ONEWEB NON-GEOSTATIONARY SATELLITE SYSTEM
V-BAND COMPONENT

ATTACHMENT A
Technical Information to Supplement Schedule S

A.1 SCOPE AND PURPOSE

This attachment contains the information required by §25.114(d) and other sections of the FCC's Part 25 rules that cannot be captured by the Schedule S software.

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))

The V-band[1] component of the OneWeb non-geostationary satellite orbit ("NGSO") system (hereafter referred to as "OW-V") is a single NGSO satellite system that will consist of two sub-constellations in orbit, as follows:

- A LEO (Low Earth Orbit) component consisting of additional communications payloads on the next generation constellation of Low Earth Orbit ("LEO") OneWeb satellites, for

[1] The term "V-band" is used throughout this document to refer to the FSS allocations between about 37 GHz and 50.4 GHz.

which an FCC application is already pending.[2] The V-band payload is completely separate from and not connected to the existing Ku/Ka-band payload of the core OneWeb satellites – it will simply share the same spacecraft bus. The V-band communications payload is intended to be implemented only on follow-on satellites after the initial OneWeb constellation is operational. The operational sub-constellation will consist of a total of 720 OneWeb satellites with V-band capability and they will operate at an altitude of 1,200 km.[3]

- A MEO (Medium Earth Orbit) component consisting of a new constellation of satellites in an orbit with a nominal altitude of 8,500 km and an inclination of 45°.[4] There will ultimately be 16 orbital planes, but with an initial deployment of 20 satellites in eight planes making a total of 160 satellites. Later phases of deployment will increase the number of planes to 16 and the number of satellites per plane from 20 to 80, making a total of 1,280 satellites.

In addition to the satellites referred to above, the OW-V system will also include V-band gateway earth stations and enhanced user terminals equipped with V-band capability.

The two constellations will provide service to the same V-band user terminals. The rationale for the two separate constellations is as follows:

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2 *See Worldvu Satellites Limited, Petition for a Declaratory Ruling Granting Access to the U.S. Market for the OneWeb System*, IB File No. SAT-LOI-20160428-00041 (filed Apr. 28, 2016) ("*OneWeb Ku-/Ka-band Petition*").

3 The OneWeb satellite system has been designed such that more satellites beyond 720 can be added to the constellation at a future time to increase capacity while still protecting GSO satellite networks. Technical design features necessary to achieve this evolutionary approach are inherent in all the satellites to be launched as part of the OneWeb system.

4 See the associated Schedule S for the details of the slight orbit altitude differences of the various MEO orbit planes, which is designed to avoid any risk of collision between satellites in different planes as they cross each other.

- The LEO component continues to provide the low latency service of the core (Ku/Ka) OneWeb system, due to its lower orbit altitude, while providing extra flexibility to allocate the satellite resources non-uniformly across the visible Earth's surface. It therefore complements the core OneWeb mission by adding the ability to address high traffic density locations within the satellite footprint.
- The MEO component, although exhibiting somewhat higher latency because of the higher orbit altitude, has the additional advantage of having even greater flexibility to allocate the satellite resources to geographic areas of need, because of the larger area of the Earth visible to the MEO satellite.

Both the LEO and MEO V-band satellites perfectly complement the core OneWeb Ku/Ka band mission by providing additional capacity worldwide and with considerable traffic assignment flexibility, overlaid on the blanket Earth coverage of the core OneWeb system. The V-band service will use steerable spacecraft antennas to "point-and-shoot" towards user terminals located in high traffic areas. Such an approach would not be optimal for a standalone system that requires more uniform service distribution to many user terminals spread over large service areas, but it is well suited to this complementary V-band system that operates in conjunction with the OneWeb Ku/Ka-band core mission. The V-band service will be potentially available anywhere in the world where high traffic density is needed, such as metropolitan areas or a geographic concentration of business/government customers with unusually high traffic requirements. It will provide the same high-quality, broadband Internet access that is to be offered by the initial Ku/Ka band OneWeb system and to similar sized user terminals. The service provided will be comparable to the broadband terrestrial services available in densely populated areas of developed countries today.

OneWeb will dynamically assign traffic between the LEO and MEO components of the V-band system depending on the instantaneous service requirements and overall traffic loading of the combined system. The users need not be aware which of the satellite orbits they are accessing at any particular time.

The OW-V system uses V-band for the RF links between the satellites and user terminals and also between the satellites and gateway earth stations, with the latter providing the interconnection to the global internet. The OW-V user terminals consist of small and inexpensive antennas (typically in the 30 cm to 75 cm range). Implementation of these antennas may involve mechanically steered parabolic reflectors and/or low-cost phased array designs, or other beam steering technology already under development. An optional built-in solar array panel can be added to battery powered terminals. The user terminals will therefore be quick and easy to deploy and can easily be used for transportable applications. The V-band gateway earth stations will typically utilize 1.2m to 3.4m antennas, depending on their location and the associated propagation characteristics and service requirements.

The frequency ranges used by both the LEO and MEO sub-constellations of the OW-V system are summarized in Table A.2-1 below. The detailed channelized frequency plan is given in the associated Schedule S. Full frequency re-use of the V-band gateway spectrum is achieved by the use of dual orthogonal polarizations on these gateway links. The V-band user link spectrum is spatially re-used a total of five times in each OW-V satellite on the user links. Spectrum that is used for both gateway and user links is also re-used between the gateway and the user links by spatial separation of the respective gateway and user beams. This results in each LEO and each MEO satellite using 10 GHz of bandwidth in each transmission direction (forward and return), taking into account the spatial and polarization re-use schemes.

Table A.2-1: Frequency bands used by the OW-V non-GSO satellite system [5]

Type of Link and Transmission Direction	Frequency Ranges
Gateway-to-Satellite	42.5 – 43.5 GHz 47.2 – 50.2 GHz 50.4 – 51.4 GHz
Satellite-to-Gateway	37.5 – 42.5 GHz
User Terminal-to-Satellite	48.2 – 50.2 GHz
Satellite-to-User Terminal	40.0 – 42.0 GHz

The frequency re-use scheme for the various parts of the V-band spectrum is summarized in Table A.2-2 below.

Table A.2-2: Frequency re-use of the V-band spectrum by the OW-V non-GSO satellite system

Frequency Range	Frequency Re-Use Scheme
37.5 – 40.0 GHz (2.5 GHz)	Satellite-to-Gateway (dual polarization)
40.0 – 42.0 GHz (2.0 GHz)	Satellite-to-Gateway (dual polarization) + Satellite-to-User Terminal (20 beams with 5-fold spatial re-use)
42.0 – 42.5 GHz (0.5 GHz)	Satellite-to-Gateway (dual polarization)

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5 The uplink and downlink bands are immediately adjacent at 42.5 GHz for the gateway links, necessitating a guard band in practice to prevent out-of-band effects causing instability in the satellite payload or the earth stations. The width of this guard band has not yet been determined.

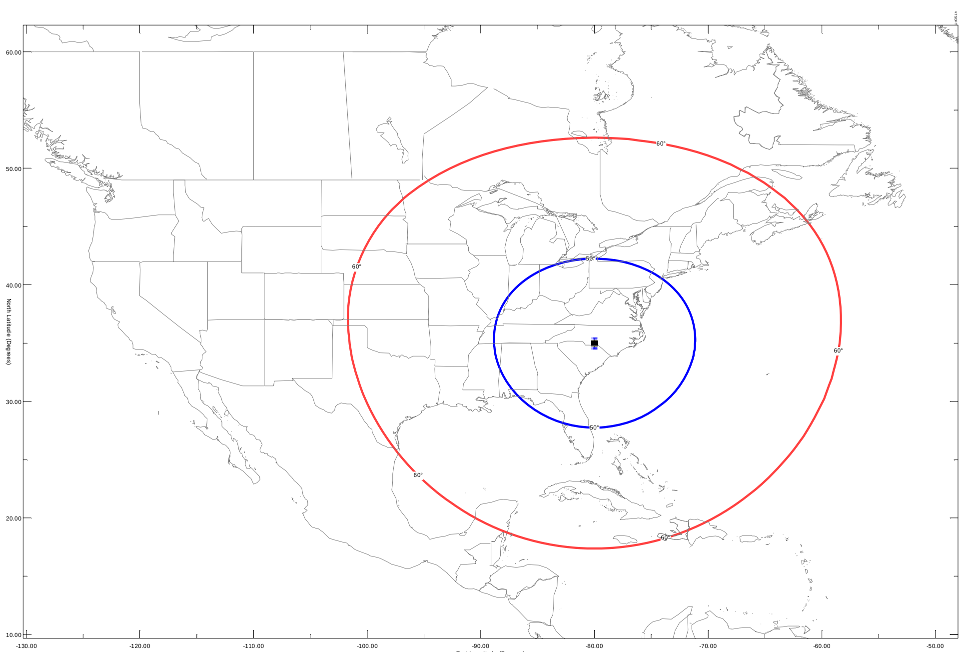
42.5 – 43.5 GHz (1.0 GHz)	Gateway-to-Satellite (dual polarization)
47.2 – 48.2 GHz (1.0 GHz)	Gateway-to-Satellite (dual polarization)
48.2 – 50.2 GHz (2.0 GHz)	Gateway-to-Satellite (dual polarization) + User Terminal-to-Satellite (20 beams with 5-fold spatial re-use)
50.4 – 51.4 GHz (1.0 GHz)	Gateway-to-Satellite (dual polarization)

The OW-V system provides broadband communications services between the user terminals and the gateway earth stations located on the global fiber network. Typically, up to ten or in some cases more OW-V gateway earth station antennas will be collocated at a gateway site in order to access a number of visible OW-V satellites simultaneously from that location. Currently, four OW-V gateway earth station sites are expected to be deployed in the USA, including gateway earth stations in Hawaii and Alaska, and likely additional sites in some US territories. The OW-V gateway earth stations will likely be collocated with OneWeb's Ka-band gateway earth stations, although there may be some exceptions to this for operational reasons. The exact locations of the gateway earth stations have yet to be determined. For the LEO satellites the OW-V gateway earth stations will only transmit and receive communications traffic as TT&C functions are performed as part of the core OneWeb system using Ka-band frequencies. For the MEO satellites certain gateways stations will additionally act as TT&C stations, with the TT&C transmissions taking place in the V-band. The V-band gateway stations are capable of serving both the LEO and MEO satellites for communications traffic.

The OW-V system will operate under the control of the core OneWeb satellite control centers that are described in the earlier OneWeb application to the FCC. Connectivity between these control centers and the TT&C and gateway earth stations will be implemented using terrestrial leased circuits and secure Internet virtual private networks (VPN).

Each OW-V satellite will have 20 identical circular *user* beams, generated by a mechanically fixed flat-plate phased-array satellite antenna, capable of being electronically steered over a user service area footprint similar to that used for the Ku-band user links of the core OneWeb mission. The user beams generated by the satellite antennas will have different beamwidths on the LEO versus the MEO satellites. For the OW-V LEO satellites, this user service area will correspond to a range of Earth locations where the elevation angle is generally greater than 50°, although there may be very limited instances where the minimum elevation angle reduces to 45°. For the OW-V MEO satellites the user service area will be considerably larger than for the LEO satellite and will correspond to Earth locations where the elevation angle is generally greater than 60°. Lower elevation angles, down to 45°, will be used in limited situations, such as for the provision of service to high latitude regions such as Alaska. Figure A.2-1 below compares these nominal user beam service areas for the LEO and MEO satellites in the OW-V system.

Figure A.2-1: Example user beam service areas for the OW-V non-GSO satellite system with a satellite over CONUS: (a) LEO satellite (blue - 50° elevation) (b) MEO satellite (red - 60° elevation)



Because of the spatial frequency re-use scheme employed for the user beams, up to four of the user beams from each satellite (LEO or MEO) may be geographically overlaid on each other to increase the capacity available to any geographic point in the service area, giving the flexibility for anything between approximately 500 MHz and 2 GHz available from a single point or small geographic area from a single OW-V satellite.

The OW-V satellites have two identical *gateway* antennas, each being mechanically steered and capable of being pointed to any part of the visible Earth.[6] In the forward link direction (gateway-to-user) the 20 uplink channels (ten in each polarization) in one gateway receive beam (the one tracking the servicing gateway) are converted to 20 downlink channels, each one routed to one of the 20 user beams, nominally at 500 MHz bandwidth in each beam. In the return link direction (user-to-gateway), 20 different uplink channels from the 20 satellite user beams are converted to 20 downlink channels (ten in each polarization) and sent back to the same gateway transmit beam ("return links"), each having a nominal channel bandwidth of 500 MHz. The second gateway antenna is tracking the next gateway earth station for handover purposes. Dual polarization is used for the gateway links to allow for 20 channels, each of nominal 500 MHz bandwidth, in the available spectrum.[7]

As mentioned above, the OW-V system uses multiple steerable user beams within the designated service areas for each satellite. As the OW-V satellites move in their orbits the electronically steerable user beams will continually be pointed towards the designated service points. As a OW-V satellite moves beyond reach of each service point, handover will occur to the next OW-V satellite so there is no service interruption to the users. The OW-V satellite phased array

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[6] Although the gateway beams can be pointed to any part of the visible Earth, in practice they will operate at elevation angles greater than 15° for the LEO and 25° for the MEO in most cases.

[7] The actual channel bandwidth is 490 MHz, as given in the associated Schedule S.

antenna will implement additional beams during the instant of handover of each user beam. Similarly, as mentioned above, handover of the OW-V satellite gateway link from one gateway earth station to another will also occur as the satellites move in their orbits using the additional satellite gateway antenna.

In the forward transmission direction (gateway-to-user) the 20 channels on each OW-V satellite will share the high power amplifiers embedded in the active phased array antenna, so there is no one-to-one correspondence between channels and HPAs. For the return transmission direction (user-to-gateway) there are a total of four HPAs in each satellite, with each gateway HPA permanently connected in one polarization on each of the gateway transmit antennas. Each HPA transmits all the channels in a single polarization for each gateway antenna, so each HPA, when active, transmits ten gateway downlink channels. Gateway beam handover from one gateway earth station to another is achieved seamlessly by ensuring simultaneous transmission to both gateways for a very short period of time during handover.

In the OW-V communications payloads there is full flexibility to interconnect any of the uplink channels to any of the downlink channels, in both forward and return transmission directions.

For each OW-V satellite (LEO and MEO), full frequency re-use will occur between the user beams and the gateway beams. This necessitates ensuring spatial separation between the gateway beams and any of the user beams on each OW-V satellite. This will be achieved by the following techniques:

(1) The user beams will generally operate only above a certain minimum elevation angle of 50° or 60° (for LEO and MEO, respectively). Therefore, any gateway beam operating with a certain minimum angular separation below these elevation angles will always have sufficient isolation to permit spatial re-use of the user beam frequencies;

(2) Gateway beams at higher elevation angles will be usable, provided the gateway locations in question are sufficiently far away from any of the target user beam locations. In general this will be feasible as the OW-V gateways will tend to be in more remote areas and the user beams will tend to be required in the more densely populated areas.

There will be additional five-fold spatial frequency reuse between user beams on each satellite. Each user channel is therefore reused on five of the user beams, and these co-frequency user beams must be geographically separated from each other to avoid self-interference. This means that up to four of the user beams on each satellite (LEO or MEO) may be collocated, or close to one another, without causing self-interference.

Based on the frequency re-use schemes described above, the requirements of §25.210(f) are fully met whether those requirements apply to V-band frequencies or not.

The transmission schemes in the OW-V system are similar to the core OneWeb system, except for the use of wider bandwidth carriers and channels in the OW-V system. The proposed scheme is described below.

Each forward channel supports a single wideband carrier. Return channels employ a number of medium bandwidth carriers, supporting a variable information data rate, depending on the instantaneous modulation and coding scheme employed. Adaptive coding and modulation (ACM) is used to ensure the optimum data throughput as a function of the link margin available at the time, which varies as a function of rain fade as well as the time varying geometry of the link due to the moving OneWeb satellite. The ACM is adapted for each transmission burst to/from a user terminal based on the specific link quality available.

Each user beam supports services to multiple user terminals within that beam. In the forward direction (gateway-to-user) there is a TDM transmission scheme in operation whereby each user beam supports a single nominally 500 MHz wideband carrier. Each user terminal in the beam receives and demodulates this carrier and extracts only the data that is destined for it, which is determined by the data headers. In the return direction (user-to-gateway) there is a Single Carrier TDMA/FDMA (SC-TDMA/FDMA) transmission scheme where each user terminal transmits time bursts of data on a relatively narrow-band carrier (typically 1.25 MHz to 50 MHz wide) to minimize the peak RF transmit power requirements of the user terminal. Multiple user terminals can access the same uplink carrier based on allocated time slots from the network control center. They can also access different uplink carriers that occupy the uplink channel used in the satellite beam in which the user is located. The multiple return carriers are then received by the gateway station. The control information between the user terminals and the network control center is carried over the same RF channels used for communications information.

The channel center frequencies and bandwidths, as well as the connectivity of those channels to the various satellite beam types in each OneWeb satellite, are defined in the associated Schedule S.

There are two broad categories of earth stations in the OW-V system – the OW-V gateway (and in some cases, also TT&C) stations and the OW-V user terminals. The gateway/TT&C sites will employ multiple active tracking antennas, each typically of 1.2 to 3.4 meters in reflector diameter. The user terminals, which will be deployed in large numbers, are typically in the range of 30 cm to 75 cm in equivalent antenna diameter and will include fixed and transportable ground-based terminals as well as mobile terminals on board aircraft, maritime vessels and land vehicles.[8] The user terminals will employ mechanically steerable parabolic reflector antennas, electronically steerable phased array antennas or other beam steering technology. User terminals will be capable of providing continuous service, allowing for handovers between active satellites. For the mechanically steered antennas, this will be achieved by the use of two independently steerable apertures or, for certain applications, with a single antenna aperture that can quickly switch pointing direction between the active satellites, using data buffering to ensure no loss of transmitted information. For the phased array implementation of the user terminal, the electronically steerable beam will instantaneously switch between active satellites using a single fixed antenna aperture.

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[8] OneWeb will separately seek authorization for its earth stations, including gateway and user terminals, operating in US territories.

The simultaneous use of the same V-band frequencies between the LEO and MEO components of the OW-V system will be controlled from the OW-V network control center in such a way that there is no unacceptable intra-system interference in the OW-V system. This will be achieved by ensuring no inline or near-inline co-frequency transmissions take place in either the uplink or downlink direction between the LEO and MEO components of the system.

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

The predicted antenna gain contours provided in this Section are the same for all beams of the same type (user or gateway) on each satellite and for all satellites within each orbital plane. They are also the same for all satellites on the LEO orbital planes and also identical for all satellites on the MEO orbital planes.

Data for the antenna gain contours shown below are embedded in the associated Schedule S submission. The Schedule S data is provided in the form of GXT files of the required contours plotted with the beam peak pointed to nadir, as required by §25.114(c)(4)(vi)(B).

A.3.1 Antenna Gain Contours for the User Beams

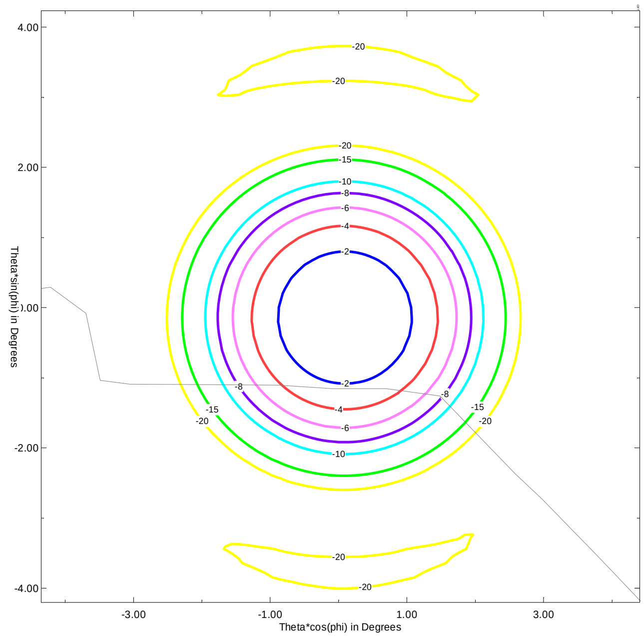
For the links between the OneWeb satellites and the users, each satellite (LEO or MEO) in the OW-V system has 20 identical steerable V-band receive and transmit spot beams generated by the satellite phased array antennas. These user beams are steerable over the user beam service area which, for the LEO satellites, is nominally defined by the 50° elevation contour, and for the MEO satellites, is nominally defined by the 60° elevation contour. Each of these spot beams is nominally circular, although the beam distorts as the scan angle increases as shown below.

Figures A.3.1-1 and A.3.1-2 below provide examples of the beam contours for the user beam transmit antennas of the LEO and MEO satellites, respectively. Two extreme cases of antenna pointing direction are shown for each: the first with the beam pointed directly to nadir, and the second with the beam pointed towards the edge of the service area (shown by the elevation contour). The beams are plotted in satellite-centered angles relative to nadir.

Figures A.3.1-3 and A.3.1-4 below provides the same information for the user beam receive antennas of the LEO and MEO satellites, respectively.

Figure A.3.1-1: User beam transmit antenna gain contours for the LEO satellites

(a) Beam pointed to nadir



(b) Beam pointed to edge of service area (north-east)

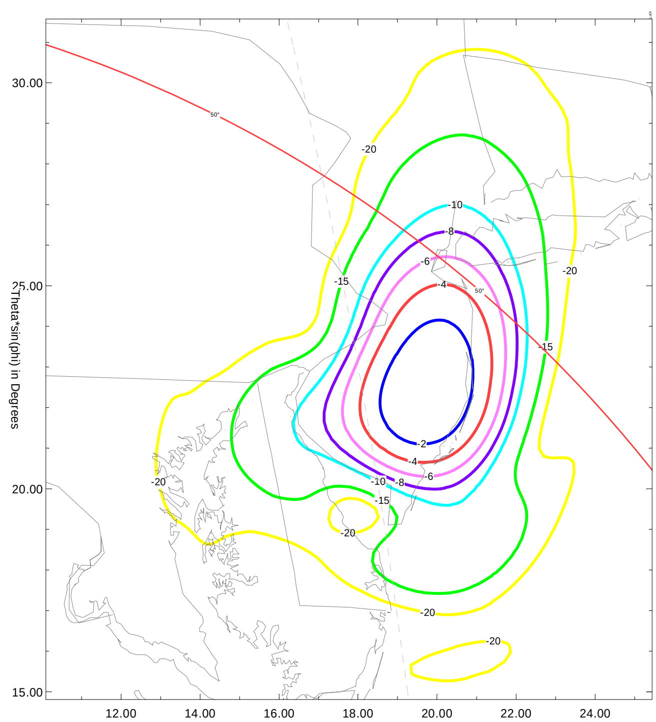
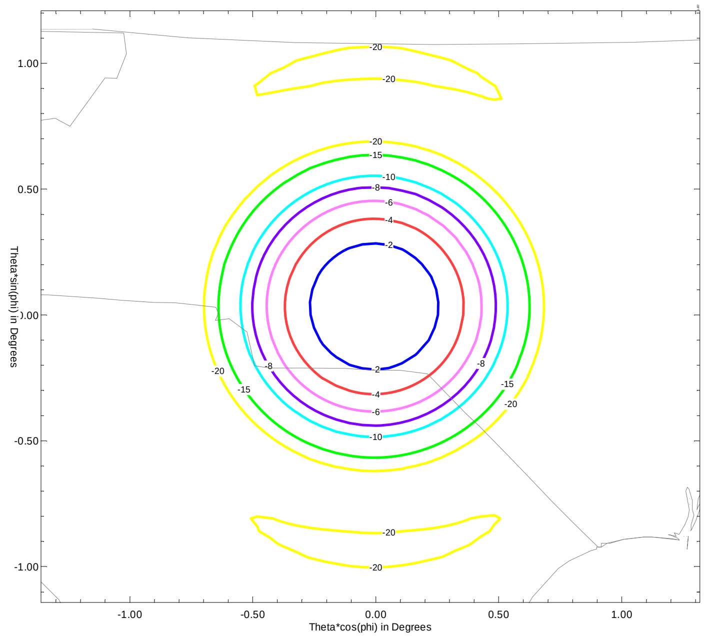


Figure A.3.1-2: User beam transmit antenna gain contours for the MEO satellites

(a) Beam pointed to nadir



(b) Beam pointed to edge of service area (north-east)

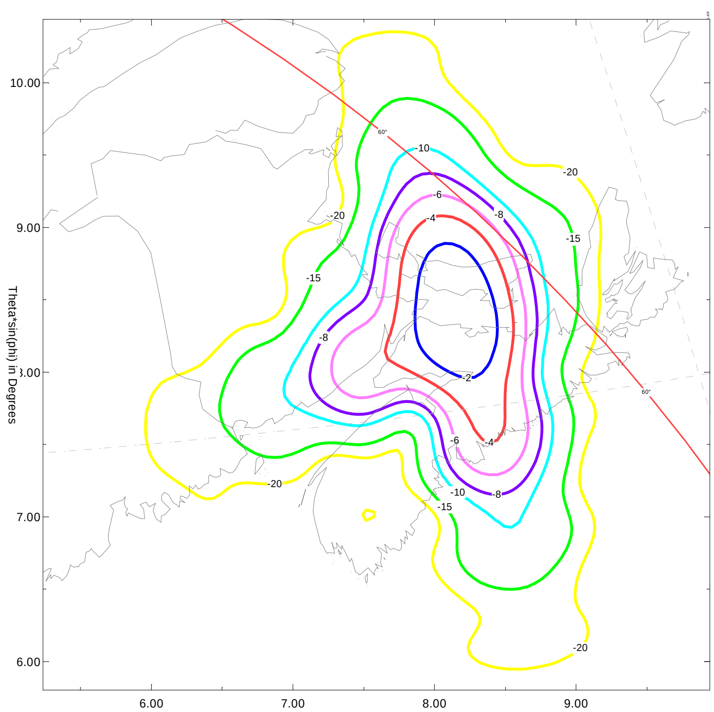
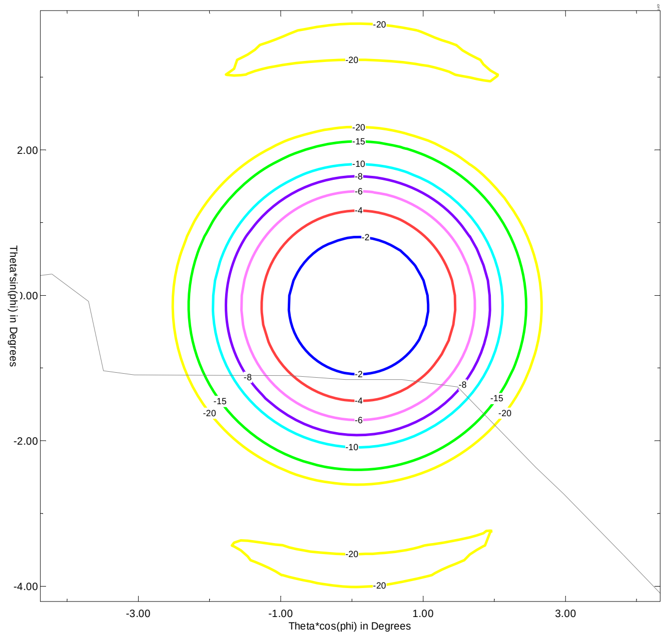


Figure A.3.1-3: User beam receive antenna gain contours for the LEO satellites

(a) Beam pointed to nadir



(b) Beam pointed to edge of service area (north-west)

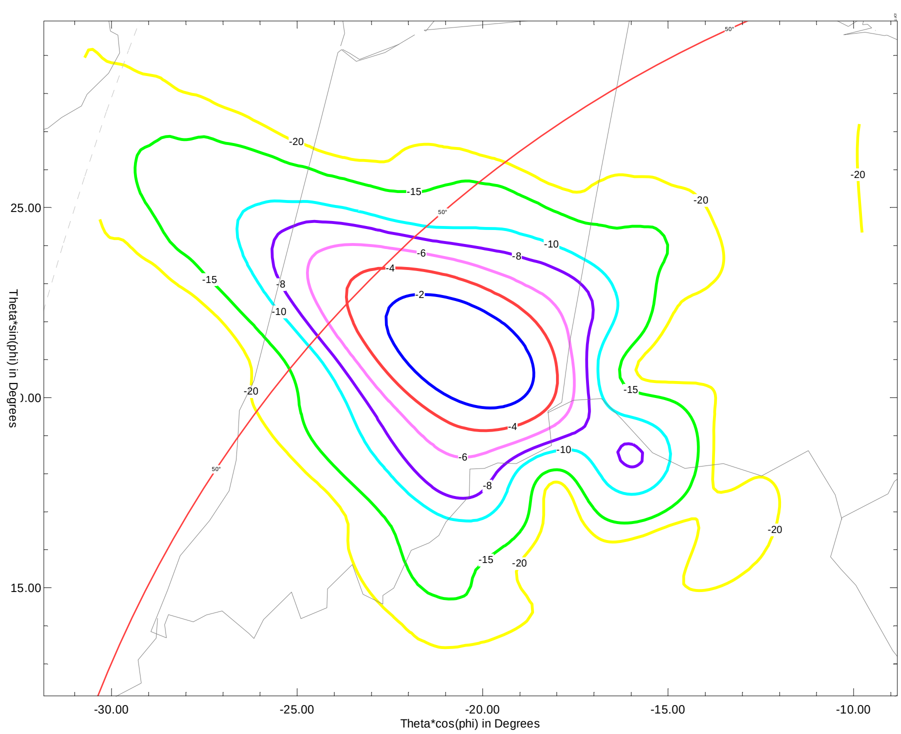
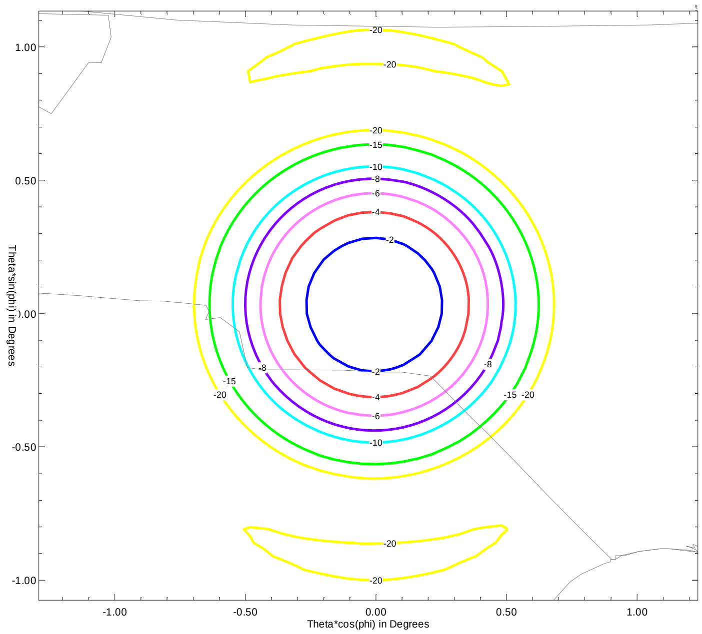
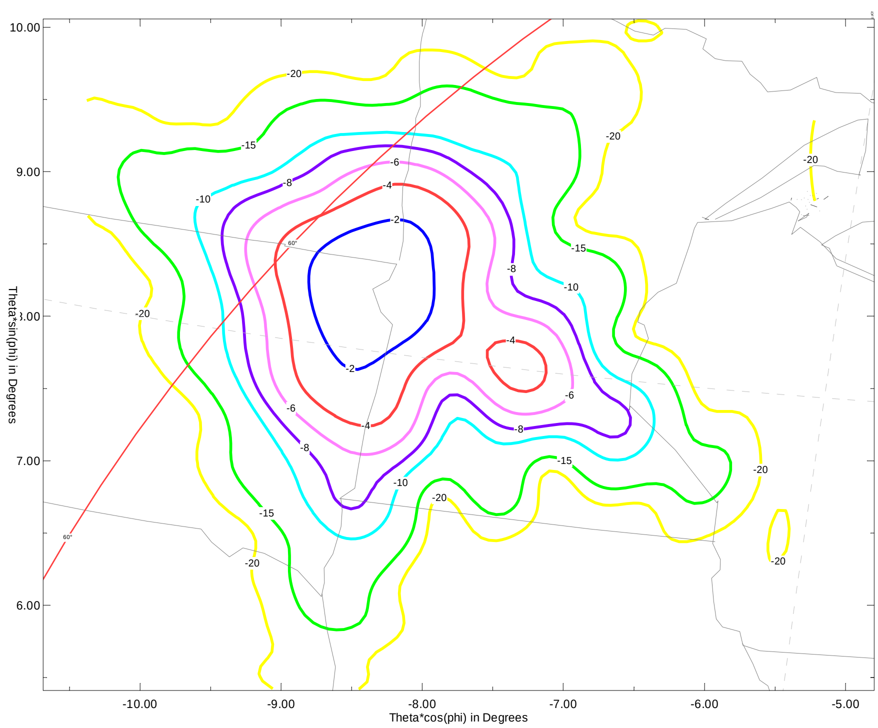


Figure A.3.1-4: User beam receive antenna gain contours for the MEO satellites

(a) Beam pointed to nadir



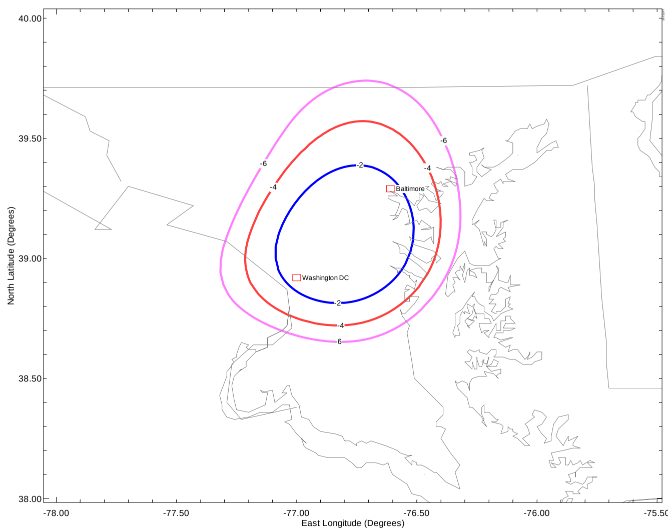
(b) Beam pointed to edge of service area (north-west)



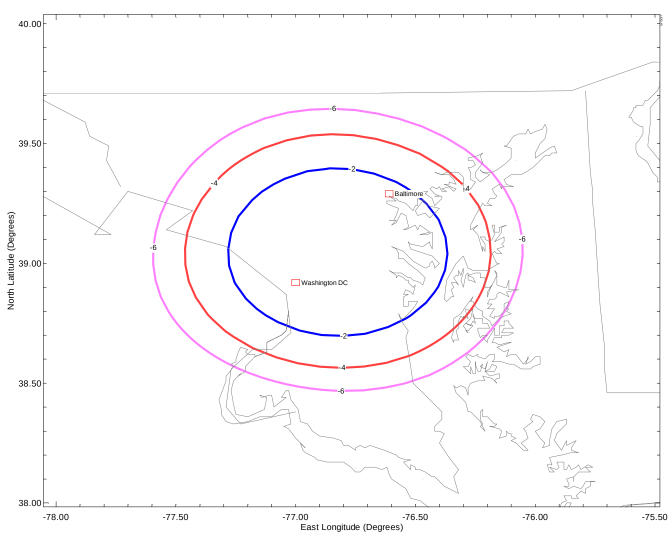
For illustrative purposes Figure A.3.1-5 below compares the user beam antenna sizes for the LEO and MEO satellites when pointed in the general direction of the Baltimore-Washington metropolitan area. The LEO and MEO satellites have the same sub-satellite position.

Figure A.3.1-5: Comparison of user beam sizes of the LEO and MEO satellites (Example shows towards Baltimore-Washington metropolitan area)

(a) LEO satellite



(a) MEO satellite



A.3.2 Antenna Gain Contours for the Gateway Beams

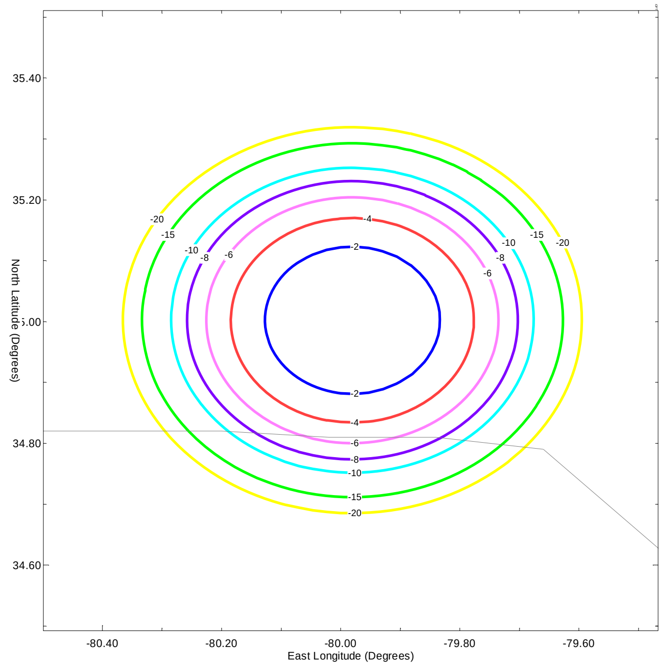
For the links between the OneWeb satellites and the gateway earth stations, there are mechanically steered satellite antennas capable of pointing the nominally circular gateway spot beams to any part of the visible Earth's surface, as explained in Section A.2 above. However, in most cases these gateway beams will not operate below 15° elevation for the LEO satellites and 25° for the MEO satellites.

Figures A.3.2-1 and A.3.2-2 below provide examples of the beam contours for the gateway beam transmit antennas of the LEO and MEO satellites, respectively. Two extreme cases of antenna pointing direction are shown for each: the first with the beam pointed directly to nadir, and the second with the beam pointed towards the minimum elevation contour (15° for the LEO and 25° for the MEO), which is the nominal edge of the gateway service area. The beams are plotted on a flat-Earth projection.

Figures A.3.2-3 and A.3.2-4 below provide the same information for the gateway beam receive antennas of the LEO and MEO satellites, respectively.

Figure A.3.2-1: Gateway beam transmit antenna gain contours for the LEO satellites

(a) Beam pointed to nadir



(b) Beam pointed to edge of service area (north-east)

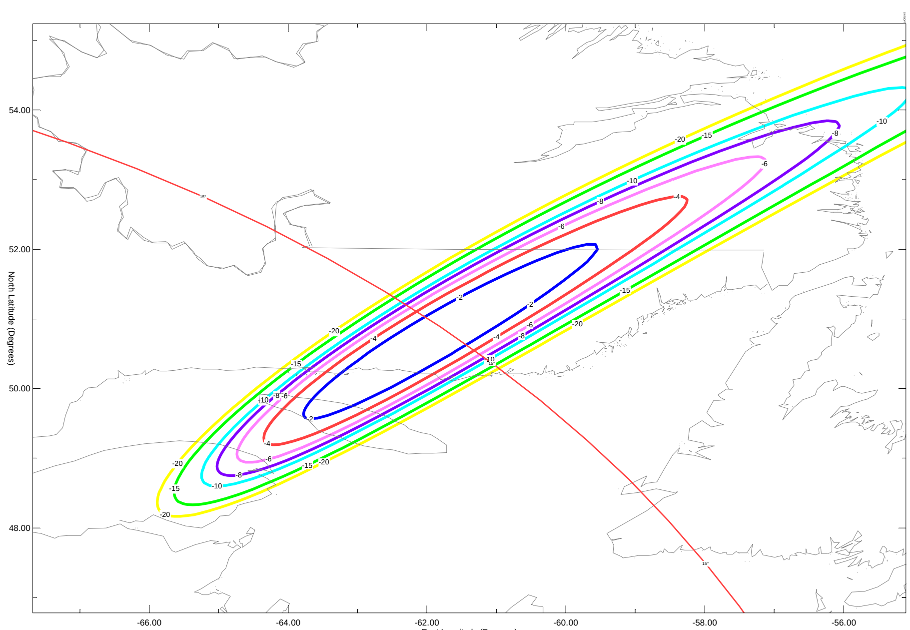
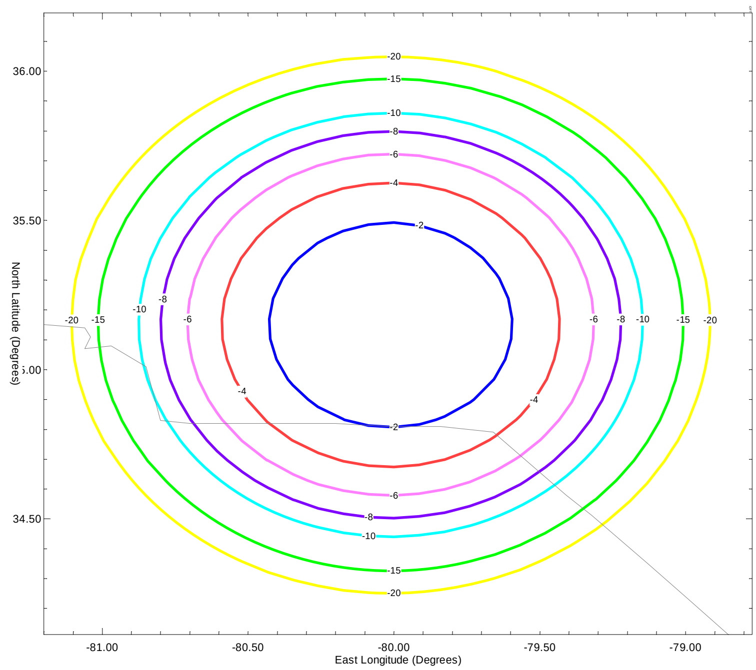


Figure A.3.2-2: Gateway beam transmit antenna gain contours for the MEO satellites

(a) Beam pointed to nadir



(b) Beam pointed to edge of service area (north-east)

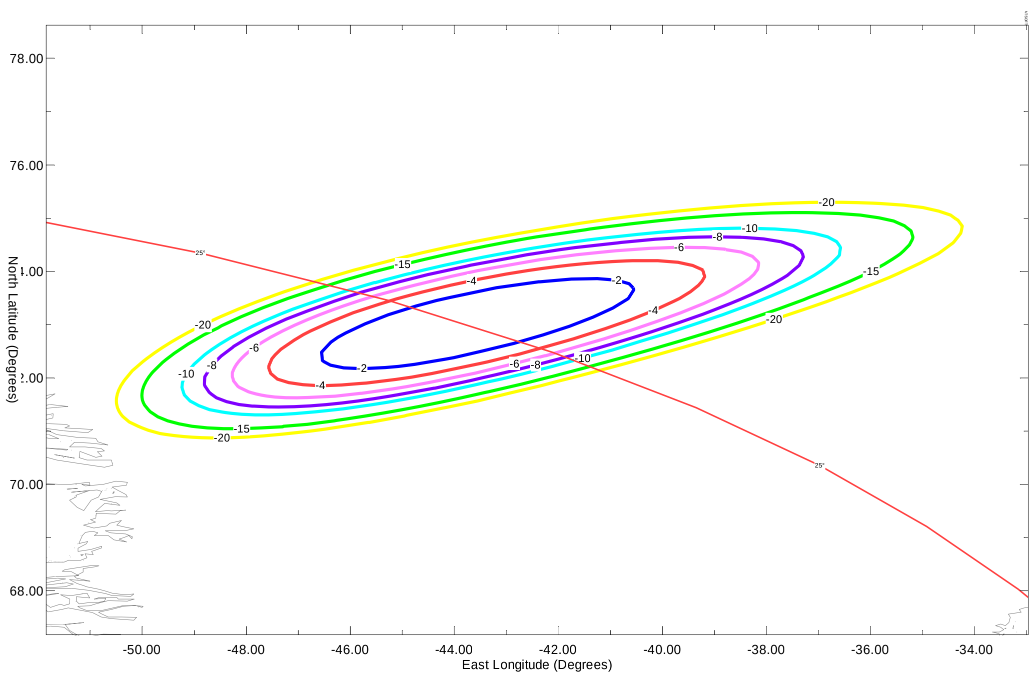
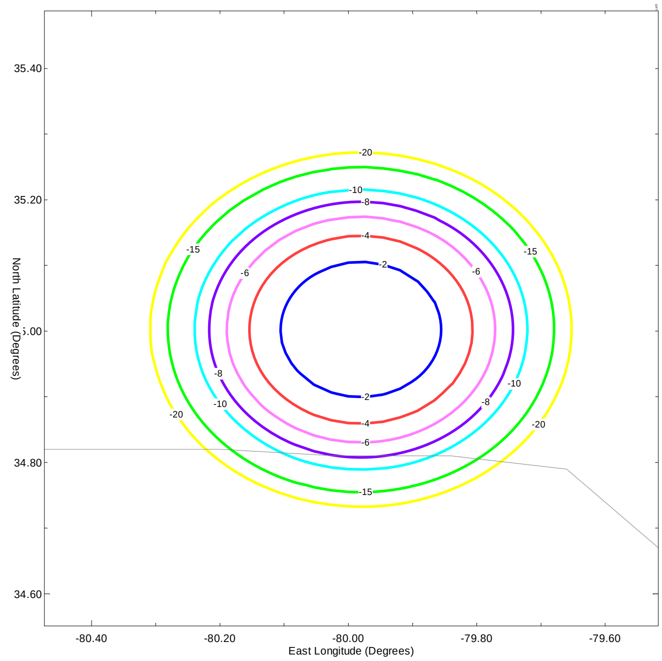


Figure A.3.2-3: Gateway beam receive antenna gain contours for the LEO satellites

(a) Beam pointed to nadir



(b) Beam pointed to edge of service area (north-west)

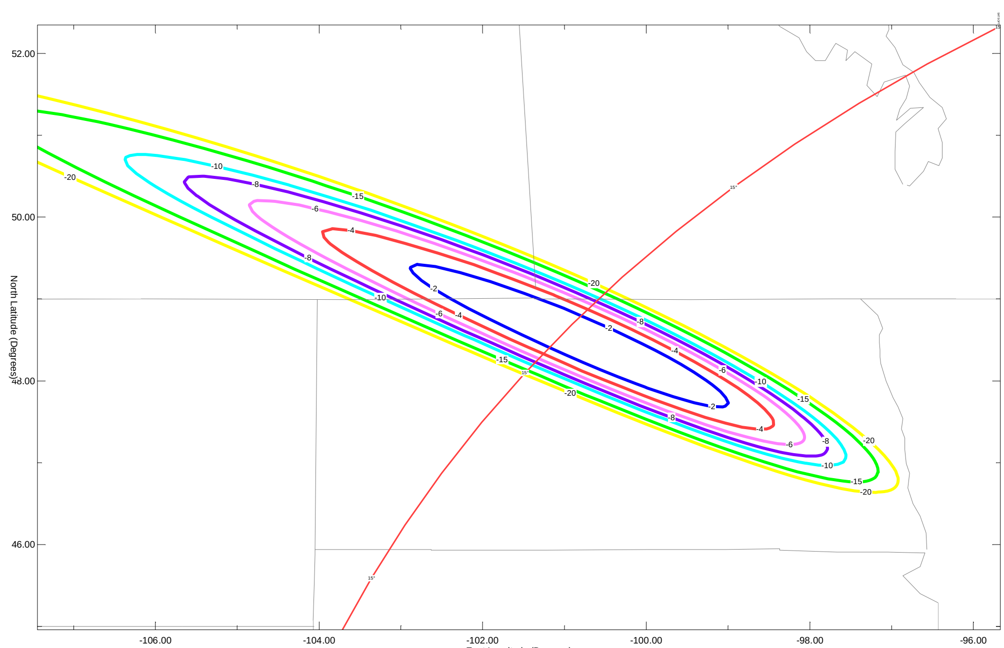
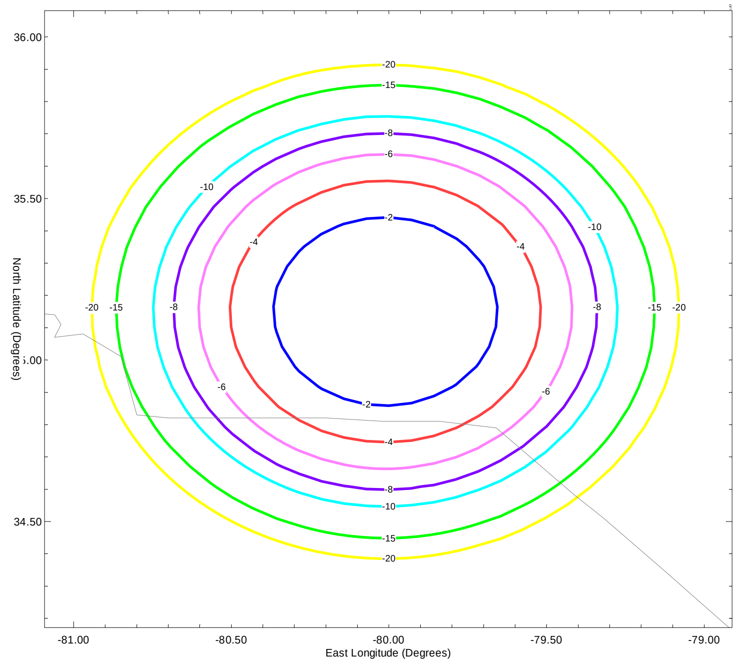
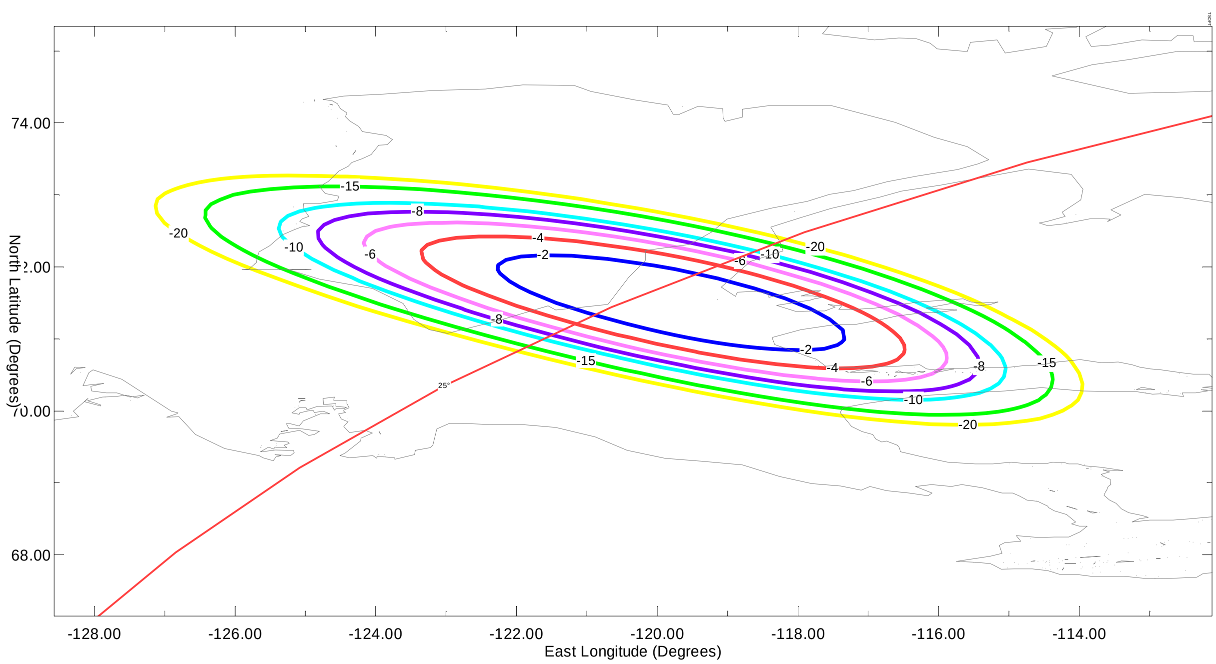


Figure A.3.2-4: Gateway beam receive antenna gain contours for the MEO satellites

(a) Beam pointed to nadir



(b) Beam pointed to edge of service area (north-west)



A.4 GEOGRAPHIC COVERAGE (§25.217(b)(1), §25.143(b)(2)(ii) and §25.143(b)(2)(iii))

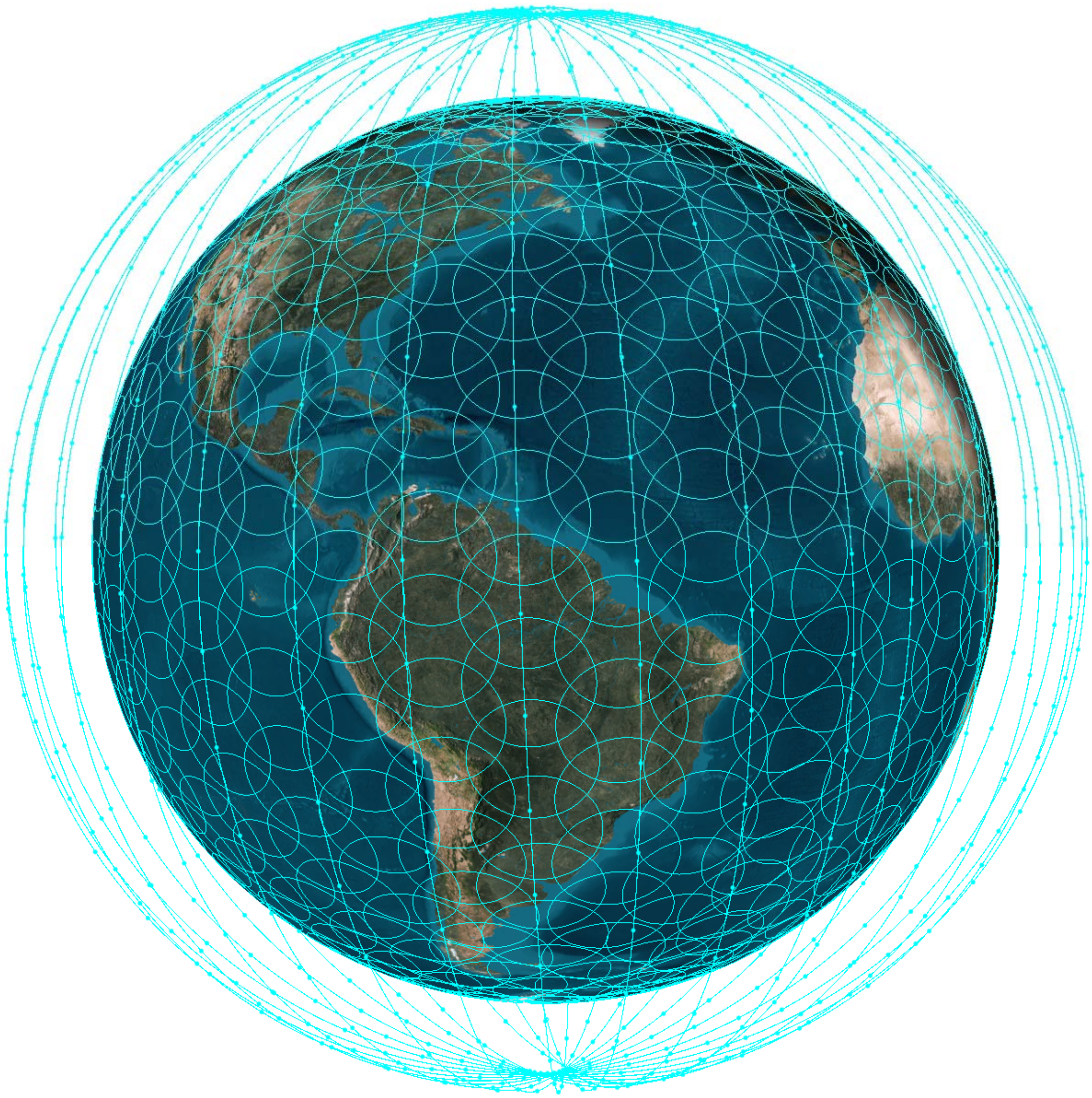
The Commission's geographic coverage requirements applicable to the V-band are established by §25.217(b)(1) which refers to §25.143(b)(2)(ii) and §25.143(b)(2)(iii). These requirements, if interpreted in the context of the Fixed-Satellite Service, are as follows:

(1) That a system proposed to operate using non-geostationary satellites be capable of providing [service] to all locations as far north as 70° North latitude and as far south as 55° South latitude for at least 75% of every 24-hour period, i.e., that at least one satellite will be visible above the horizon at an elevation angle of at least 5° for at least 18 hours each day within the described geographic area

(2) That a system proposed to operate using non-geostationary satellites be capable of providing [service] on a continuous basis throughout the fifty states, Puerto Rico and the U.S. Virgin Islands, i.e., that at least one satellite will be visible above the horizon at an elevation angle of at least 5° at all times within the described geographic areas

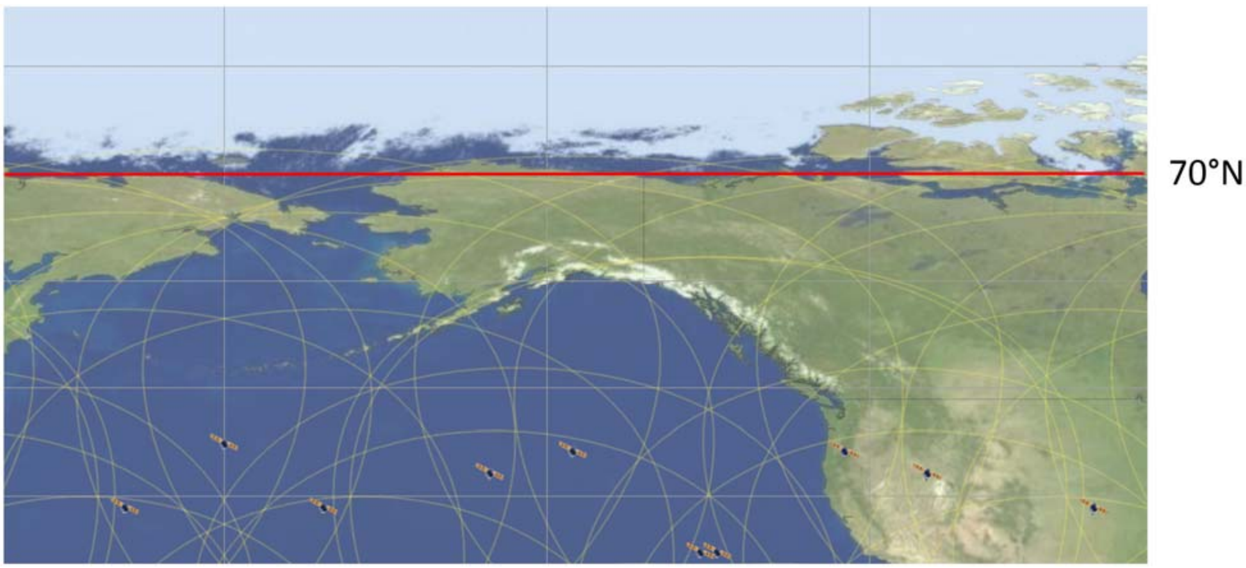
Because of the use of near-polar orbits, the satellites of the LEO component of the OW-V system pass over all parts of the Earth's surface and therefore have the ability to provide service to all Earth locations as shown in Figure A.4-1 below. Every point on the Earth's surface will see, at all times, a OneWeb satellite at an elevation no less than 55º, with increasing minimum elevation angles with latitude. For instance, users in Alaska will experience elevation angles significantly higher than 55º at all times.

Figure A.4-1: LEO satellites of the OW-V system cover the entire Earth's surface (showing user beam service areas for each satellite)



The satellites in the MEO component of the OW-V system operate in a 45° inclined orbit but due to the higher altitude of this orbit, they are able to provide continuous service to latitudes at least as high as 70°.[9] This is demonstrated in Figure A.4-2 below which shows a snapshot in time for the initial operational MEO constellation with eight orbital planes and 20 satellites per plane. The contours on the Earth are the 45° elevation contours. This demonstrates that the MEO satellites provide continuous service to 70° latitude regions by operating down to 45° elevation when required. Normal operation in lower latitude regions will involve operation at elevation angles no less than 60°.

Figure A.4-2: Coverage of high latitude regions by the MEO satellites of the OW-V system (showing 45° elevation service areas for each satellite)



Therefore the OW-V system, consisting of a combination of both LEO and MEO satellites, fully meets the Commission's geographic service requirements.

[9] Continuous service to latitude regions up to 70° ensures compliance with both §25.143(b)(2)(ii) and §25.143(b)(2)(iii), as it includes the most northerly US state, Alaska.

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

For the LEO satellites of the OW-V system there will be no separate TT&C as the OW-V payload is an additional payload on future OneWeb LEO satellites of the core constellation, identical to those satellites for which an FCC application is already pending,[10] but with this additional payload. Therefore, no additional information is required in this application concerning the TT&C for the LEO component of the OW-V system.

Concerning the MEO satellites of the OW-V system, no TT&C earth stations are foreseen to be located in US territories at present for these satellites, and so no FCC authorization is being sought for TT&C links on these satellites. Nevertheless, the basic parameters of the overall TT&C system for the MEO satellites only are described in this section.

The TT&C system for the MEO OW-V satellites provides for communications during pre-launch, transfer orbit and on-station operations, as well as during spacecraft emergencies. The TT&C system operates at the edges of the V-band frequency allocations during all phases of the mission. The TT&C controls and monitors all aspects of the spacecraft necessary for onboard equipment configuration, safe operations and health monitoring. All TT&C downlink transmissions are at EIRP density levels, on both uplink and downlink, that are no higher than the gateway communications carriers. Because these transmissions will not take place from US gateway earth stations their technical parameters are not included in the associated Schedule S.

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10 *See OneWeb Ku-/Ka-band Petition.*

A summary of the TT&C subsystem characteristics is given in Table A.5-1. The frequency ranges specified for the TT&C transmissions may be reduced further as the final operational TT&C frequencies are selected, and OneWeb will inform the Commission of this at that time.

Table A.5-1: TT&C Characteristics

Uplink Control Signal Modulation	BPSK
Uplink Control Frequencies	47,200 - 47,250 MHz (outside of USA)
Downlink Control Signal Modulation	QPSK
Downlink Control Frequencies	37,500 – 37,550 MHz (outside of USA)
Polarization of Satellite Rx/Tx Antennas	Rx: LHCP & RHCP Tx: LHCP & RHCP

A.6 CESSATION OF EMISSIONS (§25.207)

Each active satellite transmission chain (channel amplifiers and associated solid state power amplifier) can be individually turned on and off by ground telecommand, thereby causing cessation of emissions from the satellite, as required by §25.207 of the Commission's rules.

A.7 COMPLIANCE WITH PFD LIMITS (§25.208(r), §25.208(s), and §25.208(t))

There are ITU Power Flux Density ("PFD") limits in all parts of the downlink frequency bands proposed to be used by the OW-V system, which is 37.5-42.5 GHz, designed to protect the terrestrial Fixed Service ("FS") and Mobile Service ("MS") from downlink interference due to the satellite transmissions. There are also FCC PFD limits in most of this downlink band (except for 42.0-42.5 GHz). However, the FCC PFD limits are not consistent in all cases with the ITU PFD limits. Both ITU and PFD limits across the 37.5-42.5 GHz band are summarized in Table A.7-1 below.

Table A.7-1: ITU and FCC Power Flux Density Limits in the 37.5-42.5 GHz Band

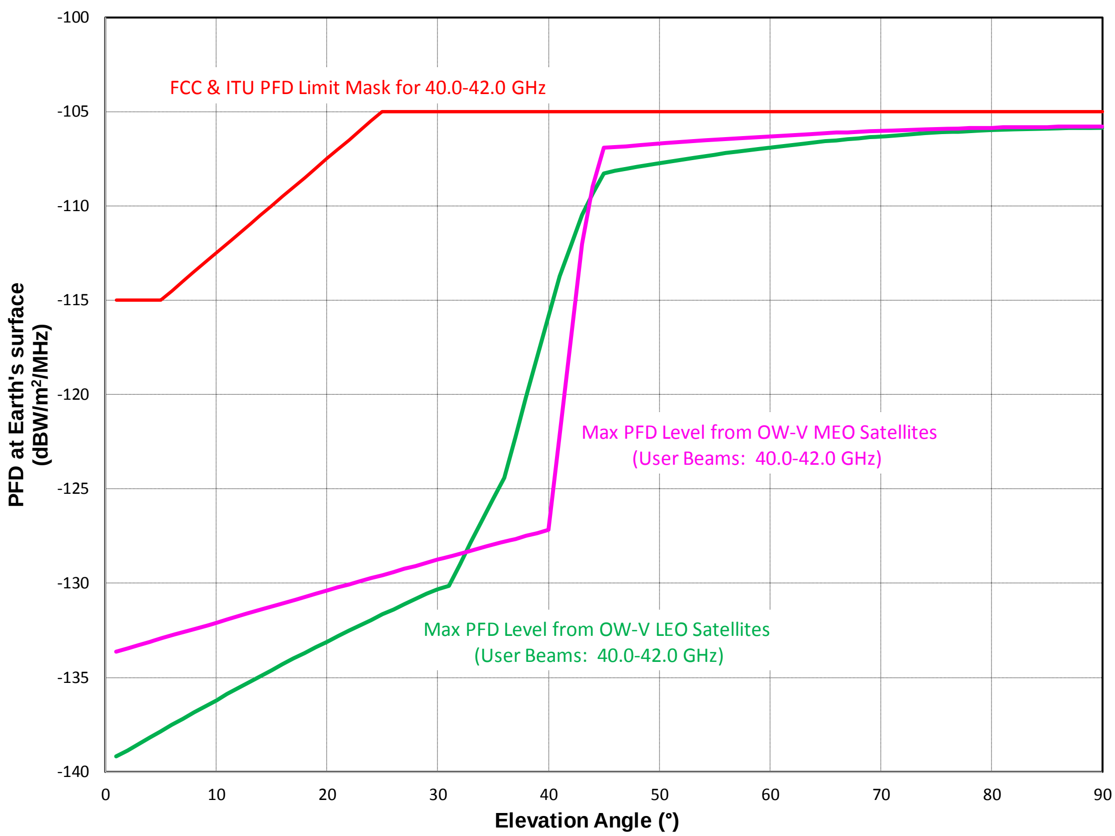
Frequency range	ITU or FCC	PFD Limit in dB(W/m^2) for angles of arrival (δ) above the horizontal plane			Reference bandwidth
		0°-5°	5°-25°	25°-90°	
37.5-40 GHz	ITU	−120	−120 + 0.75(δ − 5)	−105	1 MHz
	FCC	−132	−132 + 0.75(δ − 5)	−117	1 MHz
40-40.5 GHz	ITU	−115	−115 + 0.5(δ − 5)	−105	1 MHz
	FCC	−115	−115 + 0.5(δ − 5)	−105	1 MHz
40.5-42 GHz	ITU	−115	−115 + 0.5(δ − 5)	−105	1 MHz
	FCC	−115	−115 + 0.5(δ − 5)	−105	1 MHz
42-42.5 GHz	ITU	−120	−120 + 0.75(δ − 5)	−105	1 MHz
	FCC	No PFD Limit			

In the 37.5-40.0 GHz band the FCC PFD limit is 12 dB tighter than the ITU PFD limit at all elevation angles. In the 40.0-42.0 GHz band the FCC and ITU PFD limits are the same. In the 42.0-42.5 GHz band there are ITU PFD limits but no FCC limits.

The FCC and ITU PFD limits apply to each satellite in an NGSO system. The limits are intended to refer to the PFD at the Earth's surface under assumed free space conditions.

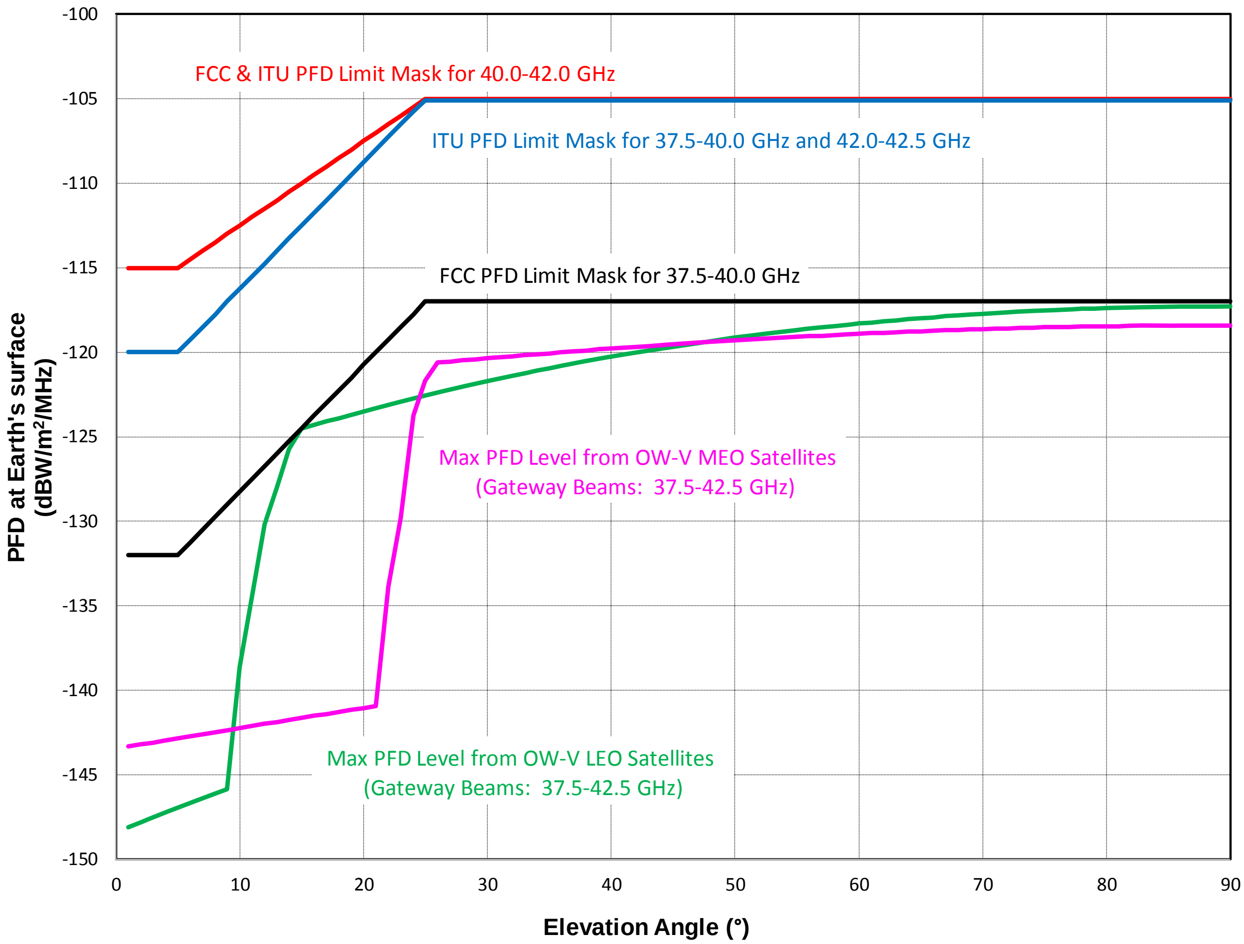
The predicted worst-case PFD levels from the OW-V system in the relevant portions of the 37.5-42.5 GHz downlink band are shown in Figures A.7-1 and A.7-2, respectively, for the user beams and the gateway beams.[11] Also shown in these diagrams are the various ITU and FCC PFD limits referred to above, with color coding to identify the frequency ranges in which they apply. From these diagrams, and noting the way in which the OW-V systems uses the 37.5-40.0 GHz band only for gateway links, it is clear that all links of the OW-V system meet all of the ITU and FCC PFD limits.

Figure A.7-1: PFD Levels from the User Downlink Beams of the OW-V System in the 40.0-42.0 GHz Band compared with ITU and FCC PFD Limits



[11] The predicted maximum PFD levels from the OW-V system take into account the worst case minimum elevation angle operation of 45° for the user beams and 15° or 25° (LEO or MEO, respectively) for the gateway beams.

Figure A.7-2: PFD Levels from the Gateway Downlink Beams of the OW-V System in the 37.5-42.5 GHz Band compared with ITU and FCC PFD Limits



A.8 INTERFERENCE ANALYSES AND FREQUENCY SHARING

Table A.8-1 below lists the V-band frequency ranges proposed to be used by the OW-V system, and indicates the ITU and FCC allocations across those frequency ranges. It also summarizes the frequency sharing conditions according to the various FCC rules and Orders that affect each of these frequency ranges. This is being provided to accompany the more detailed explanations of each sharing / interference scenario described in the sub-sections below.

Table A.8-1: ITU and FCC Frequency Allocations for the Bands to be Used by the OW-V System

Frequency Range (GHz)	ITU allocations	FCC allocations (non-Federal)	FCC conditions affecting frequency sharing and basis for OW-V operation in the band
37.5-38.0	FS FSS ↓ MS SRS ↓ EESS ↓	FS FSS ↓ MS	NG63: In the band 37.5-40 GHz, earth station operations in the fixed-satellite service (space-to-Earth) shall not claim protection from stations in the fixed and mobile services, except where individually licensed earth stations are authorized pursuant to 47 C.F.R. § 25.136. 25.202(a)(1): Use of this band by the Fixed-Satellite Service is limited to individually licensed earth stations. Satellite earth station facilities in this band may not be ubiquitously deployed and may not be used to serve individual consumers. Operations permissible subject to the terms of the *Spectrum Frontiers Order*. **OW-V proposes to operate its gateway receiving earth stations only in this band in US territories, and these earth stations will be individually licensed. No OW-V user terminals will operate in this band.**
38.0-39.5	FS FSS ↓ MS EESS ↓	FS FSS ↓ MS	
39.5-40.0	FS FSS ↓ MS MSS ↓ EESS ↓	FS FSS ↓ MS	
40.0-40.5	EESS ↑ FS FSS ↓ MS MSS ↓ SRS ↑ EESS ↓	FSS ↓ MSS ↓	US211: Applicants for space station assignments are urged to take all practicable steps to protect radio astronomy observations in the adjacent bands (RAS in the 42.5-43.5 GHz band) from harmful interference. **OW-V will operate its gateway and user receiving earth stations on a Primary basis in these bands.**
40.5-41.0	FS FSS ↓ BS BSS MS MSS ↓	FSS ↓ BS BSS FS MS MSS ↓	
41.0-42.0	FS FSS ↓ BS BSS MS	FS FSS ↓ MS BS BSS	
42.0-42.5	FS FSS ↓ BS BSS MS	FS MS	There is no FCC allocation to the FSS↓ in this band, but an ITU allocation exists. **OW-V requests a waiver of the U.S. Table of Frequency Allocations to permit it to operate its FSS gateway receiving earth stations only in this band in US territories, consistent with the ITU frequency allocations and ITU PFD limits. These gateway earth stations will be individually licensed. No OW-V user terminals operate in this band.**

42.5-43.5	FS FSS ↑ MS RAS	RAS	There is no FCC allocation to the FSS↑ in this band, but an ITU allocation exists. US342: In making assignments to stations of other services to which the bands *(only those relevant here are included below)*: 42.77-42.87 GHz* 43.07-43.17 GHz* 43.37-43.47 GHz* 48.94-49.04 GHz* arc allocated (*indicates radio astronomy use for spectral line observations), all practicable steps shall be taken to protect the radio astronomy service from harmful interference. Emissions from spaceborne or airborne stations can be particularly serious sources of interference to the radio astronomy service *(see* ITU *Radio Regulations* at Nos. 4.5 and 4.6 and Article 29). **OW-V requests a waiver of the U.S. Table of Frequency Allocations to permit it to operate its gateway transmitting earth stations in this band in US territories. No OW-V user terminals will operate in this band. These gateway earth stations will be carefully located, after coordination with the RAS community, such that no harmful interference will be caused to RAS stations.**
47.2-48.2	FS FSS ↑ MS	FS FSS ↑ MS	According to 47 C.F.R. §§ 2.106 and 25.202(a)(1) this band is Primary for FSS uplinks, despite the *V-Band Plan*[12] designating it as Secondary. **To the extent necessary, OW-V requests a waiver to operate its gateway transmitting earth stations on a Primary basis in this band, and will coordinate with the RAS to ensure no harmful interference.**
48.2-50.2	FS FSS ↑ MS	FS FSS ↑ MS	US156: In the bands 49.7-50.2 GHz and 50.4-50.9 GHz, for earth stations in the fixed-satellite service (Earth-to-space), the unwanted emissions power in the band 50.2-50.4 GHz shall not exceed -20 dBW/ 200 MHz (measured at the input of the antenna), except that the maximum unwanted emissions power may be increased to -10 dBW /200 MHz for earth stations having an antenna gain greater than or equal to 57 dBi. These limits apply under clear-sky conditions. During fading conditions, the limits may be exceeded by earth stations when using uplink power control. US342: In making assignments to stations of other services to which the bands *(only those relevant here are included below)*: 42.77-42.87 GHz*

[12] *See* 47 C.F.R. §§ 2.106 and 25.202(a)(1); *see also Allocation and Designation of Spectrum for Fixed-Satellite Services in the 37.5- 38.5 GHz, 40.5-41.5 GHz and 48.2-50.2 GHz Frequency Bands*, First Report and Order, 13 FCC Rcd 24649 (1998) ("*First V-Band Order*"); *Allocation and Designation of Spectrum for Fixed-Satellite Services in the 37.5-38.5 GHz, 40.5-41.5 GHz and 48.2-50.2 GHz Frequency Bands*, Second Report and Order, 18 FCC Rcd 25428 (2003) ("*V-Band Plan*").

			43.07-43.17 GHz* 43.37-43.47 GHz* 48.94-49.04 GHz* arc allocated (*indicates radio astronomy use for spectral line observations), all practicable steps shall be taken to protect the radio astronomy service from harmful interference. Emissions from spaceborne or airborne stations can be particularly serious sources of interference to the radio astronomy service *(see* ITU *Radio Regulations* at Nos. 4.5 and 4.6 and Article 29). **OW-V will operate its gateway and user transmitting earth stations on a Primary basis in this band, consistent with the requirements of US156 above, and will coordinate with the RAS to ensure no harmful interference.**
50.4-51.4	FS FSS ↑ MS MSS ↑	FS FSS ↑ MS MSS ↑	US156: In the bands 49.7-50.2 GHz and 50.4-50.9 GHz, for earth stations in the fixed-satellite service (Earth-to-space), the unwanted emissions power in the band 50.2-50.4 GHz shall not exceed -20 dBW/ 200 MHz (measured at the input of the antenna), except that the maximum unwanted emissions power may be increased to -10 dBW /200 MHz for earth stations having an antenna gain greater than or equal to 57 dBi. These limits apply under clear-sky conditions. During fading conditions, the limits may be exceeded by earth stations when using uplink power control. According to 47 C.F.R. § 2.106 this band is Primary for FSS uplinks, despite not being identified as FSS in either 25.202(a)(1) or the *V-Band Plan*.[13] **OW-V will operate its gateway transmitting earth stations on a Primary basis in this band, consistent with the requirements of US156 above, and will coordinate with the RAS to ensure no harmful interference. No OW-V user terminals will operate in this band. OW-V requests, to the extent deemed necessary by the Commission, an FCC waiver relating to the necessary FSS status for this band.**

Notes: 1. Red indicates Primary allocation – blue indicates Secondary.
2. Yellow highlighted indicates proposed OW-V usage.

A.8.1 Sharing with GSO Satellite Networks

[13] *V Band Plan*.

Although there are currently no non-Federal GSO satellite networks authorized by the Commission, or granted market access in the USA, in any of the frequency bands proposed to be used by the OW-V system, there could be such GSO networks in the future. There are also Federal GSO satellite networks that may operate in some of the downlink bands proposed to be used by the OW-V system.

The OW-V system will protect all GSO satellite networks by ensuring all uplink and downlink transmissions avoid the GSO arc by at least 5°. For the downlink interference into GSO receiving earth stations, this angle is measured at any potential victim GSO receiving earth station. It is the minimum angle between the direction towards any point along the visible GSO arc and the potential NGSO interfering satellite. For the uplink interference into GSO satellites, the angle is measured at the NGSO transmitting earth station and is the minimum angle between the boresight of the transmitting earth station and any point along the GSO arc.

Note that this GSO arc avoidance technique used to protect GSO satellite networks from interference from the OW-V system has the effect also of protecting the OW-V system from GSO interference, as it avoids inline and near-inline events.

GSO arc avoidance is straightforward in the OW-V system because of the use of overlapping service areas and dynamically steerable beams.[14] This combination of features permits the operation of satellite diversity within the OW-V system whenever an inline or near-inline event occurs with respect to the GSO arc. Using this technique, the OW-V network control center will constantly monitor the pointing direction of its satellite and earth station beams, and will reliably predict when a GSO inline event is approaching. At such times, and in the case of the OW-V

[14] In the case of the LEO component of the OW-V system, satellite diversity at very low latitude regions will require user terminals to operate somewhat below the nominal 50° minimum elevation angle, or resort to satellite diversity using the MEO component of the OW-V system.

user link, the network control center will instantaneously switch such links to alternate OW-V satellites (whether LEO or MEO), thereby maintaining the GSO avoidance angle at no less than 5°. In the case of the OW-V gateway links, the network control center will use gateway earth station diversity and switch any gateway links that are approaching a GSO alignment to an alternate gateway earth station where the minimum 5° GSO avoidance angle is exceeded. Thus the combination of satellite and earth station diversity will ensure that GSO satellite networks are protected at all times.

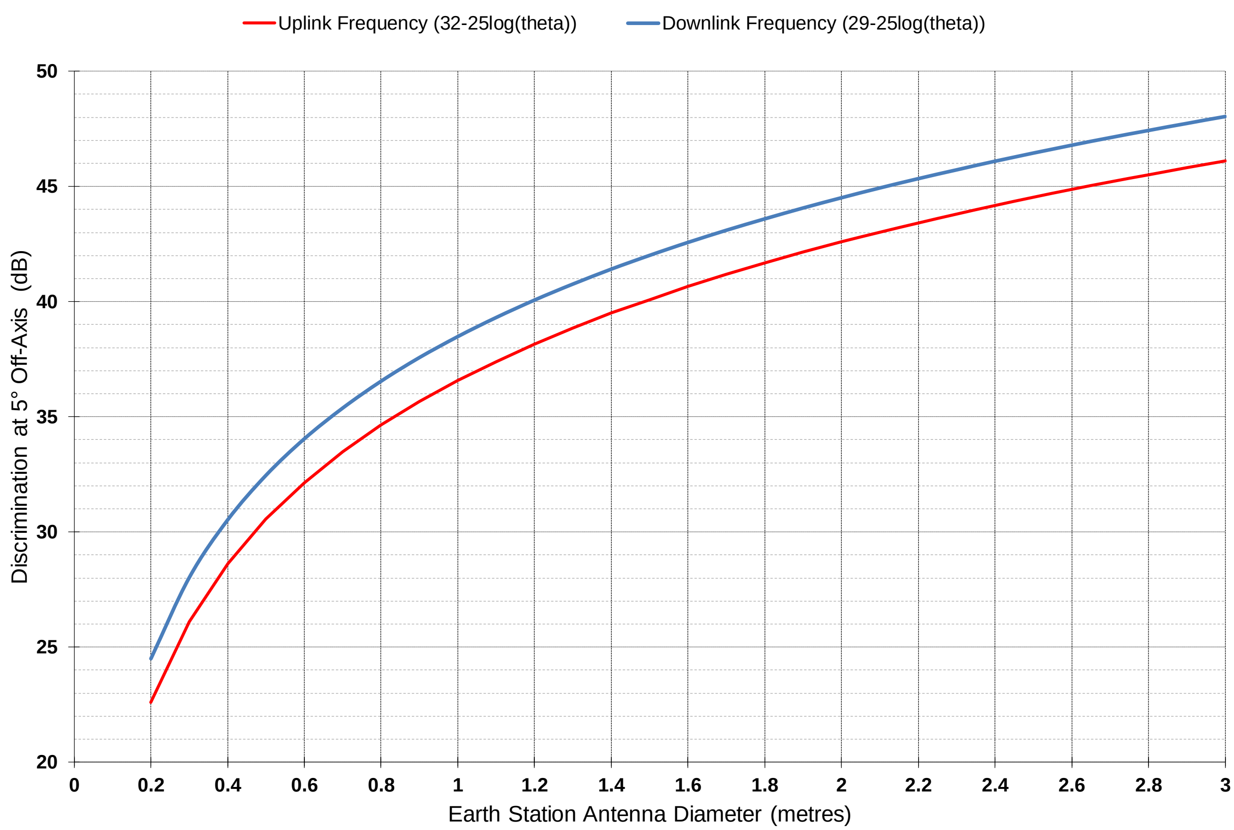
The GSO avoidance measures described above will only be necessary for user beams and associated user terminals in the lower latitude regions. Above a certain sub-satellite latitude, because the user beam service area is defined by a relatively high minimum elevation angle (50°), there will be no possibility of a GSO alignment situation, so no interference mitigation is required. Even for the gateway links, which have service areas extending to lower minimum elevation angles, there will be a certain latitude (higher than for the user beams) above which no GSO alignment can occur. These minimum latitudes above which no interference mitigation is required will be different for the LEO and the MEO satellites.

Figure A.8.1-1 below demonstrates the amount of interference isolation that will exist between GSO networks and NGSO satellite systems at V-band with a 5° GSO exclusion angle as described above. This is based on the following assumptions:

- Minimum uplink frequency = 42.5 GHz;
- Minimum downlink frequency = 37.5 GHz;
- Antenna efficiency = 65%;
- Uplink discrimination based on NGSO transmitting earth station off-axis gain, which is $32-25\log(\theta)$;
- Downlink discrimination based on GSO receiving earth station off-axis gain, which is $29-25\log(\theta)$.

The results in Figure A.8.1-1 show that, even for earth station antennas as small as 20 cm, there is in excess of 20 dB of antenna discrimination. Isolation levels are in the 35 to 45 dB range for earth station antennas between one and two meters in diameter. Although the earth station antenna discrimination alone does not determine the absolute interfering C/I level, it is the dominant isolating factor between the systems. Other factors, such as the differences in downlink PFD levels between the wanted and interfering systems, and the corresponding difference in satellite receive antenna gains between the systems, would need to be taken into account in a thorough and system-specific analysis. However, the interference between NGSO systems and GSO networks is time-varying, and the duration of the worst-case GSO avoidance angle is very short. So, the isolation between NGSO systems and GSO networks will be considerably greater for the vast majority of the time than the values corresponding to the worst-case GSO avoidance angle shown here.

Figure A.8.1-1: Off-Axis Discrimination versus Earth Station Antenna Diameter for a 5° GSO exclusion angle



There is an ITU World Radio Conference 2019 (WRC-19) agenda item that addresses the development of Equivalent Power Flux Density (EPFD) limits for the V-band as an objective regulatory means of protecting GSO satellite networks for the future.[15] The OW-V system will comply with such EPFD limits if and when they come into force in the ITU.

OneWeb will also coordinate, as necessary, with NTIA to ensure that the GSO protection measures proposed above are sufficient to protect any Federal GSO satellite systems operating, or planning to operate, in any of the frequency bands proposed to be used by the OW-V system.

A.8.2 Sharing with Other NGSO Satellite Systems

There are currently no ITU procedures relating to the coordination between NGSO satellite systems operating in the V-band frequencies proposed for the OW-V system, and no “ITU priority” regime therefore exists in these bands. Nevertheless, OneWeb is committed to working cooperatively with all other operators of V-band NGSO satellite systems, and is confident that the proposed OW-V system design is sufficiently flexible to permit frequency sharing between such systems.

Currently, there are no other non-Federal NGSO satellite systems authorized by the Commission, or granted market access in the USA, that operate within the V-band frequency ranges to be used by the OW-V system.

OneWeb is not aware of any Federal NGSO satellite systems operating, or planning to operate, in any of the frequency bands proposed to be used by the OW-V system. Nevertheless, OneWeb

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15 WRC-19 Agenda Item 1.6.

will coordinate, as necessary, with NTIA to ensure compatible operation of the OW-V system with any such Federal systems.

A.8.3 Sharing with Terrestrial Networks in the OW-V Downlink Frequency Bands

From a review of 47 C.F.R. §2.106 (the FCC's table of frequency allocations), supplemented by the *Spectrum Frontiers Order*,[16] OneWeb concludes that the only downlink frequency range proposed to be used by the OW-V system that is currently shared with a terrestrial service in the USA is the 37.5-40.0 GHz band. However, the Commission has indicated in the *Spectrum Frontiers Order* that it is also considering the possibility of authorizing fixed and mobile service operations in the 42.0-42.5 GHz band under the Part 30 Upper Microwave Flexible Use Service rules.

OneWeb will coordinate, as necessary, with NTIA to ensure compatibility with any Federal terrestrial services that may operate in any part of the frequency band that is proposed to be used for OW-V downlinks (37.5-42.5 GHz).

<u>Terrestrial Networks in the 37.5-40.0 GHz Band</u>

Regarding interference from terrestrial services into the OW-V system, receiving earth stations in the FSS in this band are protected from interference from the terrestrial (fixed and/or mobile) services if the earth stations are individually licensed according to §25.136(b). Any OW-V gateway earth stations to be operated in the USA will meet these requirements.

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16 *See Use of Spectrum Bands above 24 GHz for Mobile Radio Services*, 31 FCC Rcd 8014, 8155 (2016) ("*Spectrum Frontiers Order*").

Terrestrial services are protected from potential interference from the OW-V satellite downlink transmissions by means of the PFD limits at the surface of the Earth. The OW-V system will comply with the FCC's PFD limits that apply in the 37.5-40.0 GHz band as demonstrated in Section A.7 above.

Terrestrial Networks in the 40.0-42.0 GHz Band

Regarding interference from terrestrial services into the OW-V receiving user terminals in the FSS in this band, OneWeb participates in the Commission's Spectrum Frontier process, namely the current FNPRM that proposes to allocate this portion of the V-band for terrestrial mobile (UMFUS) services. OneWeb requests the Commission not to authorize UMFUS in this band, but should the Commission decide to proceed, the OneWeb terminals would have to operate on an unprotected basis.

OneWeb gateway earth stations operating in the U.S. would be individually site-licensed and therefore protected from interference from future terrestrial networks in this band.

Terrestrial Networks in the 42.0-42.5 GHz Band

OneWeb is requesting a waiver of 47 C.F.R. § 2.106 (the Commission's frequency allocation table) to permit it to operate FSS downlinks in the 42.0-42.5 GHz band for individually licensed gateway receiving earth stations only. If such a waiver is granted, the OW-V system may need to share spectrum with future fixed and mobile service operations that may be authorized by the Commission in this band. However, the coordination procedures associated with the individually licensed OW-V gateway receiving stations should make this sharing arrangement perfectly viable. Future terrestrial services in this band should also be adequately protected from potential interference from the OW-V satellite downlink transmissions by means of the ITU's PFD limits at the surface of the Earth. The OW-V system will comply with these ITU PFD limits in this band, as demonstrated in Section A.7 above.

A.8.4 Sharing with Terrestrial Networks in the OW-V Uplink Frequency Bands

The Federal government has various terrestrial communications systems operating in parts of the frequency bands proposed to be used for OW-V uplinks. OneWeb will therefore coordinate, as necessary, with NTIA to ensure compatibility with all of these Federal services.

Terrestrial Networks in the 42.5-43.5 GHz Band

The Commission has indicated in the *Spectrum Frontiers Order* that it is considering, by means of an NPRM, the possibility of authorizing fixed and mobile service operations in the 42.5-43.5 GHz band. OneWeb is requesting a waiver from the Commission to be able to operate gateway transmitting earth stations in this band, consistent with ITU frequency allocations.

OneWeb proposes, subject to its waiver request, to only operate transmitting OW-V gateway earth stations in this band, and believes methods can be found for these to coexist with future terrestrial services. For these OW-V earth stations, the sharing mechanism would be based on the principle of the OW-V earth station being individually licensed and thereby assured of being able to operate long-term at the stated geographic location. Very few OW-V gateway earth stations would be required in U.S. territories, so this traditional coordination approach would create very little, if any, burden for future terrestrial operators in this band.

Terrestrial Networks in the 47.2-50.2 GHz Band

The Commission discusses in the *Spectrum Frontiers Order* the potential sharing situation that might exist in the 47.2-50.2 GHz band between FSS uplinks and potential future fixed and mobile services.

The OW-V system will operate its transmitting gateway earth stations across this entire band (47.2-50.2 GHz), and believes methods can be found for these gateway earth stations to coexist with future terrestrial services based on the principle of the OW-V earth station being individually licensed and thereby assured of being able to operate long-term at the stated geographic location.

For the OW-V user terminals, which are only proposed to operate across the 48.2-50.2 GHz band, OneWeb believes an approach based on a shared database of the terrestrial receivers may be the best solution, coupled with some restrictions on the potential deployment and characteristics of those terrestrial receivers. This would enable satellite operators to adapt their operations with the necessary knowledge about the victim terrestrial receivers. The OW-V system has been designed with flexibility to allow these creative forms of frequency sharing to be efficiently employed.

Terrestrial Networks in the 50.4-51.4 GHz Band

The Commission discusses in the *Spectrum Frontiers Order* the potential sharing situation that might exist in the 50.4-51.4 GHz band between FSS uplinks and potential future fixed and mobile services.

The OW-V system will operate only transmitting OW-V gateway earth stations in this band, and believes methods can be found for these to coexist with future terrestrial services. For these OW-V earth stations, the sharing mechanism would be based on the principle of the OW-V earth station being individually licensed and thereby assured of being able to operate long-term at the stated geographic location. Very few OW-V gateway earth stations would be required in U.S. territories, so this traditional coordination approach would create very little, if any, burden for future terrestrial operators in this band.

The OW-V system would not deploy any user terminals in the 50.4-51.4 GHz band.

A.8.5 Protection of the Radio Astronomy Service (RAS)

There are important RAS allocations in the V-band frequency ranges, and OneWeb is committed to protecting these RAS allocations from both co-frequency operation in the RAS bands as well as from out-of-band emissions ("OOBE") arising from operating in the frequency bands adjacent to the RAS allocations. To this end, OneWeb will coordinate with the National Science Foundation (NSF) to ensure all U.S. RAS sites are adequately protected from interference.

In the V-band frequency ranges the primary RAS frequency range is 42.5-43.5 GHz. This is adjacent to the downlink frequency range proposed to be used by the OW-V system. OneWeb will therefore design the satellite transmitters of the OW-V system so they adequately attenuate any OOBE that could fall within the adjacent RAS band. This will be achieved by ensuring an adequate guard band between the highest operating OW-V satellite transmit channel and the edge of the RAS frequency ranges, coupled with careful output filtering and control of the satellite HPA spectral regrowth which could otherwise produce unacceptable OOBE in the RAS band. In addition, OneWeb will ensure that satellite downlink beams operating in the band immediately adjacent to the RAS band are always operated with the necessary geographic separation from the RAS stations.

The various uplinks of the OW-V system are proposed to operate both co-frequency with and separated in frequency from the RAS band of 42.5-43.5 GHz. Co-frequency operation in the 42.5-43.5 GHz band would be limited to a very small number of OW-V transmitting gateway earth stations located in U.S. territory, and the locations of these would be coordinated with the NSF to ensure that they will not cause harmful interference to the RAS. The OW-V earth stations that operate in other uplink bands that are not co-frequency with the 42.5-43.5 GHz band will benefit from a guard band that is 3.7 GHz wide, as their lowest frequency of operation is 47.2 GHz. These higher frequency earth stations will include the smaller and more numerous user terminals. OneWeb will therefore also coordinate the operation of the user terminals in these higher frequency bands so as not to cause harmful interference to the RAS. This will likely involve careful control of the OOBE of these user terminals as well as potential geographic operating constraints on their location when they are in close proximity to certain RAS sites in U.S. territories.

OneWeb will also coordinate with NSF (and NTIA, as appropriate) regarding any RAS-related frequency bands in the V-band frequency ranges other than the 42.5-43.5 GHz band that might be impacted by the OW-V system.

A.9 ITU FILINGS FOR THE OW-V SYSTEM

The OW-V system will operate under ITU filings submitted by France.

A.10 ORBITAL DEBRIS (§25.114(d)(14))

This matter is addressed in the main legal narrative part of this application.

A.11 ADDITIONAL INFORMATION CONCERNING DATA IN THE ASSOCIATED SCHEDULE S (§25.114(c))

The associated Schedule S information for the OW-V system was prepared using the FCC's new online Schedule S software.[17] The data provided in the Schedule S is consistent with the latest available FCC instructions.[18]

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17 Schedule S software is available at https://enterprisefiling.fcc.gov/schedules/

18 *See* SPECIFIC INSTRUCTIONS FOR SCHEDULE S, April 2016, *available at* https://enterprisefiling.fcc.gov/schedules//resources/Instructions%20for%20Schedule%20S%20vApr2016.pdf

The following notes are provided related to the data provided in the accompanying Schedule S for the OW-V system:

1. The associated Schedule S includes the satellite orbit information for both the LEO and MEO components of the OW-V system. However, for the LEO component, this is being provided here for information only, as that data should be identical to the information already submitted to the Commission in the Schedule S for the core OneWeb system. OneWeb is not requesting additional LEO satellites for the OW-V system, as explained in Section A.2 above.

2. The current Schedule S software assumes that all satellite beams are associated with all satellites in an NGSO system.[19] This is not the case for the OW-V system, as the satellite beams are different for the LEO versus the MEO satellites. Table A.11-1 below defines which satellite beams are associated with which satellite orbital planes in the OW-V system.

Table A.11-1: Association of Satellite Beams with Satellite Orbit Planes

Satellite Beams (in Schedule S)	**Satellite Orbit Planes (in Schedule S)**
Receiving Beams: LGR1, LGR2, LGR3, LGR4, LGR5, LGR6, LURL, LURR. Transmitting Beams: LGTL, LGTR, LUTL, LUTR.	LEO: Planes 1 to 18
Receiving Beams: MGR1, MGR2, MGR3, MGR4, MGR5, MGR6,	MEO: Planes 19 to 34

19 Note that the ITU's data collection software, SpaceCap, requires information concerning which of the space stations in the constellation are associated with each space station beam type.

MURL, MURR. <u>Transmitting Beams</u>: MGTL, MGTR, MUTL, MUTR.	

3. For satellite beams that use non-contiguous spectrum, which is the case for the OW-V gateway uplinks, the Schedule S software requires the definition of different satellite beams for each non-contiguous portion of the spectrum. This explains why there are a relatively large number of satellite receive beams in the Schedule S. The following groups of satellite receive beams are identical within each group except that they operate across different and non-contiguous portions of the uplink frequency range:
   - LGR1, LGR2 and LGR3
   - LGR4, LGR5 and LGR6
   - MGR1, MGR2 and MGR3
   - MGR4, MGR5 and MGR6

4. The Schedule S software will not accept negative values for the parameter entitled "Active Service Arc Begin Angle with Respect to Ascending Node", even though the Schedule S instructions require such negative angles to be used. So, the values entered in the OW-V Schedule S for this parameter are positive ones but should be interpreted as negative ones.

5. For the MEO component of the OW-V system, orbit adjustments of the constellation will be made to ensure that the angular separation between orbit planes of the Right Ascension of the Ascending Node is maintained as stated in the Schedule S, despite the small orbit altitude differences between the orbit planes.

6. 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.

7. For all satellite transmit beams, the parameter entitled “Maximum Transmit EIRP” is assumed to be the aggregate EIRP in that beam across the total operating bandwidth of the beam.

8. The Schedule S software does not correctly print out the satellite numbering and phase information that has been entered into the online system.

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/_________

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