Attachment 1

Technical Description

The proposed aeronautical earth station in motion (ESIM) will operate in the same Ku-band network as previously authorized under call sign E050318 (File Nos. SES-LIC-20051028-01494, as amended; SES-MFS-20090624-00789, as amended). This modification adds three new antennas to the network, and two satellites for one antenna type. Two of the new antennas, the VR-18 (45 cm) and VR-12 (30 cm) antennas, are parabolic reflectors and are compliant with 47 CFR §25.218 off-axis e.i.r.p. density limits.

The third antenna, the **Ku**Karray, is a dual band mechanically steered waveguide horn array antenna with two apertures. The Ka-band aperture is already authorized on other Viasat Ka-band licenses. See Call Signs E120075, E180006. This modification request and all antenna discussion and analysis below pertain only to the Ku-band aperture of this antenna so bold font is used for the Ku portion of the **Ku**Karray antenna name going forward. Similarly, the modification request also only applies to the specific Ku band satellites listed in the application as points of communication for this antenna. This antenna complies with the Section 25.218(f) off-axis e.i.r.p. density levels in the GSO plane for routinely licensed earth stations, but does not meet such limits for regions in the plane perpendicular to the GSO arc, and thus Viasat requests a limited waiver of this requirement. In this Technical Description, Viasat demonstrates that the operations of the **Ku**Karray antenna will be compatible with the other services authorized in this band. For ease of reference, Viasat includes technical descriptions of the network and the KuKarray antenna relevant to the sharing discussions.

Network

The **Ku**Karray antenna will operate in the same Viasat ArcLight Ku-band network, using the same frequencies and access method, as ESIM authorized under call sign E050318. The ArcLight network supports two types of user links, code reuse multiple access ("CRMA"), a Viasat proprietary CDMA-like access method, and single channel per carrier ("SCPC"). The multiple access channel is described in complete detail in the attachments listed in the original application (SES-LIC-20051028-01494). The network allows the aircraft to fly across the service area and seamlessly switch from beam to beam within the current operational satellite and to switch between satellites, as coverage and traffic demands dictate.

The SCPC channel employs adaptive coding and modulation allowing the terminals to transmit at any code and modulation point within the library of available choices that the link supports. The available symbol rates are 6 mega-symbols per second, or megabaud (MBd) and 12 MBd.

The ArcLight architecture is designed to operate at the lowest power density modulation and code point that allows the link to close. The network employs adaptive power control and reduces power when conditions permit, keeping the Es/No margin at 1 dB or less above the intended operating point.

Additionally, the network employs a skew power control for the **Ku**Karray antenna type to compensate for the increased beamwidth in the elevation plane.

Antenna Description

The **Ku**Karray is a low-profile waveguide horn array fuselage mounted antenna. The **Ku**Karray is typically mounted as depicted in Figure 1 and covered by a radome.[1] The **Ku**Karray uses a 25 W SSPA and is capable of operating over the 14.0 – 14.5 GHz band. The maximum clear sky e.i.r.p. density uses the 6 MBd rate while operating in the SCPC channel. This results in a -12.11 dBW/4 kHz maximum e.i.r.p. density.

Figure 1 Antenna Installation on Commercial Airliner

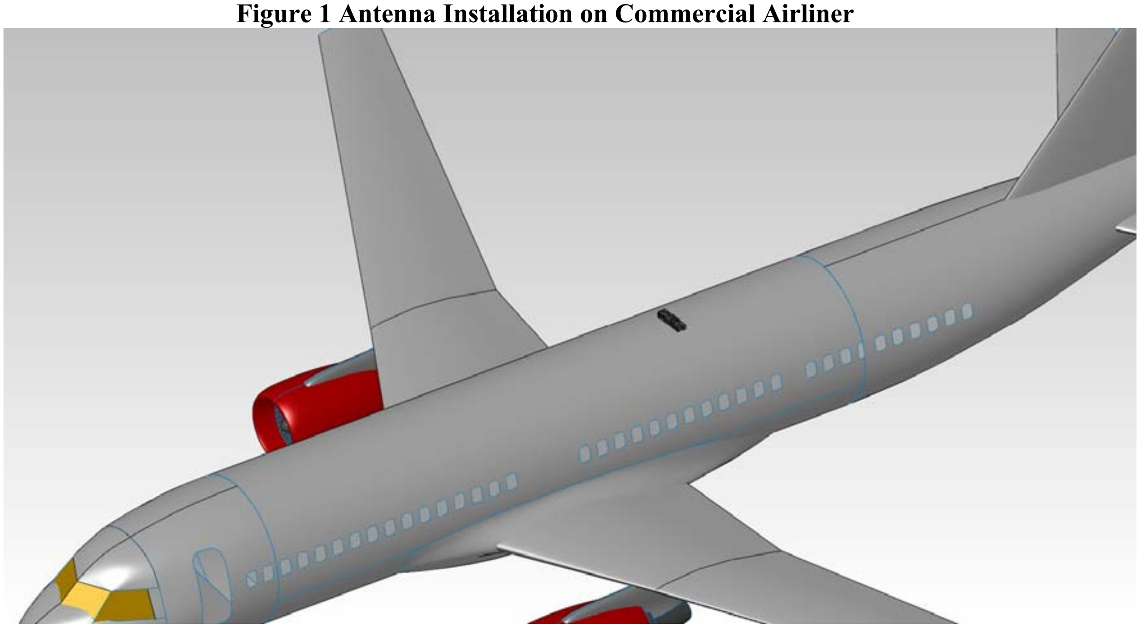


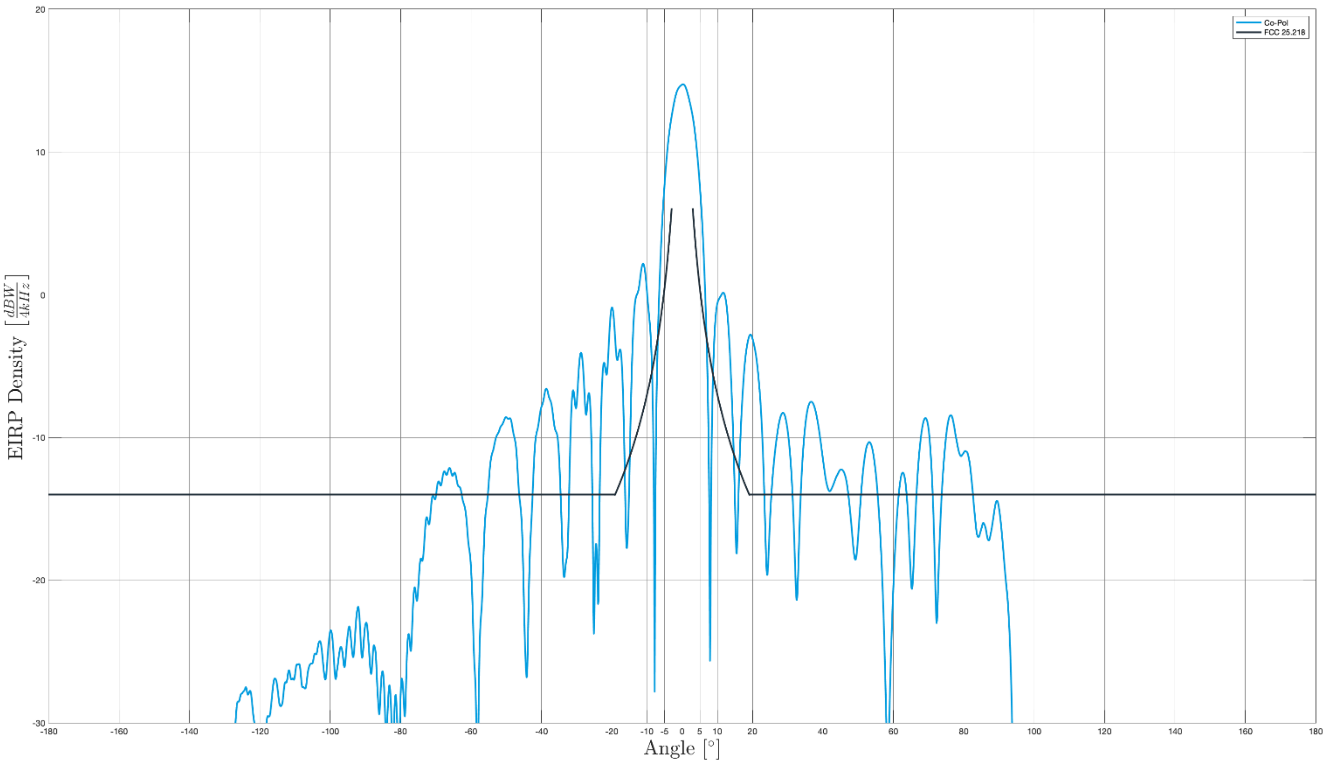
Figure 1 – Typical Antenna Mounting Location

Antenna Patterns

Viasat provides the antenna e.i.r.p. density patterns as Exhibit B to this application. The antenna patterns generated by the **Ku**Karray antenna differ from those typically encountered when considering circular or mildly elliptical reflector type antennas. The patterns for the **Ku**Karray are characterized by a narrow main beam and a line of sidelobes in the azimuth axis, a wide main beam and line of sidelobes in the elevation axis, and relatively low amplitude sidelobes elsewhere.

[1] The same radome may also house a receive-only antenna for DBS satellite TV services. The DBS satellite receive-only antenna and service are not associated with, or part of, this application.

Figure 2 Maximum Off-axis e.i.r.p. Density in Plane Perpendicular to GSO Arc



As discussed below, the e.i.r.p. density will be dynamically controlled such that the limits in the plane tangent to the GSO arc will always be met. However, the system is unable to reduce the main beam and sidelobes in the plane perpendicular to the GSO arc to levels that satisfy the limits in Section 25.218(f)(2) for skew angles less than 25 degrees therefore Viasat is seeking a waiver of this requirement as part of this application. In accordance with Section 25.115(g)(1)(viii), the exceedances of the off-axis e.i.r.p. density in the plane perpendicular to the GSO arc are shown in Exhibit C.

Protection of GSO

As a result of the wide elevation beam of the **Ku**Karray the ArcLight network employs a power control based on the skew angle. The terminal acquires the aircraft location from the antenna control unit ("ACU"), calculates the skew angle (also referred to as the tilt angle) and reduces power as needed to comply with Section 25.218 (f)(1). In this way, GSO satellites are protected as the e.i.r.p. density complies as seen from the GSO arc. Table 1 shows the reduction in e.i.r.p. as a function of the skew angle for the 6 MBd SCPC carrier.

Table 1 Skew Angle Power Control

Skew Angle [º]	Reduction in e.i.r.p. to Protect GSO [dB]
<=45	0
45 < x <= 50	0.31
50 < xº <= 55	1.38
55 < xº <= 60	2.63
60 < xº <= 65	4.07
65 < xº <= 70	5.71
70 < xº <= 75	7.52
75 < xº <= 80	9.35
80 < xº <= 85	10.82
85 < xº <= 90	12.25

Therefore, the **Ku**Karray antenna will fully comply with the limits in Section 25.218(f)(1) for the plane tangent to the GSO arc.

NGSO Sharing Analysis

The 11.7-12.2 GHz and 14.0.14.5 GHz portions of the Ku band are allocated on a primary basis to FSS operations. NGSO systems must not cause unacceptable interference to, or claim protection from, a GSO FSS network and must operate in compliance with the applicable EPFD limits in Article 22, Section II of the ITU Radio Regulations. As discussed above, the off-axis e.i.r.p. density in the plane perpendicular to the GSO arc exceed the limits in Section 25.218(f)(2), and thus, Viasat requests a waiver of this requirement. Grant of this waiver would not harm NGSO systems due to the limited nature of the exceedances and the mobile environment in which the proposed earth station and NGSO space stations operate.

Exhibit C provides the exceedances of off-axis e.i.r.p. density in the plane perpendicular to the GSO arc by frequency and skew angle. Because of the skew power control utilized to protect the GSO arc, discussed above, the exceedances do not occur for skew angles 25º and above. Figure 3 and 4 below shows the coverage area where the off-axis e.i.r.p. density could exceed the limits.

Figure 3 Coverage Area Less than 25º Skew Angle at 174°E

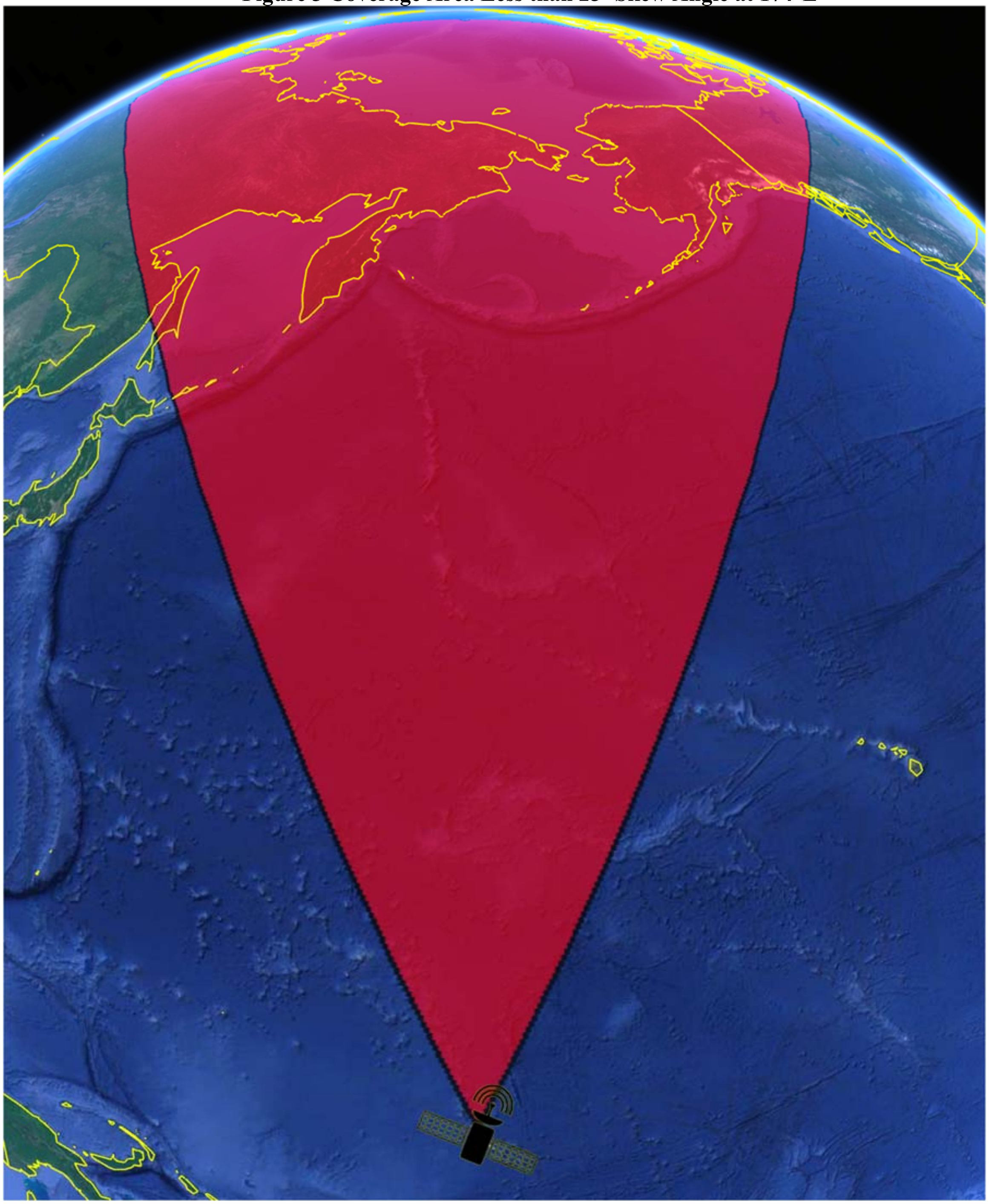
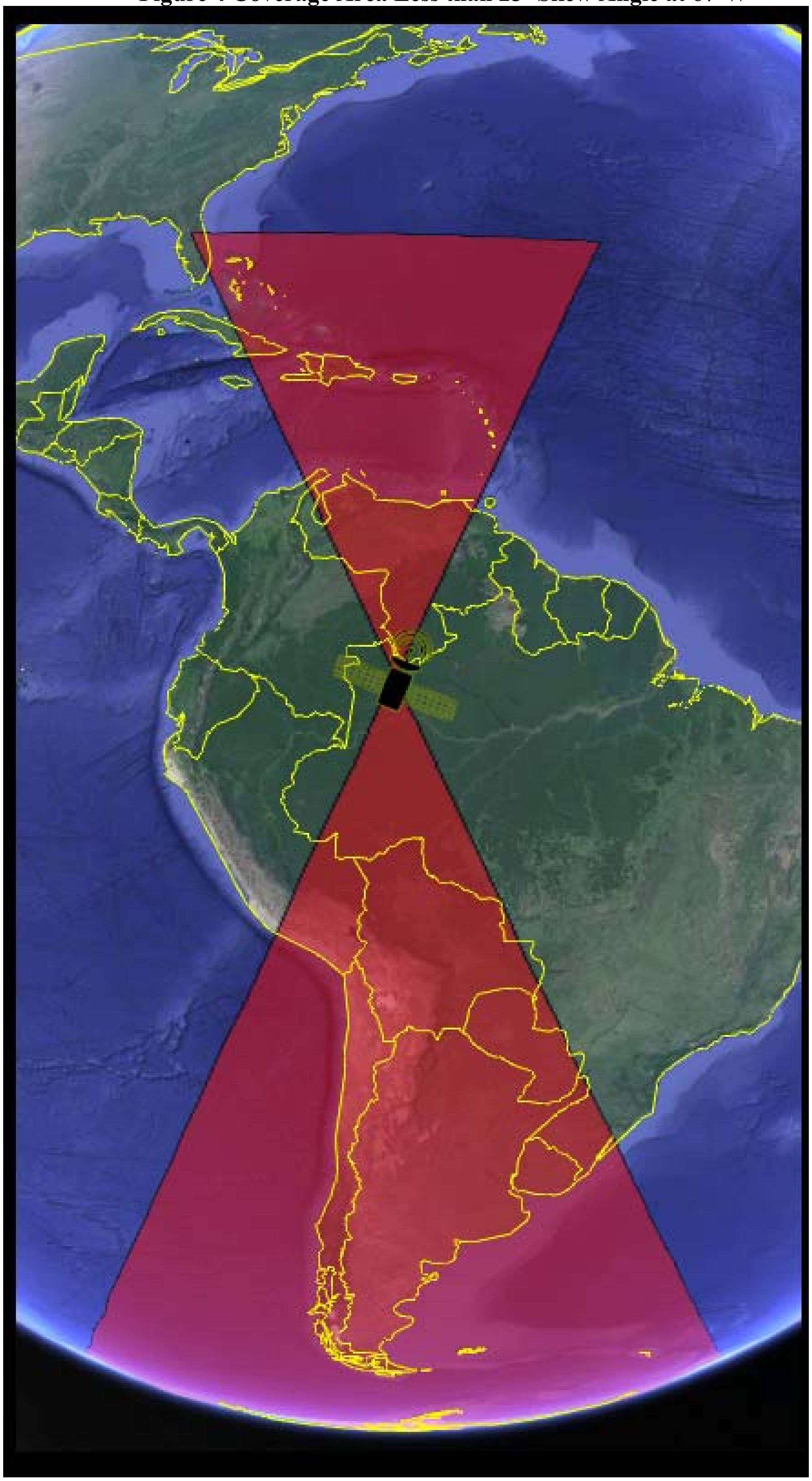


Figure 4 Coverage Area Less than 25º Skew Angle at 67ºW



Viasat conducted an interference analysis for the various NGSO systems with Ku-band payloads that have been granted market access to demonstrate compatibility with these systems. This analysis was conducted using the same methodology that Viasat provided and was approved by the Commission in the modification of Viasat's Ka-band ESIM license (SES-MOD-20190212-00172) to demonstrate that the Ka band earth stations that were the subject of that application could operate without causing harmful interference into co-frequency NGSO systems.

Analyses were performed for Space Norway, Karousel, Kepler, Theia, OneWeb, and SpaceX systems using the information in the Schedule S and technical narratives of the applications of the NGSO operators and using the technical characteristics of the **Ku**Karray from this application including the antenna pattern. The analysis for each system was conducted using the Visualyse Pro analysis software available from Transfinite Systems Ltd.

This analysis assumes the highest e.i.r.p. density operation of the **Ku**Karray antenna with respect to off-axis e.i.r.p. density, specifically, operation in an SCPC channel using the 6 Mbd carrier. Since the ESIM channel using SCPC is not a multiple-access scheme, only one ESIM transmits in a given frequency band within the regional Ku-band beam of the GSO satellite and hence within the spot beam of the NGSO systems.

In the simulation, ESIMs are placed near three U.S. airport locations in California: San Diego, Los Angeles and San Francisco. The Ku-band operating area for the **Ku**Karray will not include CONUS because the antennas will switch over to Ka band operations when approaching the West Coast of the U.S. The **Ku**Karray antenna will operate within and over Alaska and Hawaii. Because operation within CONUS will be on Ka-band, Ku-band compatibility over CONUS is not part of this analysis. Therefore, the analysis that follows considers aircraft in level flight near CONUS and during takeoff and landing within Alaska and Hawaii in the 14.0 – 14.5 GHz band.

User terminals (or gateways if operating in the 14.0 – 14.5 GHz band) of the NGSO system were placed next to the ESIM airport locations in Fairbanks, Alaska and Hilo, Hawaii. ESIM routes were simulated from Los Angeles to Tokyo, San Diego to Hawaii and San Francisco to Hawaii via Fairbanks, Alaska. These routes were repeated until the simulation ended. The orbit of the NGSO system was propagated for a 2-day period while the ESIM, flying routes within the Ku-band GSO beam, transmitted, as required to support commercial aircraft services in order to generate I/N statistic over time. These simulations use ESIM in moving scenarios, which is a realistic representation of the actual operation on the Ku-band network and was performed to develop worst-case I/N and interference statistics.

The exception to the scenario described was the Space Norway system as the service area is limited to latitudes above 55º. In this case, ESIM are located near airports in San Francisco and Los Angeles with routes to Fairbanks, Alaska and Tokyo, Japan.

While long- and short-term interference criteria have not yet been established for these NGSO systems for which Article 22 applies in this portion of Ku-band, a reasonable benchmark to check for the presence of potential interference is the 6% DT/T coordination trigger generally used by GSO FSS. The Commission's rules also utilize this threshold as the trigger for the default band-splitting procedures for sharing among NGSO FSS networks. *See* 47 C.F.R. § 25.261(c). This value is equivalent to an I/N of -12.2 dB and represents an increase in the noise floor of the receiver of just 0.25 dB. If received I/N is greater than -12.2, but only for brief intervals and for a very small percentage of time, the brief noise floor increases are generally considered short-term interference, which are typically acceptable. Higher levels of short term I/N for periods of time less than 10% are envisioned in Recommendation ITU-R S.1323 “Maximum permissible levels of interference in a satellite network (GSO/FSS; non-GSO/FSS; non-GSO/MSS feeder links) * in the fixed-satellite service caused by other codirectional FSS networks below 30 GHz.”

The results are presented in Table 2 for the simulations of the different NGSO systems under this worst-case scenario. Two of the systems, Space Norway and Karousel, showed no I/N values above the -12.2 dB threshold which is expected given the service area and/or orbit type. The remaining four systems have potential interference events above the -12.2 dB threshold. However, those events are of a short-term nature, and represent a small percentage of the simulated flight route. Only the Theia system had an interference event above -12.2 dB I/N while within the Ku-band coverage requested in this modification.

Table 2 Simulation Results for the Various NGSO systems

System	-12.2 dB I/N Exceeded	Total Exceeded (sec) / 48 hours	% Time Exceeded -12.2 dB	% Time Meeting -12.2 dB	Worst I/N (dB)	Longest Event (sec)	Separation Angle (deg)
Space Norway	No	0	0.00%	100.00%	-22.28	0	35.40
Kepler	Yes	17	0.0098%	99.99%	-2.91	9	20.00
Karousel	No	0	0.00%	100.00%	-44.70	0	35.00
OneWeb	Yes	6	0.0034%	99.997%	-10.92	6	5.90
SpaceX	Yes	17	0.0098%	99.99%	-6.55	7	22.00
Theia Holdings	Yes	8	0.005%	99.995%	-11.05	8	10.00

The results for the simulations show that a DT/T = 6% is met greater than 99.99% of the time for all NGSO systems. It should be noted that the longest interference event and the highest I/N event are not necessarily correlated. Figures 5 through 8 show the CDF curves of the worst-case I/N for the simulated 2 days.

Figure 5 Interference into Kepler System

KuKarray Ku-band Aero into Kepler User Link : Carlsbad Statistics Plot

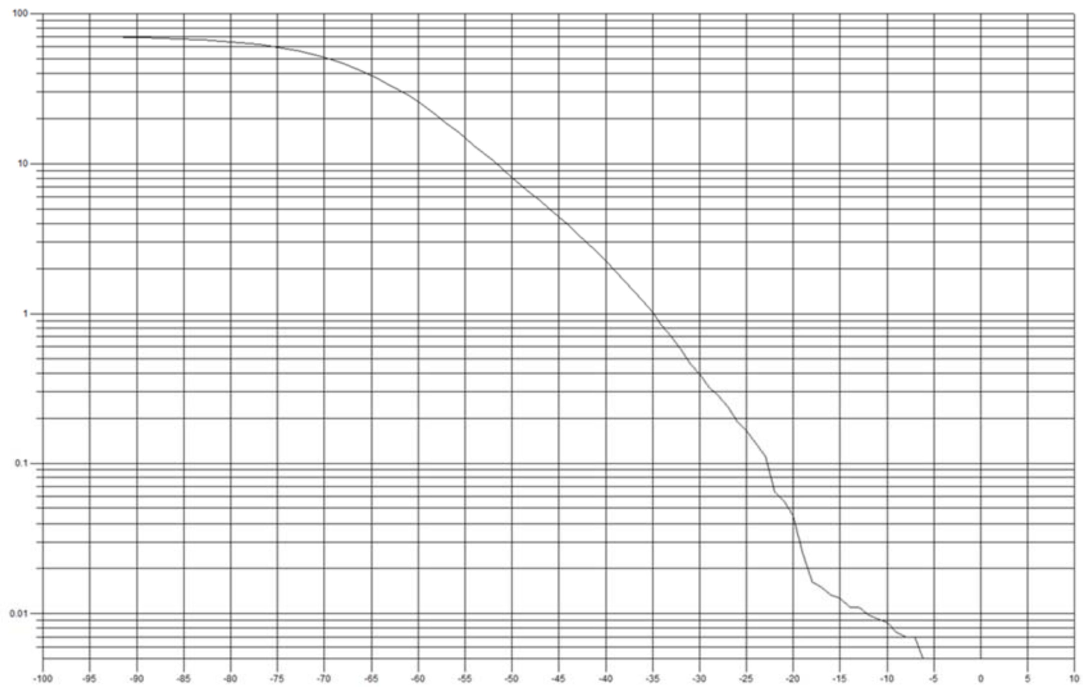


Figure 6 Interference into the OneWeb System

KuKarray Ku-band Aero into OneWeb User Link :Carlsbad Statistics Plot

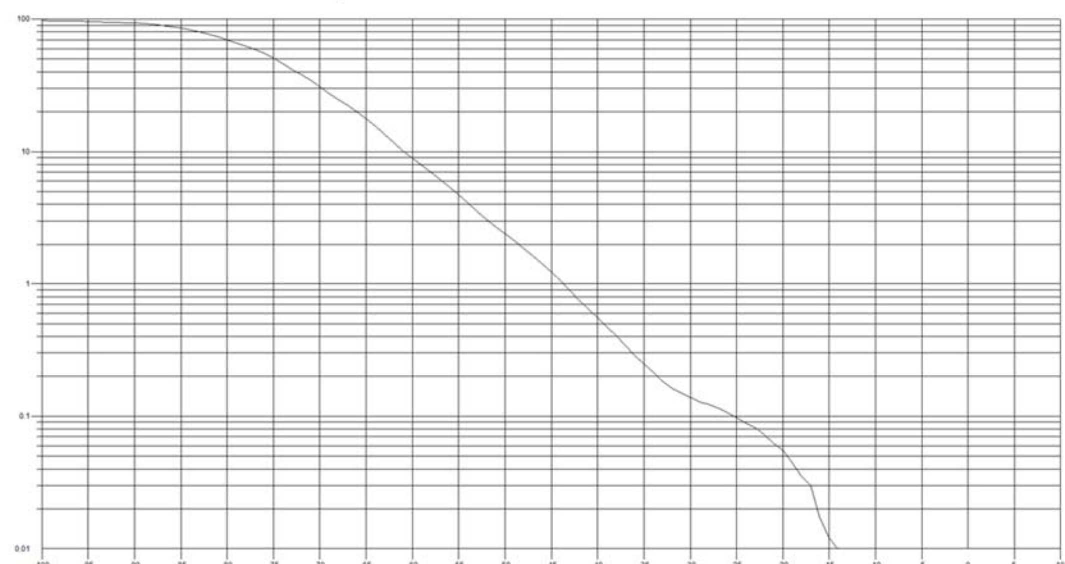


Figure 7 Interference into the SpaceX System

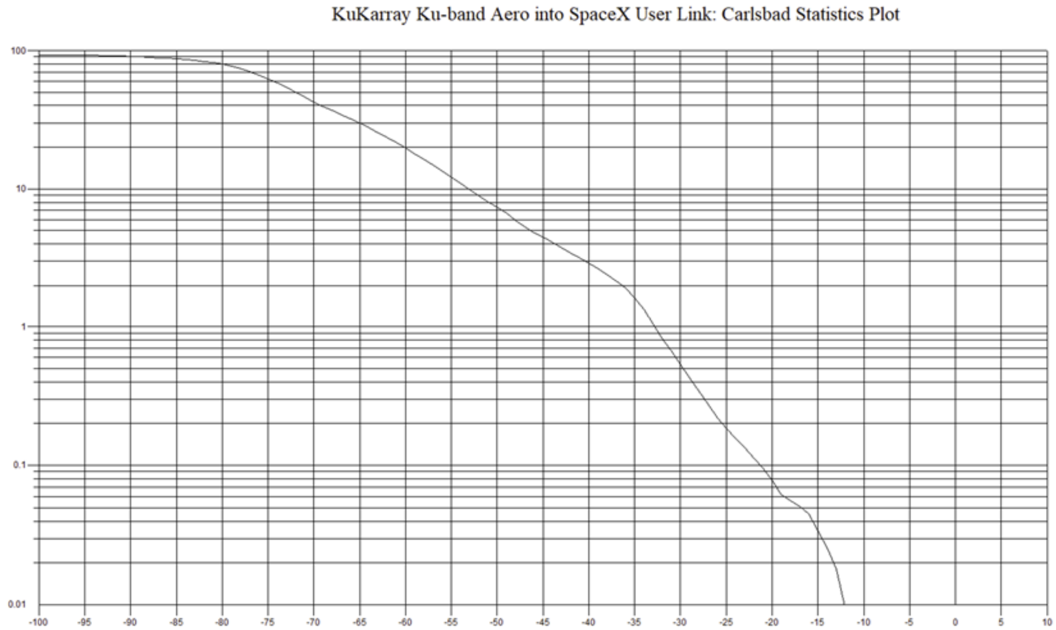
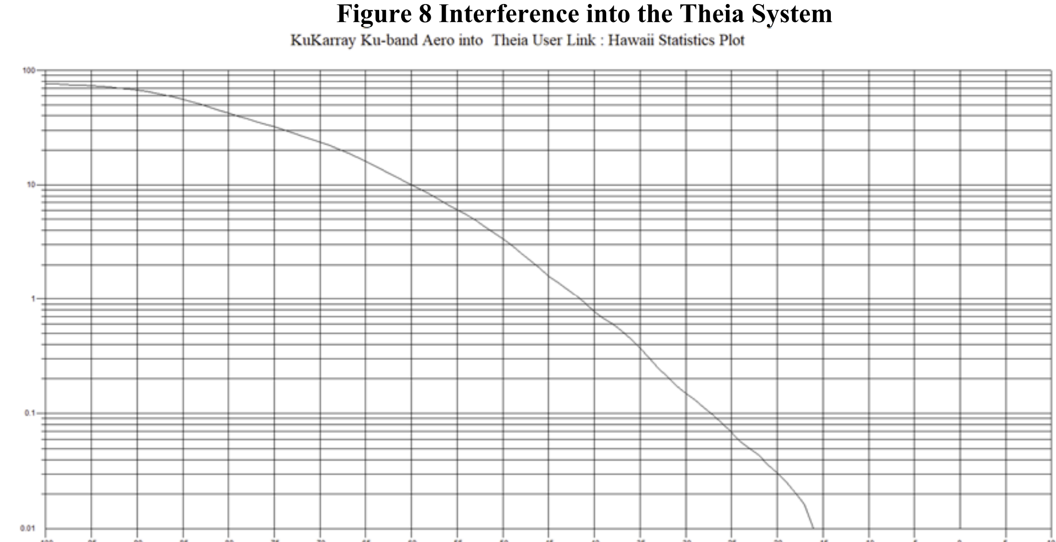


Figure 8 Interference into the Theia System



As described above, only a single ESIM may transmit at any given time within an assigned SCPC channel. The GSO receiving beams are large regional beams so only one location in that region has the potential for an alignment between the **Ku**Karray antenna and the NGSO system in a given SCPC channel. Said differently, there is only one aircraft within the large regional beam of the GSO coverage that potentially can cause interference into a given NGSO satellite for a given SCPC frequency channel. Because the aircraft and the NGSO satellite are both moving, any such interference that may occur would be of a fleeting nature.