ONEWEB NON-GEOSTATIONARY SATELLITE SYSTEM (LEO)
PHASE 1: MODIFICATION TO AUTHORIZED SYSTEM

ATTACHMENT A
Technical Information to Supplement Schedule S

A.1 SCOPE AND PURPOSE

On April 28, 2016, OneWeb requested authorization from the Federal Communications Commission ("Commission" or "FCC") to operate 720 non-geostationary ("NGSO") satellites in low Earth orbit ("LEO") in the Ku- and Ka-bands (the "OneWeb System"), triggering the 2016 Ku-/Ka-Band Processing Round.[1] On June 23, 2017 the Commission granted OneWeb's request.[2] OneWeb now seeks to modify its existing authorization for the OneWeb System by making a small reduction in the total number of satellites relative to those previously authorized by the Commission, which involves modifications to some of the orbital parameters for a number of the satellites. These proposed Phase 1 modifications will enable OneWeb to more effectively commence commercial service and efficiently utilize its spectrum resources.

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[1] *See OneWeb Petition Accepted for Filing, Cut-Off Established for Additional NGSO-Like Satellite Applications or Petitions in the 10.7-12.7 GHz, 14.0-14.5 GHz, 17.8-18.6 GHz, 18.8-19.3 GHz, 27.5-28.35 GHz, 28.35-29.1 GHz, and 29.5-30.0 GHz Bands*, Public Notice, 31 FCC Rcd 7666 (IB 2016) ("2016 Ku-/Ka-Band Processing Round").

[2] *WorldVu Satellites Limited Petition for a Declaratory Ruling Granting Access to the U.S. Market for the OneWeb NGSO FSS System*, Order and Declaratory Ruling, 32 FCC Rcd 5366 (2017) ("OneWeb Market Access Grant").

This modification to the OneWeb System in Phase 1 consists of a decrease in the number of satellites to be deployed (from 720 to 716), and an associated change to the orbit plane spacing, orbit inclination and number of satellites per plane for some of the orbit planes. The orbit altitude of all the satellites in the OneWeb System remains the same as the authorized NGSO, fixed-satellite service ("FSS") system. The proposed Phase 1 modifications to the orbital parameters are as follows:

- Reducing the number of satellites operating in orbits with 87.9° inclination from 720 to 588 and redistributing these 588 satellites in these orbit planes in an optimal manner for uniform global service. Specifically, this involves changing the number of 87.9° inclined orbit planes from 18 to 12 and increasing the number of satellites in each of these planes from 40 to 49. These satellites will be referred to as the "87.9° inclined satellites";

- Changing the orbit inclination for 128 of the satellites originally in the 87.9° inclined orbits to now be 55° inclination. These satellites will be distributed around the globe with eight evenly spaced orbit planes and 16 satellites in each plane. These satellites will be referred to as the "55° inclined satellites;" and

- Removing the remaining four satellites from the original 87.9° inclined orbit planes.

In order to operate effectively in the 55° inclined orbit, these OneWeb satellites will have a different Ku-band satellite antenna beam design but will operate with maximum Ku-band transmit EIRP density levels no higher than those previously authorized by the Commission in the OneWeb Market Access Grant. This is a key factor in ensuring that they will not degrade the interference environment for any other user of the spectrum, including other NGSO FSS systems. Similarly, these OneWeb satellites will require no additional interference protection than the OneWeb satellites already authorized. The RF performance of the Ka-band beams of the 55° inclined satellites will be identical to the already authorized OneWeb satellites. Furthermore, the initially

deployed constellation of 588 OneWeb 87.9° inclined satellites[3] will be identical to the OneWeb satellites that are already authorized, although the OneWeb System will benefit from ongoing updates to its satellite beam designs to facilitate higher levels of frequency re-use, and hence capacity, while operating within the RF envelope of the authorized satellites.[4] There are no other technical changes to the OneWeb System being requested as part of these proposed Phase 1 modifications.

A complete Schedule S, using the latest online Schedule S software, is also being submitted with this application. It contains identical information to that submitted with OneWeb's original April 28, 2016 submission ("Market Access Petition") except for the changes described above, which are detailed further in the submitted Schedule S and in this document, which contains the information required for the Phase 1 modification request by §§ 25.117(d), 25.114(d), 25.146 and other sections of the FCC's Part 25 rules that cannot be captured by the Schedule S software.[5]

The Schedule S associated with this complete application also includes data related to the Phase 2 implementation of the OneWeb System which is described in a separate Attachment B. Certain data in the Schedule S is common to both Phase 1and Phase 2, with the exception of the following:

- Orbit details in the Schedule S relate only to Phase 1 as it is not feasible to enter manually the large number of satellite phase angles required for Phase 2 into the online Schedule S software. The required orbit details for Phase 2 are being provided to the Commission in the form of a separate Excel spreadsheet that is attached to this application and structured in the same way as the Schedule S format for orbit data; and

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[3] OneWeb has already launched part of this constellation with 74 satellites currently in-orbit and operational.

[4] OneWeb is also seeking authorization to increase the total number of satellites in the OneWeb System in its proposed Phase 2 deployment, as described in Attachment B.

[5] *See* IBFS File No. SAT-LOI-20160428-00041 (Call Sign S2963).

- Certain satellite beams contained in the Schedule S are associated only with satellites in Phase 1 or Phase 2. This is clarified in Section A.3 of Attachment A and Section B.3 of Attachment B which address this topic.

A.2 OVERALL DESCRIPTION OF SYSTEM FACILITIES, OPERATIONS AND SERVICES AND EXPLANATION OF HOW UPLINK FREQUENCY BANDS ARE CONNECTED TO DOWNLINK FREQUENCY BANDS (§25.114(d)(1))

This information is available in Attachment A ("Technical Information to Supplement Schedule S") to the Market Access Petition. The only change in Phase 1 is that the total number of LEO satellites to be deployed has decreased from 720 to 716. The orbit altitude remains the same. The satellites are now distributed between a total of 20 (rather than 18) orbital planes, including both 87.9° and 55° inclinations. There will be a total of 588 satellites operating in the 87.9° inclined planes (12 planes of 49 satellites per plane) and 128 satellites operating in the 55° inclined planes (8 planes of 16 satellites per plane).

The OneWeb System will be generally deployed as stated in the Market Access Petition, but with some minor differences to accommodate the modified configuration and to accommodate launch vehicle capabilities. The changes are:

- Initial deployment of satellites in 12 orbital planes in the 87.9° inclined orbits can be achieved with 12 Soyuz launches (instead of the original plan requiring 18 launch vehicles);
- Each Soyuz launch vehicle accommodated 34 OneWeb satellites in the two most recent launches, and this may be increased to 36 satellites for future launches;
- Service provisioning with the reduced sub-constellation in the 87.9° inclined orbits can commence earlier to achieve coverage of high latitudes; and
- Additional launch vehicles, including Soyuz, Ariane 6, Virgin and/or Blue Origin can complete the mission by orbiting the 55° inclined-orbit satellites and the remaining satellites in the 87.9° inclined orbits, as dictated by commercial requirements.

OneWeb's proposed Phase 1 architecture, which relies on a slightly decreased number of satellites in the OneWeb System from that already authorized by the Commission (716 instead of 720), will mean no additional gateway earth station antennas will be required at each gateway site compared to the currently authorized system. Neither will there be a need for additional gateway sites in the United States. The current plan is therefore to maintain at least four gateway sites in the United States, consistent with the earth station applications and authorizations already approved or pending before the Commission.[6] None of the high-latitude TT&C stations are planned to be located in the United States.

The proposed changes to the orbital parameters of the OneWeb System will have negligible impact on the necessary elevation angles from the communicating earth stations, either in Ku-band or Ka-band.[7] Although the orbit plane spacing of the 87.9° inclined satellites is increased by this proposed Phase 1 modification, this is offset by the increased number of satellites in each of these orbit planes and by the presence of the 55° inclined satellites, as far as the elevation angle of visible satellites is concerned. In the Ka-band there will be no change at all as the minimum elevation angle for the OneWeb gateway links is a parameter that is set by the planned operations of the OneWeb System and is a function of the number and location of the deployed gateway earth stations. In the Ku-band, the result is that there is very little difference in terms of necessary minimum elevation angles for links to OneWeb user terminals between the existing authorized OneWeb System and the modified OneWeb System proposed in Phase 1. This is demonstrated in Figure A.2-1 below which compares the time statistics of the elevation angle of the highest

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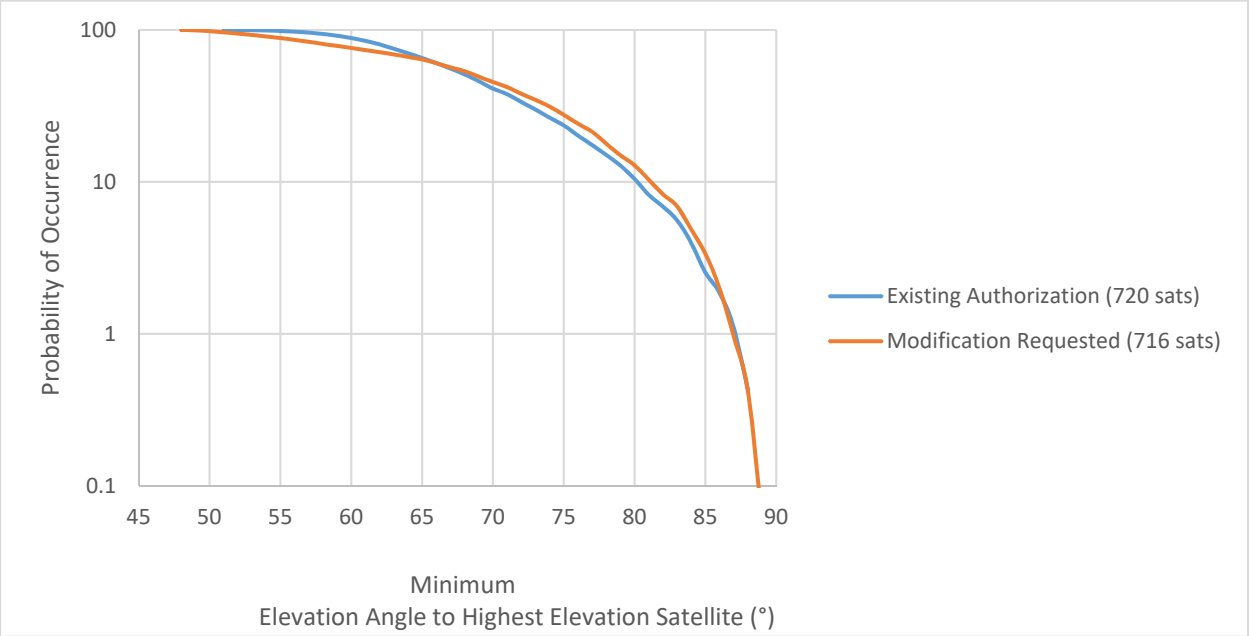
[6] *See, e.g.*, IBFS File Nos. SES-LIC-20180604-01082 (Talkeetna, AK gateway earth station granted Nov. 8, 2019); SES-LIC-20180727-02076 (application for Southbury, CT gateway earth station).

[7] The term "necessary elevation angle" used here refers to the lowest elevation angle of the highest elevation satellite at any point in time as the satellites move through their orbits.

OneWeb satellite from various latitudes (25°, 50° and 75°), which are representative of U.S. locations.[8]

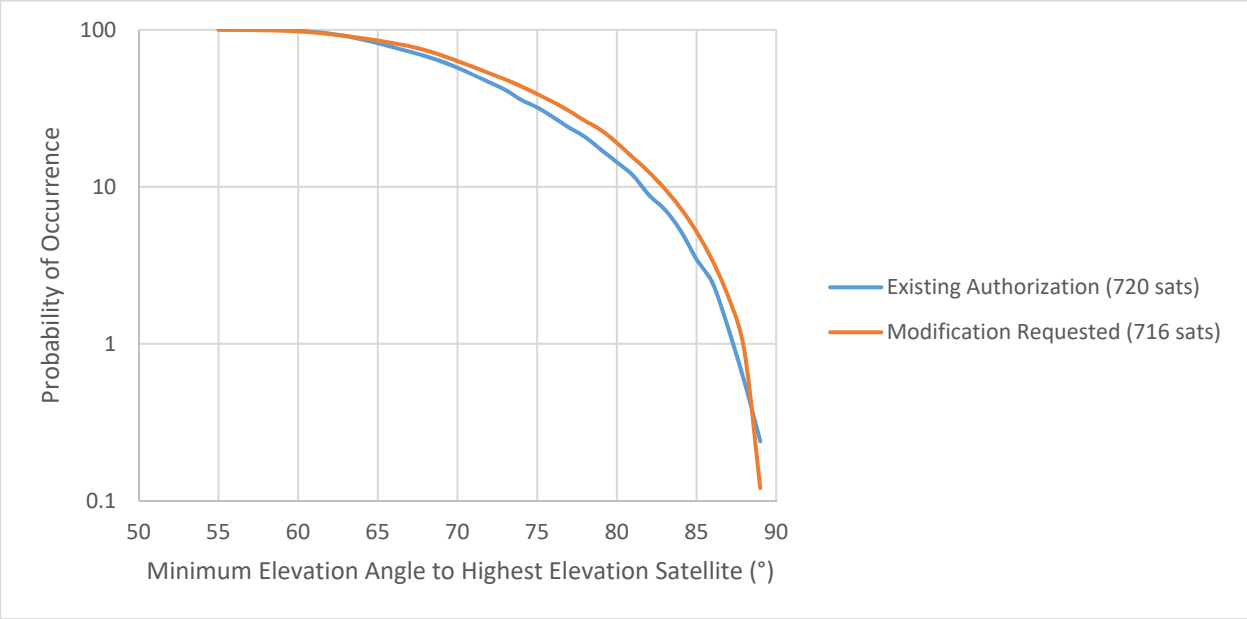
Figure A.2-1: Comparison of the Statistics of the Highest Elevation Angle to the OneWeb LEO NGSO constellation Before and After the Proposed Modification

(a) 25° Latitude Earth Location



[8] 25° and 50° latitude are representative of the most southern and northern extremes of CONUS, while 75° is representative of the most northern extreme of Alaska.

(b) 50° Latitude Earth Location



(c) 75° Latitude Earth Location

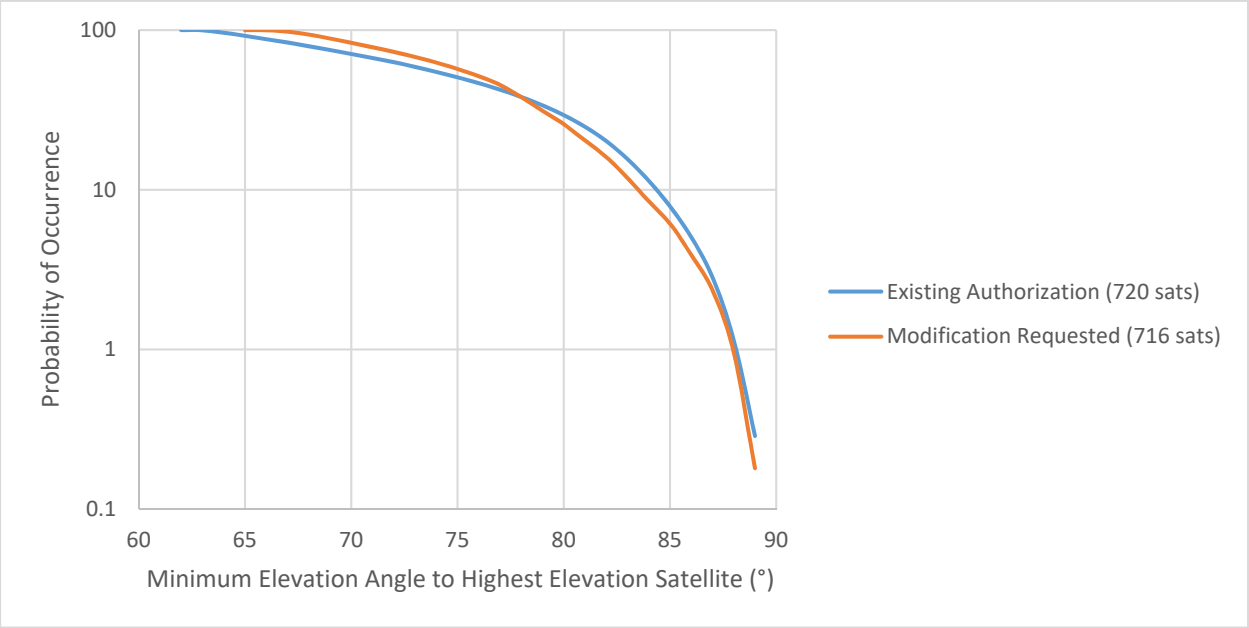


Figure A.2-1 above also demonstrates how the elevation angle for the user terminal links in the OneWeb System is somewhat dependent on the latitude of the Earth location. The lower the latitude, the lower the necessary minimum elevation angles, with a value of greater than approximately 50° applying in the worst case to the most southerly extent of CONUS (i.e., ~25° latitude) and values up to 15° higher for more northernly latitudes. The 55° inclined satellites will be capable of operating down to a 45° minimum elevation angle to provide the necessary flexibility in terms of coverage and capacity (see Section A.3 below).

The OneWeb System will continue to operate pursuant to U.K. and French registrations at the ITU that are the basis of the existing OneWeb System including the operation of the current Phase 1 satellites. Certain modifications to these existing ITU filings related to OneWeb's proposed Phase 1 operations are currently in progress.

A.3 PREDICTED SPACE STATION ANTENNA GAIN CONTOURS (§25.114(c)(4)(vi)(B))

This information is available in Attachment A to the Market Access Petition for the Ku-band beams of the 87.9° inclined satellites and for the Ka-band beams of all OneWeb satellites, as these have not been altered by this proposed Phase 1 modification. Nevertheless, this beam information has been included in the associated Schedule S as the FCC's Schedule S software has changed from when the Market Access Petition was submitted.

New information concerning the Ku-band beams of the 55° inclined satellites is also included in the associated Schedule S. Each of these 55° inclined satellites will be capable of generating up to 32 separate spot beams that are independently steerable over a large portion of the visible Earth, down to a minimum elevation angle of 45°. These beams can also be adjusted in terms of their size, and hence gain, over a wide range of values. To account for this adjustability in gain the Schedule S includes both maximum and minimum gain values for these Ku-band beams.

As mentioned above, the associated Schedule S contains the beams used for both Phase 1 and Phase 2 implementations of the OneWeb System . Only the following beams from the Schedule S are used in the Phase 1 implementation, and only for the satellite types indicated:

- Satellite receive beams:
  - Ku-band:
    - … UUAL (87.9° inclined satellites)
    - … UUBL (55° inclined satellites – lowest gain)
    - … UUCL (55° inclined satellites – highest gain)
  - Ka-band:
    - … GUAR (all satellites)
    - … GUBR (all satellites)
    - … GUAL (all satellites)
    - … GUBL (all satellites)

- Satellite transmit beams:
  - Ku-band:
    - … UDAR (87.9° inclined satellites)
    - … UDBR (55° inclined satellites – lowest gain)
    - … UDCR (55° inclined satellites – highest gain)
  - Ka-band:
    - … GDAR (all satellites)
    - … GDBR (all satellites)
    - … GDAL (all satellites)
    - … GDBL (all satellites)

A.4 GEOGRAPHIC COVERAGE (§25.146(b))

This information is available in Attachment A to the Market Access Petition. As a result of this proposed Phase 1 modification of the OneWeb System, every point on the Earth's surface will see, at all times, a OneWeb satellite at an elevation no less than 46º, and that value occurs only on the equator.

A.5 TT&C AND PAYLOAD CONTROL CHARACTERISTICS (§25.202(g))

This information is available in Attachment A to the Market Access Petition.

A.6 CESSATION OF EMISSIONS (§25.207)

This information is available in Attachment A to the Market Access Petition.

A.7 COMPLIANCE WITH PFD LIMITS (§25.146(a)(1))

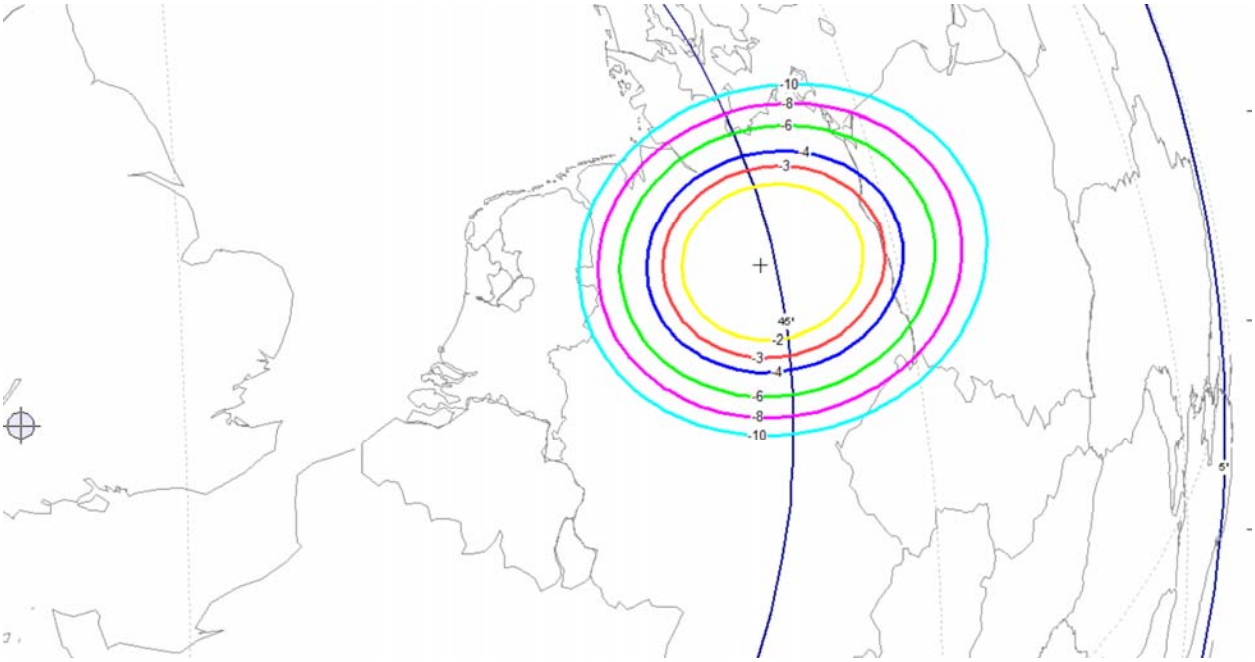
The FCC and ITU power flux density ("PFD") limits are defined per-satellite, and there are no changes to the maximum downlink EIRP densities, in either the Ku-band or Ka-band, from each satellite of the OneWeb System.

Downlink PFD Limits in Ku-band

The information provided in the Market Access Petition to demonstrate compliance with the PFD limits in the Ku-band remains valid and is consistent with the PFD limits of §25.208(b) in the 10.7-11.7 GHz band and the ITU PFD limits in the 11.7-12.7 GHz band. The analysis presented in the Market Access Petition assumed a worst case situation where the Ku-band satellite transmit beam is pointed to any visible point on the Earth's surface, and this therefore encompasses the steerable Ku-band beams of the 55° inclined satellites (see Section A.3 above and associated Schedule S). In practice, even with these beams, the PFD levels at lower elevation angles will be lower than that calculated due to the operational minimum elevation angle of 45° for these steerable beams.

Regarding the low-elevation (0° to 5°) PFD limits of §25.208(o) in the 12.2-12.7 GHz band, the analysis presented in the Market Access Petition assumed there would be at least 3 dB reduction in the EIRP density transmitted towards low elevation directions. This assumption is still valid for the steerable Ku-band beams of the 55° inclined satellites, as demonstrated below, even when operating at a minimum elevation angle of 45°. Figure A.7-1 shows the extreme case of the largest steerable Ku-band satellite transmit beam from one of the 55° inclined satellites pointing towards a location on the Earth from where the elevation angle to the satellite is exactly 45°. Note that the highest gain level of this beam that is directed towards the 5° elevation angle (i.e., the highest elevation angle to which §25.208(o) applies) contour is well below the -10 dB contour and therefore well below the -3 dB that was assumed in the analysis presented in the Market Access Petition. Therefore, the original analysis applies equally to the steerable Ku-band beams of the 55° inclined satellites.

Figure A.7-1: Demonstration that the gain roll-off of the steerable Ku-band beam of the 55° inclined satellites towards the 5° elevation contour exceeds -3 dB for the minimum elevation angle of 45° at beam peak



Therefore, based on the above, the modified Phase 1 OneWeb System will comply with all FCC and ITU PFD limits in Ku-band.

Downlink PFD Limits in Ka-band

Since the total number of satellites in the OneWeb System will decrease slightly (from 720 to 716) pursuant to the proposed Phase 1 modifications, the Ka-band downlink PFD limit, which is determined in part by the number of satellites, is slightly less constraining than for the Market Access Petition. Therefore, the same demonstration of compliance that was provided in the Market Access Petition still holds for the modified OneWeb System with 716 satellites. This is demonstrated again for the specific case of 716 satellites below.

The FCC's Ka-band downlink PFD limits applicable to NGSO systems are set forth in §25.146(a)(1). This rule incorporates by reference the ITU PFD limits that are stated in Article 21 of the ITU Radio Regulations across the entire band 17.7-19.3 GHz, which encompasses most of the Ka-band

downlink frequencies used by OneWeb. The applicable PFD limits in the 17.7-19.3 GHz band are expressed as a function of the number of satellites in the NGSO system as follows:

- -115-X dB(W/m^2) in any 1 MHz band for angles of arrival between 0 and 5 degrees above the horizontal plane;
- -115-X+((10+X)/20)(δ-5) dB(W/m^2) in any 1 MHz band for angles of arrival δ (in degrees) between 5 and 25 degrees above the horizontal plane; and
- -105 dB(W/m^2) in any 1 MHz band for angles of arrival between 25 and 90 degrees above the horizontal plane.

  Where X is defined as a function of the number of satellites in the non-GSO FSS constellation, n, as follows:

  - X = 0 dB for $n \leq 50$
  - X = (5/119) (n - 50) dB for $50 < n \leq 288$
  - X = (1/69) (n + 402) dB for $n > 288$

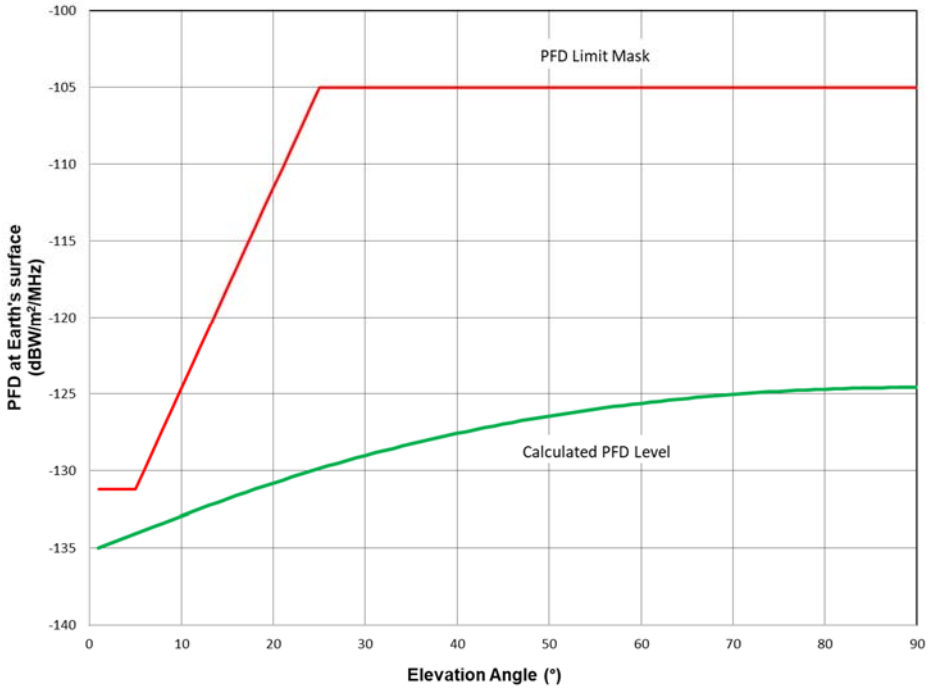
These PFD limits apply to each satellite in the OneWeb System. The value of "n" is 716, and therefore X is equal to 16.20 dB according to the above formulae, which is a 0.06 dB decrease from the Market Access Petition where the total number of satellites was 720. This results in slightly higher PFD limit levels at lower elevation angles than were applicable to the Market Access Petition.

The maximum Ka-band downlink EIRP density for the OneWeb satellites is +8.0 dBW/MHz.[9] This value is used to calculate the PFD at the surface of the Earth assuming the maximum satellite downlink EIRP density occurs in all directions, and taking account of the actual spreading loss from

[9] See also Section A.12 of the Market Access Petition.

the satellite to the surface of the Earth.[10] This is shown in Figure A.7-4 together with the PFD mask. Compliance with the PFD limit is achieved with a minimum margin of almost 3 dB at 5-degree elevation, and much greater margin at higher elevation angles.

Figure A.7-2: Compliance with the Ka-band PFD limit for NGSO systems applicable to the 17.7-19.3 GHz band using worst-case analysis (for N = 716 satellites)



[10] Note that this way of estimating the PFD at the Earth's surface is overly pessimistic because the maximum downlink EIRP density is only used in operation for pointing directions involving angles of arrival of 15° at the Earth's surface when Downlink Power Control ("DPC") is applied, which is planned for all gateway operations. For pointing directions where the path length is less, the DPC is used to maintain a near-constant PFD at the Earth's surface, so at nadir (i.e., 90° angle of arrival), the PFD would be about 7 dB lower than the case when no DPC is used, as shown in this figure.

A.8 INTERFERENCE ANALYSES

Refer to Section A.8 of Attachment A to the Market Access Petition for a summary of the designations that exist in the U.S. Table of Frequency Allocations for the bands used by OneWeb. The various sharing / interference scenarios in the following sub-sections are consistent with the current allocations.

A.8.1 Interference Protection for GSO Satellite Networks (§25.146 and §25.208)

OneWeb will ensure that the 716-satellite Phase 1 OneWeb System still provides the necessary interference protection to GSO satellite networks in both the Ku- and Ka-bands as required by §25.146 of the Commission's rules and Article 22 of the ITU Radio Regulations.

Consistent with the current FCC rules,[11] OneWeb hereby certifies as part of this application that it will comply with applicable equivalent power flux-density ("EPFD") levels in Article 22, Section II and Resolution 76 of the ITU Radio Regulations. These EPFD levels apply in the following frequency ranges to be used by the OneWeb System in the United States.:

- Ku-band:
  - Uplink: 14.0-14.5 GHz
  - Downlink: 10.7-12.7 GHz
- Ka-band:
  - Uplink: 27.5-29.1 GHz and 29.5-30.0 GHz
  - Downlink: 17.8-18.6 GHz and 18.8-19.3 GHz

[11] *See* 47 C.F.R. § 25.146(a)(1); *see also Update to Parts 2 and 25 Concerning Non-Geostationary, Fixed-Satellite Service Systems and Related Matters, Report and Order and Further Notice of Proposed Rulemaking,* 32 FCC Rcd 7809, ¶ 41 (2017).

The techniques by which compliance with the EPFD limits will be met are the same in principle for the proposed Phase 1, 716-satellite OneWeb System as for the original 720-satellite constellation. Minor adjustments to the "progressive pitch" algorithm used in the Ku-band are required to account for the Phase 1 modified number of 87.9° inclined satellites. For the steerable beams of the 55° inclined satellites a similar GSO arc avoidance technique will be used as the one described in the Market Access Petition for the steerable Ka-band beams of all the satellites.[12] In the Ka-band, no change to the GSO avoidance angle will be required for the modified constellation parameters. The net result is that the Phase 1, 716-satellite OneWeb System will meet the EPFD limits as required to protect GSO satellite networks, both in the Ku-band and the Ka-band.

A.8.2 Interference with Respect to Other NGSO Satellite Systems

The proposed Phase 1 modification to the OneWeb System proposed here will not cause any additional interference to, or from, any other non-GSO satellite system, for the following reasons:

- The total number of satellites has decreased from 720 in the existing authorization to 716 in this proposed Phase 1 modification. The Commission has concluded that a reduction in the total number of satellites is a "fundamental element" in its analysis of whether a proposed modification would cause increased interference to other NGSO FSS systems;[13]

- The nominal altitude of the proposed OneWeb satellites has not been altered from the value of 1,200 km for the existing authorization;

[12] *See* Market Access Petition, Technical Narrative at Section A.8.1.2 and Annex 2.

[13] *See Space Exploration Holdings, LLC; Request for Modification of the Authorization for the SpaceX NGSO Satellite System*, 34 FCC Rcd 2526, ¶ 11 (IB 2019).

- The maximum transmit EIRP density from the proposed OneWeb satellites, and hence the maximum PFD at the Earth's surface, in both Ku and Ka-bands, has not been altered from the values of the existing authorization;[14]

- The elevation angle statistics for the Phase 1 modified OneWeb System, as shown in Section A.2 above, have not changed significantly from those for the already authorized OneWeb System;

- Although the 55° inclined satellites will have receive beams that can operate at higher gain than for the already authorized satellites, OneWeb will not require additional uplink protection from other non-GSO satellite systems. This can be accomplished by maintaining the same earth station transmit EIRP density levels as will be used for the 87.9° inclined satellites.[15]

- The visibility statistics for the Phase 1 modified OneWeb System are similar to those of the existing authorization insofar as it affects potential interference to other non-GSO systems. Figure A.8-1 below plots the percentage of time that varying numbers of OneWeb satellites can be simultaneously seen by a particular Earth latitude, above the elevation angle corresponding to that latitude at which there is always a visible satellite. The main points arising from this are:

    - No more than one satellite is visible for 100% of the time, for all the Earth latitudes shown, both before and after the modification;

    - The percentage of time that two satellites are visible is not significantly altered by the modification;

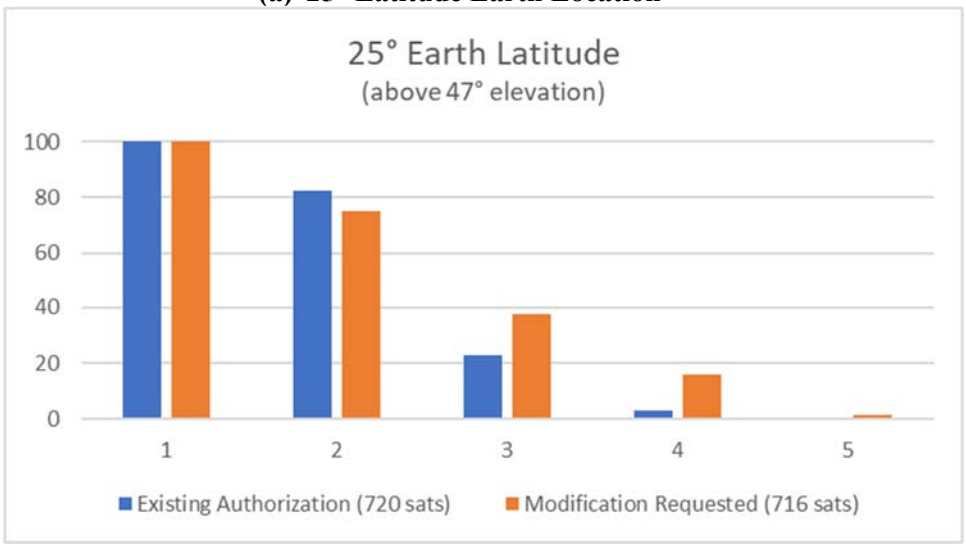
[14] Neither has the maximum transmit EIRP density of the corresponding earth stations been altered, although this parameter is addressed by the Commission only for the earth station licensing applications.

[15] With higher satellite receive gain, it would be expected that OneWeb terminals transmitting to such antennas would require less EIRP density to maintain link quality than for lower gain beams. However, if OneWeb does not receive sufficient protection for its lower EIRP operations, it can maintain the earlier stated levels without increasing interference to any other system.

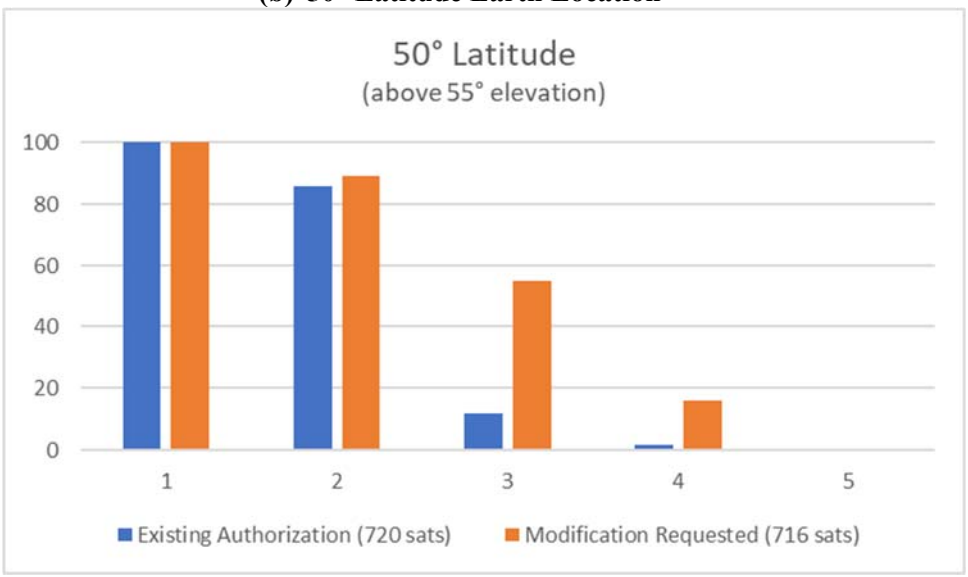
- Although there is greater variation in the percentage of time that three satellites are visible, the actual percentages are sufficiently low that OneWeb can use alternate frequencies for the multiple satellites whenever their spot beams are collocated thus preventing co-channel interference to another NGSO system's earth station from three satellites simultaneously.

Figure A.8-1: Visibility statistics above certain elevation angle for various Earth latitudes

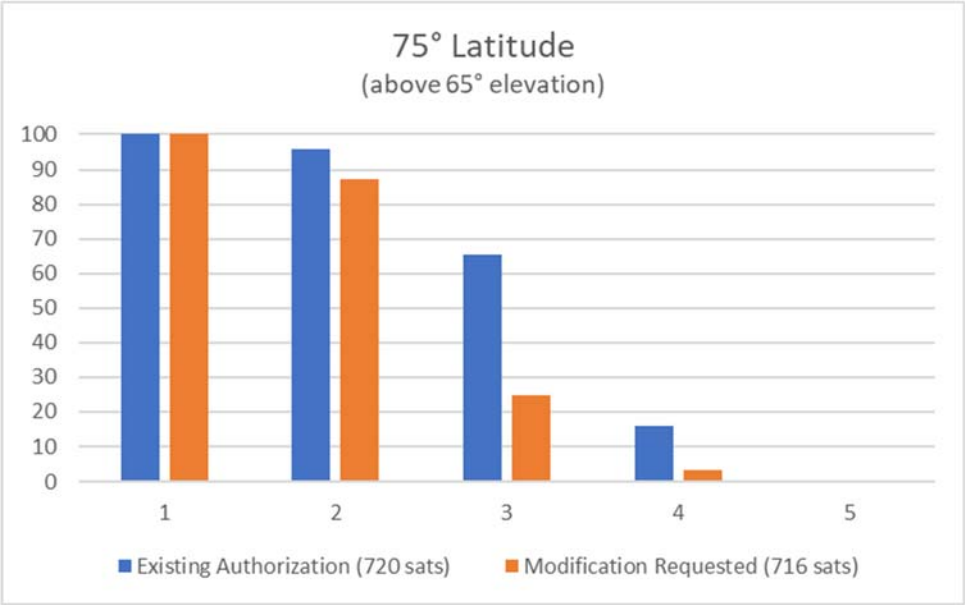
(a) 25° Latitude Earth Location



(b) 50° Latitude Earth Location



(c) 75° Latitude Earth Location

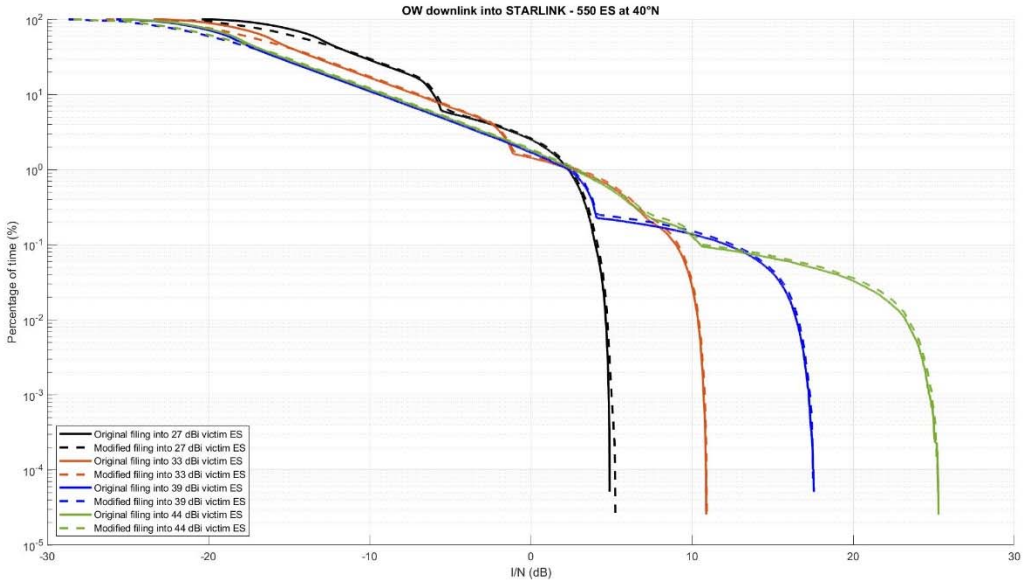


In addition, representative analyses of the I/N (Interference-to-Noise ratio) statistics for some victim NGSO systems have been performed which further confirm that there is no increase in interference to other NGSO FSS systems.

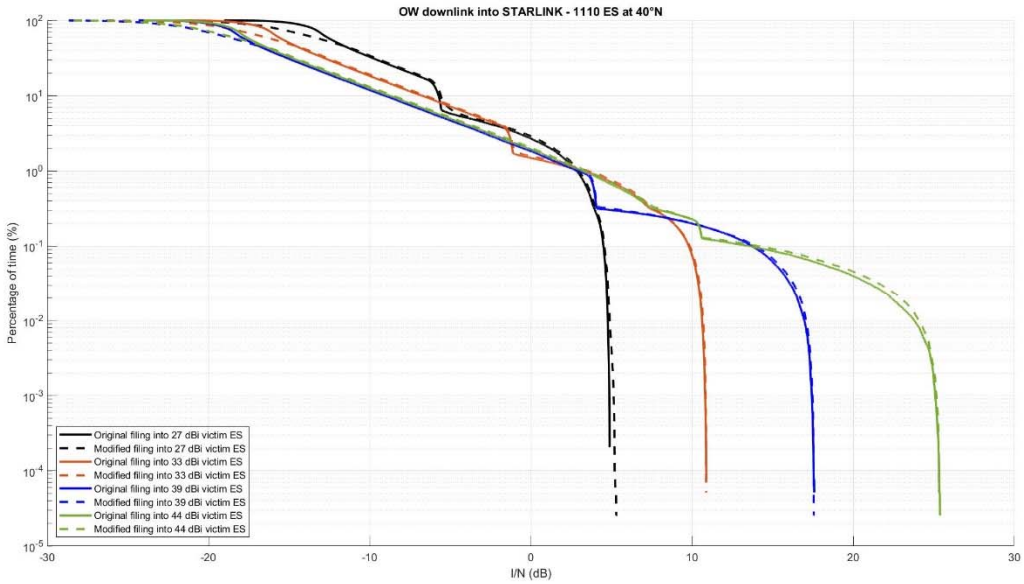
Figure A.8-2 below shows the results in the Ku-band for five different sub-constellations of SpaceX's Starlink NGSO FSS system on five different altitudes, and for a mid-range Earth location of 40°N latitude, where the OneWeb and Starlink earth stations are collocated. Each result compares the I/N statistics for the currently authorized OneWeb System (solid lines) with those resulting from the proposed Phase 1 modification requested here (dotted lines). The different sets of curves in each diagram represent different victim receiving earth station sizes, as indicated by the legend on the diagram. In all cases, there is very little difference between the I/N curves for the already authorized OneWeb system and those for the modified OneWeb System, further demonstrating that the overall interference environment in Ku-band is not impacted by this proposed Phase 1 modification.

Figure A.8-2: I/N Statistics for Ku-band interference into the Starlink NGSO system for various altitudes

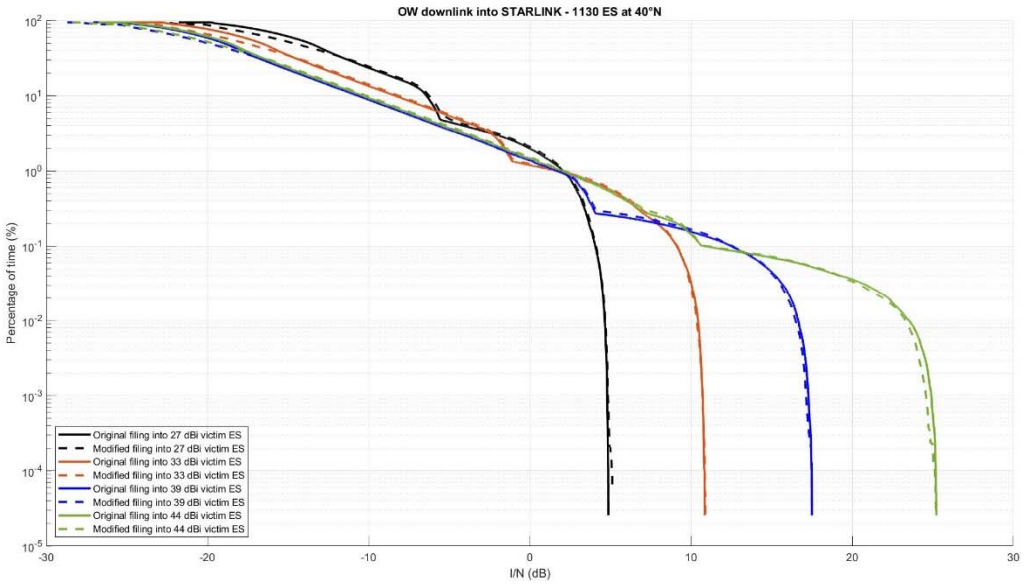
(a) 550 km



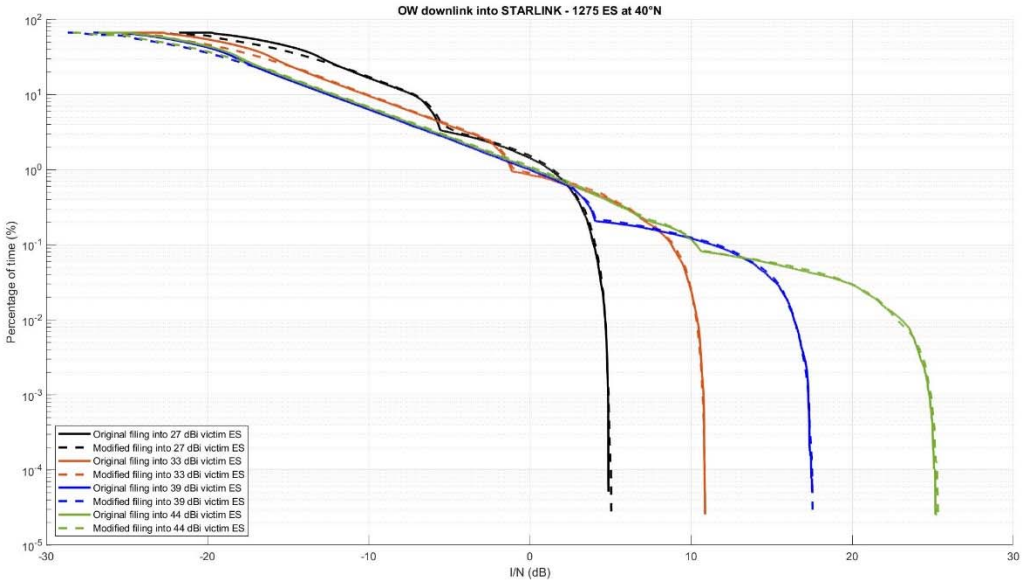
(b) 1,100 km



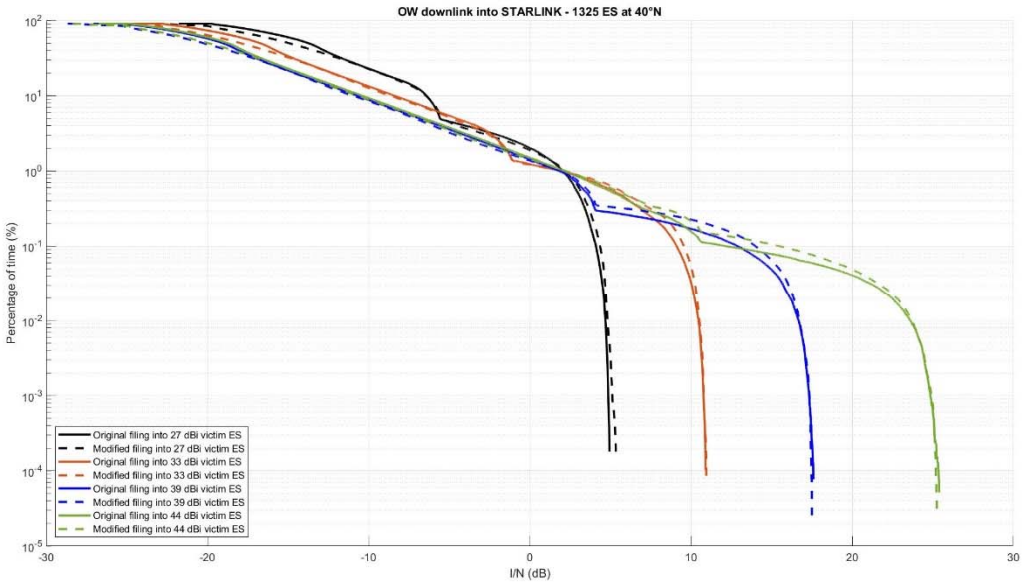
(c) 1,130 km



(d) 1,275 km



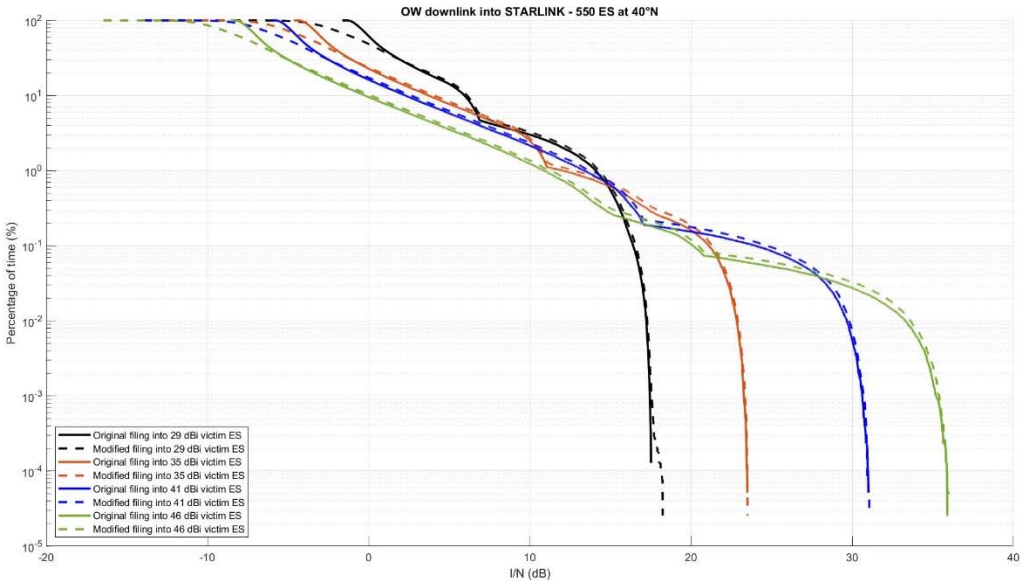
(e) 1,325 km



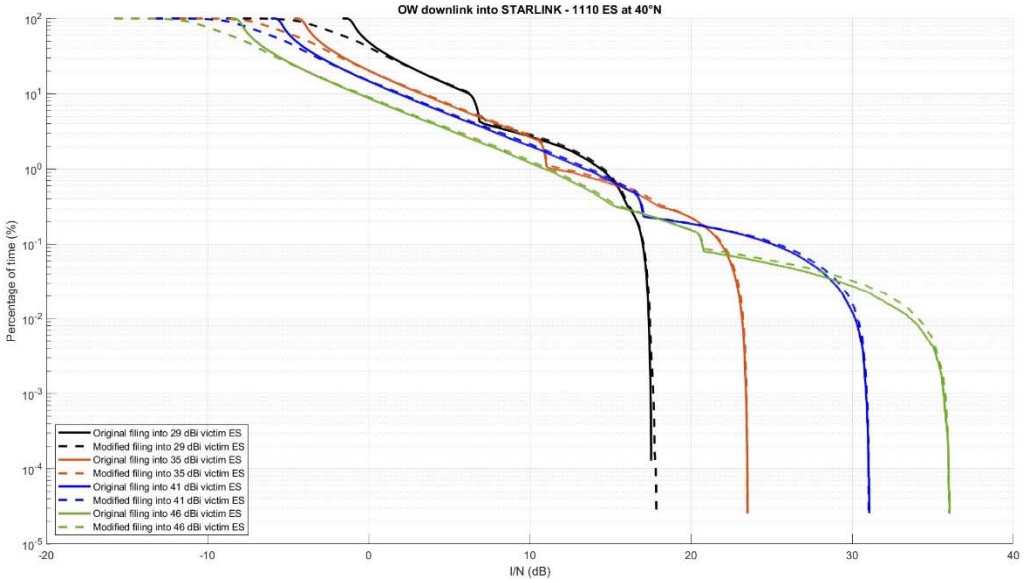
Figures A.8-3 and A.8-4 below shows similar example results in Ka-band for both the Starlink and O3b NGSO FSS systems, respectively. The results are similar to those for Ku-band in Figure A.8-2 above. There is very little difference between the solid and dotted curves which demonstrates that the overall interference environment in Ka-band is not impacted by this proposed Phase 1 modification.

Figure A.8-3: I/N Statistics for Ka-band interference into the Starlink NGSO system for various altitudes

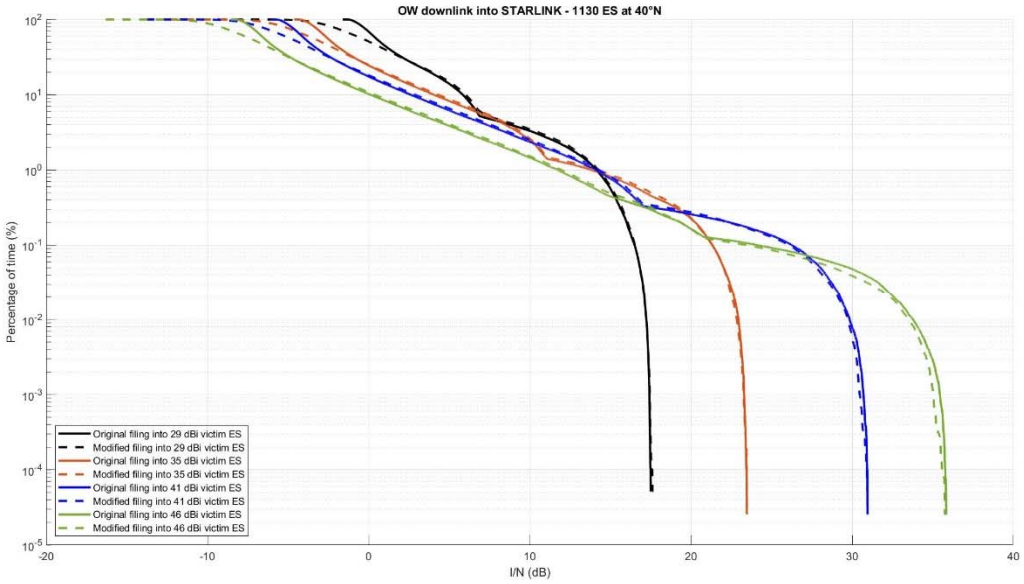
(a) 550 km



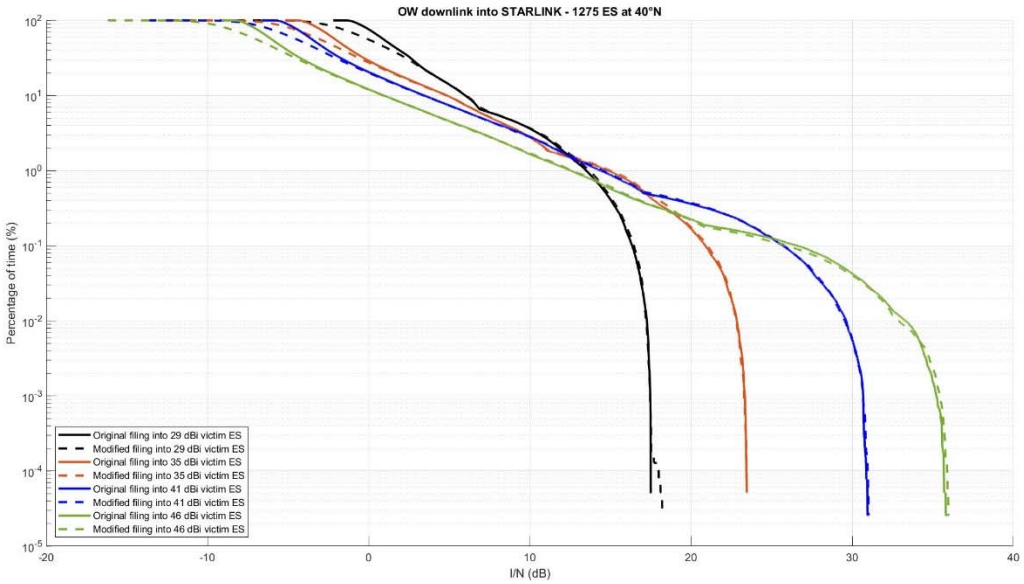
(b) 1,100 km



(c) 1,130 km



(d) 1,275 km



(e) 1,325 km

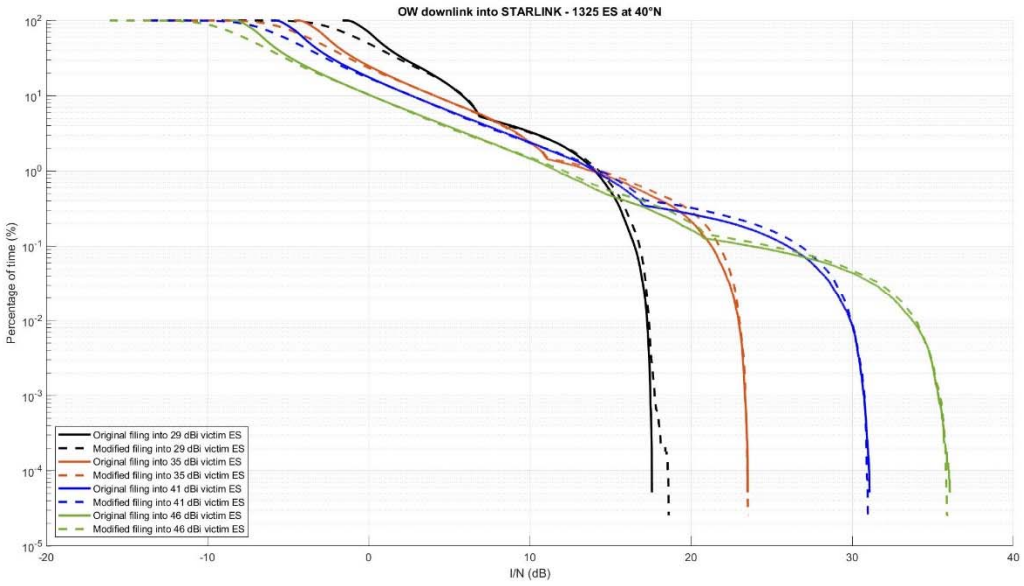
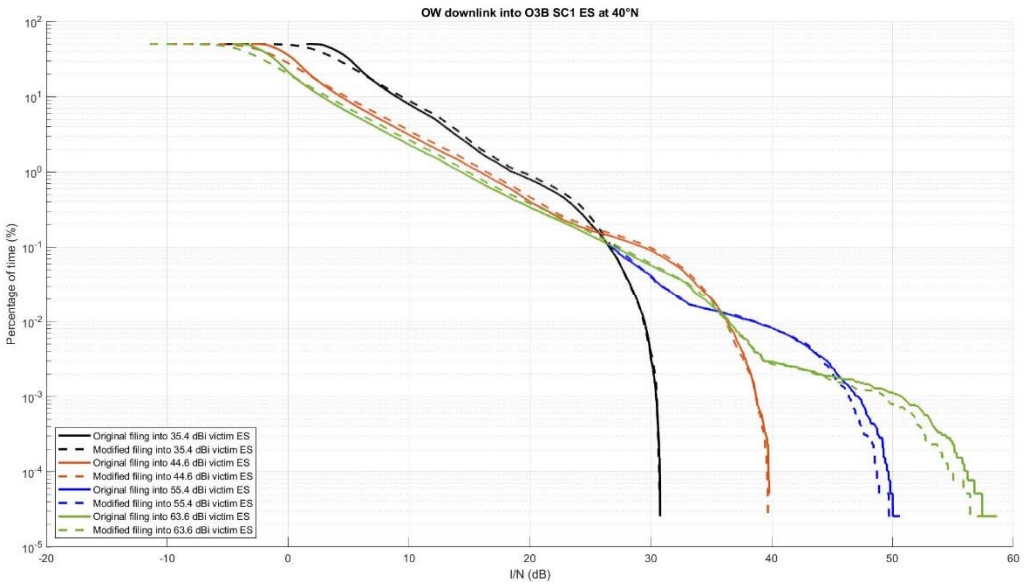
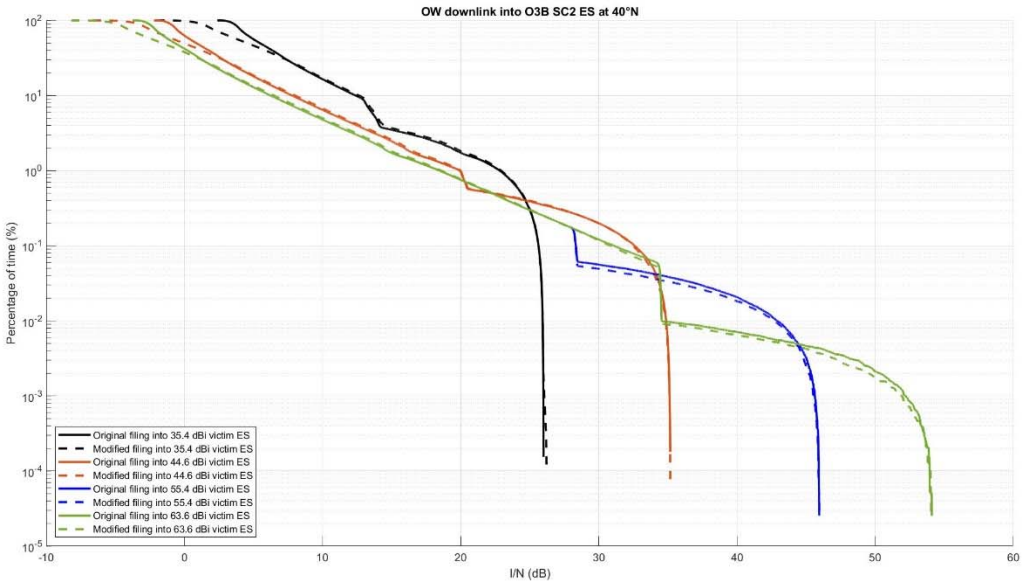

OW downlink into STARLINK - 1325 ES at 40°N
Percentage of time (%)
I/N (dB)
Original filing into 29 dBi victim ES
Modified filing into 29 dBi victim ES
Original filing into 35 dBi victim ES
Modified filing into 35 dBi victim ES
Original filing into 41 dBi victim ES
Modified filing into 41 dBi victim ES
Original filing into 46 dBi victim ES
Modified filing into 46 dBi victim ES

Figure A.8-4: I/N Statistics for Ka-band interference into the O3b NGSO system for various O3b orbit types

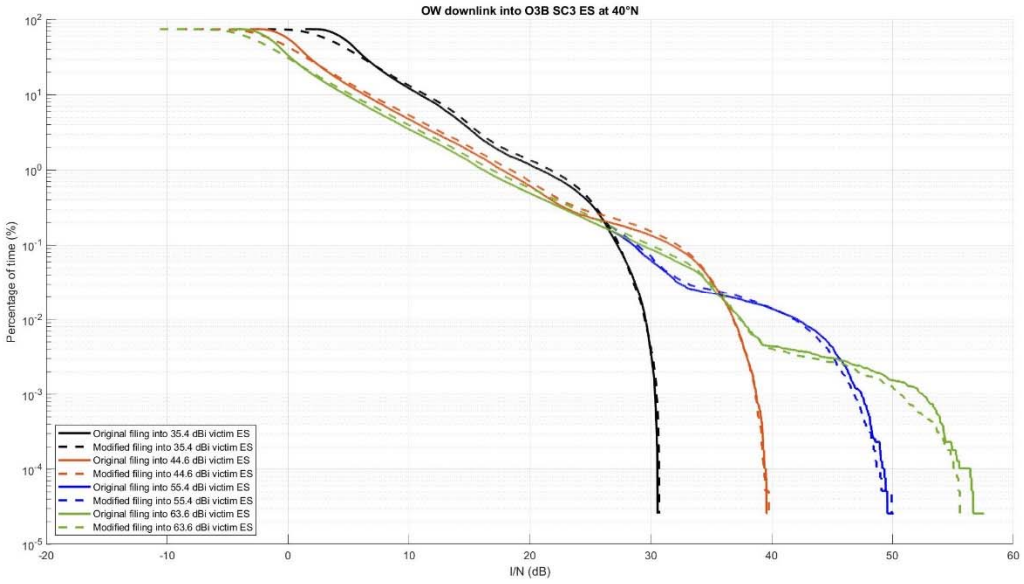
(a) 70° inclination, RAAN=0° (5 O3b satellites)
(Orbit Plane 1 from O3b Schedule S)



(b) Equatorial (32 satellites)
(Orbit Plane 2 from O3b Schedule S)



(c) 70° inclination, RAAN=180° (5 O3b satellites)
(Orbit Plane 3 from O3b Schedule S)



A.8.3 Interference with Respect to Terrestrial Networks in the 10.7-11.7 GHz Band

This information is available in Attachment A to the Market Access Petition and is unchanged by the proposed Phase 1 modification.

A.8.4 Interference with Respect to Terrestrial Networks in the 12.2-12.7 GHz Band

This information is available in Attachment A to the Market Access Petition and is unchanged by the proposed Phase 1 modification.

A.8.5 Interference with Respect to Terrestrial Networks in the 17.8-18.3 GHz Band

This information is available in Attachment A to the Market Access Petition and is unchanged by the proposed Phase 1 modification.

A.8.6 Interference with Respect to Terrestrial Networks in the 27.5-28.35 GHz Band

OneWeb acknowledges that FSS is secondary to the Upper Microwave Flexible Use Service ("UMFUS") in this band. OneWeb's operations in this band will adequately protect UMFUS operations and otherwise will be consistent with Section 25.136(a) of the Commission's rules, as described in OneWeb's license applications for gateway earth stations in the United States.[16]

A.8.7 Interference with Respect to TDRSS Receiving Ground Stations in the 14.0-14.2 GHz Band

OneWeb has been involved in coordination discussions with NASA concerning the protection of its designated tracking and data relay satellite system receiving ground stations in the U.S. from

[16] *See* n.5 above.

transmissions of the OneWeb user terminals operating in the 14.0-14.2 GHz band, consistent with the OneWeb Market Access Grant.[17] This coordination process is unlikely to be affected by the proposed Phase 1 modification since the user terminals will not transmit higher EIRP density, their antenna performance remains the same with this Phase 1 modification, and their operating elevation angle statistics remain the same.

A.8.8 Interference with Respect to the Radio Astronomy Service

OneWeb has been involved in coordination discussions with the National Science Foundation (NSF) and the Heads of various Radio Astronomy Service ("RAS") sites concerning the protection of the RAS sites in the USA and worldwide. These protection requirements have been factored into the design of the OneWeb satellites and are equally applicable to the proposed Phase 1 modification of the OneWeb System. Whilst the agreement(s) has/have not yet been signed, agreement has been reached in principle with regards to satellite unwanted emissions in the 10.6-10.7 GHz band and significant progress has been made to address the potential interference from transmitting earth stations (gateways and user terminals) to ensure protection of RAS sites. The coordination discussions are also addressing the possibility of perturbations to optical astronomy and work continues to avoid reflections from the OneWeb satellites into optical telescopes. To date, no complaint has been received from astronomers regarding the 74 operational OneWeb satellites likely due to their low reflectivity, and this can only improve as the satellites move from their current orbit to their final orbit altitude of 1200 kilometers.

[17] *See* Market Access Grant, ¶ 20.

A.9 COORDINATION WITH THE US GOVERNMENT SATELLITE NETWORKS (Footnote US334 in the FCC Table of Frequency Allocations)

OneWeb has been actively engaged since early 2017 in coordination with the US government satellite networks, as required by US334, and excellent progress has been made. OneWeb will continue the coordination and take into account the modified characteristics of the OneWeb System as detailed in this petition.

OneWeb is optimistic that coordination can be concluded in a mutually acceptable manner since there is no difference between the Ka-band portion of the 55° inclined satellites and the already authorized 87.9° inclined satellites. OneWeb will inform the Commission when it has been completed.

A.10 COORDINATION WITH VERY LARGE ANTENNAS (VLA) IN THE 10.7-12.75 GHZ BAND (§25.146(d))

OneWeb has progressed this coordination process with the representative of the operators of VLAs in various countries around the world and is optimistic that it can be concluded in the near future. OneWeb will inform the Commission when this coordination has been completed.

A.11 ORBITAL DEBRIS (§25.114(d)(14))

This matter is addressed in the Legal Narrative included with the modification application.

A.12 SATELLITE EIRP DENSITY VALUES

The satellite EIRP density values are not changed from the Market Access Petition. Refer to Attachment A to the Market Access Petition for this information. This data is now also entered into the associated Schedule S.

A.13 SATELLITE G/T AND SFD RANGE VALUES

The satellite beam-peak G/T values (for both the minimum and maximum saturation flux density values for each space station receive antenna) are not changed from the Market Access Petition. Refer to Attachment A to the Market Access Petition for this information. This data is also entered into the associated Schedule S.

A.14 ADDITIONAL INFORMATION CONCERNING DATA IN THE ASSOCIATED SCHEDULE S (§25.114(c))

The Schedule S associated with this Phase 1 of the OneWeb System also includes data relevant to Phase 2. In addition, as part of this submission there is an associated Excel spreadsheet containing orbit data for Phase 2. A detailed explanation concerning which data in the Schedule S (and the accompanying Excel spreadsheet) is common to both phases, and which is unique to one, is given in the appropriate sections of this document, as follows:

- Orbit data: See Section A.1
- Beam data: See Section A.3

The associated Schedule S information for the Phase 1 modified OneWeb System was prepared using the FCC's online Schedule S software.[18] The data provided in the Schedule S is consistent with the latest available FCC instructions.[19]

The following notes are provided related to the data provided in the accompanying Schedule S for the OneWeb System:

1. Orbit adjustments of the OneWeb System will be made to the orbit altitudes of the various orbital planes to ensure safe operation.

[18] Schedule S software is available at https://enterpriseefiling.fcc.gov/schedules/.

[19] See SPECIFIC INSTRUCTIONS FOR SCHEDULE S, April 2016, Available at https://enterpriseefiling.fcc.gov/schedules//resources/Instructions%20for%20Schedule%20S%20vApr2016.pdf .

2. For satellite transmitting and receiving beams circular polarization is used, and therefore there is no polarization alignment angle. However, the Schedule S online software defaults to a value of 45° for the polarization angle when circular polarization is selected, and this value cannot be changed, so it should be ignored.

3. The Schedule S PDF printout software does not correctly list the satellite numbering and phase information that has been entered into the online system.

4. Because of differences between the old Schedule S offline software (used for OneWeb's FCC application that resulted in the existing Market Access Grant) and the current online version of the software:

    a. Only half the number of designated channels are required with the current software, as the channel designation does not take into account the polarization used by that channel. The old software had duplicated channel designations to account for the use of dual polarization.

    b. The current software only permits channel designations with up to four characters. For this reason, the channels previously designated as PCU1 to PCU10 are now named PU1 to PU10. Similarly, channels previously designated as PCD1 to PCD10 are now named PD1 to PD10.

    c. The current software requires a separate beam designation for each contiguous frequency range and each polarization. Therefore, the single type of Ka-band beam as defined in the original application has to be duplicated firstly to account for the fact that the beam is used over two non-contiguous frequency ranges, and then duplicated again to allow for the use of dual polarization. Therefore, the Ka-band receive beam GU has become beams GUAL, GUAR, GUBL and GUBR. Similarly, the Ka-band transmit beam GD has become GDAL, GDAR, GDBL and GDBR.

CERTIFICATION OF PERSON RESPONSIBLE FOR PREPARING ENGINEERING INFORMATION

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/ *Philippe Secher*

Philippe Secher
Vice President, Spectrum Engineering
OneWeb