Supplemental Technical Annex

A.1 SCOPE AND PURPOSE

ViaSat, Inc. ("ViaSat") has Commission-authorization to operate the Ka-band VIASAT-2 satellite at 69.9° W.L. Specifically, ViaSat has been granted U.S. market access to provide FSS using the 28.1-29.1 GHz and 29.5-30 GHz bands (Earth-to-space) and the 18.3-19.3 GHz and 19.7-20.2 GHz bands (space-to-Earth). For ease of reference herein, these bands are defined as being the "upper" Ka-bands. ViaSat seeks to modify its authorization to add the 27.5-28.1 GHz band (Earth-to-space) and the 17.7-18.3 GHz band (space-to-Earth). For ease of reference herein, these bands are defined as being the "lower" Ka-bands. ViaSat has previously communicated to the Commission that the VIASAT-2 satellite is capable of operating using these lower Ka-bands.[1]

The purpose of this Annex and the associated Schedule S form is to describe the technical and operational characteristics of the 27.5-28.1 GHz and 17.7-18.3 GHz bands used by the VIASAT-2 satellite.

A.2 GENERAL

The technical parameters of the 27.5-28.1 GHz and 17.7-18.3 GHz bands used by the VIASAT-2 satellite are identical to those previously provided to the Commission for the "upper" Ka-bands of the satellite. More specifically, the following parameters are identical between the two sets of bands:

1) Peak and edge-of-coverage satellite antenna gains.

[1] See ViaSat, Inc., IBFS File No. SAT-MOD-20141105-00121, Exhibit A at 1, n.1.

2) Maximum downlink EIRP and EIRP densities (the latter with respect to the 18.8-19.3 GHz band only; see section A.5, below).
3) Maximum and minimum saturating flux-densities.
4) Satellite antenna gain contours and service areas (in both uplink and downlink directions).
5) Minimum satellite beam cross-polarization isolation performance.

The "lower" bands will not be used for TT&C purposes. The TT&C parameters set forth in A.6 of the Technical Information in Attachment A of SAT-MOD-20141105-00121 that the Commission has already approved for VIASAT-2 remain unchanged by this modification application.

A.3 FREQUENCY AND POLARIZATION PLAN

The relevant frequency plan is given in Table A.3-1, indicating channel center, polarization and bandwidth. The table also shows the connectivity between each uplink and downlink band. Circular polarization is used on both the uplink and downlink with the downlink polarization being orthogonal to the uplink polarization. The satellite re-uses the spectrum such that any channel is re-used multiple times by a combination of polarization and spatial isolation. This satisfies the requirements of §25.210(f) of the FCC's Part 25 rules (the "Rules").

Table A.3-1. Frequency Plan for U.S. Market Access

Uplink Center Frequency (MHz)	Uplink Polarization	Corresponding Downlink Center Frequency (MHz)	Downlink Polarization	Bandwidth (MHz)
27800	RHCP, LHCP	18000	LHCP, RHCP	600

A.4 SATELLITE ANTENNA BEAMS AND ANTENNA GAIN CONTOURS

The satellite's payload employs multiple spot beams in both the uplink and downlink directions. There are two types of spot beams: small beams ("A"-type beams) and larger beams ("B"-type beams). For each beam-type, the beams are nominally identical.

ViaSat has previously provided the Commission with an isoline gain contour, in both uplink and downlink directions, that depict, on a composite basis across the entire coverage area of the satellite, the maximum gain of all spot beams that may be operated within that area. In addition, the predicted antenna gain contours for one transmit and receive representative spot beam for each of the two beam types, and in both polarizations, were also provided to the Commission. As stated in section A.2 above, the satellite antenna beam gain contours applicable to the 27.5-28.1 GHz and 17.7-18.3 GHz bands are identical to those previously provided to the Commission for the "upper" Ka-bands used by the satellite. Accordingly, ViaSat incorporates those beam contours by reference, based on the waiver of Section 25.114(c)(4) that the Commission has granted to allow the beam contour information to be provided in this manner.

For ease of cross-reference, the associated Schedule S uses the beam name designations identified in the previously filed Schedule S forms for the satellite. See File Nos. SAT-MOD-20141105-00121, SAT-AMD-20150105-00002.

A.5 SPACE STATION TRANSMIT AND RECEIVE CAPABILITIES

The maximum operational downlink EIRP of all spot beams is 72.7 dBW.

The maximum operational downlink EIRP density varies by sub-band. The maximum operational downlink EIRP density towards U.S. territory in the 17.7-18.3 GHz band varies slightly depending on the spreading loss. ViaSat will not exceed a PFD on U.S. territory of -118 dBW/m^2/MHz. This PFD level will not be exceeded regardless of the angle of arrival towards U.S. territory. Because PFD is dependent on the slant path length and hence spreading loss, the maximum EIRP density from the satellite can vary accordingly. For example, for a spreading

loss of 162.1 dB, VIASAT-2 satellite transmissions would not exceed an EIRP density of 44.1 dBW/MHz. For U.S. territory that is within the service area of the VIASAT-2 satellite, the elevation angles from the 69.9° W.L. orbital location vary between approximately 14 degrees (northwest Washington State) to 69 degrees (U.S. Virgin Islands). Given this range of elevation angles, the maximum downlink EIRP densities that do not exceed a PFD of -118 dBW/m^2/MHz on U.S. territory, therefore range between 44.1 dBW/MHz to 45 dBW/MHz.

For all uplink spot beams, the minimum and maximum saturating flux densities, respectively, are: -105 dBW/m^2 and -85 dBW/m^2.

A.6 TWO DEGREE COMPATIBILITY

This section demonstrates that uplink transmissions in the 27.5-28.1 GHz band and downlink transmissions in the 17.7-18.3 GHz band are two-degree compatible.

Currently there are no operational GSO Ka-band satellites that use the 27.5-28.1 GHz and 17.7-18.3 GHz bands at or within two degrees of the 69.9º W.L. location, nor are there any pending applications before the Commission for use of these bands by a GSO satellite at or within two degrees of 69.9° W.L. Therefore, in order to demonstrate two-degree compatibility, the transmission parameters of the VIASAT-2 satellite have been assumed as both the wanted and victim transmissions.

Table A.6-1 provides a summary of the typical uplink and downlink transmission parameters used by the VIASAT-2 satellite network and which were used in the interference analysis.

Table A.6-2 shows the results of the interference calculations in terms of the overall C/I margins. The interference calculations assumed a 1 dB advantage for topocentric-to-geocentric conversion and that all wanted and interfering carriers are co-polarized. The C/I calculations were performed on a per Hz basis.

It can be seen that the C/I margins are positive in all cases, thereby demonstrating two-degree compatibility.

Table A.6-1. Typical VIASAT-2 transmission parameters.

Carrier ID	Emission Designator	Bandwidth (MHz)	Tx E/S Gain (dBi)	Uplink EIRP (dBW)	Downlink EIRP (dBW)	Rx E/S Gain (dBi)	C/I Criterion (dB)
1	600MG7D	600	64.7	74.7	67.9	48.8	20.5
2	500MG7D	500	64.7	74.7	67.9	40.2	13.8
3	500MG7D	500	64.7	74.7	67.9	40.2	7.4
4	500MG7D	500	64.7	74.7	67.9	33.2	9.3
5	6M25G7D	6.25	44.0	48.4	51.1	60.9	16.4
6	3M13G7D	3.125	44.0	48.4	45.9	60.9	15.1
7	1M56G7D	1.563	44.0	48.4	42.9	60.9	10.1
8	782KG7D	0.7813	44.0	46.4	39.9	60.9	8.9
9	3M88G7D	3.874	37.0	39.6	46.8	60.9	9.3

Table A.6-2. Summary of the overall C/I margins (dB).

		Interfering Carriers								
	Carrier ID	1	2	3	4	5	6	7	8	9
Wanted Carriers	1	7.8	7.8	7.8	7.8	3.6	4.6	2.7	2.0	2.0
	2	6.0	6.0	6.0	6.0	2.6	5.3	4.8	4.5	4.5
	3	12.3	12.3	12.3	12.3	9.0	11.7	11.1	10.9	10.9
	4	3.5	3.5	3.5	3.5	0.2	3.3	3.2	3.1	3.1
	5	19.7	19.7	19.7	19.7	7.0	4.1	1.1	0.1	0.1
	6	22.2	22.2	22.2	22.2	11.1	8.4	5.4	4.4	4.4
	7	28.5	28.5	28.5	28.5	18.8	16.3	13.4	12.4	12.4
	8	30.0	30.0	30.0	30.0	20.8	18.4	15.5	14.6	14.6
	9	18.6	18.6	18.6	18.6	7.1	4.3	1.4	0.4	0.4

A.7 POWER FLUX DENSITY AT THE EARTH'S SURFACE

§25.208 does not contain any PFD limits that apply across the entire 17.7-18.3 GHz band for GSO satellite networks, however it is noted that Article 21 of the ITU Radio Regulations does include PFD limits applicable to GSO satellites using the 17.7-18.3 GHz band. The ITU limits are identical to those in §25.208(c). Since the PFD limits of §25.208(c) apply to the 17.7-17.8

GHz and 18.3-18.8 GHz band segments, it is therefore reasonable to assume that these same PFD levels equally protect terrestrial services in the intermediate band segment (*i.e.*, 17.8-18.3 GHz) as well.

The PFD limits of §25.208(c) are as follows:

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

As stated in section A.5, ViaSat will operate the satellite such that downlink transmissions in the 17.7-18.3 GHz band will not exceed a PFD level of -118 dBW/m^2/MHz for all angles of arrival. This PFD level is lower than the -115 dBW/m^2/MHz PFD limit value that applies at elevation angles of 5° and below. Therefore compliance with the PFD limits at all angles of arrival is ensured.

A.8 SHARING WITH LMDS IN THE 27.5-28.1 GHZ BAND

In the U.S., the 27.5-28.1 GHz band is designated for LMDS use on a primary basis and it is designated for the FSS on a secondary basis to LMDS. Uplinks from FSS earth stations that are located in the United States must be operated in a manner such that they do not cause harmful interference to any current or future licensed LMDS station.

Applications for earth station antennas communicating with the VIASAT-2 satellite and using the 27.5-28.1 GHz band within the U.S. will include an appropriate demonstration that the proposed operations will not cause harmful interference into any licensed LMDS station. The earth station licensee will take appropriate actions to protect any future licensed LMDS station

that has the potential to receive harmful interference, including ceasing transmissions in the 27.5-28.1 GHz band if necessary.

A.9 SHARING WITH FIXED SERVICE IN THE 17.7-18.3 GHZ BAND

In the U.S., the 17.7-18.3 GHz band is allocated for the Fixed Service ("FS") and for government FSS systems, but does not include an allocation for commercial FSS systems. The International Table does include an allocation for the FSS in these bands. ViaSat seeks authority to operate in this band segment on a non-interference, unprotected basis. Compliance with applicable PFD limits should provide adequate protection to the FS.

A.9.1 Satellite to FS Receiver Interference

As discussed in Section A.7 above, downlink transmissions from the VIASAT-2 satellite will comply with the applicable FCC and ITU PFD limits in the 17.7-18.3 GHz band. The ITU Article 21 PFD limits were developed to protect terrestrial fixed and mobile systems from satellite downlink transmissions in frequency bands where terrestrial and space services are shared with equal rights internationally. Indeed, §25.208(c) adopts these same ITU PFD limits, although domestically, the limits only apply to the 17.7-17.8 GHz band segment (and the adjacent 18.3-18.8 GHz band segment).

As stated in Sections A.5 and A.7 above, VIASAT-2 satellite downlink transmissions in the 17.7-18.3 GHz band toward U.S. territory that is located within the satellite's service area will not exceed a PFD level of -118 dBW/m^2/MHz for all angles of arrival. This PFD level is at a minimum of 7.5 dB lower than the ITU Article 21 PFD limits and therefore ensures protection of the FS. Any FS licensee must anticipate the operation of an international GSO FSS satellite,

such as the VIASAT-2 satellite, that could transmit at the Article 21 PFD limits toward U.S. territory in full conformance with the ITU Radio Regulations.[2]

A.9.2 FS Transmitter to FSS Ground Antenna Interference

There exists the potential for interference between a transmitting FS station and a receiving FSS ground antenna if the ground antenna is too close to the FS station. Depending on the location of the FSS ground antenna relative to the FS antenna's main-beam axis direction, FSS ground antennas need to be geographically separated from the FS transmitting station by an appropriate distance or adequately shielded. Given that ViaSat's operations in the 17.7-18.3 GHz band would be on a non-conforming, unprotected basis, ViaSat accepts the potential risk from FS station interfering into ViaSat's ground antennas in this band.

A.10 SHARING WITH BSS FEEDER LINKS IN THE 17.7-17.8 GHZ BAND

In the U.S., the 17.7-17.8 GHz band is allocated for the FSS (Earth-to-space) but limited to feeder links for the broadcasting-satellite service ("BSS"). This band segment also is allocated internationally for BSS in the space-to-Earth direction. However, there is no allocation for BSS downlinks in the U.S. in the 17.7-17.8 GHz band. Therefore, consistent with the Commission's precedent, [3] this section addresses sharing by VIASAT-2 in the 17.7-17.8 GHz band only with BSS feeder links (Earth-to-space) within the U.S. Compatibility with reverse band BSS downlinks outside of the U.S. will be ensured through applicable ITU rules and the international coordination process.

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[2] See Inmarsat Mobile Networks, Inc., File Nos. SES-LIC-20120426-00397, SES-AMD-20120823-00781, SES-AMD-20150114-00008, Call Sign E120072, 30 FCC Rcd 2770 ¶ 24 (2015).

[3] See id. ¶ 25.

A.10.1 Space Path Interference

A space station transmitting in the space-to-Earth direction in the 17.7-17.8 GHz band segment has the potential to cause interference into a space station receiving Earth-to-space transmissions in the same band (*i.e.,* space path interference due to bi-directional usage). The Commission has examined the potential for such interference in the context of sharing between 17/24 GHz BSS satellites ("RDBS") and BSS feeder links.[4]

The Commission adopted an off-axis PFD coordination trigger in order to manage the potential for interference from a space station downlink transmission into a BSS receive space station. The Commission adopted a PFD coordination trigger level of -117 dBW/(m^2*100 kHz). This value is used to demonstrate that the VIASAT-2 satellite is compatible with BSS feeder links. Note that in general, the off-axis PFD trigger level would only be exceeded in cases where the two satellites are within close proximity to each other (*i.e.,* less than 0.5° orbital separation).

The U.S. BSS Region 2 Plan orbital location nearest to the VIASAT-2 satellite's location is at the nominal 61.5° W.L. slot. Taking into account the ITU's BSS "cluster" concept, the nearest a U.S. BSS satellite could potentially operate from the nominal 61.5° W.L. slot is at 61.7° W.L. (*i.e.,* ±0.2° from the nominal Plan location).

Accounting for worst-case east-west station-keeping of 0.05°, the spreading loss between the 69.85° W.L and 61.75° W.L. locations can be calculated to be -146.5 dB. As stated in section A.5, the maximum EIRP density transmitted by the VIASAT-2 satellite in the 17.7-18.3 GHz band is 45 dBW in 1 MHz, equivalent to 35 dBW in 100 kHz. Assuming a very conservative satellite antenna off-axis gain discrimination of 30 dB towards the 61.75° W.L. location, the

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[4] See Establishment of Policies and Service Rules for the Broadcasting-Satellite Service at the 17.3-17.7 GHz Frequency Band and at the 17.7-17.8 GHz Frequency Band Internationally, and at the 24.75-25.25 GHz Frequency Band for Fixed Satellite Services Providing Feeder Links to the Broadcasting-Satellite Service and for the Satellite Services Operating Bi-directionally in the 17.3-17.8 GHz Frequency Band, Second Report and Order, 26 FCC Rcd 8927 (2011).

resulting PFD can be calculated to be -141.5 dBW/m^2/100kHz; a value far lower than the -117 dBW/m^2/100kHz coordination trigger level. Thus, the VIASAT-2 satellite is compatible with U.S. BSS feeder link operations.

A.10.2 Ground Path Interference

There exists the potential for interference between a transmitting BSS feeder link station and a receiving FSS ground antenna if the ground antenna is too close to the BSS feeder link station and not adequately shielded. Given that ViaSat's operations in the 17.7-17.8 GHz band segment would be on a non-conforming, unprotected basis, ViaSat accepts this risk.

A.11 COMPATIBILITY WITH NGSO SYSTEMS

O3b Limited ("O3b") has received licenses from the Commission for fixed earth stations located in Hawaii, Texas and Virginia to communicate with O3b's constellation of NGSO satellites using the 27.6-28.1 GHz frequencies on a secondary basis to LMDS and in the 17.8-18.3 GHz frequencies on a non-interference basis.[5] ViaSat has already demonstrated in connection with the current authorization for VIASAT-2 that operations in the 28.1-28.35 GHz, 28.6-29.1 GHz and 18.8-19.3 GHz band segments are compatible with O3b's operations in the United States. The conclusion of the analysis in that submission is equally applicable to O3b's operations in the 27.6-28.1 GHz and 17.8-18.3 GHz band segments.

With respect to the operation of VIASAT-2 in the 27.5-28.1 GHz and 17.7-18.3 GHz frequencies, and the OneWeb system, WorldVu Satellites Limited d/b/a OneWeb ("OneWeb") has explained in its pending letter of intent application that its system will share spectrum used by GSO communications satellites successfully because its satellites will be orbiting in a low earth near-polar orbit, and operating in a manner that results in significant isolation from GSO

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[5] See File Nos. SES-LIC-20100723-00952; SES-LIC-20141022-00809; SES-LIC-20130124-00089; SES-LIC-20130618-00516; SES-LIC-20150310-00138.

satellites and earth stations during most of a OneWeb satellite's orbital path.[6] OneWeb explains that the techniques "used to protect GSO satellite networks from interference from the OneWeb NGSO system . . . have the effect also of protecting the OneWeb system from GSO interference, as they are based on the principle of avoiding inline and near-inline events."[7] Thus, these same techniques similarly should ensure that OneWeb will not suffer harmful interference from the operation of VIASAT-2 in the lower Ka bands. Further, OneWeb states that it "confirms that it is not claiming interference protection from GSO FSS and BSS networks operating in accordance with the Commission's part 25 rules and the ITU Radio Regulations."[8]

A.12 WAIVER REQUEST

Section 25.210(i) of the Rules, 47 C.F.R. § 25.210(i), requires that space station antennas in the FSS be designed to meet a cross-polarization isolation of 30 dB within the primary coverage area of the antenna. The VIASAT-2 satellite's transmit and receive antennas can have a cross-polarization isolation as low as 24 dB. The Commission has granted a waiver for VIASAT-2 for this lower cross-polarization isolation.[9] ViaSat requests a waiver of the 30 dB cross-polarization isolation requirement in 47 C.F.R. § 25.210(i) to the extent necessary for this request for modification to add frequencies to VIASAT-2. ViaSat incorporates by reference the justifications for such a waiver request previously provided.[10]

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6 See File No. SAT-LOI-20160428-00041, Legal Narrative at 11.

7 See id, Technical Narrative, at A.8.1.

8 See id, Technical Narrative, Annex 2 at A2-12.

9 See File Nos. SAT-MOD-20141105-00121, SAT-AMD-20150105-00002, Call Sign S2902, Condition 3 (granted Apr. 15, 2015).

10 See File Nos. SAT-MOD-20141105-00121, Attachment A, Section A.13.

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 pleading, 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 pleading, and that it is complete and accurate to the best of my knowledge and belief.

/s/

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