SPACEX NON-GEOSTATIONARY SATELLITE SYSTEM

ATTACHMENT A
TECHNICAL INFORMATION TO SUPPLEMENT SCHEDULE S

A.1 SCOPE AND PURPOSE

SpaceX has been granted authority to construct, deploy, and operate up to 7,500 satellites in its second-generation ("Gen2") non-geostationary orbit ("NGSO") Fixed-Satellite Service ("FSS") system ("Gen2 system") at altitudes of 525, 530, and 535 km and inclinations of 53, 43, and 33 degrees, respectively, using frequencies in the Ku- and Ka-band.[1] The Gen2 system is designed to provide high-speed, low-latency next generation satellite broadband service to Americans throughout the country, including those Americans living and working in unserved or underserved areas.

In the course of the proceeding leading to the Gen2 system authorization, SpaceX undertook a commitment to modify its existing authorization to operate a separate V-band NGSO system by placing V-band radio equipment on a subset of proposed Gen2 spacecraft.[2] By doing so, SpaceX would reduce the total number of authorized satellites to be deployed, enabling it to enhance space sustainability while also augmenting its ability to deliver the robust broadband service demanded by American consumers and businesses.

With this application, SpaceX proposes to fulfill that commitment. Specifically, SpaceX requests authority to modify its V-band license so that it may deploy and operate V-band payloads on up to the 7,500 Gen2 spacecraft currently authorized at altitudes of 525, 530, and 535 km and

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[1] *See Space Exploration Holdings, LLC*, FCC 22-91 (rel. Dec. 1, 2022) ("*Gen2 Authorization*").
[2] *See id.* ¶¶ 2, 4, 19.

inclinations of 53, 43, and 33 degrees, respectively.[3] By implementing SpaceX's commitment, this modification will enable SpaceX to make productive and valuable use of V-band frequencies without the need to deploy the 11,943 separately authorized space stations in SpaceX's current V-band license.[4]

In this application for modification, SpaceX also seeks to authorize V-Band communications between SpaceX satellites in the Gen2 system and earth stations (both gateways and user terminals, as in the current V-band license) at elevation angles no less than 25 degrees for three frequency bands (40.0-42.5 GHz (downlink); 47.2-50.2 GHz (uplink); and 50.4-51.4 GHz (uplink)) while maintaining the license's current minimum elevation angle of 35 degrees for the 37.5-40.0 GHz band.[5] To accommodate this change in elevation angle for the 40.0-42.5 GHz downlink band, SpaceX will reduce the maximum downlink power flux density ("PFD") on the Earth's surface by 8 dB in that band as compared to the current V-band system. These changes will make SpaceX's V-band system more efficient and better able to serve American consumers while avoiding any significant interference problem.

To operate more efficiently on the uplink and also reduce potential interference into other systems, SpaceX will also reduce maximum EIRP from its earth stations transmitting at 47.2-50.2 GHz and 50.4-51.4 GHz by 7 dB. This change primarily accounts for the difference in the

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3 We provide updated antenna beam contours in the accompanying Schedule S, as discussed in Section A.3 *infra*. SpaceX will deploy parabolic antennas for V-band operations.

4 Application for Approval of Orbital Deployment and Operating Authority for the SpaceX V-band NGSO Satellite System, IBFS File No. SAT-LOA-20170301-00027 (May 26, 2020) ("V-band Application" or "Previous Application"), Attachment A at 1-2 (4425 satellites at an altitude over 1100 km and 7518 satellites at altitudes from 335-346 km); *see also Space Exploration Holdings, LLC*, 33 FCC 11434, ¶ 3 (2018) ("*V-band Authorization*") (authorizing 7,518 space stations to operate at altitudes from 335 km to 346 km and 4,425 space stations to operate at altitudes above 1,100 km); Stamp Grant, IBFS File No. SAT-LOA_20170301-00027 (June 9, 2020) (authorizing use of the 50.4-51.4 GHz).

5 *See* V-band Application, Attachment A at 8, 18.

maximum altitude of the satellites in the Gen2 system at 535 km and the satellites in the current V-band system at 1150 km; in other words, SpaceX no longer needs to reach satellites at 1150 km altitude with V-band uplink transmissions from its earth stations so it can reduce uplink power in the amount of the spreading loss difference between 535 km and 1150 km, which is 6.64 dB.[6] This change will allow SpaceX to maintain the advantages of its modified V-band system and operate more efficiently, again without presenting a significant interference problem.

SpaceX requests no other technical changes to its authorization at this time, and certifies that all other technical information provided in its previous V-band application remains unchanged.[7]

This modification to the V-band Authorization will meet all required protection criteria for other systems operating in the same frequencies, and presents no significant interference problems for other systems authorized in the band. Moreover, because SpaceX adds no new satellites through this modification—and in fact eliminates the need to launch nearly 12,000 more satellites—SpaceX will meet or exceed all space sustainability requirements.

This attachment contains the updated technical information with respect to the newly proposed operations required under Part 25 of the Commission's rules that cannot be fully captured by the Schedule S software. The accompanying Schedule S reflects the system as it will operate once modified and fully deployed.[8]

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6 The spreading loss difference between 1150 km and 535 km is $20*\log_{10}(1150km/535km) = 6.64dB$ (~7 dB).

7 *See* 47 C.F.R. § 25.117(c); *see also* V-band Application.

8 The Schedule S includes a representative channel plan for each beam. SpaceX anticipates that these channels will either be bonded into various combinations to create larger effective channel sizes, or subdivided into smaller ones, depending on operational needs.

A.2 OVERALL DESCRIPTION

This information is generally available in Attachment A ("Technical Information to Supplement Schedule S") to the Previous Application. Based on SpaceX's success in deploying over 3,900 satellites in its first-generation NGSO FSS constellation, its success in beginning to launch satellites into its Gen2 system, and its experience in operating thousands of satellites to provide high speed, low latency broadband service to American consumers and Federal users, SpaceX now proposes a modification to eliminate its separate V-band system consisting of 11,943 separately authorized space stations and instead to deploy V-band payloads on the 7,500 satellites currently authorized in its Gen2 system. This change will result in significant reduction in the number of overall approved SpaceX satellites while maintaining and relying on the considerable space sustainability attributes of its Gen2 system.

Tables A.2-1 and A.2-2 below summarize the configuration of SpaceX's currently authorized V-band NGSO constellation, which includes satellites in low earth orbit ("LEO") and very low earth orbit ("VLEO").

Orbital Planes	32	732	8	5	6
Satellites per Plane	50	50	50	50	75
Altitude (km)	1,150	1,110	1,130	1,275	1,325
Inclination	53°	53.8°	74°	81°	70°

Table A.2-1. Currently Authorized V-Band NGSO System in LEO

Satellites per Altitude	2,547	2,478	2,493
Altitude (km)	354.6	340.8	335.9
Inclination	53°	48°	42°

Table A.2-2. Currently Authorized V-Band NGSO System in VLEO

Table A.2-3 below summarizes the configuration under the proposed modification. The modified V-band system consists of V-band radio equipment on the same satellites as in the authorized Gen2 system, consisting of V-band payloads on up to 3,360 satellites in each of the

43-degree and 53-degree inclination orbits and up to 780 satellites in the 33-degree inclination orbits.

Orbital Planes	28	28	28
Satellites per Plane	120	120	28 in 24 planes 27 in 4 planes
Altitude (km)	525	530	535
Inclination	53°	43°	33°

Table A.2-3. Summary of Proposed Modified V-Band NGSO System

A.3 PREDICTED SPACE STATION ANTENNA GAIN CONTOURS

The antenna gain contours for the transmit and receive V-band beams for a representative space station operating in the 525-535 km altitude range are embedded in the associated Schedule S, as required by Section 25.114(c)(4)(vi)(B). Below we describe the methodology for their presentation.

All downlink spot beams on each SpaceX satellite are independently steerable over the full field of view of the Earth. Yet earth stations communicate only with satellites above a minimum elevation angle. Figure A.3-1 below illustrates the steerable service range of satellite beams using generalized parameters.

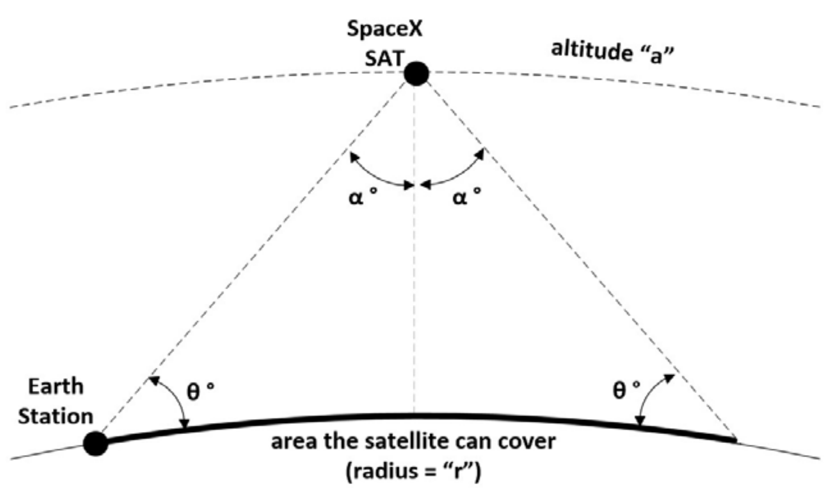

Figure A.3-1: Steerable Service Range of Satellite Beams

Tables A.3-1 and A.3-2 provide the specific values for the parameters in Figure A.3-1 for each of the orbital altitudes proposed herein for the modified V-band system based on the minimum earth station elevation angles (θ) involved. Table A.3-1 corresponds to transmissions at the minimum elevation angle for 40.0-42.5 GHz (downlink); 47.2-50.2 GHz (uplink); and 50.4-51.4 GHz (uplink). Table A.3-2 corresponds to transmissions at the minimum elevation angle for 37.5-40.0 GHz band (downlink).

altitude "a" [km]	525	530	535
Max steering angle α [deg]	56.9	56.8	56.7
Coverage radius "r" [km]	905.6	912.7	919.7

Table A.3-1: Values for 25° Minimum Elevation Angle θ

altitude "a" [km]	525	530	535
Max steering angle α [deg]	49.2	49.1	49.1
Coverage radius "r" [km]	647.3	652.4	657.7

Table A.3-2: Values for 35° Minimum Elevation Angle θ

A.3.1 V-Band Beams

Gateways and user terminals only communicate with satellites above a specified minimum elevation angle. In the current V-band license, the minimum angle is 35 degrees. As indicated above, however, this application seeks to modify the minimum elevation angle to 25 degrees in certain frequency bands so that satellites may communicate more efficiently with earth stations.

The antenna beam contours are provided in Schedule S by plotting antenna gain contours (for both uplink and downlink beams) for operations of parabolic antennas at 530 km altitude at nadir and at 25, 45, and 57 degrees away from nadir (which are essentially the same for operations at 525 km and 535 km altitudes). As illustrated in Figure A.3.1-1 and A.3.1-2 below for operations at 530 km in 40-42.5 GHz and 37.5-40 GHz, respectively, as the transmitting beam is steered, the power is adjusted to maintain a constant maximum PFD at the surface of the Earth, compensating for variations in antenna gain and path loss associated with the steering angle.

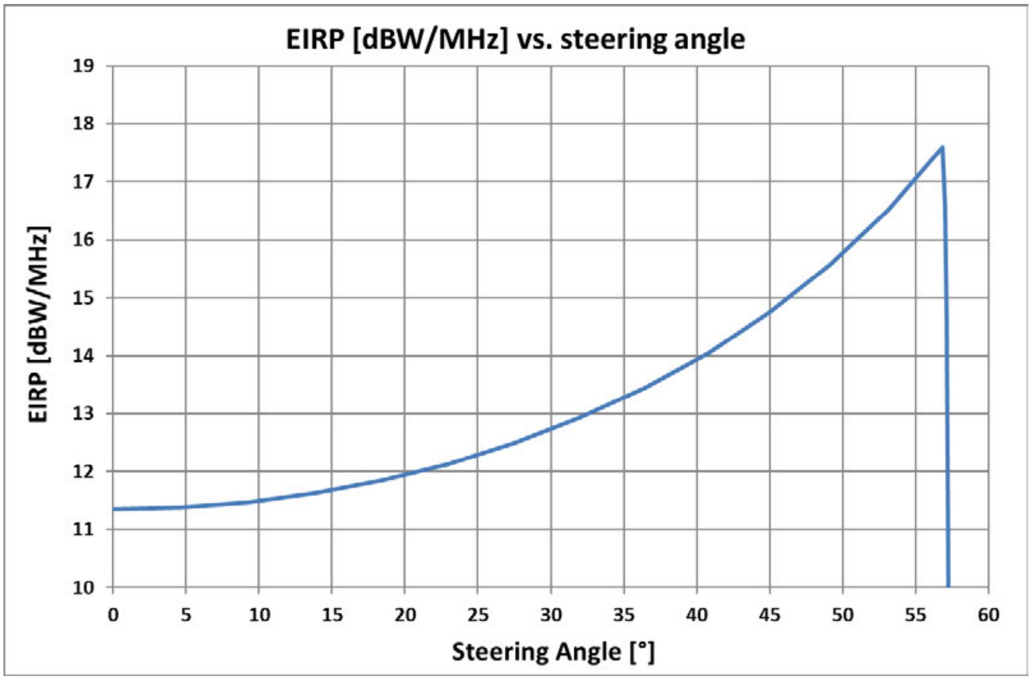

Figure A.3.1-1. EIRP Density Variation by Beam Steering Angle in 40-42.5 GHz (530 km)

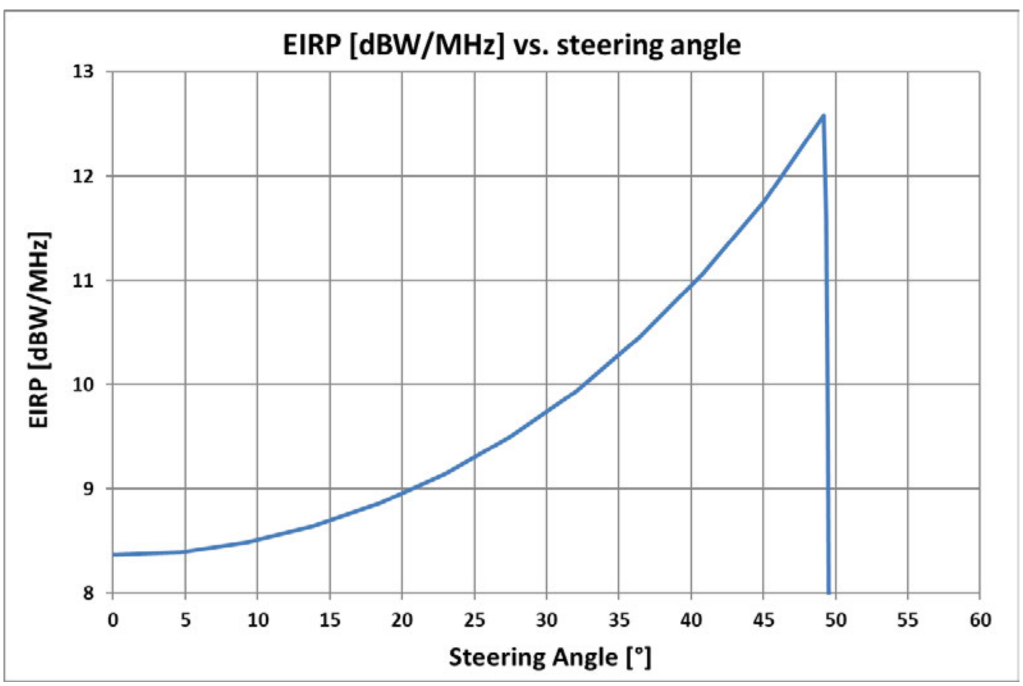

Figure A.3.1-2. EIRP Density Variation by Beam Steering Angle in 37.5-40 GHz (530 km)

Table A.3.1-1 shows the maximum equivalent isotropically radiated power ("EIRP") density at the various altitudes in the modified V-band system.[9]

Altitude [km]	Max EIRP [dBw/MHz]
525 km	17.6
530 km	17.7
535 km	17.8

Table A.3.1-1: Maximum V-Band EIRP Density by Altitude[10]

A.3.2 TT&C Beams

The modified SpaceX V-band system will rely on the authorized TT&C operations of the Gen2 system. This information is available in Attachment A to the Gen2 application, as amended,[11] and in its authorization by the Commission.[12] The modified SpaceX V-band system will not use V-band beams for TT&C.

A.4 CESSATION OF EMISSIONS

This information is available in Attachment A to the Previous Application.

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9 Section 25.114(c)(4)(v) requires both the minimum and maximum saturation flux density ("SFD") values for each space station receive antenna that is connected to transponders. The concept of SFD only applies to "bent pipe" satellite systems, and thus is not relevant to the constellation. However, because the Schedule S software requires a numerical entry for SFD (which must be different for maximum and minimum), SpaceX has entered values of "0" and "-0.1."

10 Note that the EIRP and EIRP density values provided on Schedule S reflect operations at 535 km where EIRP is highest.

11 *See* Amendment to Application for Approval of Orbital Deployment and Operating Authority for the SpaceX Gen2 NGSO Satellite System, IBFS File No. SAT-AMD-20210818-00105 (filed, Aug. 18, 2021) ("Gen2 Amendment").

12 *See Gen2 Authorization*.

A.5 COMPLIANCE WITH PFD LIMITS

A.5.1 General Discussion

Under the proposed modification, SpaceX will incorporate V-band radio technology into Gen2 systems, as approved, as reflected in Table A.2-3. The lowest orbital shell of satellites in this modified V-band system would therefore operate at an altitude of 525 km.

SpaceX plans to operate its modified V-band system in a manner that complies with applicable PFD limits.[13] To illustrate, Table A.5.1-1 below shows the PFD calculation for satellite operations at 525 km using V-band beams to communicate with earth stations at nadir, at maximum slant of 25 degrees for 40.0-42.5 GHz, and maximum slant of 35 degrees for 37.5-40.0 GHz. This table reflects satellite operation using V-band beams at the lowest altitude in the constellation at nadir and maximum slant, which presents a worst-case PFD scenario without considering any of the operational constraints discussed above.

	40.0-42.5 GHz			**37.5-40.0 GHz**	
	nadir	**35° ES elev**	**25° ES elev**	**nadir**	**35° ES elev**
EIRP in 1MHz [dBW/MHz]	11.4	15.6	17.6	8.4	12.6
Distance to Earth [km]	525	853.4	1077.9	525	853.4
Spreading loss [dB]	125.4	129.6	131.6	125.4	129.6
PFD in 1 MHz [dB(W/m^2/1MHz)]	-114.0	-114.0	-114.0	-117.0	-117.0

Table A.5.1-1. PFD at the Surface of the Earth Produced by V-band Downlink Transmissions (525 km)

In addition, because the satellite downlink transmit power is adjustable on orbit, SpaceX has the ability to manage each satellite's PFD levels during all phases of the mission, as needed. Below,

13 *See* 47 C.F.R. §§ 25.208(r), (t).

we plot these PFD values against the relevant PFD limits applicable in the various frequency bands used by the SpaceX system.

A.5.2 PFD Limits in the V-Band

The PFD limits imposed by the Commission and the International Telecommunication Union ("ITU") in the V-band apply on a per-satellite basis. In its Previous Application, SpaceX demonstrated that it would comply with applicable per-satellite PFD limits. Under the proposed modification, SpaceX would operate satellites at altitudes as low as 525 km, representing a worst-case analysis that shows how SpaceX will satisfy applicable PFD limits.

The Commission and ITU have adopted different downlink PFD limits for different portions of the V-band spectrum used by the SpaceX V-band system. For each of these limits, SpaceX demonstrates compliance by plotting the relevant limit and the worst-case PFD of a satellite operating in the 525 km shell with earth stations at a minimum elevation angle of 25 degrees for 40.0-42.5 GHz and a minimum elevation angle of 35 degrees for 37.5-40.0 GHz. [14] As stated above, for satellite operations in the 40.0-42.5 GHz frequency range, SpaceX will reduce maximum downlink PFD by 8 dB — from -106 $dBW/m^2/MHz$ in the current V-band system to -114 $dBW/m^2/MHz$ in the modified system — to ensure there is no significant interference problem.

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[14] *See id.*

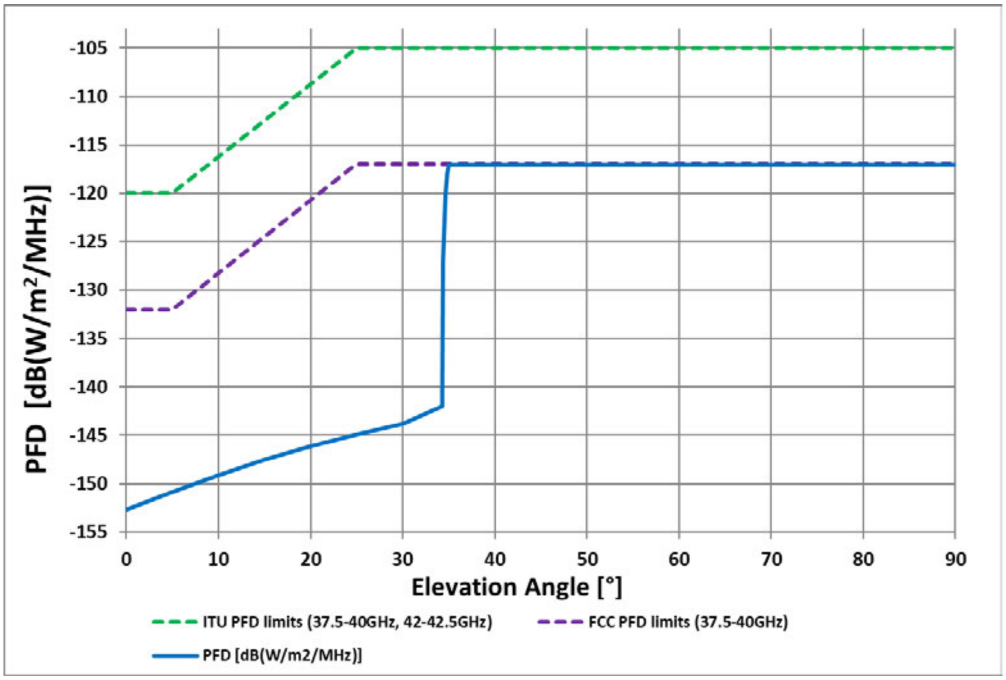

Figure A.5.2-1. Compliance with Downlink PFD Limits at 37.5-40.0 GHz (525 km)

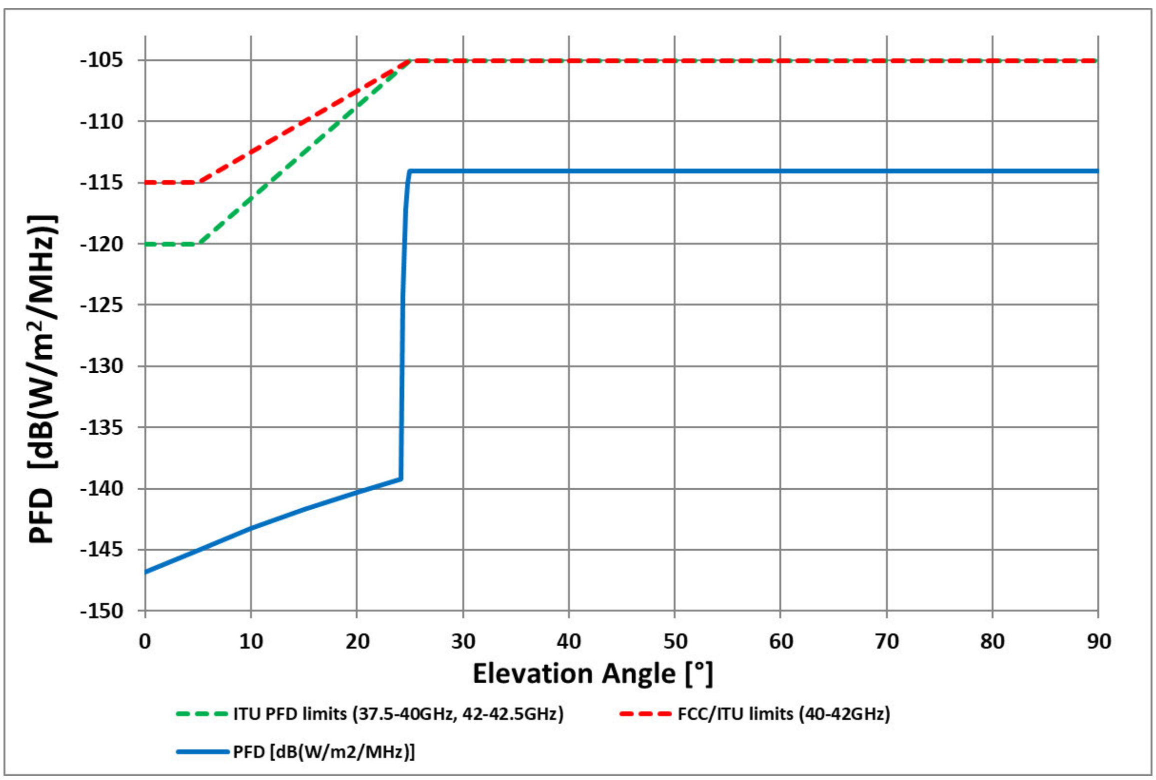

Figure A.5.2-2. Compliance with Downlink PFD Limits at 40.0-42.5 GHz (525 km)

Operations at this lowest shell provide a worst-case PFD scenario, yet as these figures demonstrate, still remain compliant. Accordingly, all V-band downlink transmissions from SpaceX satellites operating in the modified V-band system will comply with all applicable Commission and ITU PFD limits.

A.6 INTERFERENCE ANALYSES

The Commission has recognized that a proposed modification to an NGSO authorization should be granted where it "does not present any significant interference problems and is otherwise consistent with Commission policies."[15] In this case, the modification will not have any significant impact on other users of the V-band spectrum. To demonstrate this fact, SpaceX has included with this Technical Attachment an analysis of the interaction between its system as modified and other licensed systems in the band.

A.6.1 Interference with Respect to Other NGSO Satellite Systems

SpaceX has engineered its system with technical flexibility that will facilitate coordination with other NGSO satellite systems, as necessary, and is committed to achieving mutually satisfactory agreements. In this modification, SpaceX drastically reduces the number of satellites in its V-band system, by deploying V-band radio equipment on its approved Gen2 system of up to 7,500 satellites. It also reduces power in the downlink and the uplink in the frequency bands in which the minimum elevation angle for communications between SpaceX satellites and earth stations is reduced from 35 degrees to 25 degrees: 40.0-42.5 GHz; 47.2-50.2 GHz; and 50.4-51.4 GHz. This modification thus will allow SpaceX to operate its V-band system more efficiently in

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[15] *Space Exploration Holdings, LLC*, 36 FCC Rcd. 7995, ¶ 16 (2021) (quoting *Teledesic LLC*, 14 FCC Rcd. 2261, ¶ 5 (IB 1999)).

providing high-speed, low-latency service to Americans while at the same time it does not present any significant interference problem and is otherwise consistent with Commission policies.

To confirm and quantify these interference observations and SpaceX's commitment, SpaceX performed an analysis that considers the dynamic, time-varying interference expressed as a cumulative distribution function ("CDF") of the interference-to-noise ratio ("I/N"), for varying percentages of time. The I/N CDF is derived from a time-domain simulation of the two NGSO systems over a long enough time to produce meaningful statistics. The analysis considers the effect of the proposed modification on three NGSO systems hypothetically operating in the V-band — O3B, Viasat, and OneWeb. The analysis, set forth in Annex 1 to this Technical Attachment, demonstrates that the modification presents no significant interference problem for other NGSO systems.

A.6.2 Interference and Coordination with Respect to the Radio Astronomy Service and Earth Exploration-Satellite Service

This information is available in Attachment A to the Previous Applications. In addition, SpaceX's modified V-band system will comply with the out-of-band emissions limits for 50.2-50.4 GHz to avoid interference to Earth exploration-satellite service, as specified in Section 25.202(j) and footnote US156 to Section 2.106 of the Commission's rules and in ITU Resolution 750.

A.6.3 Interference with respect to GSO Satellite Networks and Earth Stations

As required by Sections 25.146(a)(2) and 25.289 of the Commission's rules, SpaceX's modified V-band system will comply with Articles 22.5L and 22.5M and Resolution 76 of the ITU Radio Regulations, which have been incorporated by reference into the Commission's rules.[16]

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[16] *See* 47 C.F.R. §§ 25.146(a)(2), 25.289.

A.6.4 Interference with Respect to Terrestrial Networks

This information is available in Attachment A to the Previous Application. In addition, as demonstrated above, the SpaceX V-band system, as modified, will comply with all relevant PFD limitations in the V-band.

The 37.5–40.0 GHz, 47.2–48.2 GHz, and 50.4–51.4 GHz bands are allocated to the Upper Microwave Flexible Use Service ("UMFUS"). In the 37.5–40.0 GHz band, SpaceX will operate space-to-Earth links and will not claim protection from UMFUS systems except when individually licensed earth stations are authorized pursuant to Section 25.136(b) and (c).[17] In the 47.2–48.2 GHz and 50.4–51.4 GHz bands, SpaceX will limit its use to individually licensed earth stations and either operate in conformance with Section 25.136(d), (e), or (f)[18] or operate on a secondary basis to UMFUS systems.

A.7 COORDINATION WITH U.S. GOVERNMENT OPERATIONS

This information is available in Attachment A to the Previous Application.

A.8 ITU FILINGS FOR SPACEX

SpaceX is preparing the modified system information for ITU publication and will submit this information when complete. SpaceX will unconditionally accept all consequent ITU cost recovery responsibility for the filings.

A.9 ORBITAL DEBRIS MITIGATION

This information is available in Attachment A to SpaceX's Gen2 system application, as amended, and its authorization by the Commission. Because this proposed modification of SpaceX's V-band license incorporates Space's V-band operations into its Gen2 system, rather

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17 *See id*. §§ 25.136(b)-(c).
18 *See id*. §§ 25.136(d)-(f).

than operating a separate system in the V-band, the modified V-band system will not change the orbital debris analysis of the approved Gen2 system. More specifically, this modification will add no new space stations in order to operate at V-band frequencies but will eliminate the 11,943 separately authorized space stations in SpaceX's current V-band license. Accordingly, SpaceX hereby incorporates by reference the orbital debris mitigation discussion from the Gen2 system application and authorization; the SpaceX V-band system, as modified, will comply with the conditions on the Gen2 system relating to orbital debris mitigation.[19]

[19] *See generally* Gen2 Amendment, Attachment A at 15-18; *Gen2 Authorization* ¶¶ 2, 70-89; Letter from David Goldman to Marlene H. Dortch, IBFS File Nos. SAT-LOA-20200526-00055 and SAT-AMD-20210818-00105, at 1-5 (Aug. 19, 2022).

ENGINEERING CERTIFICATION

I hereby certify that I am the technically qualified person responsible for preparation of the engineering information contained in this application, that I am familiar with Part 25 of the Commission's rules, that I have either prepared or reviewed the engineering information submitted in this application, and that it is complete and accurate to the best of my knowledge and belief.

/s/ *Zahid Islam*

Zahid Islam
Principal RF Engineer
SPACE EXPLORATION TECHNOLOGIES CORP.

March 22, 2023

ANNEX 1

POTENTIAL INTERFERENCE WITH RESPECT TO OTHER NGSO SATELLITE SYSTEMS

SpaceX has engineered its V-band satellite system with the technical flexibility that will facilitate necessary coordination with other NGSO satellite systems and is committed to achieving mutually satisfactory agreements. To demonstrate this point, SpaceX performed an analysis of the effect of the proposed modification on downlink and uplink interference using the characteristics of three NGSO systems authorized through the Commission's first V-band processing round — O3b, OneWeb, and Viasat.

The analysis considers the dynamic, time-varying interference expressed as a cumulative distribution function ("CDF") of the interference-to-noise ratio ("I/N"), for varying percentages of time. The I/N CDF is derived from a time-domain simulation of the two NGSO systems over a long enough time to produce meaningful statistics, using random antenna pointing. The corresponding interference levels before and after the modification are calculated and plotted. To present a worst-case, conservative assessment of the interference environment, the analysis also assumes that the two systems do not implement any interference mitigation strategies and assesses interference under clear sky conditions. As demonstrated below, in the noise-dominated environment (i.e., I/N ≤ 0 dB), the interference levels resulting from the modification are less than (or for O3B, less than or not significantly different from) the interference levels that would have been experienced with the currently authorized V-band constellation. In the interference-dominated environment (i.e., I/N > 0 dB), the victim system already typically experiences at least 3 dB receiver de-sensitivity (if not 15 dB or more) and the two systems are not likely able to share the spectrum in a meaningful way outside of band segmentation both with and without the proposed modification. In any case, the interference levels in this interference-dominated environment are also less than or not significantly different from the interference levels that would have been experienced with the current V-band constellation. The modification also will not increase the likelihood of exceeding -12.2 dB I/N (6% $\Delta T/T$) into these NGSO systems.[20]

In conducting the analysis, SpaceX used the following assumptions.

<u>For downlink interference from SpaceX satellites to a victim earth station</u>:

1. The SpaceX earth station is collocated with the victim earth station. A location at 40°N latitude is considered in this simulation.
2. The victim earth station can communicate with any satellite in its own system following the rules applicable for that system (e.g., the GSO avoidance angle or minimum elevation angle).
3. The SpaceX system places a beam per V-band spot, and any satellite in view meeting the GSO avoidance angle and the minimum elevation angle is eligible. SpaceX satellites are chosen randomly for consideration in evaluating the I/N CDF, and operate at the power flux-density levels described in the Previous Application or in this modification application.
4. The results are set forth in Figures A1-1 through A1-4 below. This simulation is conservative (i.e., it overestimates I/N), as it does not consider the effects of atmospheric attenuation.

<u>For uplink interference from SpaceX earth stations to victim satellites</u>:

1. The SpaceX earth station is collocated with an earth station from the other system. A location at 40°N latitude is considered in this simulation.

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[20] 47 C.F.R. § 25.261(c).

2. The other system's earth station can communicate with any satellite in its own system following the rules applicable for that system (e.g., the GSO avoidance angle or minimum elevation angle).
3. In the SpaceX system, an eligible satellite receives a V-band beam from a SpaceX earth station. Any satellite in view meeting the GSO avoidance angle and the minimum elevation angle is eligible. SpaceX satellites are randomly chosen for consideration in evaluating the I/N CDF. For the proposed modification application, SpaceX low- and high-gain earth stations will operate at maximum transmit EIRP of 28 dBW/MHz and 44.5 dBW/MHz, respectively, a reduction of 7 dB each for comparison.
4. The results are set forth in Figures A1-5 through A1-12 below. This simulation is conservative (i.e., it overestimates I/N), as it does not consider the effects of atmospheric attenuation.

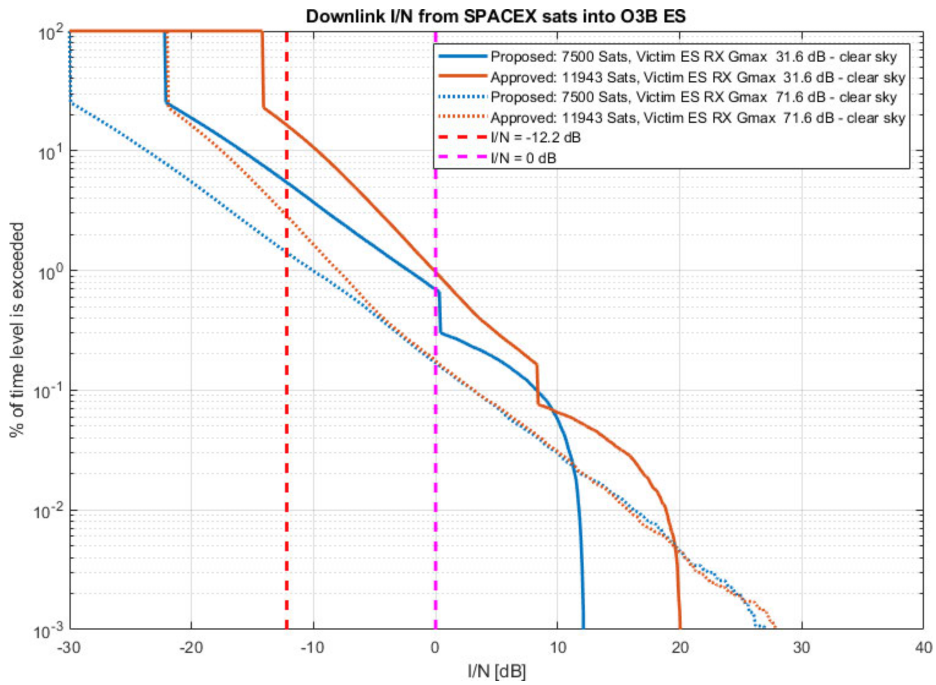

Figure A1-1. Downlink Comparison for Various O3B Antennas at 40ºN

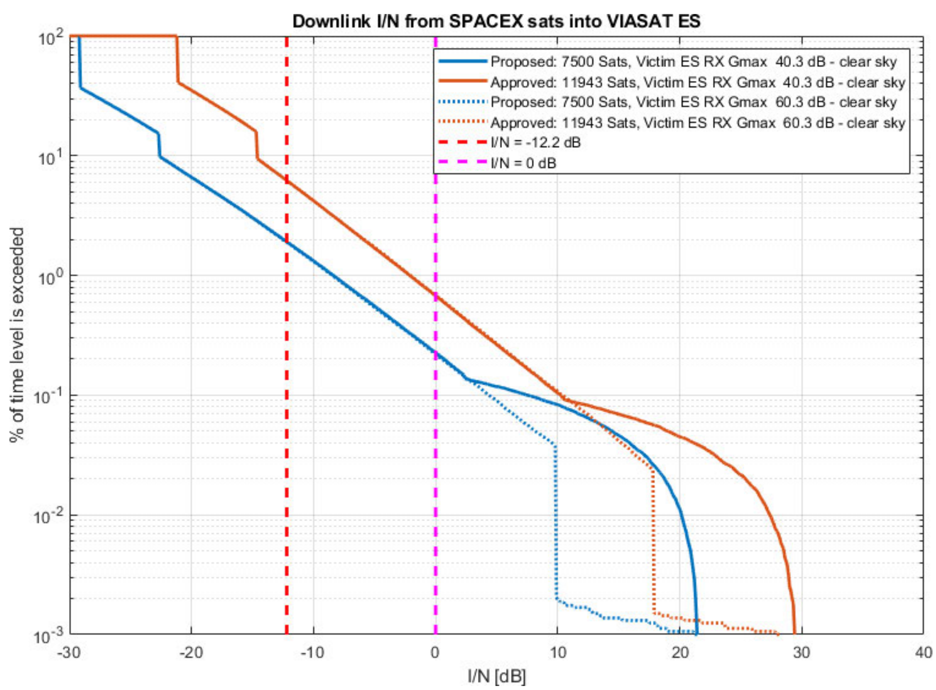

Figure A1-2. Downlink Comparison for Various Viasat Antennas at 40ºN

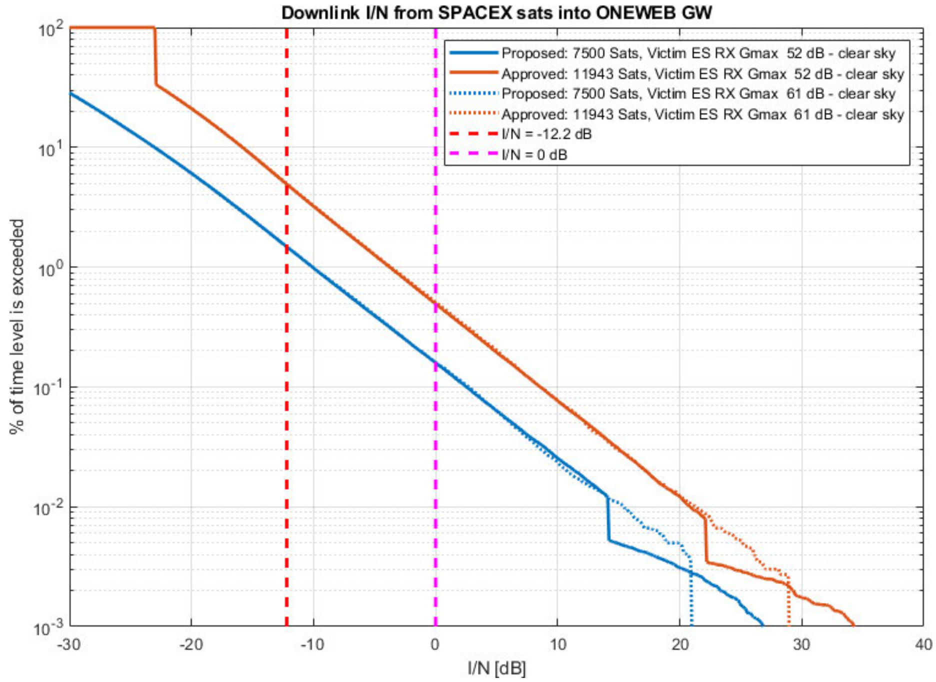

Figure A1-3. Downlink Comparison for Various OneWeb GW Antennas at 40ºN

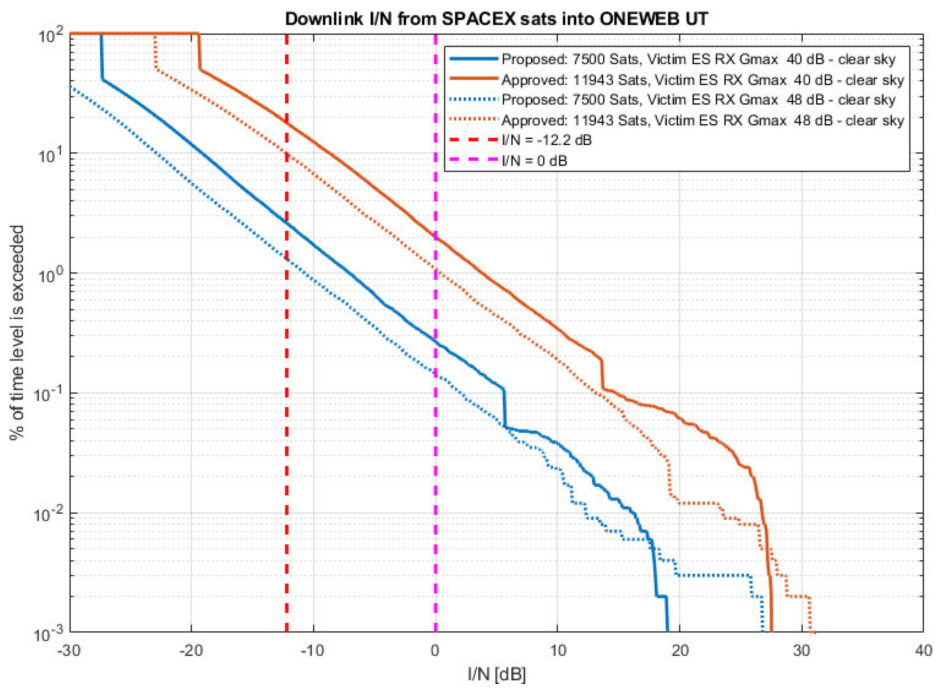

Figure A1-4. Downlink Comparison for Various OneWeb UT Antennas at 40ºN

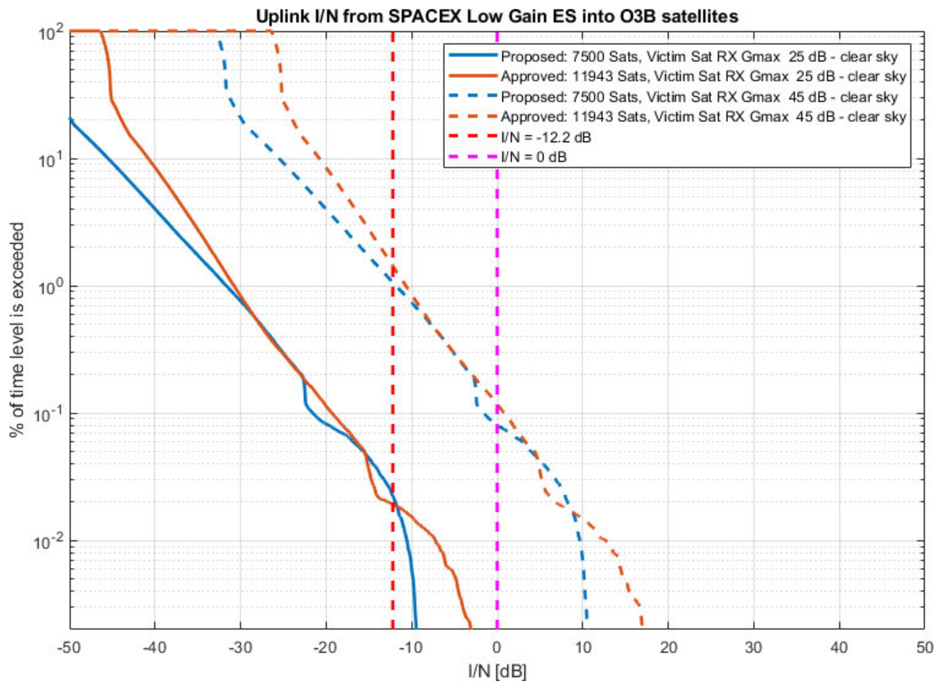

Figure A1-5. Uplink Comparison for Various O3B Antennas and SpaceX Low Gain Earth Station at 40ºN

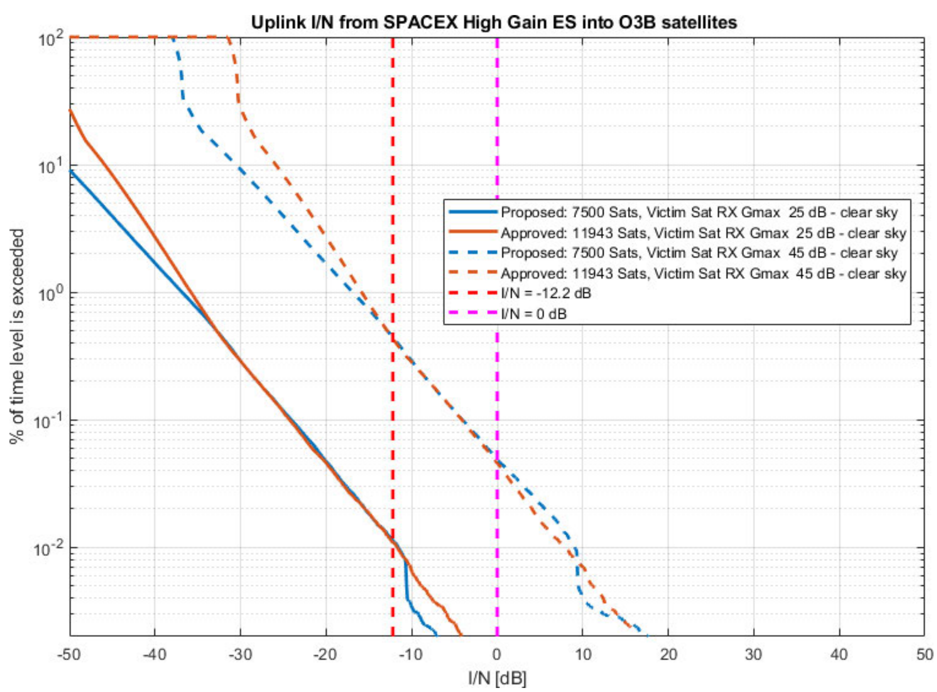

Figure A1-6. Uplink Comparison for Various O3B Antennas and SpaceX High Gain Earth Station at 40ºN

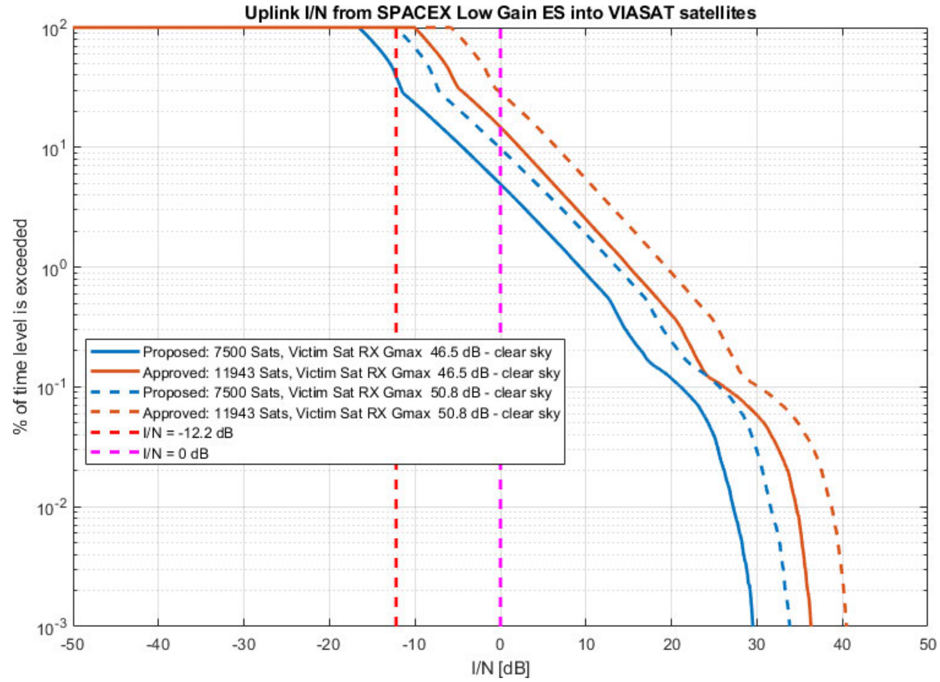

Figure A1-7. Uplink Comparison for Various Viasat Antennas and SpaceX Low Gain Earth Station at 40ºN

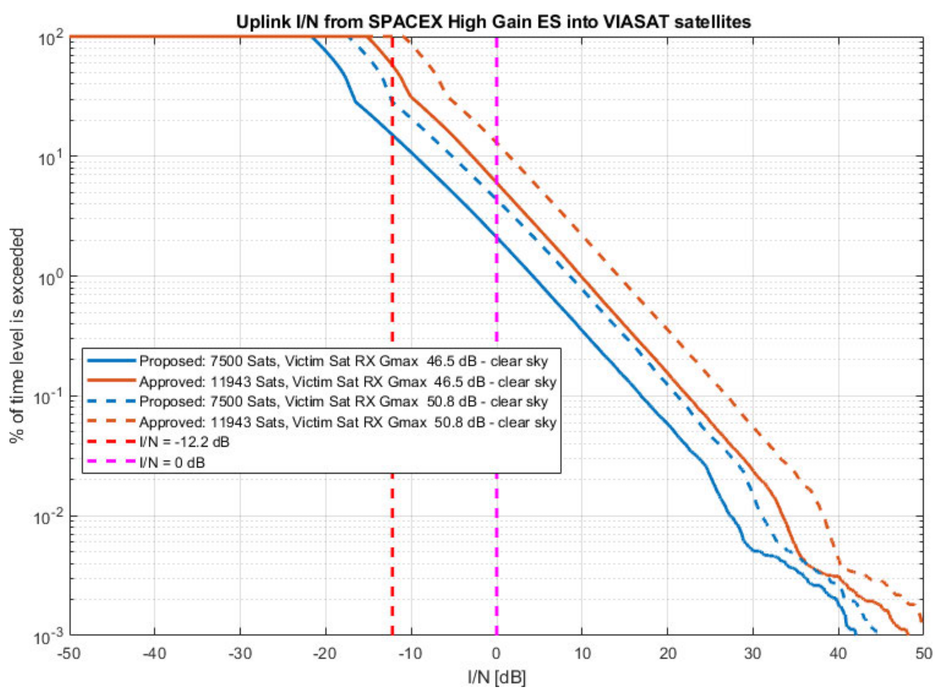

Figure A1-8. Uplink Comparison for Various Viasat Antennas and SpaceX High Gain Earth Station at 40ºN

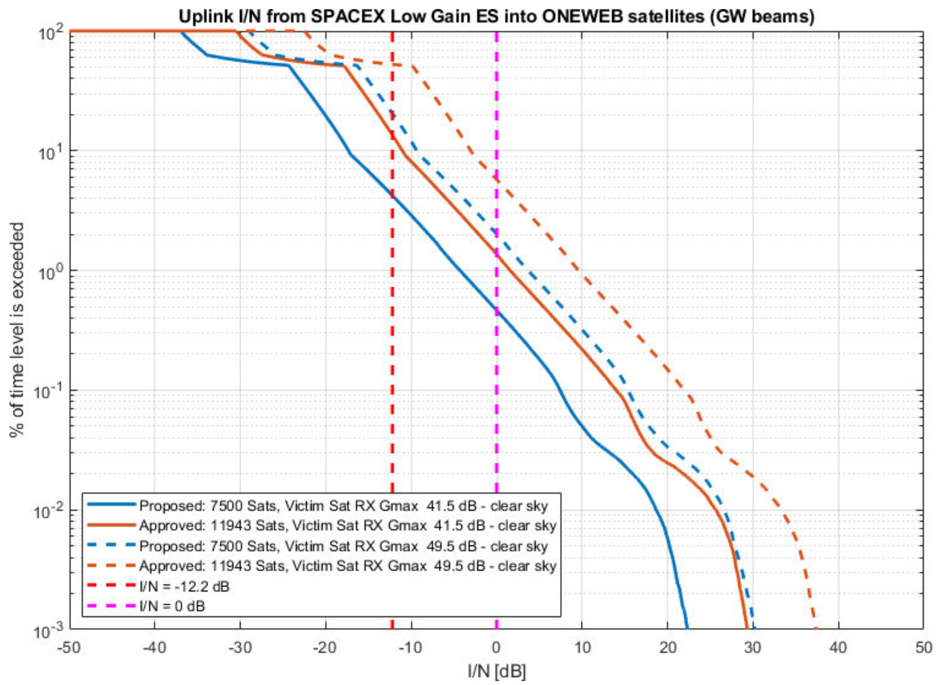

Figure A1-9. Uplink Comparison for Various OneWeb GW Antennas and SpaceX Low Gain Earth Station at 40ºN

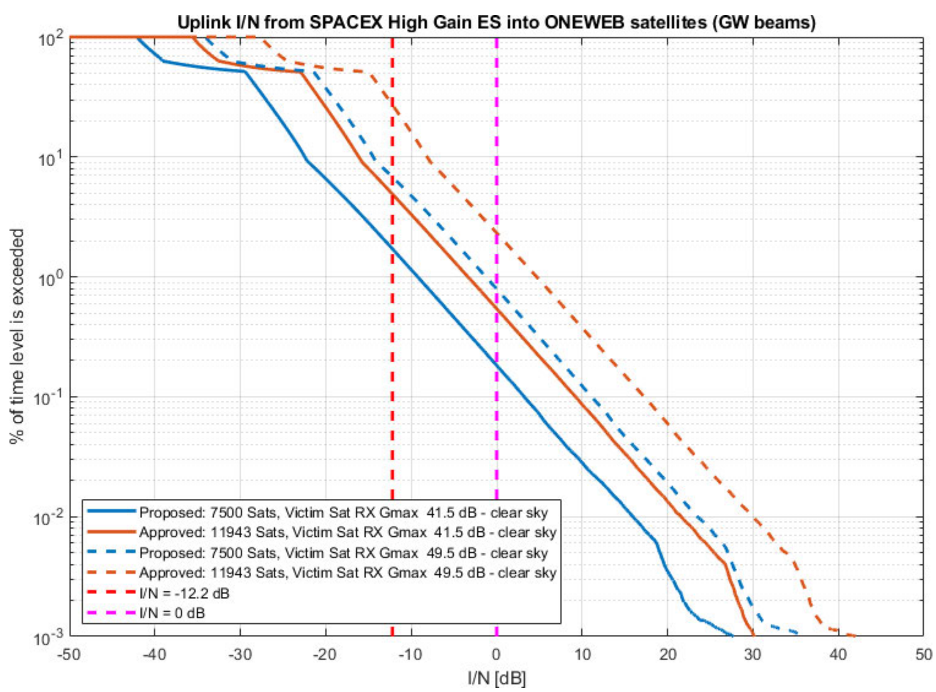

Figure A1-10. Uplink Comparison for Various OneWeb GW Antennas and SpaceX High Gain Earth Station at 40ºN

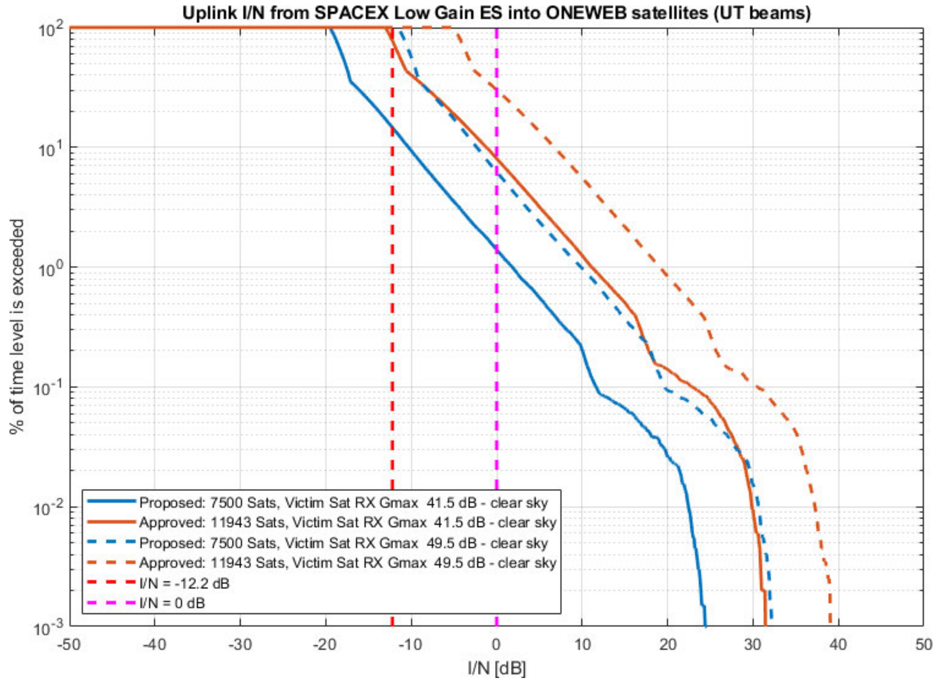

Figure A1-11. Uplink Comparison for Various OneWeb UT Antennas and SpaceX Low Gain Earth Station at 40ºN

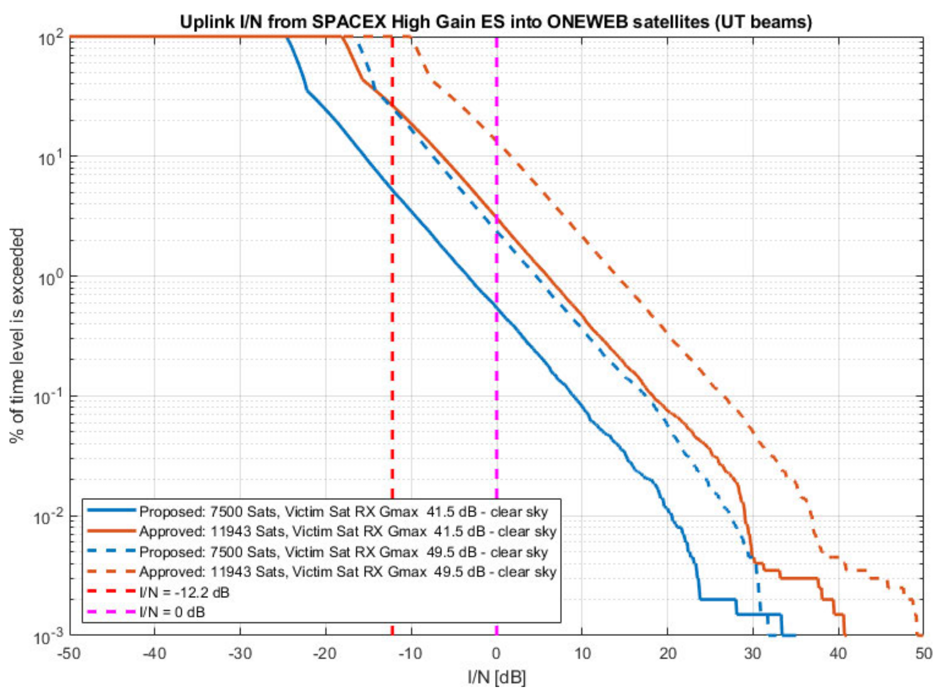

Figure A1-12. Uplink Comparison for Various OneWeb UT Antennas and SpaceX High Gain Earth Station at 40ºN