ONEWEB NON-GEOSTATIONARY SATELLITE SYSTEM
AMENDMENT OF THE MEO COMPONENT

ATTACHMENT A
Technical Information to Supplement Schedule S

A.1 SCOPE AND PURPOSE

In March 2017 OneWeb requested authorization from the Commission to operate 1,280 satellites in medium Earth orbit ("MEO").[1] OneWeb is now seeking to amend the Petition for Declaratory Ruling ("Petition") proposing this MEO component of its non-geostationary orbit ("NGSO") satellite system in light of the new Commission rules affecting NGSO systems.[2] OneWeb originally requested only the number of satellites that it was capable of deploying within six years of a potential market access grant, as per the Commission rules that were in force at the time of the market access Petitions in both the Ku-/Ka-band processing round and the V-band processing round. OneWeb now amends its Petition for the MEO component of its NGSO system as a result of the Commission's decision to change the NGSO milestone regime.[3]

This amendment to the MEO component consists of an increase in the number of satellites to be deployed in the MEO orbit (from 1,280 to 2,560) and the addition of frequency bands (Ku-, Ka-

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1 *In re WorldVu Satellites Limited, Petition for Declaratory Ruling Granting Access to the U.S. Market for the OneWeb V-Band System,* IB File No. SAT-LOI-20170301-00031 (filed Mar. 1, 2017) ("V-Band Petition") (this application sought authorization to access the U.S. market through both OneWeb's MEO constellation and its LEO constellation using V-band spectrum).

2 *In the Matter of 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, IB Docket No. 16-408, FCC 17-122 (2017) ("*NGSO R&O*").

3 *Id*. at ¶ 66-67.

and E-band) to these MEO satellites. This amended MEO component of the OneWeb system is referred to as "OW-MEO" in this attachment.

This attachment contains the information required for the instant amendment by §25.114(d), §25.146 and other sections of the Commission'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 OW-MEO component will operate simultaneously with OneWeb's low-Earth orbit ("LEO") component, for which Commission authorization has already been granted in the Ku- and Ka-bands, and for which a Petition to the Commission for use of V-band frequencies is pending.[4]

The OW-MEO component will provide additional capacity to the OneWeb system, although it will exhibit somewhat higher latency than the LEO component due to the higher orbit altitude. However, it has the advantage of greater flexibility to allocate satellite resources to geographic areas of greatest need, because of the larger area of the Earth visible to the MEO satellites.

OneWeb will dynamically assign traffic between the LEO and MEO components of its overall system depending on the instantaneous service requirements and overall traffic loading of the combined system. This unique multi-satellite combining capability will happen in the background, increasing the user capacity to over 2.5Gbps and providing a service 1.5 times faster than the current highest-speed residential fiber capacity on the market. This will allow rural populations equal access to what will be the world's fastest consumer broadband, while maintaining a basic service to 100% of the world's population.

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[4] *See* V-Band Petition.

The OW-MEO component will operate using Ku-, Ka-, V-, and E-band frequencies. It will therefore use some of the same frequencies as OneWeb's LEO component. However, there will be no self-interference between the two constellations. OneWeb's network control center will ensure that 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 OneWeb NGSO system.

The OW-MEO component will operate with 2,560 satellites in circular inclined orbits with a nominal orbit altitude of 8,500 km and a nominal orbit inclination of 45°.[5] There will ultimately be 32 orbital planes with 80 satellites per plane, but with an initial deployment of 8 planes, an interim deployment of 16 planes, and an increasing number of satellites per plane over time.

In addition to the satellites referred to above, the OW-MEO component will also include Ku-, Ka-, V-, and E-band gateway earth stations and Ku-, Ka- and V-band user terminals. All of these earth stations will operate in the Fixed-Satellite Service ("FSS"), with the exception of certain types of user terminals that will operate in the Mobile-Satellite Service ("MSS").[6] Any user terminals operating in the MSS will only be operated outside of the U.S. and will have technical characteristics that are consistent with user terminals operating in the FSS.

The OW-MEO component uses Ku-, Ka-, and V-band frequencies for the RF links between the satellites and user terminals. For the links between the satellites and the gateway earth stations, which provide the interconnection to the global Internet, the V- and E-band frequencies, plus a portion of the Ku-band (12.75-13.25 GHz, 13.75-14.5 GHz and 15.43-15.63 GHz)[7] and Ka-band

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[5] In practice, the orbital planes will be at slightly different altitudes in order to avoid any risk of collision between satellites in different planes.

[6] The MSS user terminals may operate in internationally recognized MSS frequency allocations such as 19.7-20.2 GHz, 29.5-30.0 GHz, 40.0-40.5 GHz, and 50.4-51.4 GHz.

[7] The 15.43-15.63 GHz band is allocated by the Commission (footnote US359 to the U.S. table of frequency allocations), and also by the ITU (Article 5, note 5.511A), to feeder uplinks to the MSS in NGSO systems. OneWeb will connect the uplinks in this band to downlinks in the 19.7-20.2 GHz band that are destined for MSS terminals (outside of the U.S.).

(17.8-18.1 GHz, 19.3-19.7 GHz and 27.5-30.0 GHz) are used.[8] The OW-MEO 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 and mobile applications. The gateway earth stations will typically utilize 2.4 m to 4.5 m antennas, depending on their location and the associated propagation characteristics and service requirements.[9]

The frequency ranges used by the OW-MEO component are summarized in Table A.2-1 below. The detailed channelized frequency plan is given in the associated Schedule S. This results in the MEO satellites using up to 77.0 GHz of bandwidth in the forward transmission direction (gateway to user) and 41.6 GHz in the return transmission direction (user to gateway), considering the polarization and spatial frequency re-use schemes that will be used.

Table A.2-1: Frequency bands proposed to be used by the OW-MEO component

Notes:
1. **Bold font** indicates additional frequencies in this modification request compared to the original Petition for the MEO component.
2. Some frequency ranges listed below are shown as being used both for gateway and user links. Such dual usage will not occur on the same satellite, but will occur between different satellites in the OW-MEO component. This flexible mode of operation is explained further in this document.
3. The 71.0-76.0 GHz frequency band is allocated, according to the ITU and U.S. Tables of Frequency Allocations, for use in the space-to-Earth (downlink) transmission direction. However, OneWeb intends to also use this frequency band for gateway-only links in the

8 The 19.3-19.6 GHz band is allocated by the Commission (footnote NG166 to the U.S. table of frequency allocations), and also by the ITU (Article 5, notes 5.523B and 5.523D), to feeder downlinks for the MSS in NGSO systems. OneWeb will therefore connect the downlinks in the 19.3-19.7 GHz band to uplinks in the 29.5-30.0 GHz band that are from MSS terminals (outside of the U.S.).

9 Any OW-MEO transmitting gateway earth stations operating in 13.75-14.0 GHz frequency range will have an antenna diameter not less than 4.5 m, consistent with footnote 5.502 to the ITU Table of Frequency Allocations (Article 5 of the Radio Regulations) and footnote US356 to the U.S. Table of Frequency Allocations (§ 2.106). In addition, gateway earth stations operating in this frequency range will be coordinated and will operate consistent with the requirements of footnotes US337 and US357 to the U.S Table of Frequency Allocations (§ 2.106).

Earth-to-space (uplink) transmission direction as well as in the space-to-Earth (downlink) direction, but not simultaneously from the same satellite. This flexible mode of operation is explained further in this document.

Type of Link and Transmission Direction	Frequency Ranges
Gateway-to-Satellite	**12.75 – 13.25 GHz** **13.75 – 14.5 GHz** **15.43 – 15.63 GHz** **17.8 – 18.1 GHz** **27.5 – 30.0 GHz** 42.5 – 43.5 GHz 47.2 – 50.2 GHz 50.4 – 51.4 GHz **71.0 – 76.0 GHz** **81.0 – 86.0 GHz**
Satellite-to-Gateway	**19.3 – 19.7 GHz** 37.5 – 42.5 GHz **71.0 – 76.0 GHz**
User Terminal-to-Satellite	**12.75 – 13.25 GHz** **14.0 – 14.5 GHz** **17.8 – 18.1 GHz** **28.35 – 29.1 GHz** **29.5 – 30.0 GHz** 47.2 – 50.2 GHz 50.4 – 51.4 GHz
Satellite-to-User Terminal	**10.7 – 12.7 GHz** **18.1 – 18.6 GHz** **18.8 – 19.4 GHz** **19.6 – 20.2 GHz** 37.5 – 42.5 GHz

Dual circular polarization is used for the both the gateway and user links in the OW-MEO component.

The frequency re-use scheme is as follows:

- For the gateway links, there will be two times (2x) spatial frequency re-use in addition to dual polarization, making a total frequency re-use factor of four times (4x).
- For the user links, the spatial frequency reuse will vary but will not be less than four times (4x). In addition, dual polarization will be used on these links making a total frequency re-use factor of at least eight times (8x).

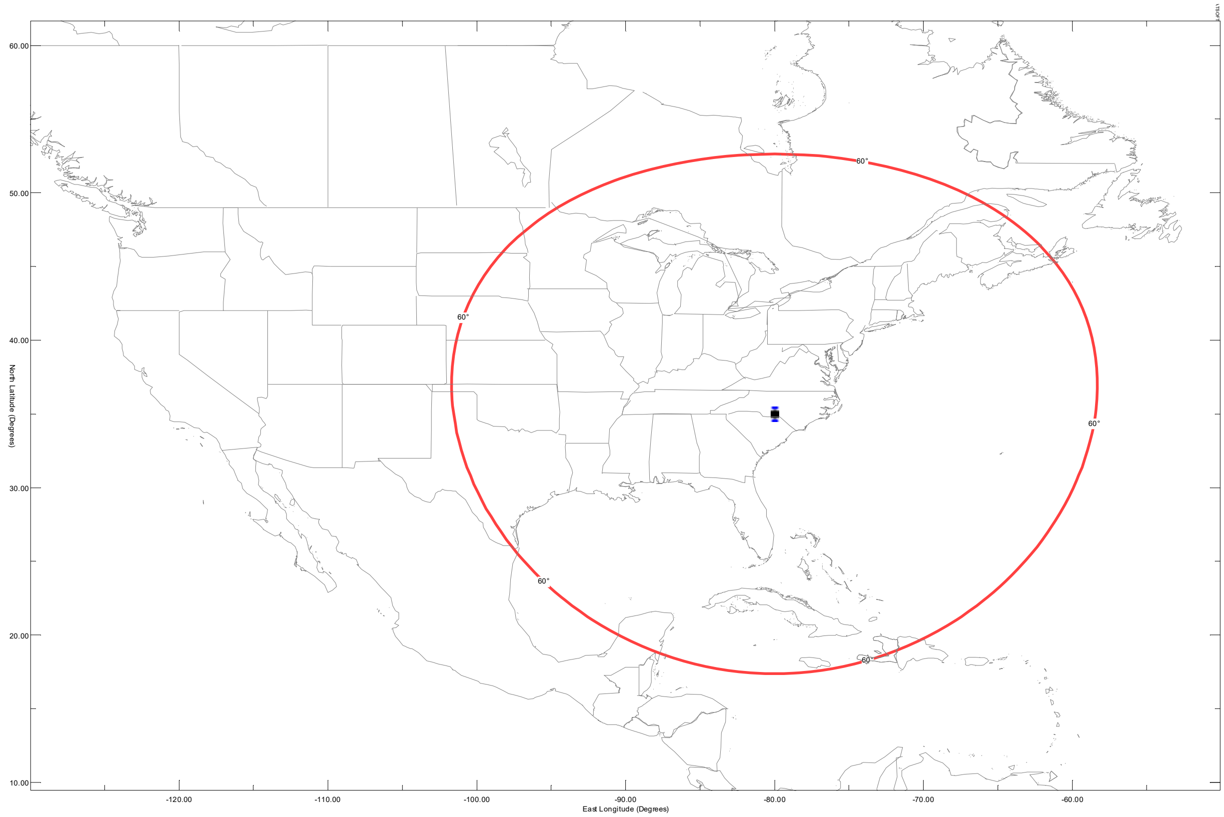
Therefore, the requirements of §25.210(f) are fully satisfied.

The OW-MEO component provides broadband communications services between the user terminals and the gateway earth stations located on the existing global fiber network. Multiple OW-MEO gateway earth station antennas will be collocated at a gateway site in order to access a number of visible OW-MEO satellites simultaneously from that location. At least four OW-MEO gateway earth station sites are expected to be deployed in the U.S., including gateway earth stations in Hawaii and Alaska, and likely additional sites in some U.S. territories. The OW-MEO gateway earth stations will likely be collocated with OneWeb's Ka-band gateway earth stations that service its LEO component, although there may be some exceptions to this for operational reasons. The exact locations of the gateway earth stations have yet to be determined. Certain gateway earth stations, but not those in the U.S., will additionally act as TT&C stations for the OW-MEO component, with the TT&C transmissions taking place in the Ka-band.

The OW-MEO component will operate under the control of the core OneWeb satellite control centers that are described in the earlier OneWeb Petitions to the Commission. 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 (VPNs).

Each OW-MEO satellite will have up to seven identical circular *user* beams in Ku-, Ka-, and V-band. The beams are capable of being steered over the visible Earth's surface. The user service area 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 A2-1 below shows this nominal user beam service area (60° elevation) for the OW-MEO component.

Figure A.2-1: Example user beam service area for the OW-MEO component with a satellite over CONUS (60° elevation)



Each of the OW-MEO user beams will carry the available Ku-, Ka-, or V-band user link frequencies. Beams from more than one OW-MEO satellite may be located over the same geographic area to increase the traffic capacity available to that location.

The OW-MEO satellites have several identical *gateway* antennas, each capable of being pointed to any part of the visible Earth.[10] This will provide continuous service to and from the corresponding gateway earth station and allow for seamless handover between active gateway earth stations.

Table A.2-2 below identifies which beams (designated in the associated Schedule S) are *user* beams and which are *gateway* beams as well as showing the transmission direction of each.

Table A.2-2: Beam designations used in Schedule S

Satellite *Gateway* Receive Beams	Satellite *Gateway* Transmit Beams	Satellite *User* Receive Beams	Satellite *User* Transmit Beams
GRKA	GTKA	URKA	UTKA
GRKB	GTKB	URKB	UTKB
GRKC	MGTL	URKC	UTKC
GRKD	MGTR	URKD	UTKD
GRKE	GTEA	URKE	UTKE
GRKF	GTEB	URKF	UTKF
GRKG		URKG	UTKG
GRKH		URKH	UTKH
GRKI		URKI	UTKI
GRKJ		URKJ	UTKJ
MGR1		MURL	MUTA
MGR2		MURR	MUTB
MGR3		URVA	MUTL
MGR4		URVB	MUTR
MGR5		URVC	
MGR6		URVD	
GREA			
GREB			
GREC			
GRED			

Each OW-MEO satellite can operate in one of two operating modes – Mode 1 or Mode 2 – independent of the operating mode of the other satellites in the constellation. In Mode 1 the

10 Although the gateway beams can be pointed to any part of the visible Earth, in practice they will operate at elevation angles greater than 25° for the Ka-band, and in the case of the V-band gateway downlink beams, they will not operate below an elevation angle of 20°.

throughput capacity of the satellite is optimized for the forward (gateway-to-user) transmission direction. In Mode 2 there is a greater amount of return capacity (user-to-gateway) at the expense of a reduction in forward capacity of the satellite. The OW-MEO component is capable of adapting to changing traffic requirements of the users, which may be as a function of time, or geographic region of the users, or both. The ability to change the number of visible satellites and their use of capacity operating in Mode 1 versus Mode 2 configuration provides considerable flexibility to allow OneWeb to optimize the service provided to the end users. This innovative flexibility of the MEO constellation acts as a capacity multiplier to the preset configuration of the LEO component, enabling a highly efficient system which will have tremendous benefits for rural consumers.

The main differences in the way the RF spectrum is used by each satellite between the Mode 1 and Mode 2 configurations are as follows:

- Portions of Ku- and Ka-band uplink frequency ranges (12.75-13.25 GHz, 14.0-14.5 GHz, 17.8-18.1 GHz, 28.35-29.1 GHz, 29.5-30.0 GHz) are used for gateway uplinks in Mode 1, whereas in Mode 2 they are used for user terminal uplinks;
- The Ka-band MSS feeder downlink spectrum 19.4-19.6 GHz is used for gateway downlinks in Mode 2 only;
- The entire V-band downlink spectrum is used for user terminal downlinks in Mode 1, whereas in Mode 2 only a portion (40.0-42.0 GHz) is used for user terminal downlinks;
- The entire V-band uplink spectrum is used for gateway uplinks in Mode 1, whereas in Mode 2 portions of the V-band spectrum (47.2-50.2 GHz and 50.4-51.4 GHz) are used for user terminal uplinks and the remaining portion (42.5-43.5 GHz) is used for gateway uplinks;
- The E-band frequency range 71.0-76.0 GHz is used as a gateway uplink in Mode 1, whereas in Mode 2 it is used as a gateway downlink;
- There are other operational differences between Mode 1 and Mode 2 that will be employed to optimize the throughput of the OW-MEO component.

As mentioned above, the OW-MEO component uses multiple steerable user beams within the designated service areas for each satellite. As the OW-MEO satellites move in their orbits, the steerable user beams will continually be pointed toward the designated service points. As an OW-

MEO satellite moves beyond the optimum reach of each service point, handover will occur to another high elevation OW-MEO satellite so there is no service interruption to the users.

In the OW-MEO communications payloads there is flexibility to interconnect uplink channels to downlink channels, in both forward and return transmission directions, using signal processing and management techniques.

The transmission schemes in the OW-MEO component are similar to the OneWeb LEO component. The proposed schemes are described below.

Each forward channel supports a single wideband carrier. Narrower 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 or from a user terminal based on the specific link quality available.

Each user beam supports services to multiple user terminals. In the forward direction (gateway-to-user) there is a TDM transmission scheme in operation whereby each user beam supports a single 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 whereby each user terminal transmits time bursts of data on a relatively narrow-band carrier (typically 1.25 MHz to 20 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 received by the satellites and downlinked appropriately to the gateway receiving earth 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 beam types in each OW-MEO satellite, are defined in the associated Schedule S.

There are two broad categories of earth stations in the OW-MEO component – the OW-MEO gateway (and in some cases, also TT&C) stations and the OW-MEO user terminals. The gateway/TT&C sites will employ multiple active tracking antennas, each typically of 2.4 to 4.5 meters in reflector diameter. The user terminals 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.[11] 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, by 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 steerable beam will dynamically switch between active satellites using a single fixed antenna aperture.

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

The predicted antenna gain contour data for all of the satellite beam types in the OW-MEO component have been uploaded to the online Schedule S. This beam data is provided in the form of the required contours in the ITU's GXT format plotted on the surface of the Earth and with the beam peak pointed to nadir, as required by §25.114(c)(4)(vi)(B) and the Schedule S instructions.[12]

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

[12] Federal Communications Committee, "Specific Instructions for Schedule S," April 2016, *available at* https://enterpriseefiling.fcc.gov/schedules//resources/Instructions%20for%20Schedule%20S%20vApr2016.pdf ("Schedule S Instructions").

A.4 GEOGRAPHIC COVERAGE (§25.146(b))

Following the adoption of the *NGSO R&O*,[13] the Commission's geographic coverage requirements applicable to NGSO systems are contained in §25.146(b) which reads as follows:

> (b) [A]n NGSO FSS applicant proposing to operate in the 10.7-12.7 GHz, 12.75-13.25 GHz, 13.75-14.5 GHz, 18.8-19.3 GHz, or 28.6-29.1 GHz bands must provide a demonstration that the proposed system is capable of providing FSS on a continuous basis throughout the fifty states, Puerto Rico, and the U.S. Virgin Islands.

The Commission also requires applicants in bands with a domestic frequency allocation but no service rules in place to comply with § 25.143(b)(2)(iii),[14] which reads as follows:

> (2) [E]ach applicant and petitioner must demonstrate the following:
>
> (iii) That a system proposed to operate using non-geostationary satellites be capable of providing Mobile-Satellite 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.

The satellites in the OW-MEO component operate in a 45° inclined orbit, enabling them to provide continuous service to latitudes at least as high as the most northerly latitudes of Alaska (approximately +71.5°N). This is demonstrated in Figure A.4-1 below, which shows a snapshot in time for an initial operational OW-MEO constellation with 16 orbital planes and 40 satellites per plane. The contours shown in Figure A.4.1-1 are the 45° elevation contours and there is always

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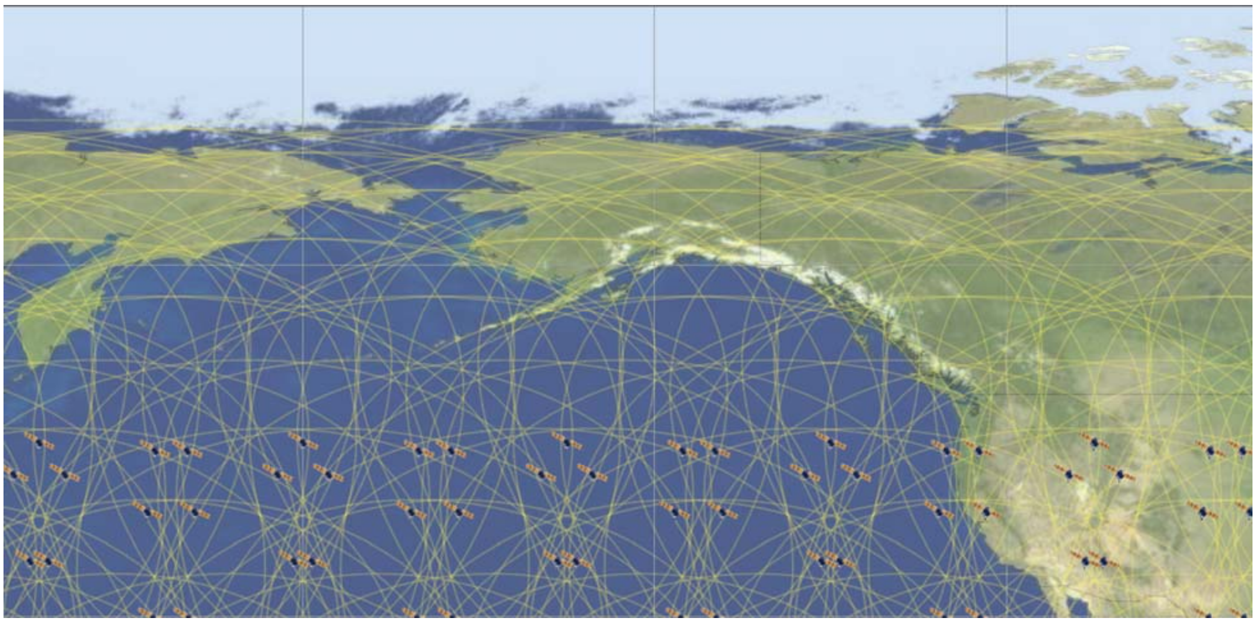
[13] *See NGSO R&O* at ¶ 76.

[14] *See NGSO R&O* at 47 C.F.R. § 25.217(b)(1). *See also* 47 C.F.R. § 25.143(b)(2)(iii).

at least one OW-MEO satellite visible above this elevation angle at the most northerly point of Alaska. This demonstrates that the OW-MEO component provides continuous service to Alaska, which is the highest latitude region of the territories listed in §25.146(b), 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.4-1: Coverage of high latitude regions by the MEO satellites of the OW-MEO component (showing 45° elevation service areas for each satellite; 640 satellites in operation)



The OW-MEO component will also be capable of providing continuous coverage to the entire continental U.S., Puerto Rico, and the U.S. Virgin Islands. Therefore, the OW-MEO component fully meets the Commission's geographic service requirements.

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

For the OW-MEO component, no TT&C earth stations are foreseen to be located in the U.S. territories at present for these satellites, and so no Commission 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 and complement the information provided in the associated Schedule S submission.

The TT&C system for the OW-MEO satellites provides for communications during post-launch, transfer orbit and on-station operations, as well as during spacecraft emergencies. The TT&C system operates at the edges of the Ka-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 toward U.S. territories are at EIRP density levels that are no higher than the gateway communications carriers. Because these transmissions will not take place from U.S. gateway earth stations, their technical parameters are not fully included in the associated Schedule S.

A high-level 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 TT&C Signal Modulation	BPSK
Uplink TT&C Frequencies	27500 - 27550 MHz (outside of U.S.)
Downlink TT&C Signal Modulation	QPSK
Downlink TT&C Frequencies	19700 - 19770 MHz (outside of U.S.)
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(b), §25.208(c), §25.208(e), §25.208(o), §25.208(r), §25.208(s) and §25.208(t))

The OW-MEO component complies with all applicable Commission and ITU Power Flux Density ("PFD") limits, which are designed to protect terrestrial services from downlink interference due to the satellite transmissions. The Commission 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.

Downlink PFD Limits in Ku-band

The Commission's Ku-band downlink PFD limits which apply across the 10.7-11.7 GHz band are given in §25.208(b) and are as follows:

- -150 dB(W/m^2) in any 4 kHz band for angles of arrival between 0 and 5 degrees above the horizontal plane;
- -150+(δ-5)/2 dB(W/m^2) in any 4 kHz band for angles of arrival δ (in degrees) between 5 and 25 degrees above the horizontal plane; and
- -140 dB(W/m^2) in any 4 kHz band for angles of arrival between 25 and 90 degrees above the horizontal plane.

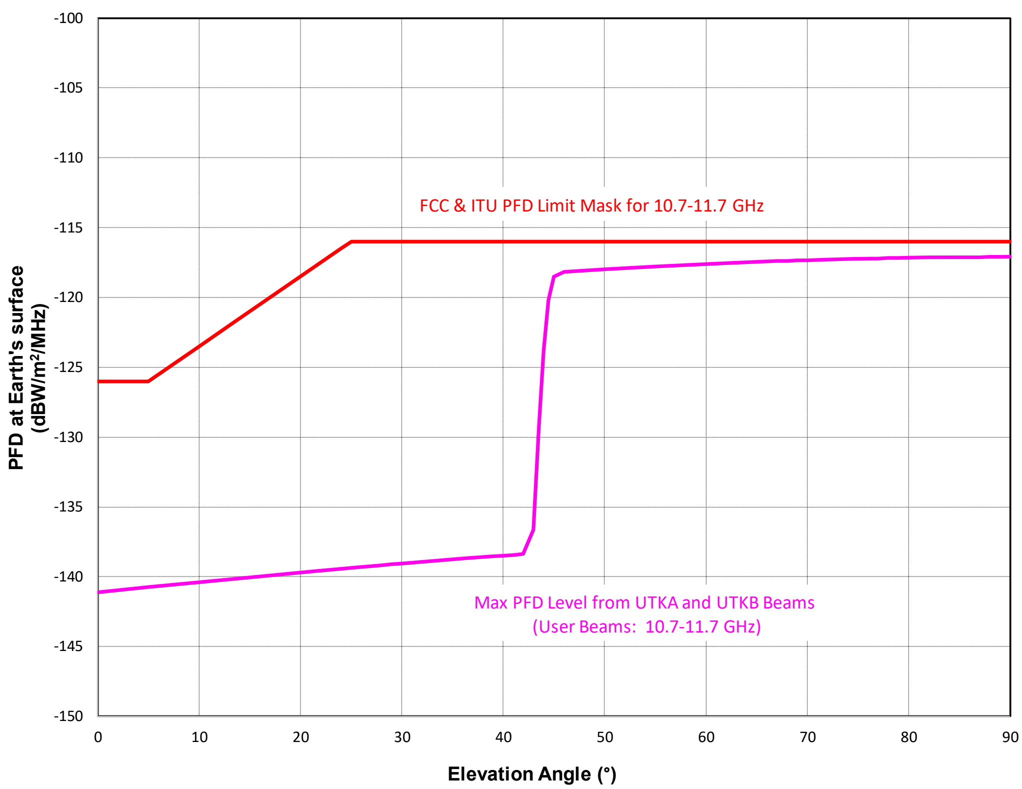
The above-mentioned Commission PFD limits are essentially the same as the ITU PFD limits applicable to NGSO systems in the 10.7-11.7 GHz band, which are given in Table 21-4 of the ITU Radio Regulations.[15]

Figure A.7-1 below plots the maximum clear-sky PFD for the OW-MEO satellite user beams that transmit in the 10.7-11.7 GHz band (i.e., beams UTKA and UTKB according to the beam designations in the associated Schedule S) alongside the Commission and ITU PFD mask that

[15] The ITU PFD limits applicable to NGSO systems in the 10.7-11.7 GHz and 11.7-12.7 GHz bands are defined in a 1 MHz reference bandwidth, whereas the corresponding Commission PFD limits are defined in both 1 MHz and 4 kHz reference bandwidths.

applies. This takes account of the beam gain roll-off, the path length to the surface of the Earth and the possible beam pointing directions corresponding to an elevation angle for the boresight of the beam of no less than 45° at the surface of the Earth. From Figure A.7-1 it can be seen that the OW-MEO Ku-band downlink transmissions in this frequency range are compliant with the PFD limit in §25.208(b).

Figure A.7-1: Compliance of the maximum Ku-band PFD levels of the OW-MEO component with the Commission and ITU PFD masks for the 10.7-11.7 GHz band



In the 11.7-12.2 GHz downlink frequency band there are no Commission PFD limits. There are, however, ITU PFD limits in the 11.7-12.7 GHz band which are effectively 2 dB higher than the Commission PFD limits in the 10.7-11.7 GHz band. The OneWeb system will therefore also be compliant with these ITU PFD limits across the entire 11.7-12.7 GHz band.

The Commission has specific low elevation PFD limits in §25.208(o) which apply in the 12.2-12.7 GHz band in order to protect the MVDDS service. These limits, which relate to the PFD into an actual operational MVDDS receiver, are defined as follows:

- -158 dB(W/m^2) in any 4 kHz band for angles of arrival between 0 and 2 degrees above the horizontal plane;
- -158+3.33(δ-2) dB(W/m^2) in any 4 kHz band for angles of arrival δ (in degrees) between 2 and 5 degrees above the horizontal plane.

Figure A.7-2 below plots the maximum clear-sky PFD for the OW-MEO satellite user beams that transmit in the 11.7-12.7 GHz band (i.e., beams UTKC and UTKD according to the beam designations in the associated Schedule S) alongside the ITU PFD mask that applies. This takes account of the beam gain roll-off, the path length to the surface of the Earth and the possible beam pointing directions corresponding to an elevation angle for the boresight of the beam of no less than 45^o at the surface of the Earth. From Figure A.7-2 it can be seen that the OW-MEO Ku-band downlink transmissions in this frequency range are compliant with the ITU's PFD limit in Table 21-4 of Article 21 of the Radio Regulations.

Figure A.7-2: Compliance of the maximum Ku-band PFD levels of the OW-MEO component with the ITU PFD mask for the 11.7-12.7 GHz band

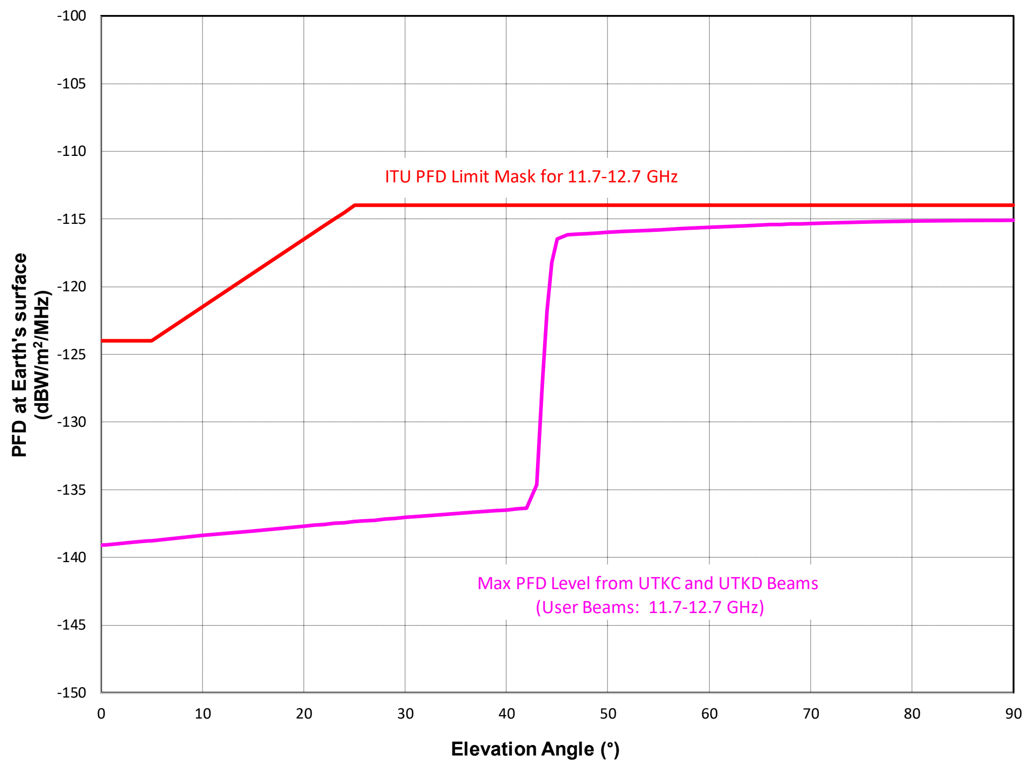
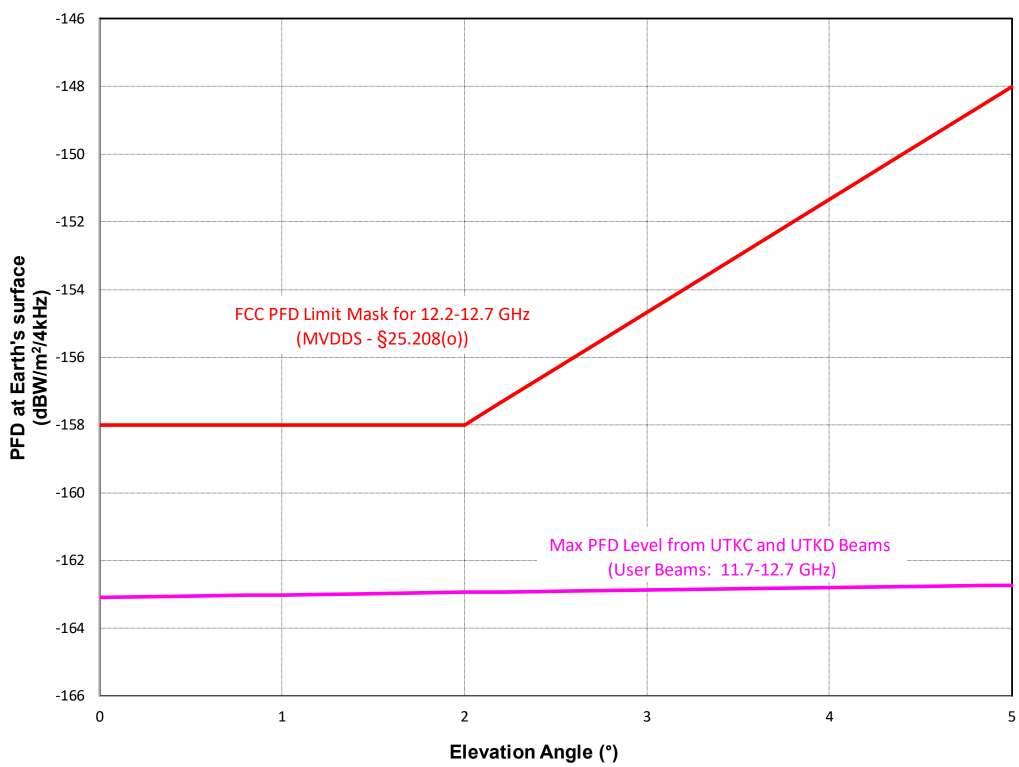


Figure A.7-3 below plots the maximum clear-sky PFD for the OW-MEO satellite beams that transmit in the 12.2-12.7 GHz band (i.e., beams UTKC and UTKD according to the beam designations in the associated Schedule S) alongside the Commission's PFD mask to protect the MVDDS (§25.208(o)). This takes account of the beam gain roll-off, the path length to the surface of the Earth and the possible beam pointing directions corresponding to an elevation angle of no less than 45° at the surface of the Earth. From Figure A.7-3 it can be seen that the OW-MEO Ku-band downlink transmissions in this frequency range are compliant with the PFD limit in §25.208(o).

Figure A.7-3: Compliance of the maximum low-elevation Ku-band PFD levels of the OW-MEO component with the Commission PFD mask for the 12.2-12.7 GHz band to protect the MVDDS (§25.208(o))



Therefore, all the Ku-band downlink transmissions from the OW-MEO satellites comply with all the Commission and ITU PFD limits.

Downlink PFD Limits in Ka-band

In the past, the Commission PFD limits in the Ka-band differed in some portions of the band from those of the ITU. Following the *NGSO R&O*, the Commission's new rules require that an NGSO system comply with any applicable power flux-density levels in Article 21, Section V, Table 21-4 of the ITU Radio Regulations (incorporated by reference, *see* § 25.108), except that in the 19.3-19.4 GHz and 19.6-19.7 GHz bands applicants must certify that they will comply with the ITU PFD limits governing NGSO FSS systems in the 17.7-19.3 GHz band.[16] In the 19.7-20.2 GHz band, there are no PFD limits in the Commission's rules nor in the Radio Regulations.[17]

The result of this is that a single set of PFD limits applies across the 17.7-19.3 GHz band, as well as the 19.3-19.4 GHz and 19.6-19.7 GHz bands. These PFD limits 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 $50 < n \leq 288$

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[16] *See NGSO R&O* at ¶ 30.

[17] *See* Int'l Telecomm. Union, Radio Regulations, Article 21, Table 21-4.

- 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 2,560 and therefore X is equal to 42.9 dB according to the above formulae. This results in the PFD mask shown in Figures A.7-4 and A.7-5 below.

Figure A.7-4 below plots the maximum clear-sky PFD for the OW-MEO satellite user beams that transmit in portions of the 18.1-19.4 GHz and 19.6-19.7 GHz bands (i.e., beams UTKE, UTKF, UTKG and UTKH according to the beam designations in the associated Schedule S) alongside the Commission and ITU PFD mask that applies. This takes account of the beam gain roll-off, the path length to the surface of the Earth and the possible beam pointing directions corresponding to an elevation angle for the boresight of the beam of no less than 45º at the surface of the Earth. It also properly takes account of the X-factor in the PFD limit formula of §25.208(e) and Article 21 of the ITU Radio Regulations. From Figure A.7-4 it can be seen that the OW-MEO Ka-band downlink transmissions in this frequency range are compliant with the PFD limits in §25.208(c), §25.208(e) and Article 21 of the ITU Radio Regulations.

Figure A.7-5 below shows the comparable information for the OW-MEO satellite gateway downlink beam that operates in the 19.3-19.7 GHz band (i.e., beams GTKA and GTKB), which also demonstrates compliance with the PFD limits.

Figure A.7-4: Compliance of the maximum Ka-band PFD levels for the user downlink beams of the OW-MEO component with the Commission and ITU PFD masks

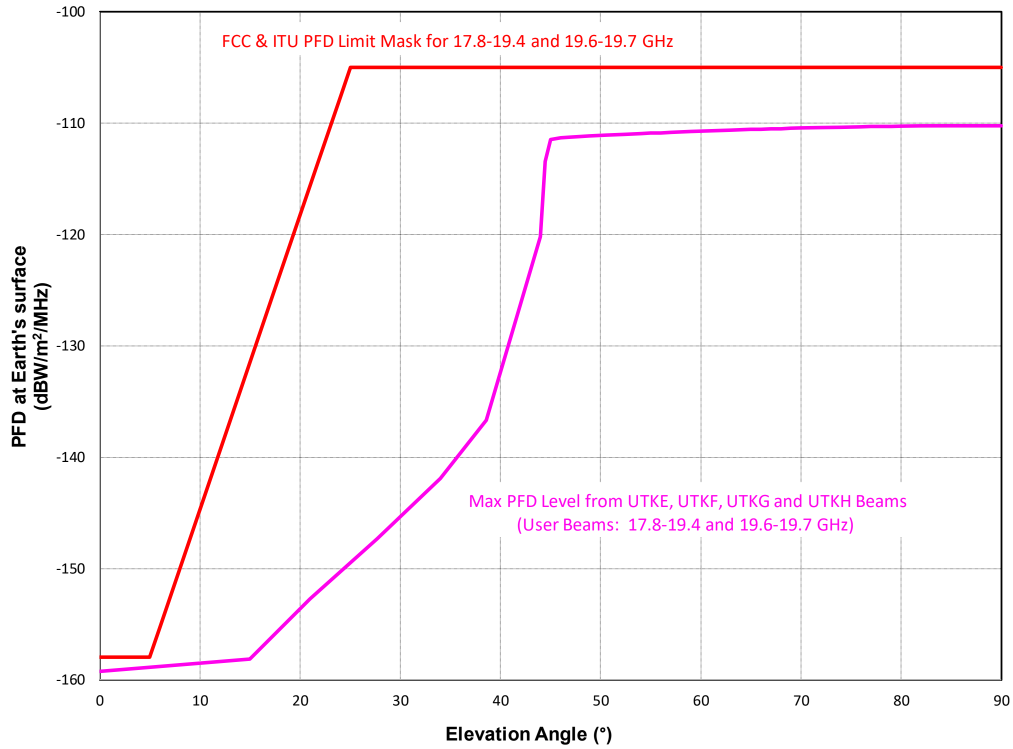
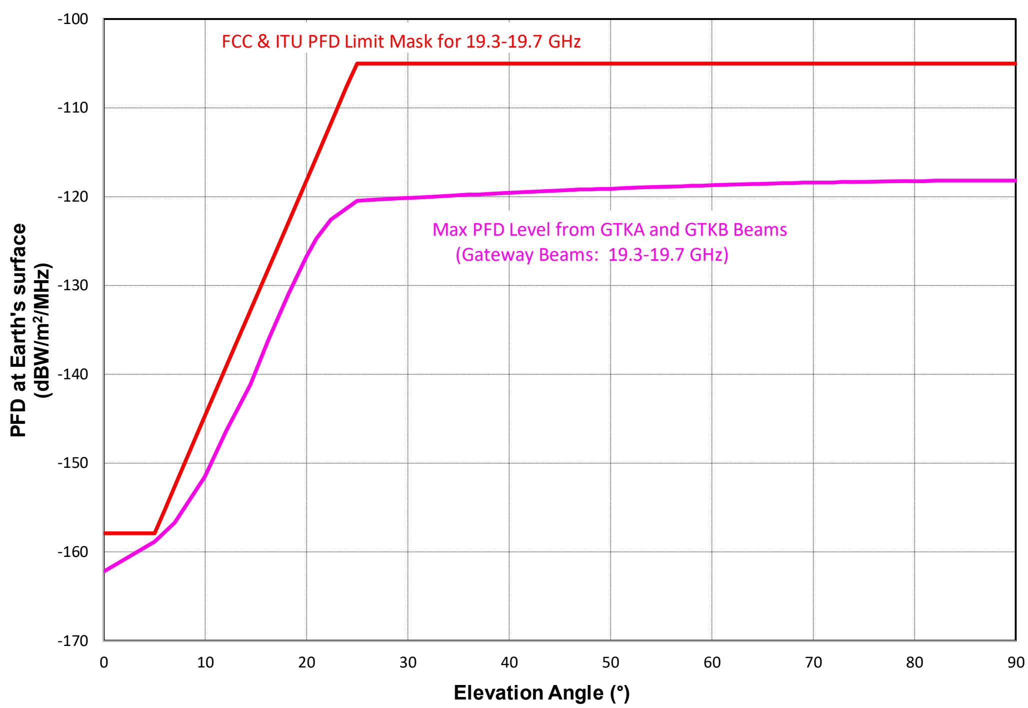


Figure A.7-5: Compliance of the maximum Ka-band PFD levels for the gateway downlink beams of the OW-MEO component with the Commission and ITU PFD masks



Downlink PFD Limits in V-band

There are ITU PFD limits in all parts of the V-band downlink frequency range proposed to be used by the OW-MEO component, which is 37.5-42.5 GHz.[18] These are designed to protect the terrestrial Fixed Service ("FS") and Mobile Service ("MS") from downlink interference due to the satellite transmissions. There are also Commission PFD limits in most of this downlink band (except for 42.0-42.5 GHz). However, the Commission PFD limits are not consistent in all cases with the ITU PFD limits. Both Commission and ITU PFD limits across the 37.5-42.5 GHz band are summarized in Table A.7-1 below.

Table A.7-1: ITU and Commission PFD 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	$-120 + 0.75(\delta - 5)$	−105	1 MHz
	FCC	−132	$-132 + 0.75(\delta - 5)$	−117	1 MHz
40-40.5 GHz	ITU	−115	$-115 + 0.5(\delta - 5)$	−105	1 MHz
	FCC	−115	$-115 + 0.5(\delta - 5)$	−105	1 MHz
40.5-42 GHz	ITU	−115	$-115 + 0.5(\delta - 5)$	−105	1 MHz
	FCC	−115	$-115 + 0.5(\delta - 5)$	−105	1 MHz
42-42.5 GHz	ITU	−120	$-120 + 0.75(\delta - 5)$	−105	1 MHz
	FCC	No PFD Limit			

In the 37.5-40.0 GHz band, the Commission PFD limit is 12 dB tighter than the ITU PFD limit at all elevation angles, although the Commission permits the PFD levels to be the same as the ITU PFD limit in this band (i.e., 12 dB higher than the value given in Table A.7-1 above) under conditions where the NGSO satellite transmits at higher power levels to compensate for rain-fade

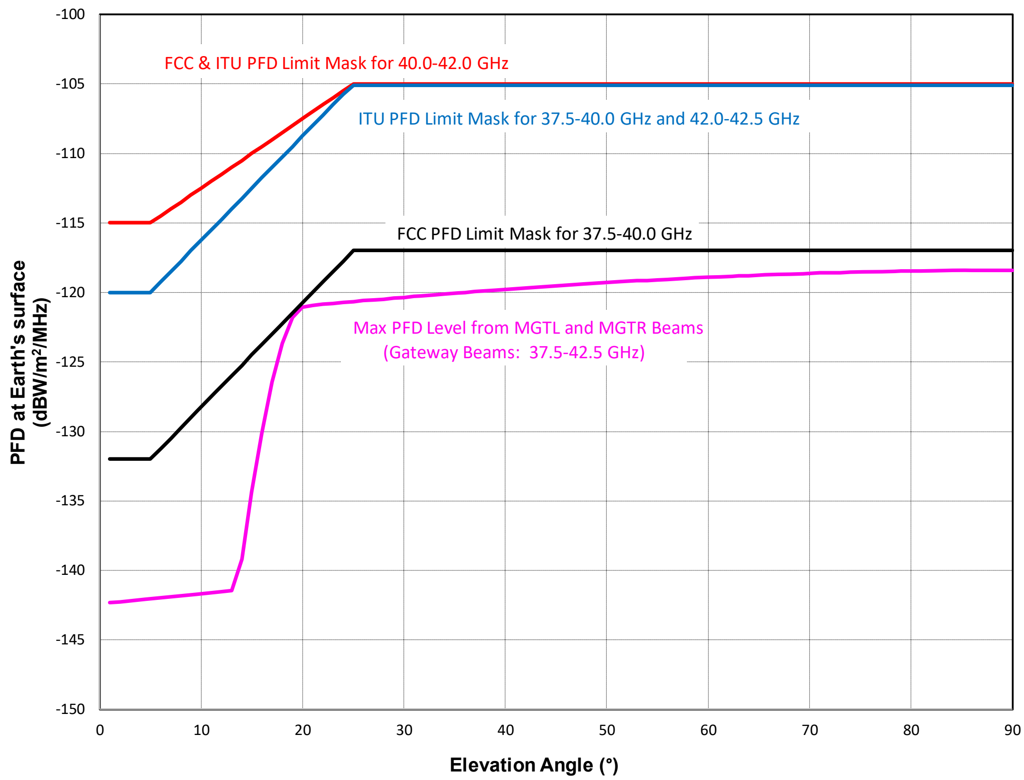
[18] The downlink frequency range of 37.5-42.5 GHz referred to here as "V-band" is also sometimes referred to as "Q-band".

conditions at its receiving earth stations.[19] In the 40.0-42.0 GHz band the Commission and ITU PFD limits are the same. In the 42.0-42.5 GHz band there are ITU PFD limits but no Commission limits.

Figure A.7-6 below plots the maximum clear-sky PFD for the OW-MEO satellite *gateway* beams that transmit in the 37.5-42.5 GHz bands (i.e., beams MGTL and MGTR, according to the beam designations in the associated Schedule S) alongside the Commission and ITU PFD masks that apply. This takes account of the beam gain roll-off, the path length to the surface of the Earth and the possible beam pointing directions corresponding to an elevation angle for the boresight of the beam of no less than 20º at the surface of the Earth, which is the value that applies for the V-band *gateway* beams. From Figure A.7-6 it can be seen that the OW-MEO V-band *gateway* downlink transmissions in this frequency range are compliant with the PFD limits in §25.208(r), §25.208(s), §25.208(t) and Article 21 of the ITU Radio Regulations.

[19] The Commission rule (§ 25.208(r)) relating to this increased PFD level in the 37.5-40 GHz band has the caveat that the matter is under further study and subject to a further rulemaking.

Figure A.7-6: Compliance of the maximum V-band PFD levels from the *gateway* downlink beams of the OW-MEO component with the Commission and ITU PFD masks in the 37.5-40.0 GHz and 42.0-42.5 GHz band



Figures A.7-7 and A.7-8 below plot the maximum clear-sky PFD for the OW-MEO satellite *user* beams that transmit in the 37.5-40.0 GHz and 40.0-42.5 GHz bands, respectively, alongside the Commission and ITU PFD masks that apply. This takes account of the beam gain roll-off, the path length to the surface of the Earth and the possible beam pointing directions corresponding to an elevation angle for the boresight of the beam of no less than 45° at the surface of the Earth, which is the value that applies for the *user* beams. From Figures A.7-7 and A.7-8 it can be seen that the OW-MEO V-band *user* downlink transmissions in these frequency ranges are compliant with the PFD limits in §25.208(r), §25.208(s), §25.208(t) and Article 21 of the ITU Radio Regulations.

Figure A.7-7: Compliance of the maximum V-band PFD levels from the *user* downlink beams of the OW-MEO component with the Commission and ITU PFD masks in the 37.5-40.0 GHz band

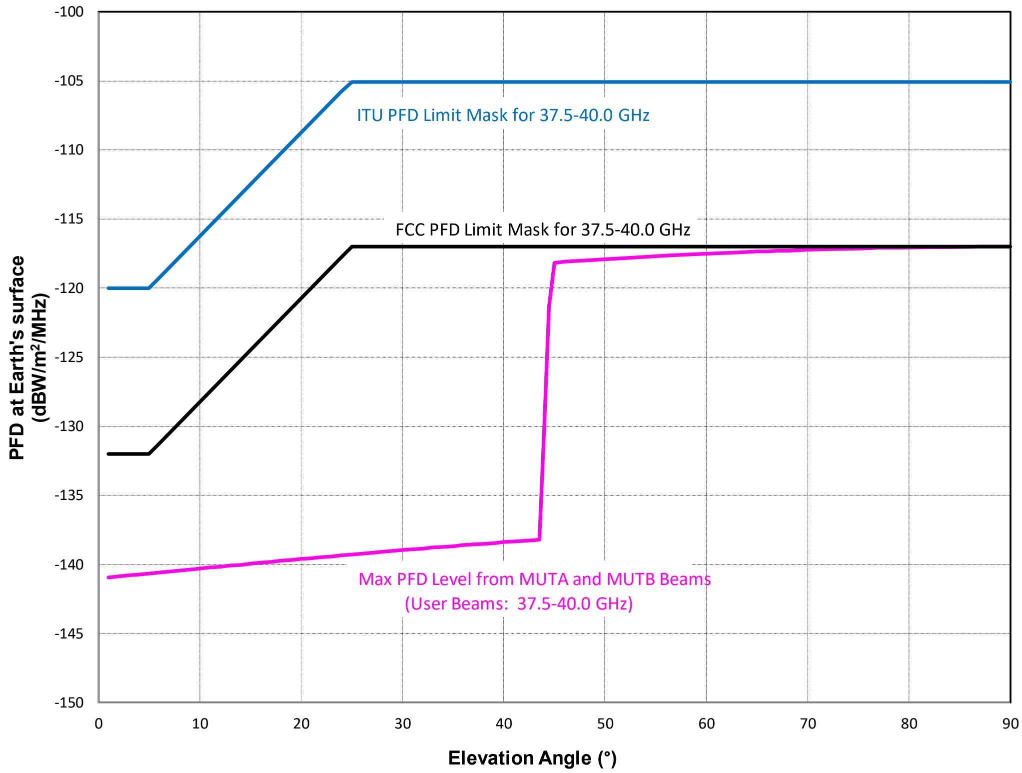
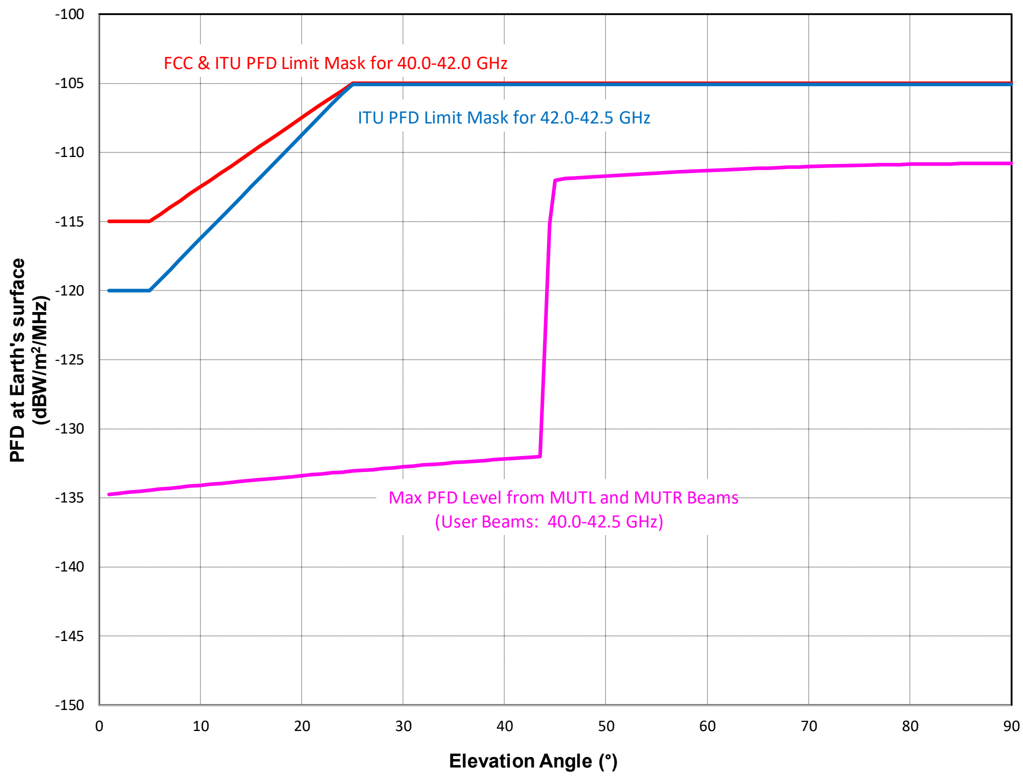


Figure A.7-8: Compliance of the maximum V-band PFD levels from the *user* downlink beams of the OW-MEO component with the Commission and ITU PFD masks in the 40.0-42.5 GHz band



<u>Downlink PFD Levels in E-band</u>

There are no ITU or Commission PFD limits in E-band.

A.8 INTERFERENCE ANALYSES AND FREQUENCY SHARING

The sub-sections below address the frequency sharing and interference issues with respect to each category of other services that are allocated the same spectrum in the U.S.

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

The OW-MEO component has been designed to provide the necessary interference protection to GSO satellite networks in all of the frequency bands used by the OW-MEO component. Although the regulatory situation is different between the various frequency bands (e.g., equivalent power flux-density ('EPFD') limits exist in some bands but not others), the OW-MEO component will employ the same interference protection approach to all frequency bands. By having a significant number of OW-MEO satellites visible to any transmitting or receiving earth station in the OW-MEO component, the satellite used for communicating will be selected to ensure a certain minimum GSO avoidance angle at all times. The exact GSO avoidance angle will vary somewhat with the frequency band, such that protection of GSO networks will be ensured in accordance with ITU and Commission rules. The definition of this GSO avoidance angle and the way in which it is implemented is explained further below.

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 toward 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-MEO component also has the effect of protecting the OW-MEO component from GSO interference, as it avoids inline and near-inline events.

GSO arc avoidance is straightforward in the OW-MEO component. Use of overlapping service areas permits the operation of satellite diversity within the OW-MEO component whenever an inline or near-inline event occurs with respect to the GSO arc. Using this technique, the OW-MEO network control center will constantly adjust the pointing direction of the satellite and earth station beams, and will reliably predict when a GSO inline event is approaching. At such times, in the case of OW-MEO user links, the network control center will instantaneously switch such links to alternate OW-MEO satellites, thereby maintaining the minimum GSO avoidance angle. In the case of the OW-MEO 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 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.

Internationally-recognized interference protection levels required to protect GSO satellite networks exist for the Ku-band and the majority of the Ka-band frequency ranges and take the form of the EPFD limits in Article 22 of the Radio Regulations.[20] These EPFD limits are now incorporated by reference into the Commission's new rules that will apply to NGSO systems in both the Ku- and Ka-bands.[21] The OW-MEO component will meet these ITU EPFD limits in the Ku-band and Ka-band frequency ranges as part of its ITU frequency registration process. In addition, OneWeb hereby certifies as part of this amendment that it will comply with the applicable EPFD levels found in the ITU Radio Regulations. These EPFD levels apply in the following frequency ranges to be used by the OneWeb system:

- Ku-band:
  - Uplink: 12.75-13.25 GHz, 13.75-14.5 GHz and 17.8-18.1 GHz
  - Downlink: 10.7-12.7 GHz
- Ka-band:
  - Uplink: 27.5-28.6 GHz and 29.5-30.0 GHz
  - Downlink: 17.8-18.6 GHz and 19.7-20.2 GHz

OneWeb hereby also commits to coordinating its downlink transmissions in the 10.7-12.7 GHz band with GSO FSS earth stations operating in this band that are registered as specific earth stations at the ITU by the U.S., when:

(1) The GSO receiving earth stations in question have maximum antenna isotropic gain greater than or equal to 64 dBi and a G/T of 44 dB/K or higher and an emission bandwidth of 250 MHz or greater; and

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20 *See* Int'l Telecomm. Union, Radio Regulations, Article 22, Section II.

21 *NGSO R&O* at ¶ 35.

(2) The $EPFD_{down}$ radiated by the NGSO satellite system into the GSO specific receive earth stations in question, either within the U.S. for domestic service or any points outside the U.S. for international service, as calculated using the ITU software for examining compliance with EPFD limits, exceeds −202 dB(W/(m^2/40kHz)) for any percentage of time.[22]

In frequency bands where EPFD limits exist (Ku-band and parts of Ka-band), or may exist in the future (V-band), the increase in the number of OW-MEO satellites (from 1,280 to 2,560) will not change the fact that the OW-MEO component will comply with the EPFD limits and therefore protect GSO networks to the level necessary according to the ITU Radio Regulations and the Commission's rules. The aggregate effect of transmissions from and to multiple OW-MEO satellites will be correctly taken into account in the EPFD analysis that is required by the ITU and the Commission's procedures.

Note that the OW-MEO component frequency plan includes some portions of Ka-band spectrum that are also shared with GSO satellite networks, where no EPFD limits exist in the ITU Radio Regulations. These include the 28.6-29.1 GHz uplink and 18.8-19.3 GHz downlink frequency bands, which are allocated to NGSO satellites on a primary basis according to the Commission's Ka-band frequency plan.[23] According to ITU procedures applicable to these frequency ranges (RR 9.11A), coordination between NGSO and GSO systems is on a first-come, first-served basis, depending on the ITU date priority of the relevant ITU filings. OneWeb has started coordination, and in many cases completed coordination, with GSO satellite networks in these frequency ranges concerning its LEO component, and is confident that compatibility with all GSO satellite networks in this band can be achieved for its OW-MEO component using a similar GSO arc avoidance methodology to the one adopted in the parts of Ka-band where EPFD limits apply.

[22] *See id.* at 47 C.F.R. § 25.146(d)(2). The lower limit value of -202 dB(W/(m^2/40kHz)) is used because the OW-MEO satellites will all operate above 2,500 km altitude.

[23] *Id.* at ¶ 14.

In addition, use of the 19.3-19.7 GHz downlink and 29.1-29.5 GHz uplink frequency bands for feeder links for the MSS is co-primary with GSO networks according to the ITU Radio Regulations, and OneWeb's usage of these bands in this way will be coordinated with GSO networks.[24]

The proposed OW-MEO use of the 19.3-19.4 GHz and 19.6-19.7 GHz downlink frequency bands for its service to user terminals, using the NGSO FSS allocation as opposed to the MSS feeder links, will be subject to the Commission's recently-adopted rules concerning these bands.[25] The Commission's rules require NGSO FSS systems to be secondary with respect to GSO networks. The OW-MEO component will comply with this by operating its downlink transmissions in these bands to user terminals such that the EPFD into GSO networks does not exceed the EPFD limits applicable to the 17.8-18.6 GHz band.[26]

The ITU regulatory requirement for the protection of GSO satellite networks in the V-band and E-band currently relies on ITU Radio Regulation 22.2, which reads as follows:

> "Non-geostationary-satellite systems shall not cause unacceptable interference to and, unless otherwise specified in these Regulations, shall not claim protection from geostationary satellite networks in the fixed-satellite service and the broadcasting-satellite service operating in accordance with these Regulations."

However, current work in the study groups of the ITU will likely lead to EPFD limits of one form or another, or other sharing regulations, being established in the Radio Regulations for the V-band at the ITU World Radio Conference 2019 (WRC-19). OneWeb commits that the OW-MEO component will comply with any new regulations that may be established by WRC-2019 in the V-band frequencies (37.5-42.5 GHz, 42.5-43.5 GHz, 47.2-50.2 GHz and 50.4-51.4 GHz).

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24 *See* Int'l Telecomm. Union, Radio Regulations, Article 5.

25 *NGSO R&O* at ¶¶ 19-21.

26 *See* Int'l Telecomm. Union, Radio Regulations, Article 22, Table 22-1B.

OneWeb will also coordinate, as necessary, with NTIA to ensure that OneWeb's proposed GSO protection measures 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-MEO component.

A.8.2 Interference with Respect to Other NGSO Satellite Systems

According to ITU procedures (RR 9.12), for all of the Ku-band and Ka-band frequency ranges to be used by the OW-MEO component, coordination amongst NGSO systems is on a first-come, first-served basis, depending on the ITU date priority of the relevant ITU filings.

There are currently no ITU procedures relating to the coordination between NGSO satellite systems operating in the V-band or E-band frequencies proposed for the OW-MEO component, and no "ITU priority" regime therefore exists in these bands.

Regardless of the ITU procedures, OneWeb is committed to working cooperatively with all other operators of Ku-, Ka-, V-, and E-band NGSO satellite systems.

As part of its coordination agreements with other NGSO operators, and consistent with the latest Commission rules governing spectrum sharing among NGSO systems, OneWeb will make its ephemeris data available to all relevant parties.[27]

The increase in the number of OW-MEO satellites (from 1,280 to 2,560) will not negatively impact the coordination process and interference avoidance with respect to other NGSO systems. Other than frequency or service area avoidance, the operational technique that allows NGSO systems to co-exist is based on the avoidance of in-line interference. This requires one or both NGSO systems to resort to either satellite or earth station diversity when in-line events are predicted to occur. Having more OW-MEO satellites in operation increases the scope of possibility to resolve such short-term spectrum conflicts. Indeed, increasing the number of OW-MEO satellites is responsive

27 *See NGSO R&O* at 47 C.F.R. § 25.146(e).

to §25.116(c)(1), which states that an amendment that "… resolves frequency conflicts with authorized stations or other pending applications but does not create new or increased frequency conflicts" does not constitute a major amendment. Having additional OW-MEO satellites able to serve the same geographic area inevitably increases the scope for using satellite diversity to resolve such frequency conflicts. As OneWeb pointed out to the Commission in the NGSO rulemaking proceeding, its proposed band segmentation rules may inadvertently allow operators of large constellations to force band segmentation on earlier-filed systems. OneWeb has no intention of forcing such band segmentation during in-line events and continues to assert that it can and will protect NGSO systems filed before its own MEO filing as per ITU rules, as long as the Commission strictly enforces this condition on all NGSO operators.

Currently, there is only one other NGSO satellite system (Space Norway) licensed by the Commission, or granted market access in the U.S., that plans to operate within the Ku-band frequency ranges to be used by OneWeb.[28]

In the Ka-band frequency ranges to be used by the OW-MEO component, there are currently two operational NGSO satellite systems licensed by the Commission or granted market access in the U.S., namely O3b and Iridium.[29] In addition, the Commission recently granted U.S. market access to two NGSO constellations who propose to operate in the Ka-band: Telesat and Space Norway.[30] These are addressed below.

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[28] *See In the Matter of Space Norway AS, Petition for a Declaratory Ruling Granting Access to the U.S. Market for the Arctic Satellite Broadband Mission*, Order and Declaratory Ruling FCC 17-146 (rel. Nov. 3, 2017) ("Space Norway Grant"). Although not licensed by the Commission, there is a U.S. government NGSO satellite system with which coordination is required under footnote US334 to the Commission's Table of Frequency Allocations. This is addressed in Section A.10.

[29] *In the Matter of O3b Limited, Petition for a Declaratory Ruling Granting Access to the U.S. Market for the O3b MEO Satellite System*, Stamp Grant, File No. SAT-LOI-20141029-00118 (Jan. 22, 2015); *In the Matter of Iridium Constellation LLC, Application for Modification of License to Authorize a Second-Generation NGSO MSS Constellation*, DA 16-875 (rel. Aug. 1, 2016).

[30] Space Norway Grant; *In the Matter of Telesat Canada Petition for Declaratory Ruling to Grant Access to the U.S. Market for Telesat's NGSO Constellation*, Order and Declaratory Ruling, FCC 17-147 (rel. Nov. 3, 2017).

The O3b MEO system operates in an equatorial orbit of 8,062 km altitude. OneWeb is already in coordination discussions with O3b concerning OneWeb's LEO component and is confident that mutually agreeable conditions can be reached with O3b to allow interference-free coexistence with respect to the OW-MEO component as well. OneWeb is coordinating its LEO component with SES/O3b and will extend these efforts to its proposed MEO component. The known and limited O3b orbit inherently serves to facilitate coordination with the O3b network as it operates in the equatorial plane.

The Iridium system operates its feeder links in the 19.4-19.6 GHz downlink and 29.1-29.3 GHz uplink frequency bands with a limited number of feeder link earth stations in operation in the U.S. Frequency ranges are proposed to be used by the OW-MEO component for its gateway links that overlap with these frequencies used by Iridium. Nevertheless, OneWeb is confident that it can efficiently share the spectrum used by Iridium without causing any interference or operational disruption to the Iridium system. This will be achieved through coordination with Iridium, and placement of the OW-MEO U.S. gateway earth stations such that there is sufficient geographic separation between the gateway stations of Iridium and those of OneWeb. This approach to frequency sharing is very effective due to the narrow satellite beams used by both Iridium and the OW-MEO component for their gateway links. Such a frequency sharing scheme likely avoids the need for the parties to exchange detailed operational information (such as orbit ephemeris data), based solely on the interference isolation achieved by geographically separating their gateway earth stations.

Similarly, OneWeb has engaged with both Telesat and Space Norway to coordinate its LEO component under the ITU rules and will extend this effort to include its MEO component.

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

OneWeb is not aware of any Federal NGSO satellite systems operating, or planning to operate, in the V-band or E-band frequency ranges proposed to be used by the OW-MEO component. Nevertheless, OneWeb will coordinate, as necessary, with NTIA to ensure compatible operation of the OW-MEO component with any such Federal systems.

A.8.3 Interference with Respect to Terrestrial Networks

The sub-sections below address the frequency sharing and interference issues with respect to each frequency range and category of other services that are allocated the same spectrum in the U.S.

Note that the sharing issues discussed below pertain only to the potential interference to or from the OW-MEO earth stations located in the U.S. There will be no unacceptable interference from the OW-MEO satellite downlink transmissions into the terrestrial services that may share these bands because the OW-MEO downlink transmissions comply with all relevant PFD limits at the surface of the Earth, as demonstrated in Section A.7 above.

<u>10.7-11.7 GHz Band</u>

This band is proposed to be used by the OW-MEO component for downlinks to user terminals.

The only part of the Ku-band downlink spectrum to be used by the OW-MEO component that is shared with terrestrial fixed services in the U.S. is the 10.7-11.7 GHz band. In this band, which is shared on a co-primary basis between the FSS and FS, the Commission has now permitted blanket licensing of ubiquitous receiving earth stations on an unprotected basis.[31]

Regarding OneWeb's operations in this frequency band:

(a) The satellite downlink transmissions in the 10.7-11.7 GHz band will comply with the existing Commission PFD limits as demonstrated in Section A.7 above. These PFD limits are intended to protect the FS from interference from the satellite downlinks, and the Commission has determined that such limits are sufficient for this purpose.[32]

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[31] *NGSO R&O* at ¶ 25.

[32] *See generally NGSO R&O*.

(b) The receiving earth stations will not seek any interference protection from the FS and so their operation will not constrain the further development of the FS in this band.

<u>12.2-12.7 GHz Band</u>

This band is proposed to be used by the OW-MEO component for downlinks to user terminals, which would be operated on a non-interference basis.

There are currently 46 grandfathered FS links in the 12.2-12.7 GHz band that have legacy licenses under old Commission allocations. No new FS links will be authorized by the Commission in this band. OneWeb will accept any interference from these 46 legacy FS links. As in the 10.7-11.7 GHz band discussed above, the OW-MEO downlink transmissions in the 12.2-12.7 GHz band will comply with the ITU PFD limits as demonstrated in Section A.7. These PFD limits are intended to protect the FS from interference from the satellite downlinks and so will ensure there is no downlink interference into these 46 legacy FS links.

The Commission has authorized the Multichannel Video Distribution and Data Service (MVDDS) in the 12.2-12.7 GHz band, and this was auctioned by the Commission in 2006. The Commission established technical and service rules for MVDDS in the 12 GHz band in the *Second Report and Order*, which specifically states that the MVDDS providers will share the 12 GHz band with new NGSO FSS operators on a co-primary basis.[33]

To account for the particular interference mechanisms between MVDDS and NGSO systems, the Commission adopted the following operating requirements for each system[34]:

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33 *See In the Matter of Amendment of Parts 2 and 25 of the Commission's Rules to Permit Operation of NGSO FSS Systems Co-Frequency with GSO and Terrestrial Systems in the Ku-Band Frequency Range; Amendment of the Commission's Rules to Authorize Subsidiary Terrestrial Use of the 12.2-12.7 GHz Band by Direct Broadcast Satellite Licensees and Their Affiliates; and Applications of Broadwave USA, PDC Broadband Corporation, and Satellite Receivers, Ltd. to Provide A Fixed Service in the 12.2-12.7 GHz Band*, Memorandum Opinion & Order and Second Report & Order, 17 FCC Rcd 9614, 9617 ¶ 3 (2002) ("*Second Report and Order*").

34 *Second Report and Order* at ¶¶ 112-125.

MVDDS Operating Requirements:

(i) PFD at a distance: To promote MVDDS and NGSO FSS band sharing, the PFD of an MVDDS transmitting system shall not exceed -135 $dBW/m^2/4$ kHz measured and/or calculated at the surface of the earth at distances greater than 3 km from the MVDDS transmitting site.

(ii) The maximum MVDDS EIRP shall not exceed 14 dBm per 24 MHz, but there is no restriction on the polarization of the MVDDS transmission.

(iii) The MVDDS transmitting antenna may not be installed within 10 km of any pre-existing NGSO FSS receiver unless the affected licensees agree to a closer separation.

NGSO FSS Operating Requirements:

(iv) Later-in-time NGSO FSS receivers must accept any interference resulting from pre-existing MVDDS transmitting antennas.

(v) Low angle PFD limits on NGSO FSS downlinks in 12.2-12.7 GHz band: For elevation angles from 0º to 2º above the horizontal plane, NGSO FSS downlinks must meet a reduced PFD level of -158 $dBW/m^2/4kHz$, and for elevation angles from 2º to 5º degrees above the horizontal plane, a reduced PFD level of $-158 + 3.33 (\delta-2)$ $dBW/m^2/4kHz$, where δ is the elevation angle in degrees.

To allow the sharing mechanisms of (i), (iii) and (iv) above to be implemented, the MVDDS and NGSO FSS operators must maintain and share databases of their respective transmitters and receivers, as required by the MVDDS *Second Report and Order* cited above.[35] OneWeb is committed to this sharing arrangement and will comply with the requirements of the *Second Report and Order* for the OW-MEO component.

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35 *Id*. at ¶ 124.

OneWeb will also comply with the requirements of (v) above concerning the low elevation angle PFD limits in the 12.2-12.7 GHz band, as demonstrated in Section A.7 above.

12.75-13.25 GHz Band

This band is proposed to be used by the OW-MEO component for uplinks from both gateway earth stations and user terminals. This represents an opportunity to exploit available technology to facilitate efficient sharing of spectrum in this band with current and potential future terrestrial users of the band, as explained below.

Both types of uplink service envisaged in this band for the OW-MEO component can be made to share effectively with terrestrial users of the band. The OW-MEO user terminals, although geographically ubiquitous as compared to gateway earth stations, exhibit the key feature of only transmitting at high elevation angles, typically in excess of 60º, thereby providing very large angular discrimination toward any potential victim terrestrial receiver in the band. In addition, the frequencies to be used by any OW-MEO user terminal can be adjusted in real time by the network control center, making it possible to instantaneously select a frequency that will not interfere with any nearby terrestrial receiver. The OW-MEO gateway earth stations, although operating to lower elevation angles (typically down to 25º), have larger antennas and therefore more gain discrimination in the directions toward potential victim terrestrial receivers. Also, there will be only a few OW-MEO gateway earth stations within the U.S., likely located in less populated areas, further reducing the risk of any interference to terrestrial users.

15.43-15.63 GHz Band

This frequency range is allocated according to the ITU and U.S. Tables of Frequency Allocations and associated footnotes to NGSO FSS feeder uplinks for the MSS.[36] The OW-MEO component will use this frequency band for the feeder uplink signals destined for downlink transmissions to

[36] 47 C.F.R. § 2.106, n.US359; Int'l Telecomm. Union, Radio Regulations, Article 5 & n.5.511A.

terminals operating in the MSS, outside (but potentially near) the U.S.[37] OneWeb will operate any gateway transmitting earth stations in the 15.43-15.63 GHz band consistent with ITU-R Recommendation S.1340, as required by footnote 5.511C of the ITU's Table of Frequency Allocations. This will involve limiting the EIRP density transmitted by the OW-MEO gateway earth stations in this band and observing the required coordination distances from aeronautical radionavigation systems as required by this ITU Recommendation. Since there will only be a few such gateways – perhaps as few as four – in the U.S., such coordination will pose no problem.

17.8-18.3 GHz Band

OneWeb proposes to use the 17.8-18.1 GHz portion of this band for uplinks from both gateway earth stations and user terminals in the OW-MEO component. The remainder of the band (18.1-18.3 GHz) is proposed to be used for user terminal downlinks in the OW-MEO component.

The 17.8-18.3 GHz band is allocated on a primary or co-primary basis according to the U.S. Table of Frequency Allocations to FS systems in the U.S. These systems are individually site licensed by the Commission under Parts 74F, 78 and 101 of the Commission's rules.[38]

For the same reasons as explained above in the context of the 12.75-13.25 GHz band, sharing between the proposed OW-MEO gateway and user uplinks in the 17.8-18.1 GHz band should be possible with the existing and planned terrestrial users of this band. Similar geometry considerations apply, and the same method for sharing between services can be implemented. The OW-MEO uplink transmissions can operate without causing any unacceptable interference to the

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37 For example, the frequency range 19.7-20.2 GHz is allocated for MSS downlinks on a primary basis according to the U.S. Table of Frequency Allocations and the ITU Table of Frequency Allocations, but MSS is not included in the Commission's *Ka-band Plan*. At this time, OneWeb is not seeking authority to operate MSS earth stations in the United States. However, such feeder link usage in the United States to serve MSS terminals in oceanic areas outside U.S. territory would be entirely consistent with the ITU Radio Regulations and the Commission's rules.

38 *See* 47 C.F.R. § 2.106.

terrestrial users of this band, based on technical information on terrestrial receivers in this band that is maintained in the Commission's database, to which OneWeb has access.

OneWeb's proposed operations in the 18.1-18.3 GHz band for user terminal downlinks in the OW-MEO component are consistent with the rules adopted in the *NGSO R&O*.[39] The risk of any interference from terrestrial transmitters into the OW-MEO receivers is particularly low in the case of the OW-MEO user terminal links because of the high minimum elevation angle of 60º that is typically used for these links. Nevertheless, in this frequency band OneWeb accepts the risk of potential interference into its receiving user terminals, and will take mitigating action in the event such interference arises.

<u>27.5-28.35 GHz Band</u>

OneWeb proposes to use the 27.5-28.35 GHz band for uplinks from gateway earth stations in the OW-MEO component.

The 27.5-28.35 GHz band is allocated by the Commission's *28 GHz First Report & Order* to the terrestrial LMDS (Local Multipoint Distribution System) service on a primary basis and to the fixed-satellite service on a secondary basis in the U.S.[40] More recently, in addition to extending mobile operating rights to existing LMDS licensees, the Commission adopted licensing and operating rules for deployment of Upper Microwave Flexible Use Service (UMFUS) in this band.[41] LMDS and UMFUS systems are licensed by the Commission on a geographic area basis. As OneWeb uses this frequency band in the Earth-to-space direction for gateway links only with a

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39 *NGSO R&O* at ¶¶ 7-8.

40 *See Rulemaking to Amend Parts 1, 2, 21, and 25 of the Commission's Rules to Redesignate the 27.5-29.5 GHz Frequency Band, to Reallocate the 29.5-30.0 GHz Frequency Band, to Establish Rules and Policies for Local Multipoint Distribution Service and for Fixed Satellite Service*, First Report & Order and Fourth Notice of Proposed Rulemaking, 11 FCC Rcd 19005, 19025, ¶ 45 (1996) ("*28 GHz First Report & Order*").

41 *See In re Use of Spectrum Bands Above 24 GHz for Mobile Radio Services*, Report & Order and Further Notice of Proposed Rulemaking, 31 FCC Rcd 8014 (2016) ("*First Spectrum Frontiers Order*").

minimum uplink elevation of 20°, the only potential interference path from OneWeb is from the sidelobes of the transmitting OneWeb gateway earth station into the LMDS or UMFUS receivers.

In compliance with Sections 2.105(c)(2)(i) and § 25.136(a) of the Commission's rules, uplinks from gateway 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/UMFUS station. OneWeb will put in place procedures to protect such operations in the 27.5-28.35 GHz frequency band. These will involve careful coordination with any operators in the area of existing UMFUS or LMDS stations where gateway earth stations are proposed. OneWeb will also assess the impact of its proposed Earth stations against the criteria contained in §25.136(a)(4) to show that they will not impact future UMFUS deployments. Since there will be few OneWeb gateway sites in the U.S., and considering that the UMFUS deployments are likely only to occur mostly in urban areas due to the severe propagation conditions in this band, it should be relatively easy to locate OneWeb gateways outside the main commercial target areas of the UMFUS proponents.

§ 2.105(c)(2)(ii) requires OneWeb, as a secondary user, to accept incoming interference from a primary user. Transmitting LMDS or UMFUS stations cannot cause harmful interference into the OneWeb receiving earth stations since the earth stations do not receive transmissions in the 27.5-28.35 GHz band. Harmful interference occurring from the aggregation of transmitting UMFUS stations into a receiving spot beam of the OneWeb satellites is considered to be very unlikely, as long as such stations are deployed with the technical characteristics that were proposed by terrestrial operators during the UMFUS proceeding. Nevertheless, issues surrounding the protection of satellites from transmitting UMFUS stations are to be assessed by the Commission based on relevant data demonstrating changes in the amount of aggregate interference as UMFUS services are deployed, to be submitted by the parties in the docket the International Bureau, the Office of Engineering and Technology, and the Wireless Telecommunications Bureau have jointly established regarding aggregate interference in the 28 GHz band.[42]

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[42] *See First Spectrum Frontiers Order* at ¶¶ 61-69; *Docket Established for 28 GHz Aggregate Interference Analysis*, Public Notice, 32 FCC Rcd 5022 (IB 2017).

37.5-42.5 GHz Band

OneWeb proposes to use the entire 37.5-42.5 GHz band for downlinks to both gateway earth stations and user terminals.

From a review of the U.S. Table of Frequency Allocations, supplemented by the *First Spectrum Frontiers Order*, OneWeb concludes that the only portion of this downlink frequency range for which terrestrial service rules have been established and terrestrial services operate on a co-primary basis with FSS in the U.S. is the 37.5-40.0 GHz band. However, the Commission indicated in the *First 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 UMFUS rules.[43] The *Second Spectrum Frontiers Order* does not address possible UMFUS rules in this 500 MHz.[44]

OneWeb will also 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-MEO downlinks (37.5-42.5 GHz).

37.5-40.0 GHz sub-band

OneWeb proposes to operate its receiving user terminals in the 37.5-40.0 GHz band on a non-protected basis. The risk of any interference from terrestrial transmitters, namely the new UMFUS transmitters, into the OW-MEO receivers is particularly low in the case of the OW-MEO user terminal links because of the high minimum elevation angle of 60º that is typically used for these

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[43] *See First Spectrum Frontiers Order* at ¶ 403.

[44] *See In re Use of Spectrum Bands Above 24 GHz for Mobile Radio* Services, Second Report & Order, Second Further Notice of Proposed Rulemaking, Order on Reconsideration, and Memorandum Opinion & Order, 2017 WL 5654766, FCC 17-152 (rel. Nov. 22, 2017) ("*Second Spectrum Frontiers Order*").

links. Nevertheless, in this frequency band OneWeb accepts the risk of potential interference into its receiving user terminals, and will take mitigating action in the event such interference arises.

OneWeb proposes to operate its receiving gateway earth stations in the 37.5-40.0 GHz band on an individual site-licensed basis, coordinated with UMFUS licensees in accordance with § 25.136(c) and (d) of the Commission's rules.[45]

<u>40.0-42.0 GHz sub-band</u>

Regarding the 40.0-42.0 GHz band, the risk of any interference from terrestrial transmitters into the OW-MEO receivers is negligible since the Commission declined to propose mobile use and reserved the 40-42 GHz band for FSS.[46]

OneWeb proposes to operate its receiving gateway earth stations in the 37.5-40.0 GHz band on an individual site-licensed basis.

<u>42.0-42.5 GHz sub-band</u>

In the underlying Petition, OneWeb requested a waiver of the U.S. Table of Frequency Allocations to permit it to operate downlinks to both gateway earth stations and user terminals in the 42.0-42.5 GHz band. If such a waiver is granted, the OW-MEO component may need to share spectrum with fixed and mobile service operations that may be authorized by the Commission in the future in this band. To facilitate this, the OW-MEO component will operate its user terminals that receive downlink transmissions in this band on a non-protected basis, relative to potential interference from future fixed and mobile services. The risk of any interference from terrestrial transmitters into the OW-MEO receivers is particularly low in the case of the OW-MEO user terminal links because of the high minimum elevation angle of 60º that is typically used for these links.

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45 47 C.F.R. § 25.136(c), (d).

46 *See Second Spectrum Frontiers Order* at ¶¶ 190-192.

Nevertheless, in this frequency band OneWeb accepts the risk of potential interference into its receiving user terminals, and will take mitigating action in the event such interference arises.

OneWeb proposes to operate its receiving gateway earth stations in the 42.0-42.5 GHz band on an individual site-licensed basis.

42.5-43.5 GHz Band

OneWeb proposes to use the 42.5-43.5 GHz band for uplinks from gateway earth stations in the OW-MEO component.

OneWeb will coordinate, as necessary, with NTIA to ensure compatibility of its uplink transmissions in this band with any Federal government terrestrial services that might be operating co-frequency.

The Commission has indicated in the *First Spectrum Frontiers Order* that it is considering, by means of an NPRM, the possibility of establishing service rules for the fixed service to operate in the 42.5-43.5 GHz band.[47] In its Petition, OneWeb requested 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-MEO gateway earth stations in this band, and believes methods can be found for these to coexist with future terrestrial services. For these OW-MEO earth stations, the sharing mechanism would be based on the principle of the OW-MEO earth station being individually licensed and thereby assured of being able to operate long-term at the stated geographic location. Very few OW-MEO gateway earth stations would be required within U.S. territory, so this traditional coordination approach would create little or no burden for future terrestrial operators in this band.

[47] *See First Spectrum Frontiers Order* at ¶ 404.

47.2-50.2 GHz Band

OneWeb proposes to use the 47.2-50.2 GHz band for uplinks from both gateway earth stations and user terminals in the OW-MEO component. OneWeb believes methods can be found for these to coexist with future terrestrial services.

The Commission discussed in the *First 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.[48] The Commission concluded in its *Second Spectrum Frontiers Order* that to retain the broad flexibility of satellite systems in the band 48.2-50.2 GHz, it would decline to authorize fixed and mobile services in this band.[49] As for the lower 1 GHz of spectrum in the adjacent 47.2-48.2 GHz band, the Commission did adopt an UMFUS designation,[50] but nevertheless allows the deployment of individually-licensed Earth stations, which "can share the band with minimal impact on terrestrial operations."[51]

For the OW-MEO gateway earth stations, the sharing mechanism would be based on the principle of the OW-MEO earth station being individually licensed and thereby assured of being able to operate long-term at the stated geographic location.

For the OW-MEO user terminals, the risk of any potential interference from transmitting OW-MEO user terminals into the terrestrial receivers is particularly low in the case of the OW-MEO user terminal links because of the high minimum elevation angle of 60º that is typically used for these links.

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48 *See First Spectrum Frontiers Order* at ¶¶ 410-417.

49 *See Second Spectrum Frontiers Order* at ¶¶ 185-189.

50 *Id*. at ¶ 47.

51 *Id*. at ¶ 54.

50.4-51.4 GHz Band

OneWeb proposes to use the 50.4-51.4 GHz band for uplinks from both gateway earth stations and user terminals in the OW-MEO component. OneWeb believes methods can be found for these to coexist with future terrestrial services.

The Commission discussed in the *First 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.[52]

For the OW-MEO gateway earth stations, the sharing mechanism would be based on the principle of the OW-MEO earth station being individually licensed and thereby assured of being able to operate long-term at the stated geographic location.

The risk of any potential interference from transmitting OW-MEO user terminals into the terrestrial receivers is particularly low in the case of the OW-MEO user terminal links because of the high minimum elevation angle of 60º that is typically used for these links.

71.0-76.0 GHz Band

The proposed use for gateway downlink transmissions in the 71-76 GHz band by the OW-MEO component is consistent with the U.S. Table of Frequency Allocations. Although the Commission reports there to be 22,600 registered fixed links in the 71-76 GHz and 81-86 GHz bands, these links are concentrated in a limited number of metropolitan areas, as shown in Figure A.8.3-1 below.[53]

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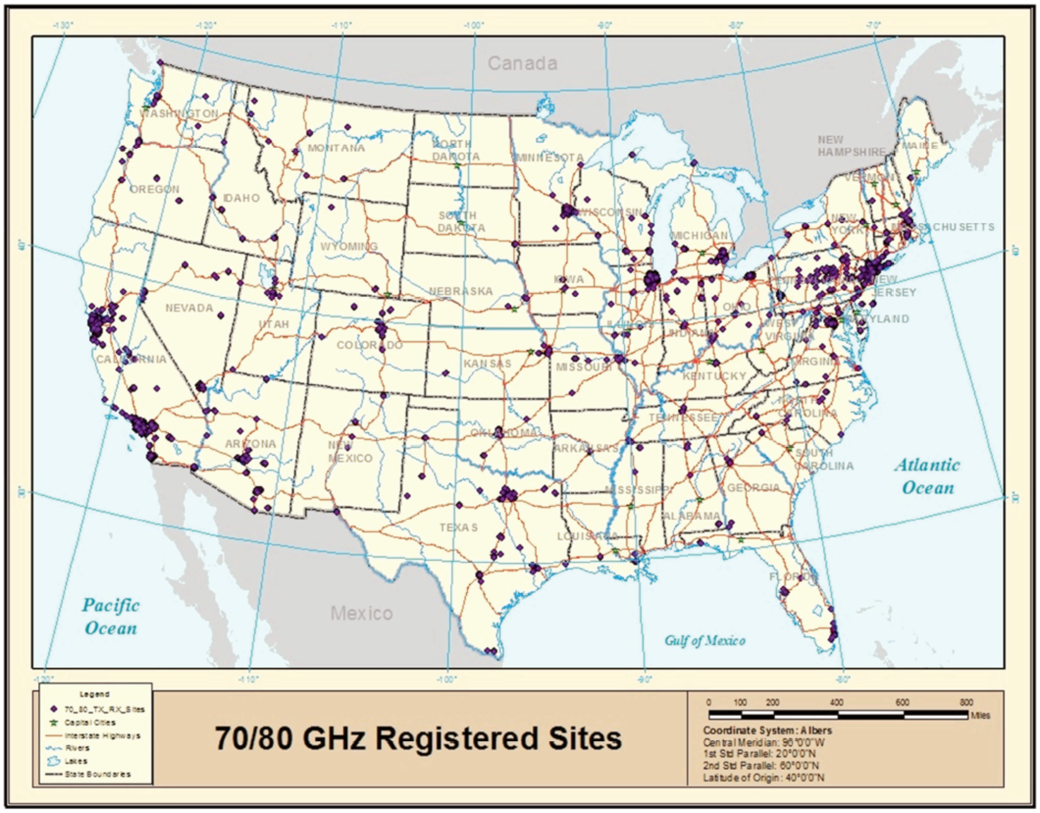
[52] *See First Spectrum Frontiers Order* at ¶¶ 420-423.

[53] *Id*. at ¶ 432, fig. 3.

Figure A.8.3-1: Registered fixed links in the 71-76 GHz and 81-86 GHz frequency bands



The OW-MEO receiving earth stations would be individually site licensed and would be benign users of the spectrum, given their likely geographic location in remote areas. Coordination of these gateway earth stations should be straightforward.

The proposed OW-MEO usage of the 71-76 GHz band for gateway uplink transmissions is not consistent with either the U.S. or ITU Tables of Frequency Allocations, which designate this band for use in the downlink (space-to-Earth) direction. Nevertheless, such reverse-band operation is technically feasible, would not significantly impact any other user of the spectrum, and would provide invaluable flexibility to the OW-MEO component.[54] Any uplink transmissions in this band

54 OneWeb will manage the potential earth station-to-earth station interference in the 71-76 GHz band by ensuring that any gateway earth station does not simultaneously transmit and receive in the 71-76 GHz band. OneWeb will also ensure there is sufficient geographic separation between gateway earth stations that are simultaneously

should also be straightforward to coordinate with terrestrial users of the band. An earth station in the 71-76 GHz band that is transmitting at a relatively high elevation angle (typically greater than 25º) would present no greater an interference source to other terrestrial users than a terrestrial transmitter and would be coordinated in the same way, on an individual site-licensed basis. Again, the small number of such gateway earth stations in the U.S. makes this non-conforming usage of the band an efficient and pragmatic way of using the spectrum.

Potential impact on other satellite users of the 71-76 GHz band, whether they are GSO or NGSO satellites, will be minimal given the small number of such OW-MEO gateway earth stations that would exist in the U.S. The transmitting OW-MEO gateway earth station would appear to an FSS receiving earth station as just another potential terrestrial user of the band, with which coordination will be required. In other words, the presence of a small number of transmitting OW-MEO gateway earth stations in the 71-76 GHz band does not materially affect the interference and coordination environment in which other FSS users would need to operate.[55]

<u>81.0-86.0 GHz Band</u>

The OW-MEO component would operate gateway uplinks only in the 81-86 GHz band, with the few U.S. gateway earth station sites likely being in geographically remote areas. These gateway earth stations would be site-licensed and coordination with the other users of the spectrum is expected to be straightforward. As this band is currently almost unutilized, such uplinks could be easily sited in the U.S.

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transmitting and receiving in this band to avoid any potential interference between them. Similarly, the potential satellite-to-satellite interference will be managed by not uplinking and downlinking simultaneously to the same satellite in overlapping frequency ranges within the 71-76 GHz band. In addition, the potential for interference between any two OW-MEO satellites, one receiving and one transmitting simultaneously in this band, will be managed by careful design of the OW-MEO satellites and the operational procedures that determine which frequency plan each satellite is operating under (either receiving or transmitting in the 71-76 GHz band).

[55] The Commission has also noted that it would "maintain multiple services in the allocation table and address possible sharing criteria [for the 71-76 GHz and 81-86 GHz bands] in the future." *See In the Matter of Allocations and Service Rules for the 71-76 GHz, 81-86 GHz and 92-95 GHz Bands; Loea Communications Corporation Petition for Rulemaking*, Report and Order, 18 FCC Rcd 23318 ¶ 62 (2003).

A.8.4 Interference with Respect to TDRSS Receiving Ground Stations in the 14.0-14.2 GHz Band

OneWeb will coordinate with NASA concerning the protection of the designated TDRSS receiving ground stations in the U.S. from transmissions of the OW-MEO user terminals operating in the 14.0-14.2 GHz band, consistent with § 25.226(c) and § 25.227(c).

A.8.5 Interference with Respect to the Radio Astronomy Service

Several footnotes to the U.S. Table of Frequency Allocations address the need for satellite downlink transmissions to adequately protect the Radio Astronomy Service ("RAS") at specific sites in the U.S. These are addressed below.

Footnote US131 directly addresses NGSO systems operating in the 10.7-11.7 GHz band and the need to coordinate with and protect the RAS observatories listed in this footnote, which operate in the 10.6-10.7 GHz band. OneWeb has started the process of coordinating with the RAS community regarding its LEO component and will also pursue this coordination regarding the OW-MEO component to ensure all necessary coordination is completed.

Footnote US211 addresses the more general matter of taking all practical steps to protect RAS observatories in the U.S. that operate in the RAS frequency ranges listed in this footnote. This footnote also makes reference to footnote US74 regarding the extent of the protection needed. Footnote US74 makes further reference to footnote US385, which lists the geographic locations at which such RAS observations are performed. OneWeb will take these footnotes into account in determining the specifications of its satellite transmitters and, as necessary, its operations with respect to these specific geographic locations.

OneWeb will also coordinate with the National Science Foundation regarding transmissions from its user terminal earth stations in the 14.47-14.5 GHz band, consistent with §25.226(d) and §25.227(d) of the Commission's rules.

There are also important RAS allocations in and near the V-band and E-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 continue to coordinate with the National Science Foundation (NSF) to ensure all U.S. RAS sites are adequately protected from interference.

In the V-band, 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-MEO component. OneWeb will therefore design the satellite transmitters of the OW-MEO component 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-MEO 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.

The various uplinks of the OW-MEO component 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-MEO transmitting gateway earth stations located in U.S. territory, and the locations of these would be coordinated with NSF to ensure they will no cause harmful interference to the RAS. The OW-MEO 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 other than the 42.5-43.5 GHz band that might be impacted by the OW-MEO component.

There are also RAS frequency ranges in the E-band, starting at the top end of the 71.0-76.0 GHz FSS allocation and continuing up to overlap entirely the 81.0-86.0 GHz FSS allocation and beyond. OneWeb will coordinate with the RAS community to ensure these allocations are properly protected from interference.

A.9 ITU FILINGS FOR THE OW-MEO COMPONENT

The OW-MEO component will operate under ITU filings submitted by the United Kingdom and French administrations.

A.10 ORBITAL DEBRIS (§25.114(d)(14))

This matter is addressed in the Legal Narrative for this Amendment.

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

The associated Schedule S information for the OW-MEO component was prepared using the Commission's new online Schedule S software.[56] The data provided in the Schedule S is consistent with the latest available Commission instructions.[57]

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

1. Orbit adjustments of the OW-MEO 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.

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56 Schedule S software is available at https://enterpriseefiling.fcc.gov/schedules/.

57 *See* Schedule S Instructions.

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. 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.

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

5. The Schedule S software requires an entry in the Saturation Flux Density field, which may not be appropriate for the OneWeb system design, so this has been populated with values of -110 and -100 for minimum and maximum saturation flux density, respectively. This data should be ignored.

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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