under non-exclusive nationwide licenses and recorded in a link registration database. This paper explores the interference potential between Aeronet's systems and the incumbent fixed link service and whether the Aeronet systems are compatible with the existing link registration database.

Factors that enhance compatibility between the Aeronet systems and fixed links are: use of high gain and highly directional antennas by Aeronet and the fixed service, Aeronet use of automatic power control, absorption losses due to gases in the lower atmosphere, and rain fading correlation of desired and interference signals. The paper investigates levels that could result from possible boresight-to-boresight antenna exposures and how to manage such exposures. Boresight exposure requires geographic proximity as well as alignment in azimuth and elevation.

Aeronet's proposal to use a minimum elevation angle of 5 degrees for ground-to-aircraft links mitigates much of their interference potential since fixed link antenna elevation angles are concentrated near zero. Fixed link antenna altitudes (AMSL) are concentrated near sea level

[1] An aerostat is a tethered airship at a fixed location above international waters functioning as a repeater station.

where absorption loss is significant. However, lower absorption losses at high altitude fixed stations and for paths to up-tilted antennas must be considered.

Aeronet's fixed ground stations transmitting to aircraft, shore stations transmitting to ships, and links between shore stations and aerostats may be recorded and analyzed using the existing link registration system. Wide-beam antennas would be used in the link database to cover the variable narrow-beam transmission directions of ground stations transmitting to aircraft and shore stations transmitting to ships. These wide-beam antennas would be directed away from fixed service stations -- upwards for ground stations and seaward for shore stations.

The analysis shows Aeronet's aircraft transmitting to ground stations and ships transmitting to shore stations can potentially produce levels into fixed service receivers high enough that the exposures must be managed. Off-axis antenna discrimination in azimuth or elevation would resolve nearly all exposures, but a coordination area is needed for fixed service links near Aeronet's ground and shore stations. Since it will not be practical to represent these transmitters in the existing link registration database, new data, analysis, and coordination capabilities separate from, but comparable to, the existing system will be required. Aeronet should foster protection and growth of the incumbent fixed service by developing and providing these enhancements with transparency. The needed new data, analysis, and coordination functions involve recording coordination zones, implementing proximity triggers, applying antenna beam offset checks, and calculating worst-case levels. Comsearch anticipates that implementing this functionality would be straightforward; however, detailed requirements – beyond the scope of this paper – would be needed to quantify the effort.

Finally, the analysis shows that other aspects of the Aeronet systems – links between aircraft, links between ships, and links between aerostats and ships – have a lower interference potential and can avoid a requirement to register link information if Aeronet adopts reasonable limitations on its operations to manage exposures to FS receivers.

1 Introduction

Aeronet filed rulemaking petitions to allow Aviation and Maritime Scheduled Dynamic Datalinks in the E-band (71-76 GHz, 81-86 GHz, and 92-95 GHz) on February 6, 2019. Aeronet proposes to implement broadband shore-to-ship, shore-to-aerostat, aerostat-to-ship, ship-to-ship, ground-to-aircraft, and aircraft-to-aircraft communications links in the E-band (71-76 GHz/81-86 GHz). The incumbent E-band service is fixed terrestrial point-to-point links that are authorized under non-exclusive nationwide licenses and recorded in a link registration database. Aeronet's goal is to gain FCC regulatory approval of its proposed operations. This paper explores the interference potential between Aeronet's systems and the incumbent fixed link service and whether the Aeronet systems are compatible with the existing link registration database such that they may be recorded there using the existing structures and definitions. Aeronet requested that Comsearch prepare this paper as an independent review of these issues based on our status as an FCC-selected third-party database manager for the E-band and our expertise on spectrum management for fixed microwave services.

2 Background

2.1 Link Registration System

Users of the E-band under Part 101 are required to obtain a non-exclusive nationwide license to use the band. Specific point-to-point links under the license are then registered in the link database through a third-party database manager. Figures 1-4 show the link registration form and data elements. The data includes sites, geographic coordinates, ground elevations, antenna

heights, antennas models and details, radio models and details, transmitter powers, fixed losses, frequencies, and bandwidths.

The system can analyze new proposed links against the existing database of links and report a green light ("all clear") or a yellow light ("potential interference identified"). The trigger for a yellow light in the analysis automatically performed by the registration system is interference above a conservative I/N=-6 dB criterion. The automatic analysis calculates the interference versus all links in the area and reports the details of any exposure with interference near or above I/N=-6 dB, taking frequency offset improvements into account. The system also automatically interacts with the NTIA coordination system designed to protect federal systems and radio astronomy receivers.

Links receive first-in-time protection based on the registration date and time. The protection is against harmful interference in operation. To register a link, a licensee provides an interference analysis that demonstrates there is no harmful interference with any link in the database. A "green light" report showing the detailed results from the automatic analysis with no exposure above I/N=-6 dB fulfills this requirement. A "yellow light" report with some interference above I/N=-6 dB can also fulfill the requirement if the licensee reviews the cases and determines they would not be harmful in operation. Or, if the interference can be mitigated with planning techniques such as changing frequency, transmitter power, polarization, or any technical parameters, the licensee can modify the proposal to receive a "green light".

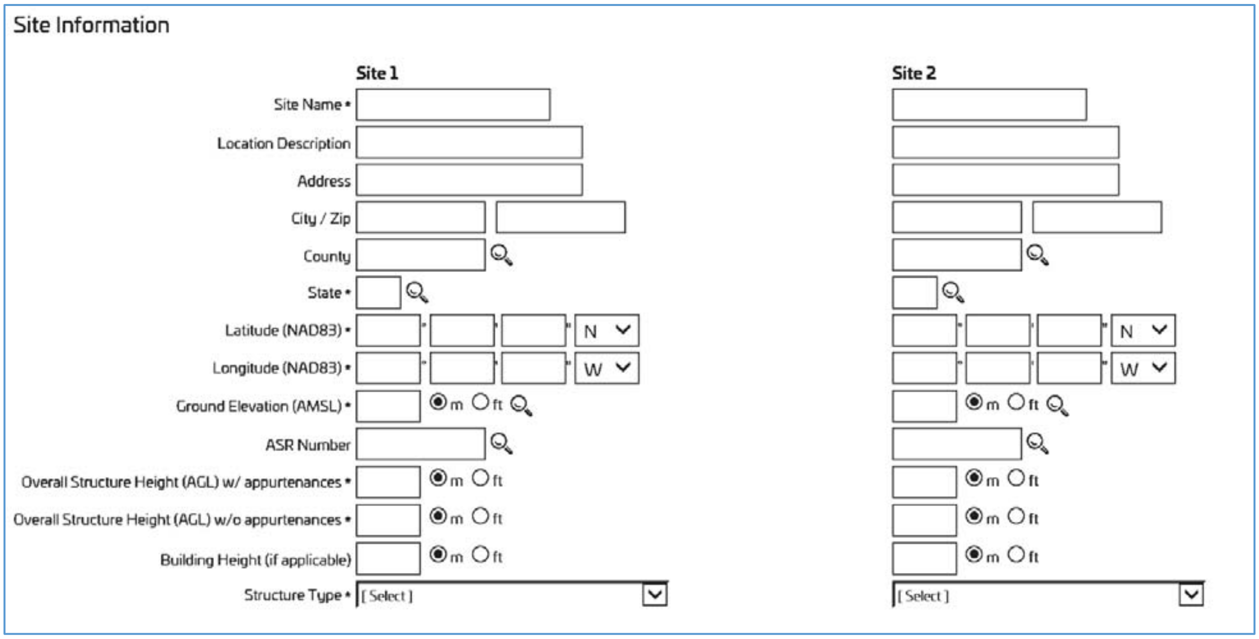

Figure 1: Link Registration Data - Site Information

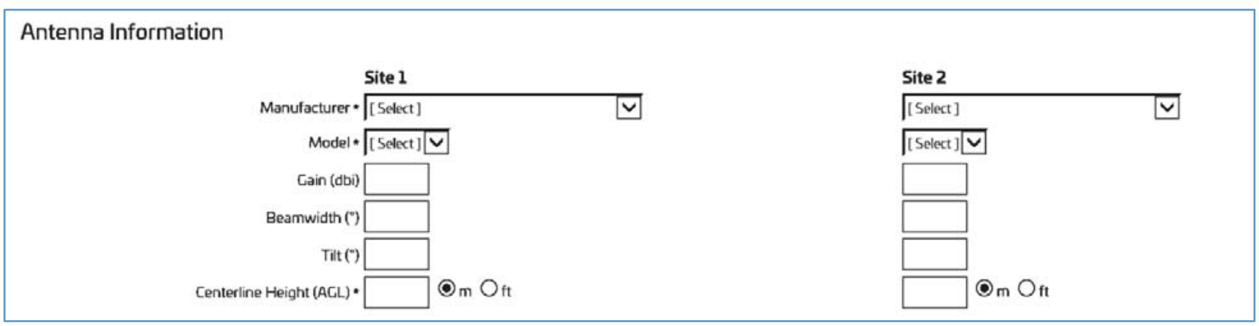

Figure 2: Link Registration Data – Antenna Information

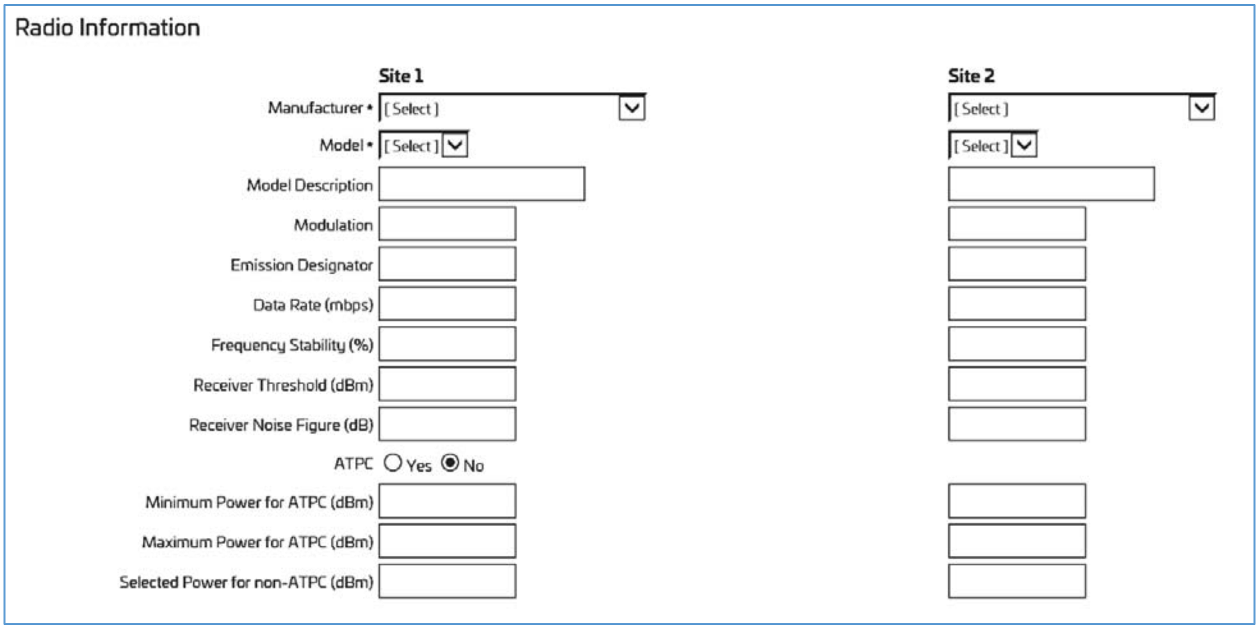

Figure 3: Link Registration Data – Radio Information

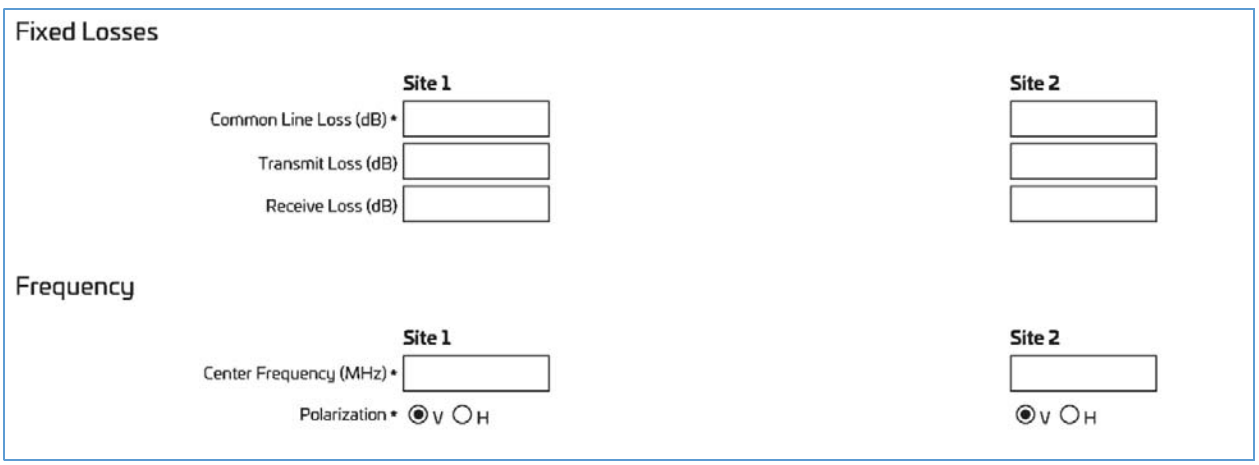

Figure 4: Link Registration Data – Fixed Losses and Frequency

2.2 Directional Antenna Patterns

E-band links use high-gain antennas with correspondingly narrow beam-widths and directional patterns. Methods to calculate reference radiation patterns are available in recommendation

ITU-R F.699-8. A common antenna gain category for the Part 101 fixed service is 44 dBi, just above the minimum 43 dBi currently allowed. This applies to an antenna of about 1 ft (0.3 m) diameter. Antennas of a 51 dBi gain (2 ft / 0.6 m diameter) category are also commonly used. Aeronet proposes to use antennas equivalent or superior to this larger category for its systems. Figure 5 and Figure 6 show the reference radiation patterns for 44 dBi and 51 dBi gain, respectively. Table 1 summarizes the beam-widths of these antennas at the half-power (3 dB), 10 dB, 20 dB, and 30 dB suppression levels.

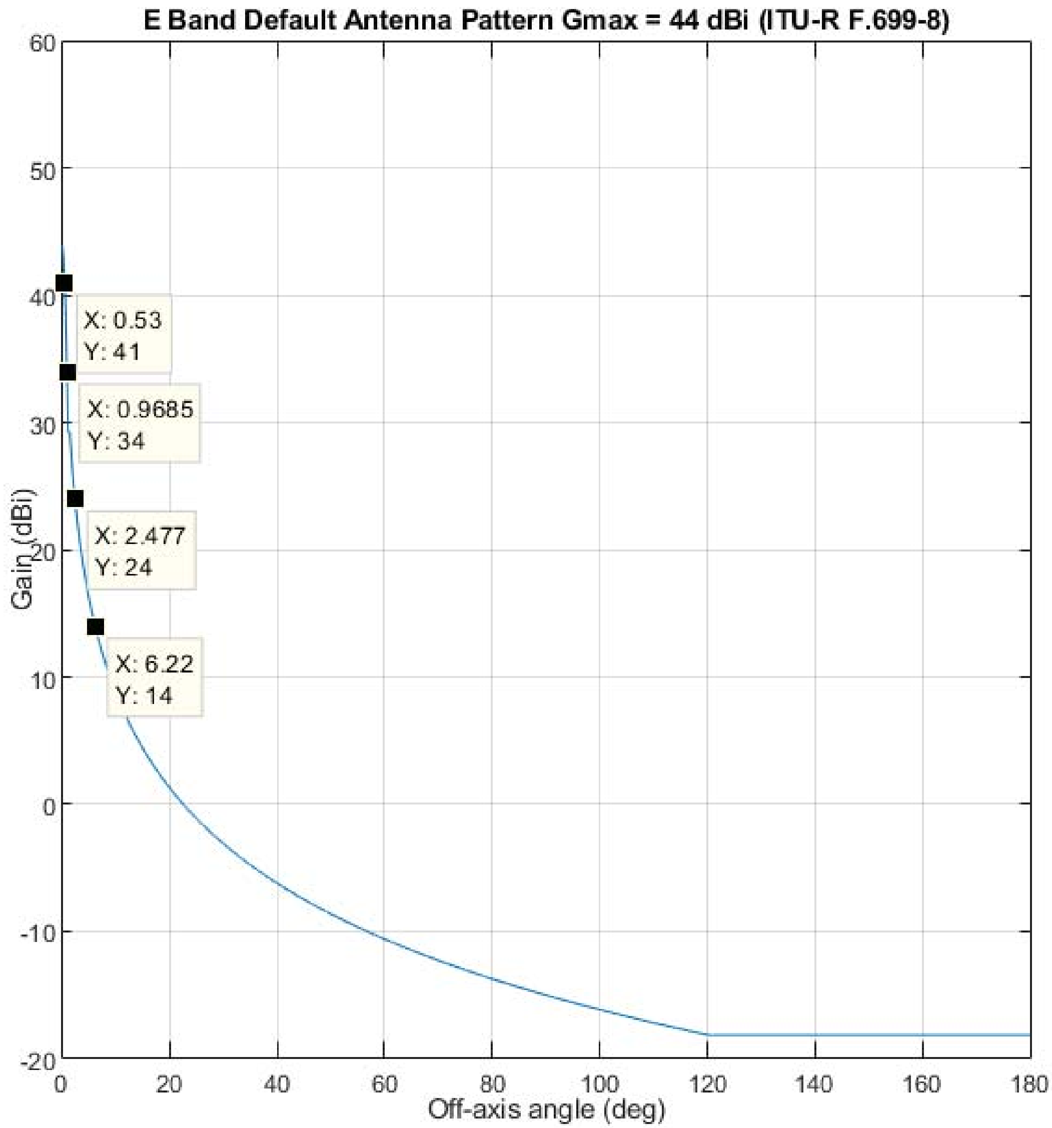

Figure 5: ITU-R F.699-8 Antenna Pattern with Gmax = 44 dBi

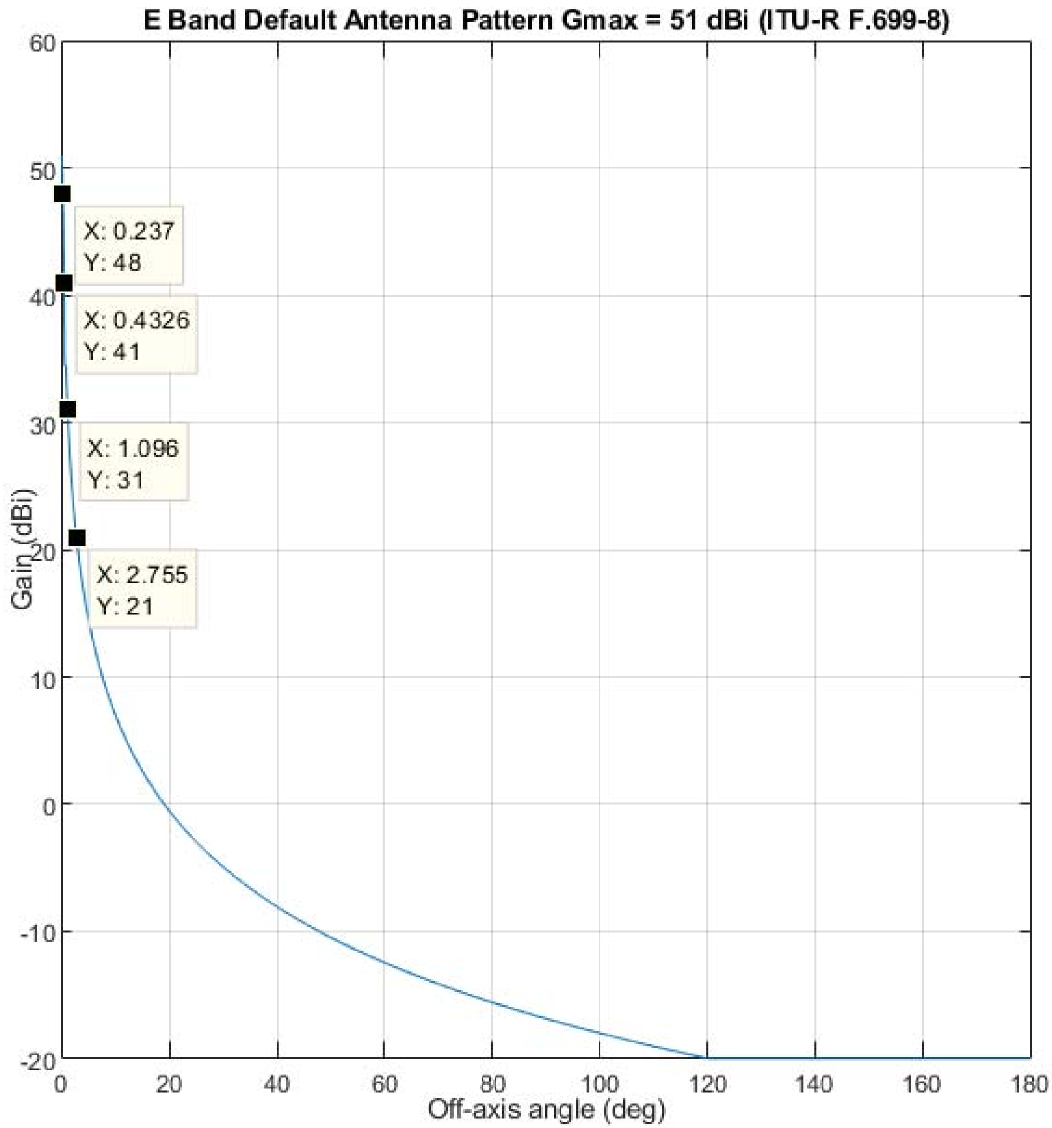

Figure 6: ITU-R F.699-8 Antenna Pattern with Gmax = 51 dBi

	Full Beam-width (deg)	
Off-Axis Suppression (dB)	44 dBi Antenna	51 dBi Antenna
3	1.2	0.5
10	2.0	0.9
20	5.0	2.2
30	12.5*	5.6
*47 CFR §101.115 Requires 35 dB suppression at +/-5 degrees		

Table 1: E Band Antenna Suppression Beam-widths (ITU-R F.699-8)

2.3 Atmospheric Absorption Loss

In the E-band, horizontal paths through the troposphere are usually subject to significant losses due to gaseous absorption by oxygen and particularly by water vapor. The height of the FS link (AMSL) is also an important factor in absorption loss as is the path elevation (tilt) angle – paths at high altitudes and paths with large elevation angles (e.g. greater than 5 degrees) have much less absorption loss than horizontal paths at sea level. Methods to predict the gaseous absorption losses are given in recommendation ITU-R P.676. Calculations for slant paths in these analyses use the method of Annex 2 of ITU-R P.676-10 with the mean annual global atmospheric parameters of recommendation ITU-R P.835-6. Calculations for horizontal terrestrial paths use a typical loss rate of 0.4 dB/km.

2.4 Link Database Statistics

Fixed Service (FS) links in the E-band use antennas with highly directional patterns as required by the FCC rules. Similarly, Aeronet proposes to use highly directional antennas. As discussed further below, interference levels will be well below receiver thermal noise power except in rare orientations. Higher levels should only occur with geographic proximity and then with alignment of azimuth and elevation angles to set up main-beam-to-main-beam antenna coupling.

From the current link database, Figure 7 shows the elevation angles used by Fixed Service (FS) antennas in the E-band are highly concentrated near horizontal (0 deg elevation). Table 2 shows 81% of antennas use elevation angles below 1 degree, and 91% are below 3 degrees. On the other hand, the registration data shows 1,855 of 31,772 antennas (5.8%) use an elevation angle above 5 degrees. Further, Figure 8 and Table 3 show the breakdown of FS antennas by elevation

angle and main-beam gain (thus antenna size) category. The link data shows that antennas oriented near horizontal are predominantly of a higher 51 dBi size/gain category. On the other hand, a larger elevation (tilt) angle strongly suggests that the link is of a short distance. Hence, the data shows such antennas are very likely to be of a lower 44 dBi size/gain category. If projected growth of short E-band links for small cell backhaul occurs, we anticipate that most of these antennas will be of smaller size and lower gain.

Figure 9 and Table 4 show that the E band FS antenna altitudes (heights above mean sea level) are concentrated near sea level as might be expected since that aligns with population centers in the US. The number of FS receivers above 600 m AMSL is 1,920 (6%).

For main-beam to main-beam alignment exposures from Aeronet aircraft antennas,
FS antennas using significant up-tilt may involve only minimal to moderate atmospheric absorption loss on the interference path. High altitude of a FS receiver is another significant factor for lower absorption losses on an interference path.

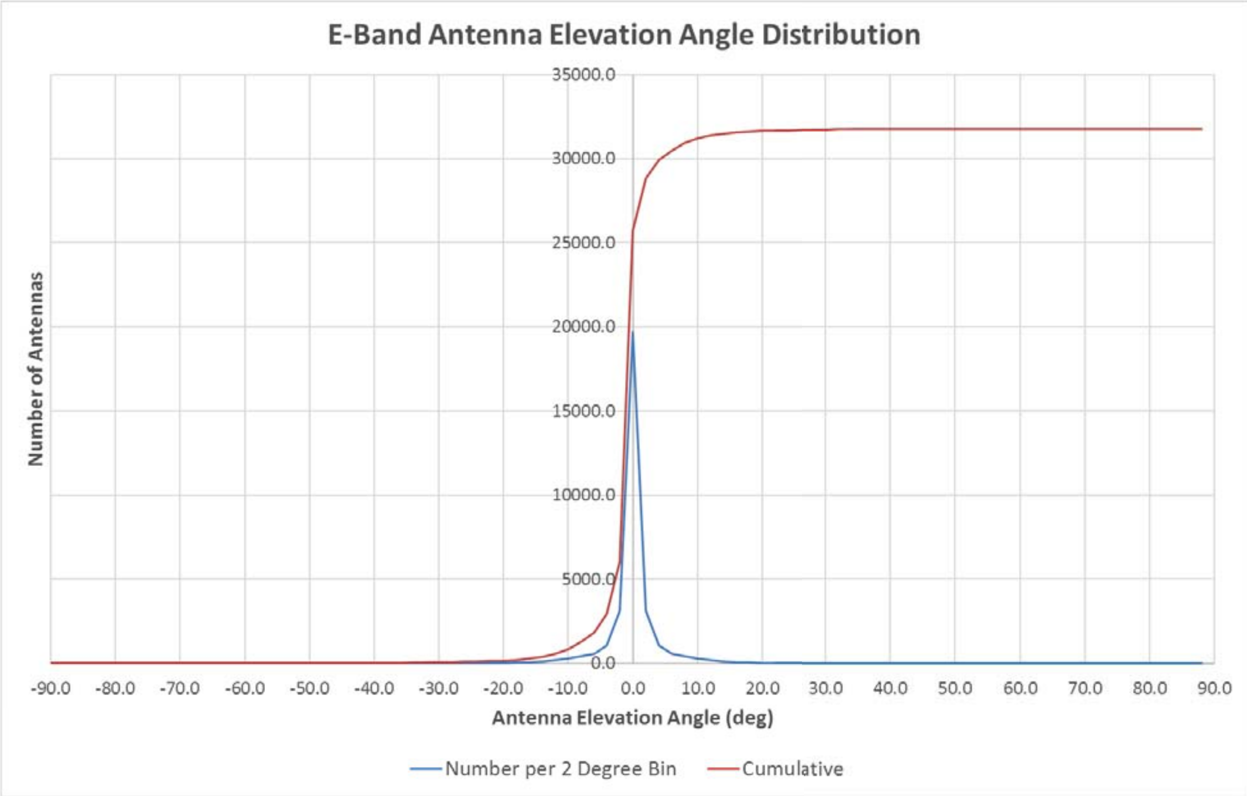

Figure 7: Elevation Angle Distribution (Link Registration Data as of 02/25/2019, 31,772 total antennas)

Elevation Angle (deg)	Number of Antennas
< 1	25750
1 to 3	3104
3 to 5	1063
5 to 7	574
7 to 9	438
9 to 11	277
11 to 13	205
13 to 15	87
15 to 17	64
17 to 19	61
19 to 21	23
21 to 23	22
23 to 25	20
25 to 27	13
27 to 29	19
29 to 31	12
31 to 33	8
33 to 35	4
35 to 37	5
37 to 39	5
39 to 41	3
>= 41	15

Table 2: Elevation Angle Distribution (Link Registration Data as of 02/25/2019, 31,772 total antennas)

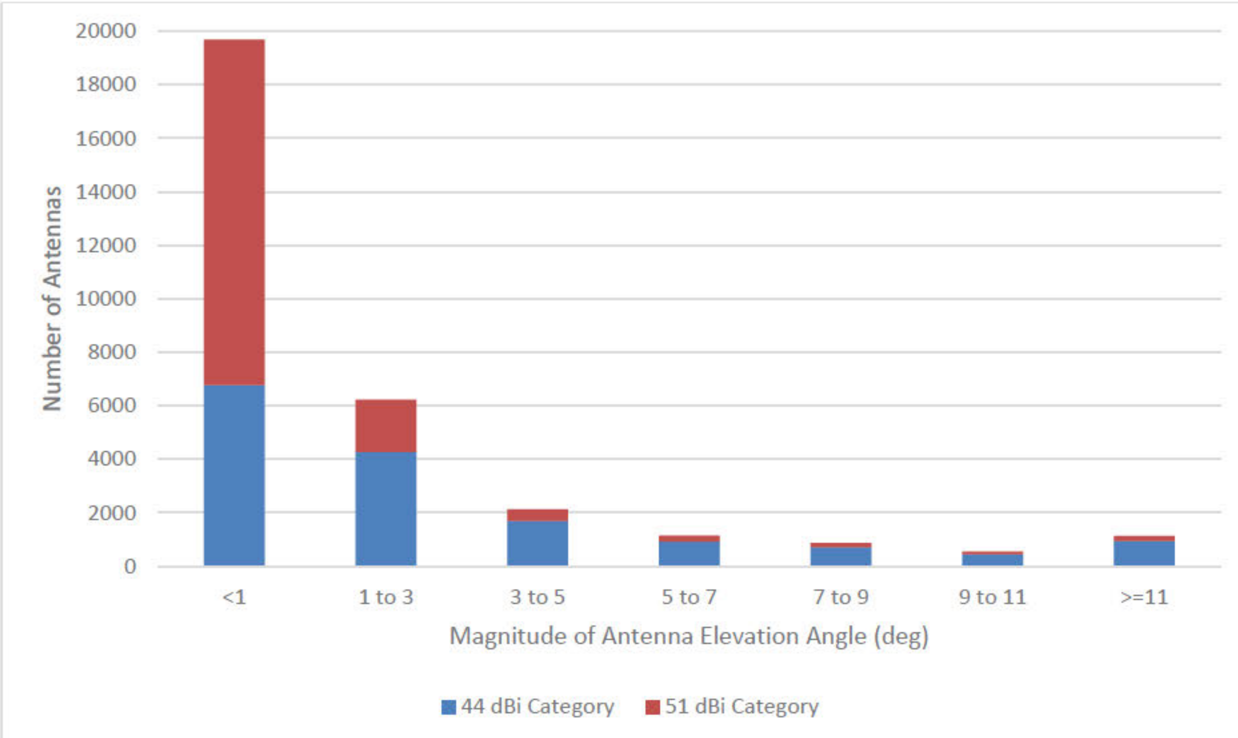

Figure 8: Fixed Service Magnitude (Absolute Value) of Antenna Elevation Angle and Antenna Gain

Elevation Angle Magnitude (deg)	Number of Antennas 44 dBi Category	Number of Antennas 51 dBi Category	Total Antennas
<1	6763	12936	19699
1 to 3	4273	1960	6233
3 to 5	1685	443	2128
5 to 7	915	234	1149
7 to 9	708	169	877
9 to 11	438	116	554
>=11	940	192	1132

Table 3: Fixed Service Magnitude (Absolute Value) of Antenna Elevation Angle and Antenna Gain

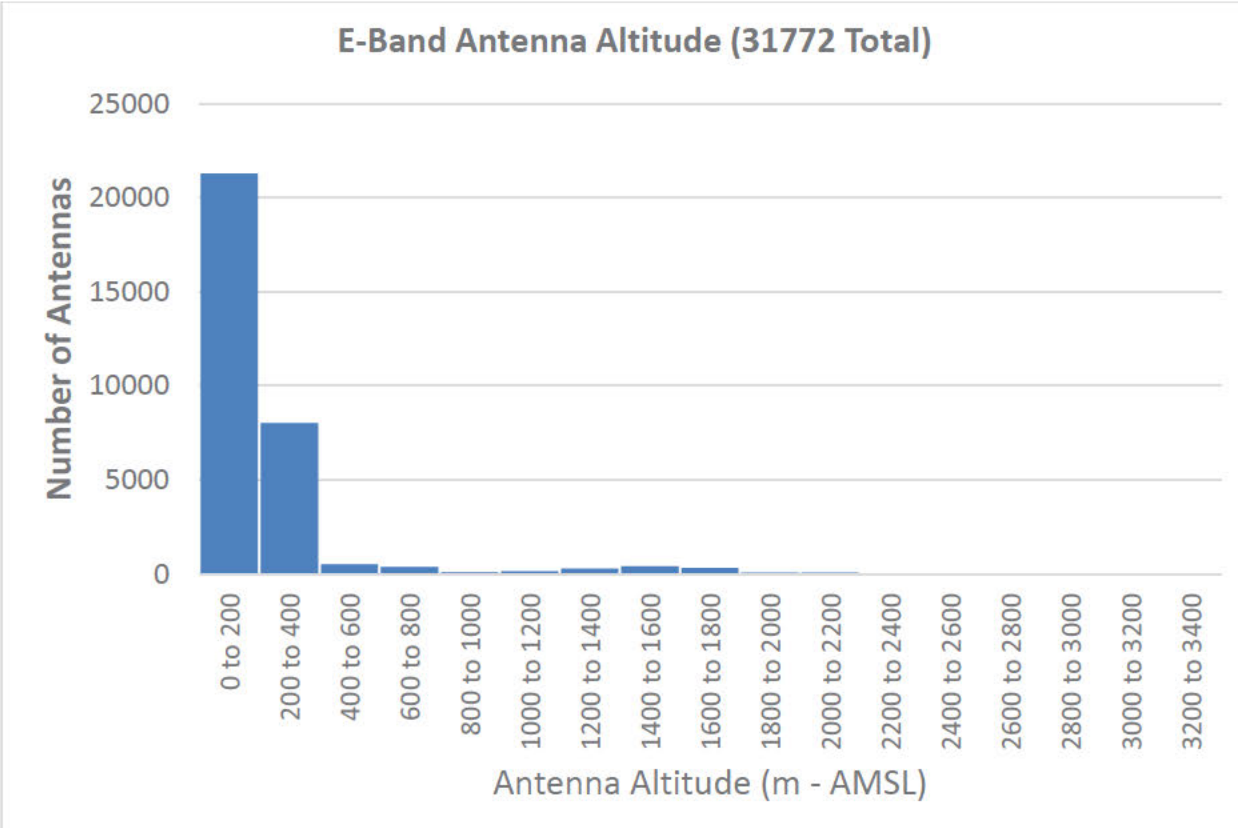

Figure 9: Fixed Service Antenna Altitude (Link Registration Data as of 02/25/2019, 31,772 total antennas)

Altitude AMSL (m)	Number of Antennas
0 to 200	21300
200 to 400	8040
400 to 600	512
600 to 800	382
800 to 1000	89
1000 to 1200	146
1200 to 1400	306
1400 to 1600	423
1600 to 1800	336
1800 to 2000	76
2000 to 2200	72
2200 to 2400	47
2400 to 2600	28
2600 to 2800	8
2800 to 3000	1
3000 to 3200	3
3200 to 3400	3

Table 4: Fixed Service Antenna Altitude (Link Registration Data as of 02/25/2019, 31,772 total antennas)

2.5 Interference Objectives

The initial interference objective for analysis into FS receivers is the I/N=-6 dB criterion. In the link registration system, proposals that meet this objective receive a "green light". For a bandwidth of 1000 MHz (1 GHz) and noise figure of 7 dB, this corresponds to an objective of I=-83 dBm. Interference below this level is not considered harmful. Interference above this level in clear air (without rain fade) may not be harmful if the interference does not use up the receiver fade margin and can be seen, based on the case geometry, to fade along with the desired signal in rain.

By power addition, the relation between the margin to the I/N=-6 dB interference objective and threshold degradation when that interference level occurs is shown in Table 5.

Margin (dB)	Threshold Degradation (dB)
0	0.97
-1	1.19
-2	1.46
-3	1.76
-4	2.12
-5	2.54
-6	3.01
-7	3.54
-8	4.12
-9	4.76
-10	5.46
-15	9.51
-20	14.17
-25	19.05
<-25	Margin - 6

Table 5: Threshold Degradation vs. Margin to Objective

2.6 Interference Mitigation Factors

In the link registration system, a proposal with predicted interference above the initial I/N=-6 dB criterion would receive a "yellow light". If this happens, there are several considerations that can be used to show that harmful interference still would not occur:

- Correlated Rain Fading: FS receivers in the E-band generally use large fade margins to overcome rain fade for high availability. The geometry of the interfering link, victim link, and the path of interference may be arranged so that the interference would fade along with the desired signal in rain. For instance, correlated rain fading occurs when interference enters from the main-beam direction of an FS receiver antenna and the interfering transmitter is further away than the desired transmitter. With correlated fading, receiver fade margin as designed would still be available to protect availability.
- Interference path blockage: terrain, clutter, or buildings can block a path to resolve predicted interference.
- Short-term Interference: interference that occurs at a small annual time percentage, as opposed to constantly, may not be harmful.

3 Interference Scenarios

In its rulemaking petitions, Aeronet describes its proposed system of aviation and maritime scheduled dynamic datalinks ("SDDLs"). The various SDDL configurations that Aeronet proposes involve interference scenarios that require analysis to show compatibility with terrestrial fixed links. Compatibility may be based on antenna off-axis discrimination or distance

separation. In some scenarios, exposure from mobile transmitters may be temporary (short-term).

There are ten cases that must be considered with respect to fixed link receivers – three for aviation and seven for maritime:

System	Scenario
Aviation	Aircraft transmitting to Ground Stations
Aviation	Ground Stations transmitting to Aircraft
Aviation	Aircraft transmitting to Aircraft
Maritime	Ships transmitting to Shore Stations
Maritime	Shore Stations transmitting to Ships
Maritime	Ships transmitting to Aerostats
Maritime	Aerostats transmitting to Ships
Maritime	Ships transmitting to Ships
Maritime	Shore Stations transmitting to Aerostats
Maritime	Aerostats transmitting to Shore Stations

Table 6: Potential Interference Cases to be Examined -- Aeronet into Fixed Service Receivers

The following general assumptions are used in the interference assessments:

Frequency	80 GHz (Nominal for 71-76/81-86 GHz)
K Factor	4/3
Atmosphere	Mean Annual Global (ITU-R P.835-6)
Atmospheric Gas Attenuation	ITU-R P.676-10 Annex 2
Bandwidth (Aeronet and FS)	1 GHz
Receiver Noise Figure (Aeronet and FS)	7 dB
Receiver Noise Power (Aeronet and FS)	-77 dBm
Aeronet Antenna Gain (TX and RX)	51 dBi
Aeronet C/N Target	15 dB
Aeronet Maximum EIRP	87 dBm
Aeronet ATPC design	Maintain Target C/N
Aeronet ATPC activity trigger	Increased pathloss
FS Receiver Antenna Gain (Aviation Scenarios)	44 dBi
FS Receiver Antenna Gain (Maritime Scenarios)	51 dBi
FS Receiver Initial Interference Objective	-83 dBm (I/N=-6 dB)

Table 7: General Analysis Parameters

Based on the link and antenna data discussed above, a 44 dBi antenna is representative for the up-tilted FS antennas of concern with the Aeronet aviation system, while a 51 dBi antenna is representative for the horizontal FS antennas of concern with the Aeronet maritime system.

As the following calculations demonstrate, Aeronet's use of automatic transmitter power control (ATPC) can limit interference to meet the I/N=-6 dB criterion in nearly all cases. In infrequent situations interference might occur at levels above the I/N=-6 dB criterion. Nevertheless, the interference in these rare situations is expected still to be low enough that it may be considered not to be harmful based on other factors.

3.1 Aviation System

Aircraft using the Aeronet aviation system will establish SDDL links with fixed ground stations and with other aircraft. The interference potential of each aspect of the aviation system is analyzed below.

3.1.1 Aircraft Transmitting to Ground Stations

The aviation system involves aircraft transmitting to ground stations that are the interface to public telecommunications networks. These ground stations are intended to be located away from urban and suburban areas where Part 101 fixed service use of E-band is concentrated, and growth is likely. The minimum elevation angle Aeronet will use for a link is 5 degrees at the ground station. Boresight antenna coupling will not occur for most fixed service receivers because of their lower antenna elevation angles. Nevertheless, in cases where fixed service

antennas use unusually high elevation angles and are aligned in azimuth with the aircraft-to-ground station link, boresight coupling could occur. For this worst-case alignment, in clear air the Aeronet ATPC will, as shown in Table 8, maintain the interference 14 dB above the -83 dBm objective (corresponding to 8.6 dB of threshold degradation). From the reference patterns shown previously, an off-axis angle of 1.2 deg from the FS antenna or 0.6 deg from the aircraft antenna would resolve this margin.

For the worst-case values of 5 degrees elevation and aircraft at 15.24 km altitude (50,000 ft.), the 20 dB full beam-width of the aircraft antenna (2.2 degrees) illuminates an area on the ground of up to 35 km from the ground station. Thus, this radius could define a zone around Aeronet ground stations to coordinate new FS links. Links passing any of the following screening steps may be said not to have a potential for interference above I/N=-6 dB:

1. FS link not aligned in azimuth with ground station within 20 dB FS antenna half beam-width (e.g. +/- 2.5 degrees)
2. FS receiver antenna elevation angle more than 20 dB half beam-width below 5 degree minimum Aeronet elevation angle (i.e. FS antenna below 2.5 degrees elevation.)
3. FS receiver aligned in azimuth and elevation, but more than 35 km from ground station

Locating new FS links inside the coordination zone would not involve a concern for interference except in cases of direct antenna alignment in azimuth and elevation. These rare cases of proximity and direct alignment would require more detailed coordination. In some geometries, the interference may be predicted to fade with the desired signal in rain, preventing any harmful effect. Otherwise, frequency planning could be used to avoid co-channel operation. Depending

on air routes, Aeronet may need to form SDDL links only in limited azimuth and elevation directions to or from a ground station, rather than fully 360 azimuth degrees down to 5 elevation degrees. Where applicable these azimuth and elevation limitations could be included to further enhance coordination.

Ground Station Antenna Altitude (km)	Aircraft Altitude (km)	Ground Station Antenna Elevation Angle (deg)	Slant Path Distance (km)	Aircraft Antenna Elevation Angle (deg)	Aircraft to Ground Station Atmos. Absorption Loss (dB)	Aircraft TX ATPC Power Reduction (dB)	Aircraft TX EIRP (dBm)	Aeronet C/N (dB)	Int. to FS (dBm)	Margin (dB)
0.2	3.048	5	32.0	-5.2	5.5	33.90	53.10	15	-69	-14
0.2	3.048	10	16.3	-10.1	2.8	42.48	44.52	15	-69	-14
0.2	3.048	20	8.3	-20.1	1.4	49.69	37.31	15	-69	-14
0.2	3.048	40	4.4	-40.0	0.7	55.82	31.18	15	-69	-14
1.0	3.048	5	23.1	-5.2	2.9	39.27	47.73	15	-69	-14
1.0	3.048	10	11.7	-10.1	1.5	46.62	40.38	15	-69	-14
1.0	3.048	20	6.0	-20.0	0.7	53.20	33.80	15	-69	-14
1.0	3.048	40	3.2	-40.0	0.4	59.03	27.97	15	-69	-14
2.0	3.048	5	11.9	-5.1	1.1	46.89	40.11	15	-69	-14
2.0	3.048	10	6.0	-10.0	0.5	53.36	33.64	15	-69	-14
2.0	3.048	20	3.1	-20.0	0.3	59.50	27.50	15	-69	-14
2.0	3.048	40	1.6	-40.0	0.1	65.10	21.90	15	-69	-14
0.2	9.144	5	96.4	-5.6	7.6	22.25	64.75	15	-69	-14
0.2	9.144	10	50.7	-10.3	3.8	31.60	55.40	15	-69	-14
0.2	9.144	20	26.0	-20.2	1.9	39.25	47.75	15	-69	-14
0.2	9.144	40	13.9	-40.1	1.0	45.60	41.40	15	-69	-14
1.0	9.144	5	88.2	-5.6	4.8	25.76	61.24	15	-69	-14
1.0	9.144	10	46.2	-10.3	2.4	33.78	53.22	15	-69	-14
1.0	9.144	20	23.7	-20.2	1.2	40.76	46.24	15	-69	-14
1.0	9.144	40	12.7	-40.1	0.7	46.79	40.21	15	-69	-14
2.0	9.144	5	77.9	-5.5	2.8	28.91	58.09	15	-69	-14
2.0	9.144	10	40.6	-10.3	1.4	35.94	51.06	15	-69	-14
2.0	9.144	20	20.8	-20.1	0.7	42.42	44.58	15	-69	-14
2.0	9.144	40	11.1	-40.1	0.4	48.20	38.80	15	-69	-14
0.2	15.24	5	156.2	-6.0	7.9	17.69	69.31	15	-69	-14
0.2	15.24	10	84.3	-10.6	4.0	27.00	60.00	15	-69	-14
0.2	15.24	20	43.7	-20.3	2.0	34.66	52.34	15	-69	-14
0.2	15.24	40	23.4	-40.1	1.1	41.04	45.96	15	-69	-14
1.0	15.24	5	148.6	-6.0	5.1	20.92	66.08	15	-69	-14
1.0	15.24	10	79.9	-10.5	2.6	28.86	58.14	15	-69	-14
1.0	15.24	20	41.4	-20.3	1.3	35.85	51.15	15	-69	-14
1.0	15.24	40	22.1	-40.1	0.7	41.89	45.11	15	-69	-14
2.0	15.24	5	139.0	-5.9	3.0	23.63	63.37	15	-69	-14
2.0	15.24	10	74.4	-10.5	1.5	30.55	56.45	15	-69	-14
2.0	15.24	20	38.5	-20.2	0.8	37.02	49.98	15	-69	-14
2.0	15.24	40	20.6	-40.1	0.4	42.81	44.19	15	-69	-14

Table 8: Aircraft → Ground Station Interference to FS Receivers if Boresight-to-Boresight

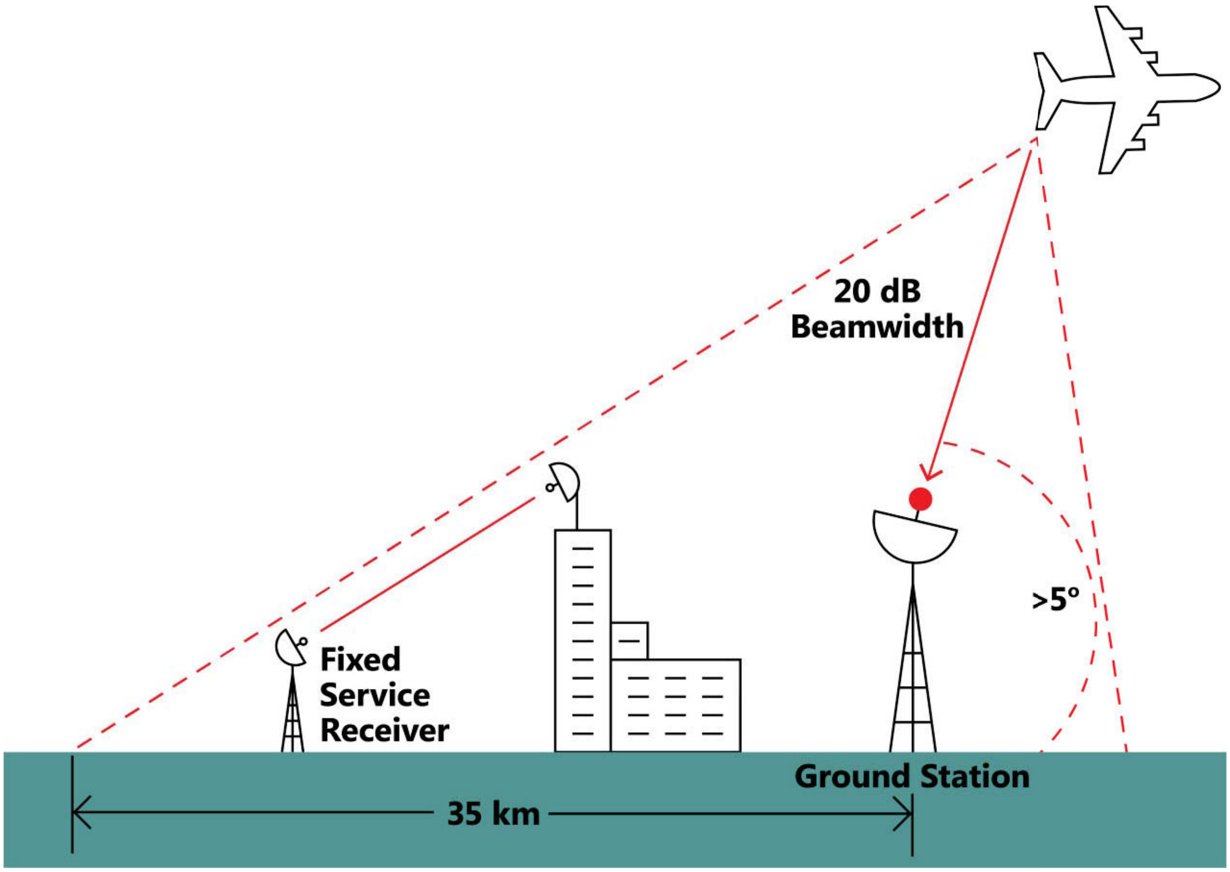

Figure 10: Aircraft transmitting to Ground Station

3.1.2 Ground Stations transmitting to Aircraft

The ground stations transmitting to aircraft are fixed and may be recorded and analyzed as a link-end in the existing registration database. A link record with a cone-shaped "antenna pattern" – down to 5 degrees elevation with the required roll-off below 5 degrees – facing upward could be entered in the database. This would alert for interference potential with a proposed fixed link through the standard analysis. The link database validation rules would need to be updated to accommodate the wide-beam antenna.

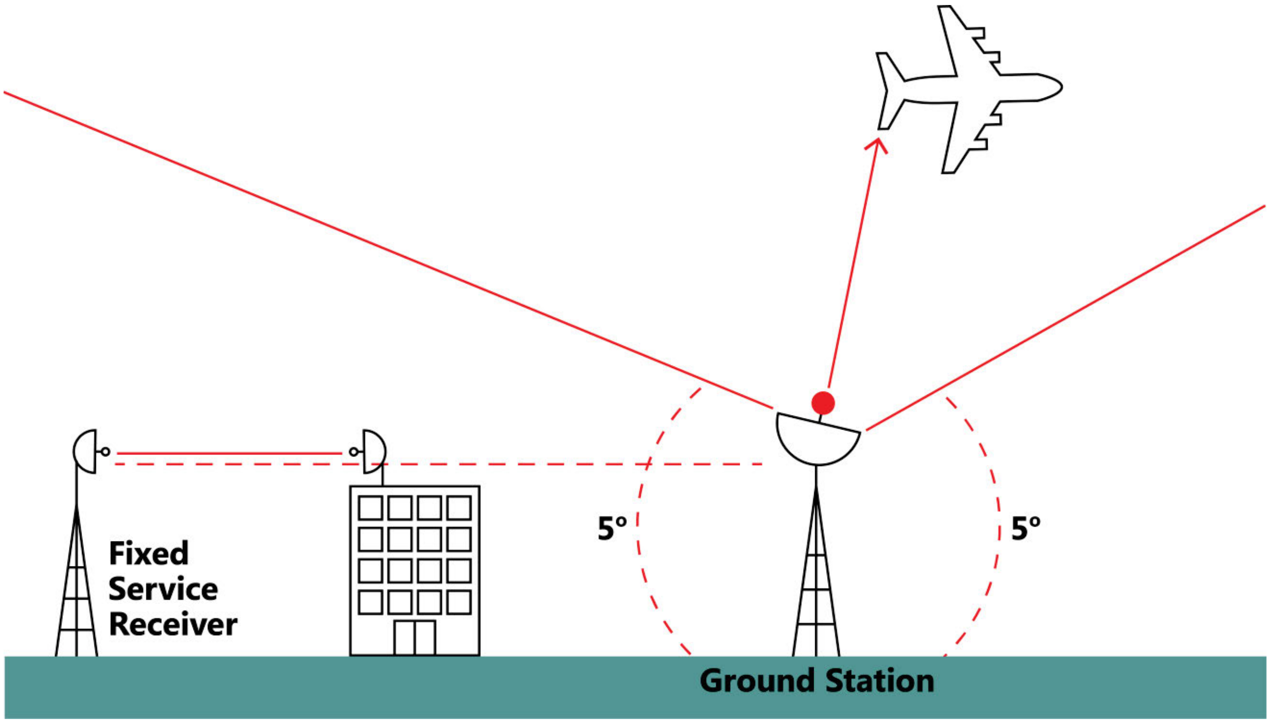

Figure 11: Ground Station transmitting to Aircraft

3.1.3 Aircraft transmitting to Aircraft

For a FS receive antenna aligned at a typical near-horizontal elevation angle, an interference signal entering the antenna main-beam would traverse a significant distance of the low atmosphere and be deeply attenuated by gaseous absorption losses. Aeronet aircraft to aircraft links operating near horizontal (e.g. between aircraft at about the same cruising altitude) can only couple into the main-beam of FS receivers at very low or negative elevation angles and at large distances. Thus, most typical operating scenarios will meet the initial interference objective.

However, it should be noted that above small elevation angles, paths through the atmosphere have reduced absorption losses as a function of increasing angle. Thus, if the Aeronet system

forms links between aircraft at different altitudes such that a significant elevation angle is used, a signal from the upper aircraft could occur above the initial interference objective. This could happen if an FS receive antenna using a corresponding up-tilt is illuminated by the upper aircraft antenna main-beam and is aligned in azimuth. Further, the potential level is greater if the FS receiver is a high altitude (AMSL) site since this condition is also associated with reduced absorption losses and reduced distance to the aircraft. But, the up-tilt and high altitude conditions of concern are likely to be rare as borne out by the current link database statistics.

Table 9 shows representative boresight-to-boresight interference calculations for an upper aircraft into a FS receiver. The calculations miss the I/N = -6 dB objective by as much as 13 dB (corresponding to 7.8 dB of threshold degradation) for large elevation angles and high FS altitude. Such interference exposures above the I/N=-6 dB objective would be transitory due to the aircraft motion and probably rather random with respect to hitting any FS receiver. Because the FS link is beyond the end of the air to air link in these scenarios, rain fade on the FS link would be very likely to also attenuate the interference so there should not be harmful degradation when the receiver needs its fade margin.

The existing link registration database system is not set up to handle the mobile aircraft-to-aircraft links. Rather than registering data for these links, Aeronet should adopt operational limitations to ensure harmful interference to FS receivers does not occur. Figures 13 to 16 describe useful limits. Interference up to 10 dB above the I/N=-6 dB objective should not be harmful based on the FS receiver fade margins, correlated rain fading, and transitory exposure. This level is satisfied below a particular FS antenna elevation value, as a function of FS antenna

altitude AMSL. This interference limit is the blue line in the figures. The great majority of elevation/altitude occurrences in the present link database, also plotted, satisfy this condition.[2] Any fixed service antenna (present registrations shown as red dots) below the blue line in each figure will not receive harmful interference. First, Aeronet should adopt a minimum aircraft to aircraft slant path distance for its links. Since the altitude difference between aircraft is 40,000 ft or less, a minimum slant path distance sets a maximum elevation angle for the aircraft to aircraft links. Fixed service antennas above this elevation angle would be protected because the upper aircraft antenna could not align boresight-to-boresight. The green line in Figure 13 and Figure 15 shows this limit in terms of the fixed service antenna elevation angle as a function of FS antenna altitude for a 35 km minimum distance. Similarly, the green line in Figure 14 and Figure 16 shows this limit as a function of FS antenna altitude for a 50 km minimum distance. Any fixed service antenna above the green line has an elevation angle steeper than allowed by the minimum distance constraint and therefore cannot align with the aircraft beam, thus avoiding interference. In each figure, the FS altitude and elevation angle combinations of concern are above the blue line (interference limit) but below the green line (distance limit). Second, Aeronet should consider adopting a lower aircraft minimum height (to form a link with another aircraft) of 10,000 ft. above the altitude of all exposed FS antennas. Use of this limit shifts the interference limit and distance limit lines as shown in Figure 14 and Figure 16, reducing the region of concern. Finally, for any remaining FS receiver in the database with an altitude/elevation angle combination above the interference limit line and below the distance limit line, Aeronet would have to evaluate further and potentially avoid use that would cause a

[2] To the extent the actual FS antenna gain is higher than 44 dBi, the level would be higher. However, the interference still would not be harmful because up-tilted FS antennas correspond with short links, and higher gain antennas on short links add up to large fade margins.

co-channel main-beam to main-beam exposure. To decide on the necessary operational limits, Aeronet should further balance how the distance and possible altitude difference conditions would restrict its operations versus the number of FS receivers in the geographic region of concern it would have to avoid.

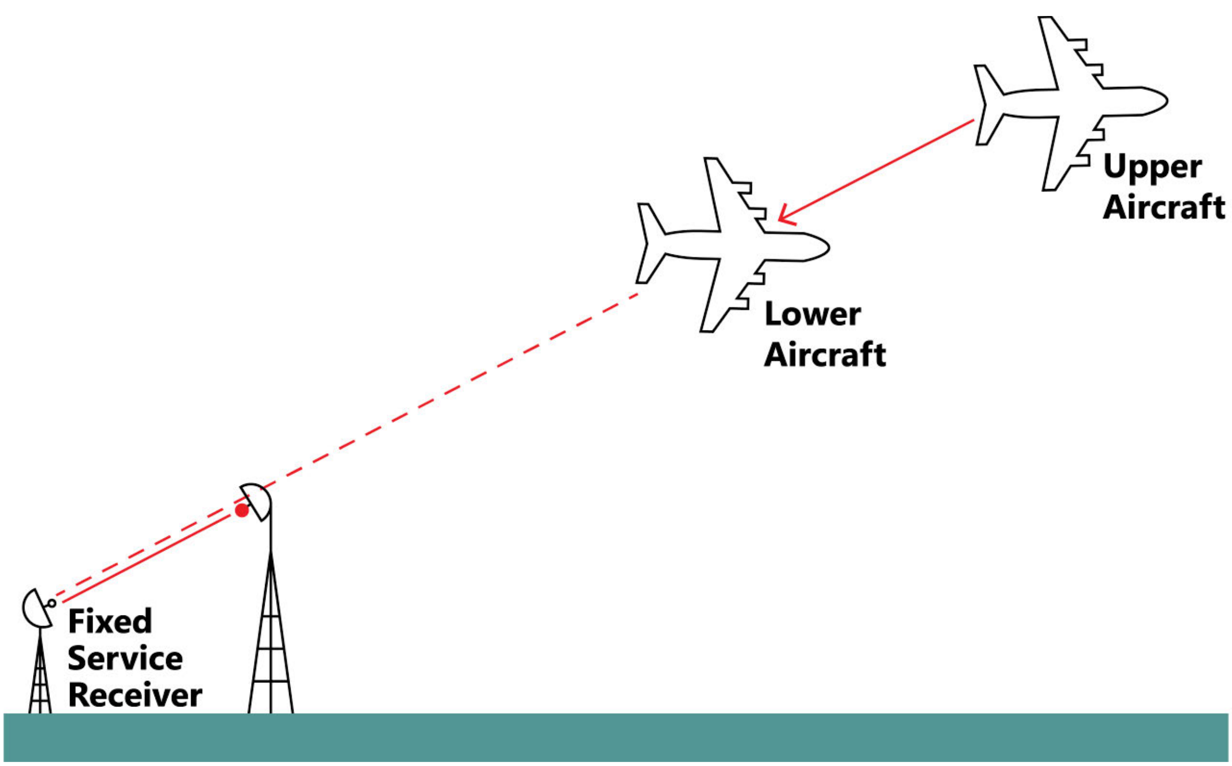

Figure 12: Aircraft transmitting to Aircraft

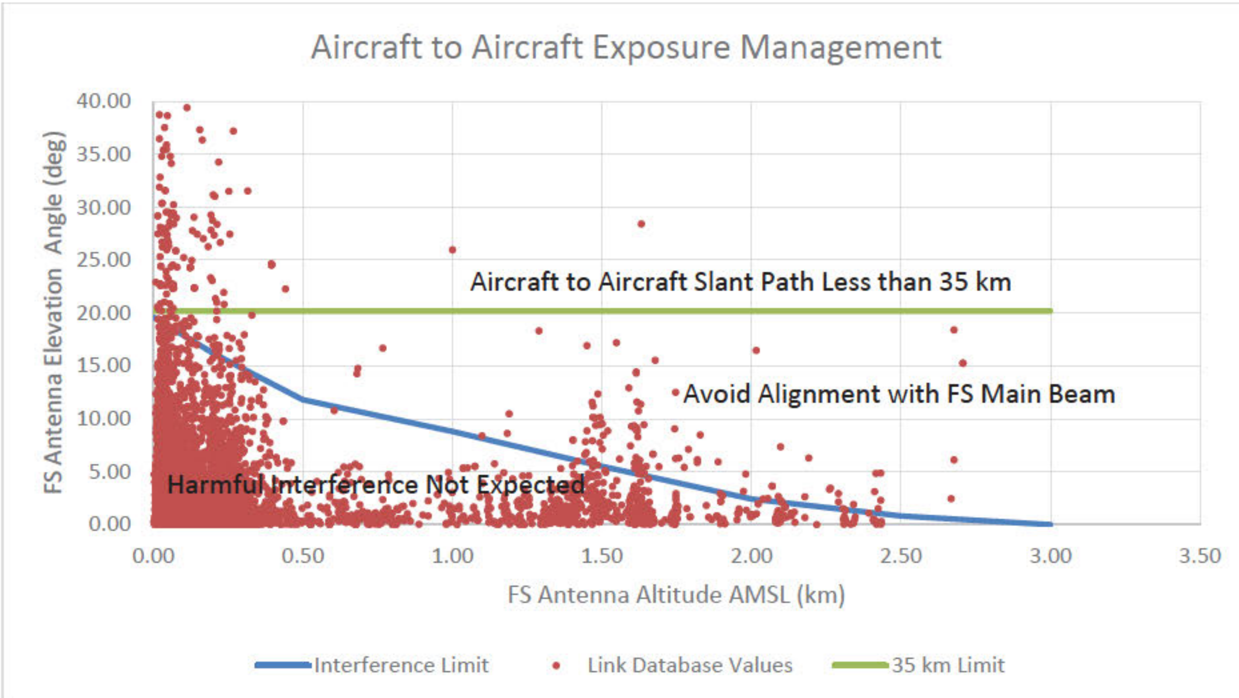

Figure 13: Aeronet Operating Conditions to Manage Interference Exposures

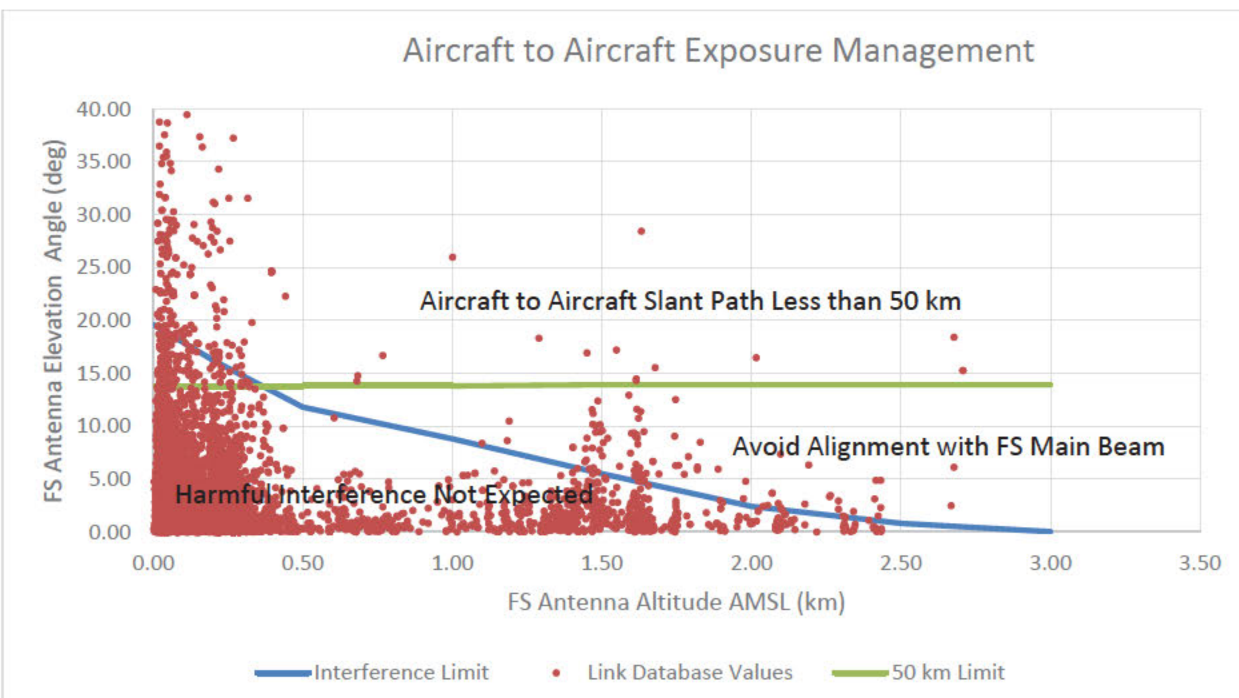

Figure 14: Aeronet Operating Conditions to Manage Interference Exposures

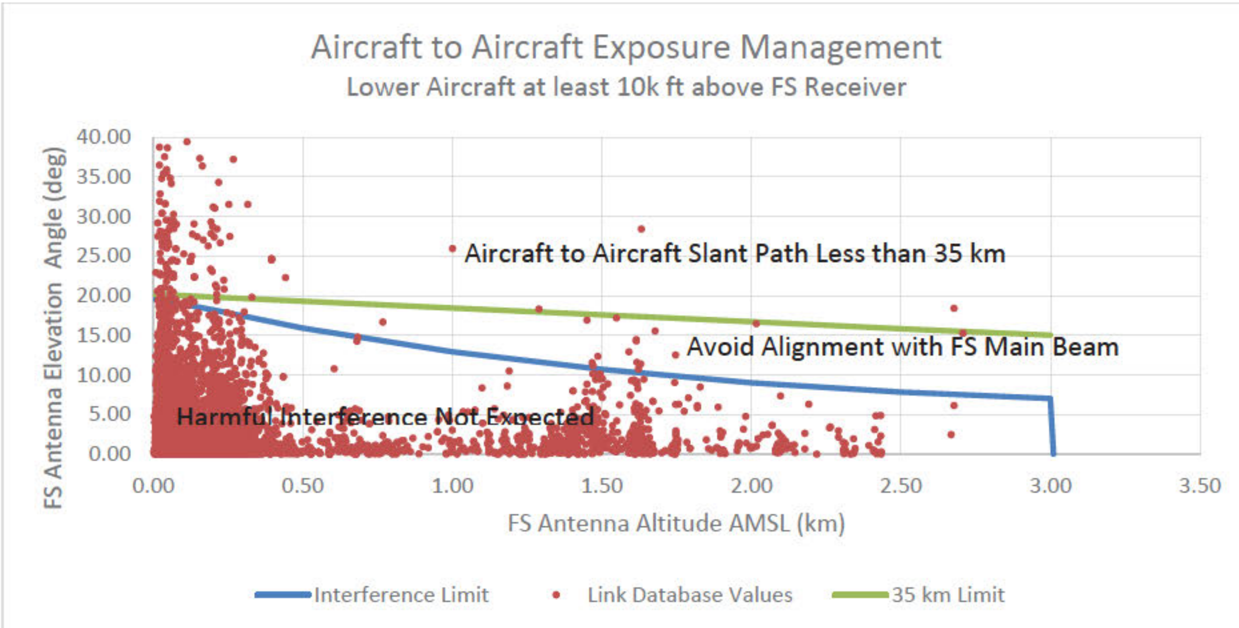

Figure 15: Aeronet Operating Conditions to Manage Interference Exposures

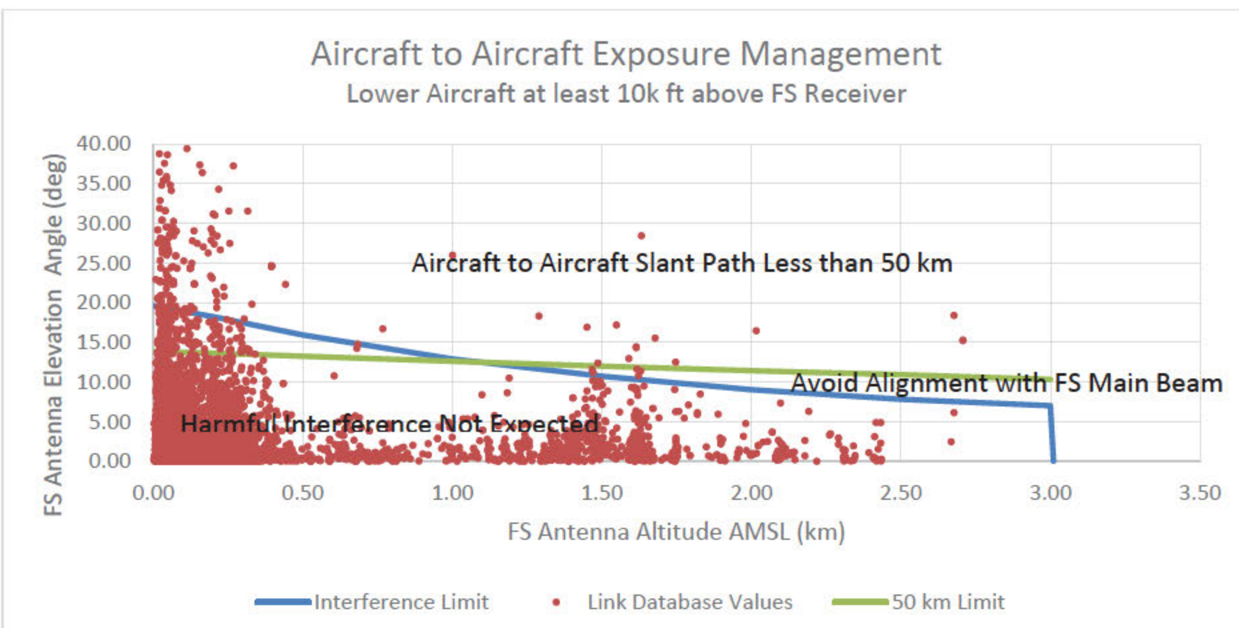

Figure 16: Aeronet Operating Conditions to Manage Interference Exposures

Upper Aircraft Altitude (km)	Lower Aircraft Altitude (km)	Lower Aircraft Antenna Elevation Angle (deg)	Upper Aircraft to Lower Aircraft Slant Distance (km)	Upper Aircraft Antenna Elevation Angle (deg)	FS Antenna Altitude (km)	Upper Aircraft to FS Slant Distance (km)	FS Antenna Elevation Angle (deg)	Upper Aircraft TX ATPC Power Reduction (dB)	Upper Aircraft TX EIRP (dBm)	Aeronet C/N (dB)	Upper Aircraft to FS Atmospheric Absorption Loss (dB)	Int. to FS (dBm)	Margin (dB)
14.296	3.048	20	32.7	-20.2	2.0	35.8	20.0	38.8	48.2	15	0.8	-70.1	-12.9
14.296	3.048	9	70.1	-9.5	2.0	76.8	9.0	31.6	55.4	15	1.7	-70.5	-12.5
9.724	3.048	3	113.2	-3.8	2.0	133.7	2.9	26.0	61.0	15	4.5	-72.5	-10.5
14.296	6.096	20	23.9	-20.2	2.0	35.9	19.9	41.8	45.2	15	0.8	-73.2	-9.8
7.620	3.048	2	110.5	-2.7	2.0	142.2	1.8	25.6	61.4	15	6.2	-74.3	-8.7
14.296	3.048	9	70.1	-9.5	0.2	88.4	8.9	31.6	55.4	15	4.5	-74.5	-8.5
11.248	3.048	6	75.3	-6.5	0.2	103.0	5.8	30.6	56.4	15	6.7	-77.0	-6.0
9.724	3.048	4	89.1	-4.6	0.2	131.4	3.7	28.6	58.4	15	9.7	-80.3	-2.7
7.620	3.048	2	110.5	-2.7	0.2	208.1	1.3	25.6	61.4	15	21.3	-92.7	9.7

Table 9: Aircraft → Aircraft Interference to FS Receivers if Boresight-to-Boresight (Representative of 963 total calculations)

3.2 Maritime System

Aeronet intends to identify operating areas for ships using its system. Ships in these areas will establish links with fixed shore stations, with tethered aerostats in international waters at heights up to 304.8 m (1000 ft.), and with other ships. The interference potential of each aspect of the maritime system is analyzed below.

3.2.1 Ships Transmitting to Shore Stations

A ship transmitting to a shore station may produce a boresight-to-boresight interference exposure to a FS receiver further ashore. Aeronet reports the longest maritime links it can use in its lower-power trials (experimental call sign WJ2XPI) are under 30 km. Aeronet expects that when authorized, its full-power maritime links will be under 40 km due to line-of-sight limitations.

The calculations in Table 10 show that out to 40 km from shore, a ship can cause interference somewhat above the I/N=-6 dB criterion to an FS receiver a short distance behind the shore station. But, if the hypothetical FS receiver is located further ashore the interference potential can be resolved. It is possible to define a coordination distance further ashore from the shore station beyond which harmful interference would not occur. A 30 km distance mitigates the interference concern into the fixed service. This distance along with the azimuth range to the ship operating area, plus an angle allowance for roll-off of the FS antenna pattern, could define a coordination zone. Proposed FS links inside the coordination zone would require additional analysis. In such cases, FS antennas aimed away from the shore station in azimuth (more than 2.5 deg off-axis) would not receive harmful interference. If the FS antenna were aligned in azimuth near the shore station, its elevation angle might be sufficiently offset from paths to the

ship operating area, or its visibility to the ship operating area might be blocked by terrain, clutter, or buildings. If necessary, a prediction of the interference level would be calculated using the Aeronet and FS link parameters. Interference below the I/N=-6 dB criterion would resolve the case, and a higher level might be considered not to be harmful based on correlated rain fading. Moreover, frequency planning could be used to avoid co-channel operation.

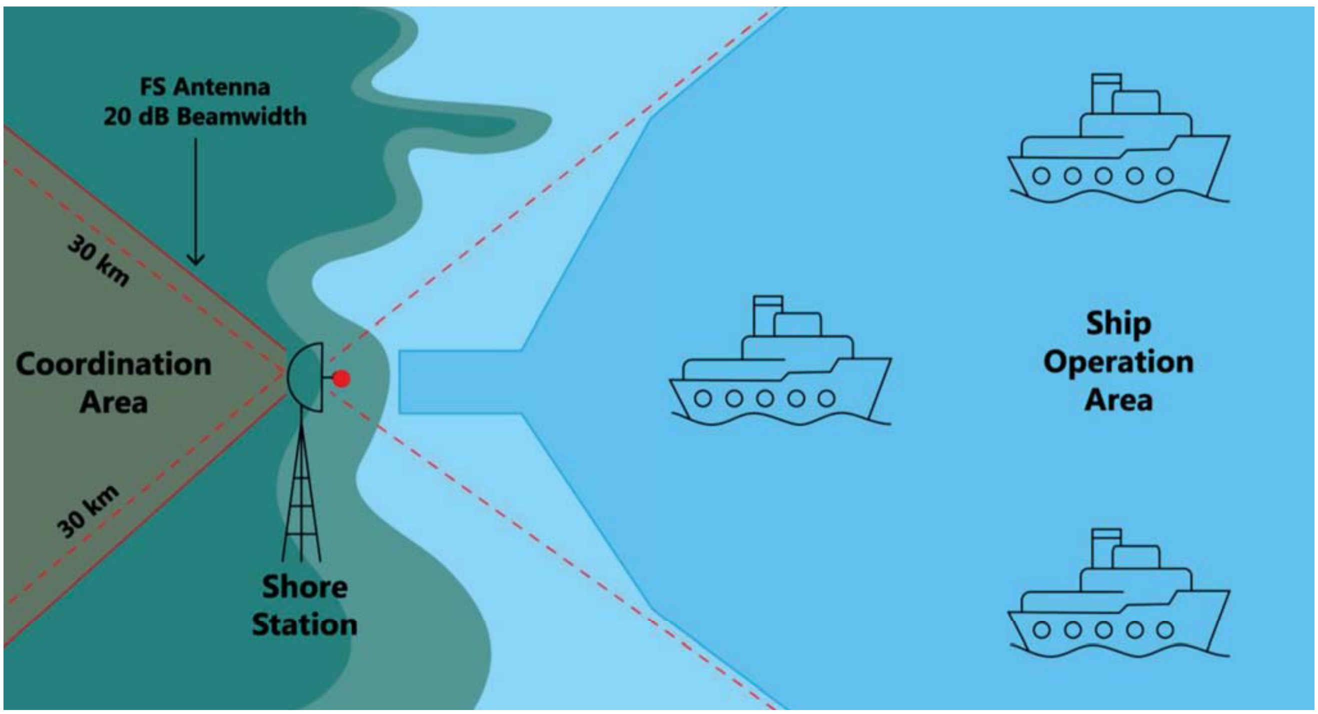

Figure 17: Coordination Zone for Ships transmitting to Shore Station

3.2.2 Shore Stations Transmitting to Ships

The shore stations transmitting to ships are fixed and may be recorded and analyzed as a link-end in the existing registration database. A link record with a fan-shaped (in the horizontal plane) “antenna pattern” covering the range of azimuths to the ship operation area, plus beam roll-off

outside that range, could be entered in the database. This would alert for interference potential with a proposed fixed link through the standard analysis. Shore station antennas directed towards the ship operation area will usually be directed away from and thus avoid potential interference with FS receivers. Only in rare situations would there be an FS receiver potentially in the main beam of a shore station antenna. In any event, the standard analysis run would calculate the levels between fixed shore station antenna and FS receivers and report the results with green or yellow light as appropriate.

The link database validation rules would need to be updated to accommodate the wide-beam antenna.

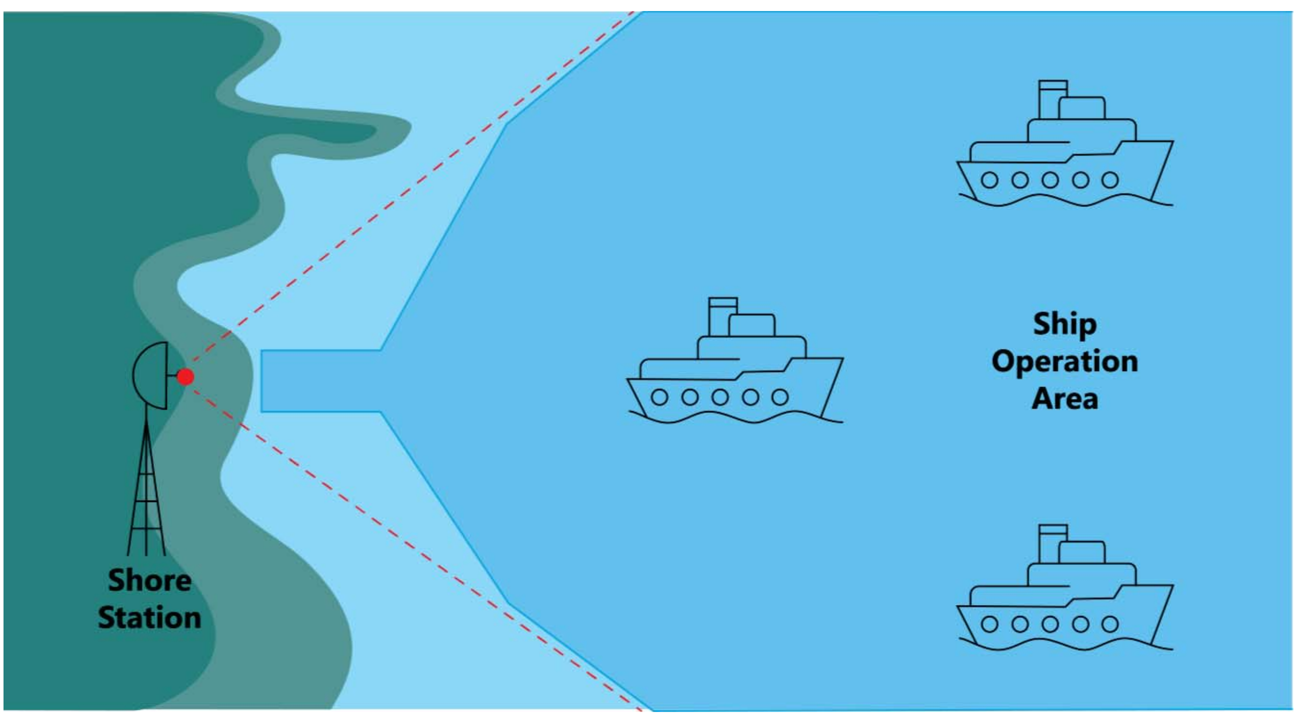

Figure 18: Shore Station transmitting to Ships

3.2.3 Ships Transmitting to Aerostats

Aerostats will be tethered in international waters -- at least 20 km (12 mi) offshore. Ship to Aerostat links will be used to extend the coverage of the Aeronet maritime system further seaward. Table 11 shows calculations for this scenario. Because these links can involve a significant elevation angle, off-axis discrimination based on elevation offset is included in the calculations. The aerostat offshore distance in addition to the ship to aerostat distance means that boresight-to-boresight interference from a ship to an FS receiver would not be harmful as shown in Table 11.

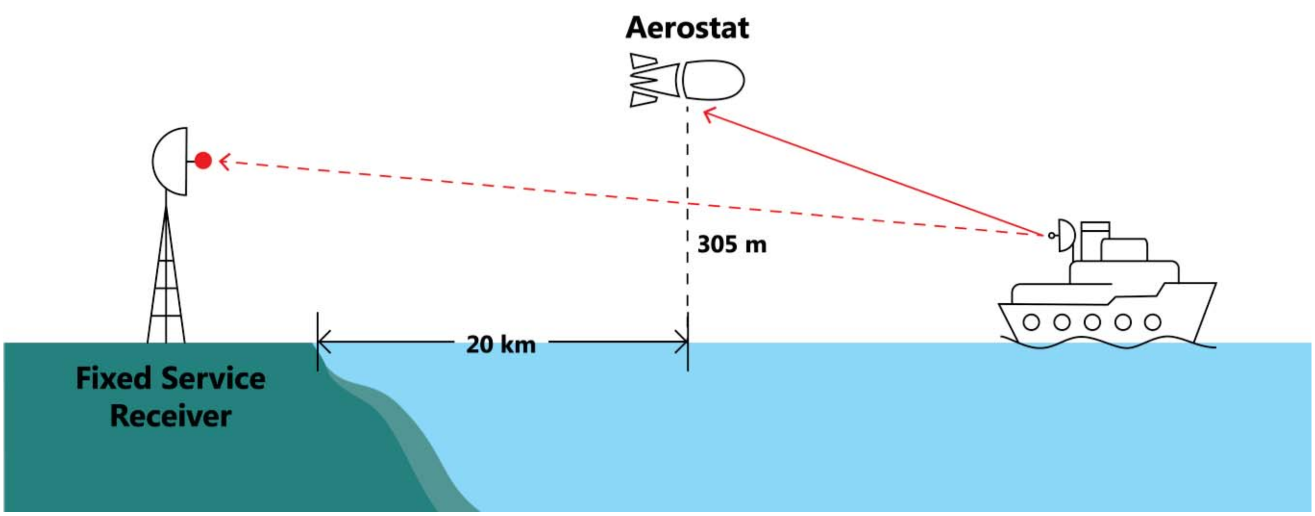

Figure 19: Ship transmitting to Aerostat

Ship Antenna Height AMSL (m)	Shore Station Antenna Height AMSL (m)	Ship to Shore Station Distance (km)	Ship to Shore Station Atmospheric Absorption Loss (dB)	Ship TX ATPC Power Reduction (dB)	Ship TX EIRP (dBm)	Aeronet Actual C/N (dB)	FS Receive Antenna Height AMSL (m)	FS Receiver Distance Behind Shore Station (km)	Ship to FS Receiver Distance (km)	Ship to FS Absorption Loss (dB)	Interference Level (dBm)	Margin (dB)
50	125	1	0.4	69.1	17.9	15	100	1	2	0.8	-68.4	-14.6
50	125	2	0.8	62.7	24.3	15	100	1	3	1.2	-65.9	-17.1
50	125	5	2.0	53.5	33.5	15	100	1	6	2.4	-64.0	-19.0
50	125	10	4.0	45.5	41.5	15	100	1	11	4.4	-63.2	-19.8
50	125	15	6.0	40.0	47.0	15	100	1	16	6.4	-63.0	-20.0
50	125	20	8.0	35.5	51.5	15	100	1	21	8.4	-62.8	-20.2
50	125	30	12.0	27.9	59.1	15	100	1	31	12.4	-62.7	-20.3
50	125	40	16.0	21.4	65.6	15	100	1	41	16.4	-62.6	-20.4
50	125	1	0.4	69.1	17.9	15	100	30	31	8.4	-103.8	20.8
50	125	2	0.8	62.7	24.3	15	100	30	32	8.8	-98.1	15.1
50	125	5	2.0	53.5	33.5	15	100	30	35	10.0	-90.9	7.9
50	125	10	4.0	45.5	41.5	15	100	30	40	12.0	-86.0	3.0
50	125	15	6.0	40.0	47.0	15	100	30	45	14.0	-83.5	0.5
50	125	20	8.0	35.5	51.5	15	100	30	50	16.0	-82.0	-1.0
50	125	30	12.0	27.9	59.1	15	100	30	60	20.0	-80.0	-3.0
50	125	40	16.0	21.4	65.6	15	100	30	70	24.0	-78.9	-4.1

Table 10: Ship → Shore Station Interference to FS Receivers if Boresight-to-Boresight

Ship Antenna Height AMSL (m)	Aerostat Antenna Height AMSL (m)	Ship to Aerostat Distance (km)	Ship to Aerostat Antenna Elevation Angle (deg)	Ship to Aerostat Atm. Abs. Loss (dB)	Ship TX ATPC Power Reduction (dB)	Ship TX EIRP (dBm)	Aeronet C/N (dB)	FS Receive Antenna Height AMSL (m)	FS Receiver Distance Behind Aerostat (km)	Ship to FS Receiver Distance (km)	Ship to FS Antenna Elevation Angle (deg)	Ship Antenna Off-Axis Angle (deg)	Ship Antenna Off-Axis Disc. (dB)	Ship to FS Atm. Abs. Loss (dB)	Int. Level (dBm)	Margin (dB)
50	304.8	1	14.6	0.4	69.1	17.9	15	100	20	21	0.1	14.5	47.7	8.4	-144.1	61.1
50	304.8	2	7.3	0.8	62.7	24.3	15	100	20	22	0.1	7.2	40.1	8.8	-131.0	48.0
50	304.8	5	2.9	2.0	53.5	33.5	15	100	20	25	0.0	2.9	30.4	10.0	-114.4	31.4
50	304.8	10	1.4	4.0	45.5	41.5	15	100	20	30	0.0	1.4	22.9	12.0	-102.4	19.4
50	304.8	15	0.9	6.0	40.0	47.0	15	100	20	35	0.0	1.0	18.4	14.0	-95.8	12.8
50	304.8	20	0.7	8.0	35.5	51.5	15	100	20	40	-0.1	0.7	16.5	16.0	-92.5	9.5
50	304.8	30	0.4	12.0	27.9	59.1	15	100	20	50	-0.1	0.5	12.8	20.0	-87.3	4.3
50	304.8	40	0.2	16.0	21.4	65.6	15	100	20	60	-0.2	0.4	7.7	24.0	-81.2	-1.8

Table 11: Ship → Aerostat Interference to FS Receivers

3.2.4 Aerostats Transmitting to Ships

Aerostats will be tethered in international waters -- at least 20 km (12 mi) offshore. Interference from aerostats to FS receivers will not occur if the 20 dB beam-width of the aerostat antenna is not directed towards land. For links from aerostats to ships further out to sea, this condition will be satisfied. If it is necessary to form links from aerostats to ships closer to shore, these also should be able to operate without interference to FS receivers if the down-tilt of the aerostat antenna provides enough off-axis angle towards land. Aeronet should incorporate the condition of a minimum off-axis angle towards land into its operations, either by only directing aerostat to ship transmissions out to sea, or by using down-tilt that ensures at least 20 dB off-axis discrimination towards land – a 1.1 degree separation for the 51 dBi antenna.

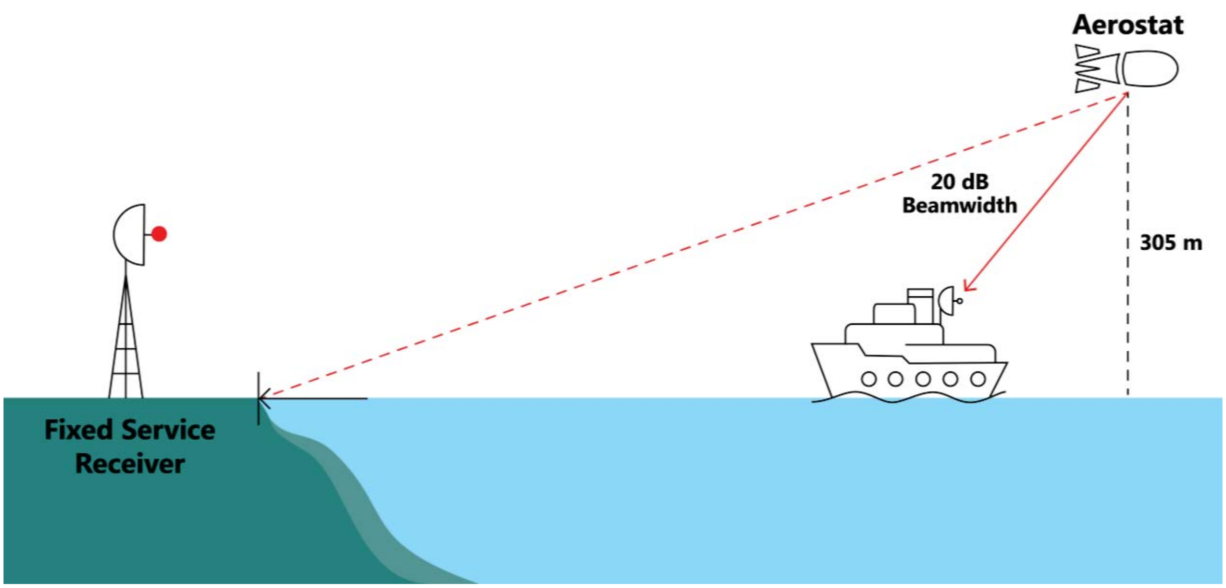

Figure 20: Aerostat transmitting to Ship

3.2.5 Ships Transmitting to Ships

Table 12 shows calculations for this scenario. Ship to ship links will be used to extend the range of the Aeronet system further out to sea. Therefore, for the boresight-to-boresight cases in the table (ship off-axis angle of zero), the ship to FS distance includes a 30 km offshore distance. This distance is sufficient to avoid harmful interference. If a ship to ship link must be used closer to shore, it will be necessary to ensure the ship antenna main beams are directed away from land. The last row in Table 12 represents a ship transmitting close to shore, but harmful interference is avoided by a 15 deg off-axis angle. To avoid the possibility of interference to FS receivers from its ship to ship links, Aeronet should incorporate the conditions of a minimum offshore distance or a minimum off-axis angle towards land into its operations.

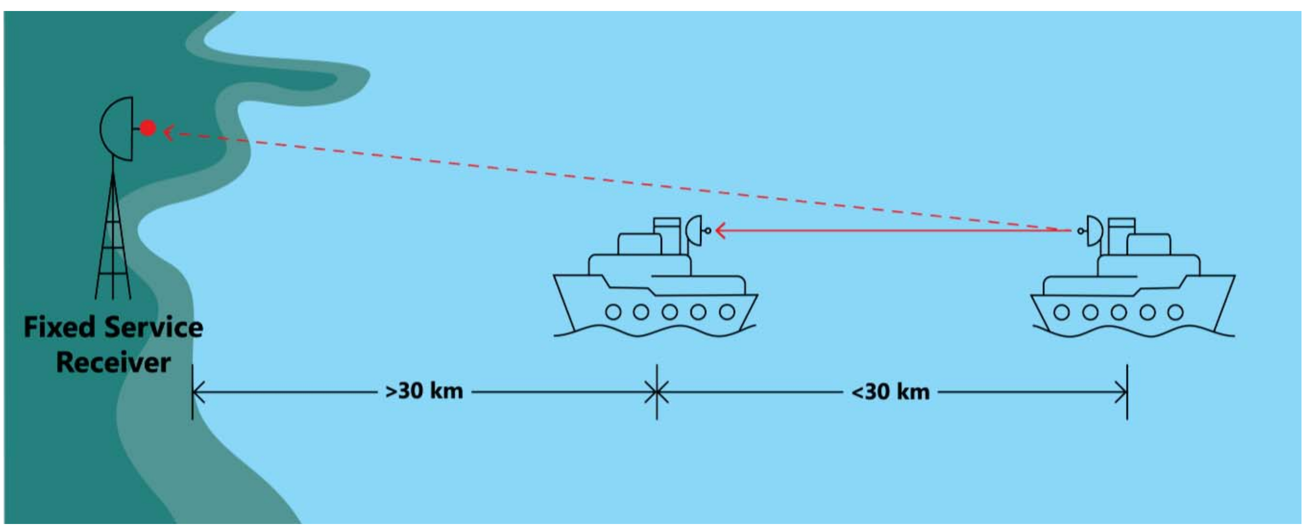

Figure 21: Ship transmitting to Ship

Ship to Ship Dist. (km)	Ship to Ship Atm. Abs. Loss (dB)	Ship TX ATPC Power Reduction (dB)	Ship TX EIRP (dBm)	Aeronet C/N (dB)	Ship to FS Receiver Distance (km)	Ship to FS Absorption Loss (dB)	Ship Antenna Off-Axis Angle (deg)	Ship Antenna Off-Axis Discrimination (dB)	Interference Level (dBm)	Margin (dB)
1	0.4	69.1	17.9	15	31	8.4	0	0.0	-103.8	20.8
2	0.8	62.7	24.3	15	32	8.8	0	0.0	-98.1	15.1
5	2.0	53.5	33.5	15	35	10.0	0	0.0	-90.9	7.9
10	4.0	45.5	41.5	15	40	12.0	0	0.0	-86.0	3.0
15	6.0	40.0	47.0	15	45	14.0	0	0.0	-83.5	0.5
20	8.0	35.5	51.5	15	50	16.0	0	0.0	-82.0	-1.0
30	12.0	27.9	59.1	15	60	20.0	0	0.0	-80.0	-3.0
30	12.0	27.9	59.1	15	4	0.8	15	48.4	-82.5	-0.5

Table 12: Ship → Ship Interference to FS Receivers

3.2.6 Shore Station to Aerostat and Aerostat to Shore Station

Aside from limited motion of the tethered aerostats, the shore station to aerostat links should operate like fixed links and can use the existing link database. The shore station to aerostat links will be at least 20 km (12 mi) long since the aerostats will be tethered in international waters.

Aeronet reports that the station-keeping of the tethered aerostats will be within the following limits: +/- 135 m laterally and -11 m vertically. For a link of greater than 20 km distance, the lateral allowance could cause the link azimuth to vary by less than 0.4 degree, while the vertical allowance could cause the link elevation angles to vary by less than 0.04 degree. The azimuth angle variation could be of consequence as the Aeronet antennas track each other, since an 0.4 degree difference in off-axis angle corresponds with up to a 9 dB difference in gain on the representative 51 dBi antenna pattern. The elevation angle variation is negligible. To ensure a conservative analysis for compatibility with other registered fixed links, Aeronet should use three registrations to represent the shore station to aerostat links in the database: the link with

the nominal or mean aerostat coordinates, and links with aerostat coordinates +/- 135 m perpendicular to the link azimuth.

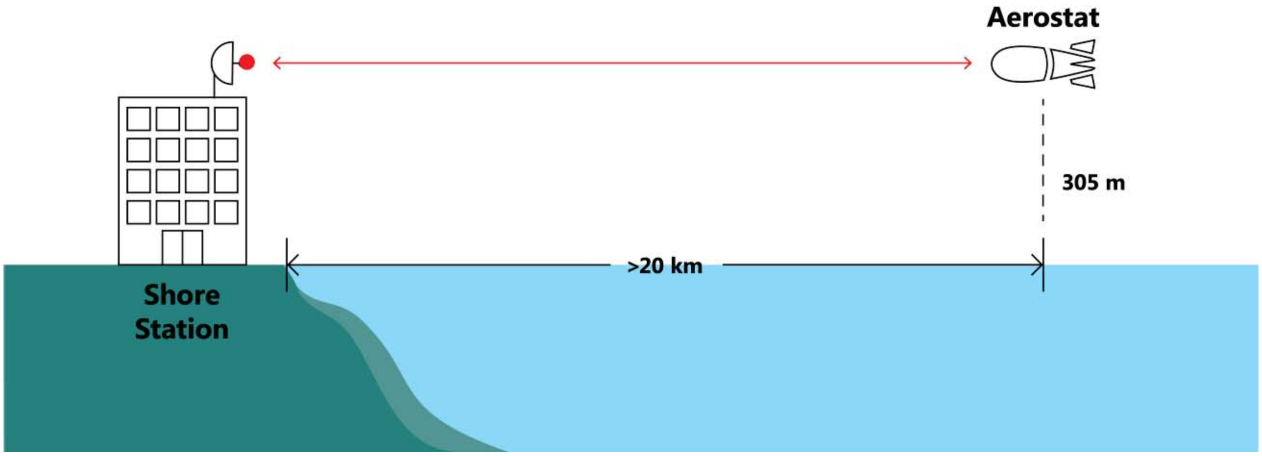

Figure 22: Shore Station to Aerostat Link

4 Recommendations and Conclusions

As described, fixed or quasi-fixed aspects of the Aeronet systems can be recorded and analyzed using the existing link registration database system. However, coordination zones near ground stations and shore stations will require development of new data, analysis, and coordination capabilities. New processes would be required to show compatibility between the Aeronet systems and fixed links in these areas. Aeronet should foster protection and growth of the incumbent fixed service by developing and providing these enhancements with transparency. Aircraft to aircraft and other maritime cases can avoid a requirement to register link information provided that Aeronet limits its operations to manage exposures to FS receivers.

For the aviation system, Aeronet will need to register its fixed ground stations. With minor changes to the data rules to allow wide beam antennas, the ground stations can be entered as link-ends in the existing link registration system. Potential interference into proposed FS links from the ground stations transmitting to aircraft would be addressed using the existing link by link interference calculations. Potential interference from aircraft transmitting to the ground stations would be analyzed using a new process triggered by proximity within 35 km of a proposed FS link to a ground station. Within this zone azimuth or elevation angle offset outside the 20 dB beam-width of the FS antenna would resolve nearly all cases. The few remaining cases would need to be evaluated using a new calculation of the worst-case interference from alignment of aircraft and FS antennas.

For aircraft transmitting to aircraft, Aeronet should restrict the number of fixed service antennas with any chance of harmful interference by using operational limitations of (1) a minimum slant

path distance and (2) possibly a minimum lower aircraft altitude above fixed service antennas in the geographic region. Under such limitations, the number of fixed service antennas that could be subject to boresight antenna alignment would be reduced from the total in the database to a manageable number. Aeronet would then have to keep track of these fixed service receivers and avoid forming co-channel links with boresight alignment to them. In these areas, one strategy would be to implement ground stations that would reduce the need for aircraft to aircraft links.

For the maritime system, Aeronet will need to register its fixed shore stations and aerostats and identify the ship operation areas. Links between shore stations and aerostats can be registered and their potential interference to FS receivers can be analyzed using the existing link registration system. With minor changes to the data rules to allow wide beam antennas, the shore stations can be entered as link-ends in the existing link registration system. Aeronet would have to identify the beam-width of the shore station antenna as the azimuth range that would include all possible paths to the ship operation area. Potential interference to proposed FS receivers from shore stations transmitting to ships would then be addressed using the existing link by link interference calculations. Potential interference into FS receivers from ships transmitting to shore stations would be analyzed using a new process triggered by location of a proposed FS link in a coordination zone inland from the shore station. The coordination zone would be a mirror image of the azimuth range from the shore station to the ship operation area (plus allowance for antenna roll-off) to a distance 30 km inland from the shore station. Within this zone azimuth or elevation angle offset outside the 20 dB beam-width of the FS antenna would resolve nearly all cases. The few remaining cases would need to be evaluated using a new calculation of the worst-case interference from alignment of ship and FS antennas. Interference

into FS receivers from ships transmitting to aerostats would not be harmful as shown. To avoid any possibility of interference into an FS receiver from an aerostat transmitting to a ship, Aeronet should use the operational limitation that aerostats should not direct the antenna towards land within the 20 dB beam-width. To avoid the possibility of harmful interference into an FS receiver from a ship transmitting to a ship, Aeronet should use operational limitations that a ship should be at least 30 km offshore to form an SDDL with another ship, or that a separation angle of at least 15 degrees towards land should be maintained.

The needed new data, analysis, and coordination functions involve recording coordination zones, implementing proximity triggers, applying antenna beam offsets, and calculating worst-case levels. Minor changes to the data rules of the existing link database would also be needed as discussed. Comsearch anticipates that implementing this functionality would be straightforward; however, detailed requirements – beyond the scope of this paper – would be needed to quantify the effort.

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