ONEWEB NON-GEOSTATIONARY SATELLITE SYSTEM
V-BAND AND E-BAND COMPONENT
PHASE 2: MODIFICATION TO AUTHORIZED SYSTEM

TECHNICAL ATTACHMENT B
Technical Information to Supplement Schedule S

B.1 SCOPE AND PURPOSE

In March 2017, OneWeb filed a petition for declaratory ruling seeking a Federal Communications Commission ("Commission" or "FCC") grant of market access to provide service in the United States with the OneWeb V-band non-geostationary satellite orbit ("NGSO") system ("OW-V").[1] The OW-V system consisted of two sub-constellations—a 720-satellite Low Earth Orbit ("LEO") component and a 1,280-satellite Medium Earth Orbit ("MEO") component—operating across the same range of V-band frequencies.[2] In August 2020, the Commission granted OneWeb's petition.[3]

OneWeb now seeks to both: (a) modify its existing authorization for the OW-V system (Phase 1) and (b) request market access for a future Phase 2 V-band system. This Attachment B addresses

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[1] *See WorldVu Satellites Limited, Petition for a Declaratory Ruling Granting Access to the U.S. Market for the OneWeb V-Band System*, IBFS File No. SAT-LOI-20170301-00031 (filed Mar. 1, 2017) ("V-Band Market Access Petition").

[2] The term "V-band" is used throughout this document to refer to the FSS allocations between 37.5 and 51.4 GHz.

[3] *WorldVu Satellites Limited, Debtor-in-Possession, Petition for Declaratory Ruling Granting Access to the U.S. Market for the OneWeb V-Band System*, Order and Declaratory Ruling, 35 FCC Rcd 10150 (2020) ("V-Band Market Access Grant").

the Phase 2 component of the OW-V system only. Phase 1 of the OW-V system is addressed in detail in Attachment A. Phase 2 of the OW-V system includes more satellites, a different channelization scheme, adjustment of some satellite performance parameters, and additional V- and E-band frequency ranges compared to Phase 1 of the OW-V system.

This Attachment contains the information required by §§25.114, 25.117(d), and other sections of the FCC's Part 25 rules that cannot be captured by the Schedule S software. It details the proposed Phase 2 deployment of the OW-V system, which will build on the Phase 1 configuration to compromise of a total of 6,372 satellites. Phase 2 of the OW-V system will allow OneWeb to greatly increase the capacity offered to its customers by launching additional satellites in the 1,200 km orbital shell.

The Schedule S associated with this application also includes data related to the Phase 1 implementation of the OW-V system, which is described in Attachment A. Certain data in the Schedule S is common to both Phase 1 and Phase 2, while other data is unique to Phase 1 or Phase 2. This is addressed in detail in Section B.10 below.

B.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 Phase 2 OW-V system consists of a constellation of 6,372 LEO satellites, plus in-orbit spares, in a combination of three circular orbit types of altitude around 1,200 km, as well as associated ground control facilities, gateway earth stations, and end user earth stations ("user terminals"). The orbital configuration for the Phase 2 OW-V system is identical to that of the Phase 2 modified

Ku/Ka band OneWeb system,[4] and the Phase 2 OW-V satellite payloads will be hosted on future generation OneWeb satellites. Table B.2-1 below shows the proposed orbital configuration of the Phase 2 OW-V system which consists of a number of planes of 87.9° inclined satellites combined with planes of satellites operating in 40° and 55° inclined orbits.

Table B.2-1: Orbital Characteristics of the OW-V Phase 2 non-GSO satellite system

Max. Number of Planes	Max. Number of satellites per plane	Inclination	Maximum total for orbit shell
36	49	87.9°	1764
32	72	40°	2304
32	72	55°	2304

The OW-V Phase 2 system complements the core OneWeb Ku/Ka band mission as well as the Phase 1 OW-V system by providing additional capacity worldwide. The V-band service will use steerable spacecraft antennas to "point-and-shoot" towards user terminals located in high traffic areas, as well as for additional gateway capacity. The additional V- and E-band gateway links will further increase the capacity of the system. The service will be 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, low-latency broadband Internet access that is to be offered by the OneWeb Ku/Ka band system and the Phase 1 OW-V system and to similarly sized user terminals and gateway earth

[4] *See Modification Application of WorldVu Satellites Limited*, IBFS File No. SAT-MPL-20200526-00062, Call Sign S2963 (filed May 26, 2020) *as amended by Amendment to Modification Application for U.S. Market Access Grant for the OneWeb Ku- and Ka-Band System*, IBFS File No. SAT-APL-20210112-00007, Call Sign S2963 (filed Jan. 12, 2021).

stations. The user terminal service provided will be comparable to the broadband terrestrial services available in densely populated areas of developed countries today.

The Phase 2 OW-V system uses V-band frequencies 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. In addition, it uses E-band for additional gateway link capacity.

The Phase 2 OW-V user terminals consist of small, inexpensive antennas (typically in the 20 cm to 75 cm range) and will include fixed and transportable ground-based terminals as well as mobile terminals on board aircraft, maritime vessels, and land vehicles. Larger user terminals may also be employed in some situations, such as for enterprise applications with different service requirements. The Phase 2 user terminals will use low-cost phased array designs, or other beam steering technologies which are already under development. User terminals will be able to be operated totally off-grid using an optional built-in solar array panel and battery for power supply to enable truly ubiquitous service, regardless of terrestrial infrastructure. The user terminals will therefore be quick and easy to deploy and can easily be used for transportable applications.

The V- and E-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. Each satellite will be equipped with three gateway antennas in V-band which will allow continuous gateway communications with two servicing gateway sites, with the third gateway antenna being used for handovers. There will be two E-band gateway antennas on each satellite to enable continuous E-band gateway service to one gateway site at a time, with the second gateway antenna being used for handover purposes. The satellite antennas used to communicate with user terminals will generate up to 32 separate steerable spot beams from each Phase 2 OW-V satellite.

The frequency ranges used by the Phase 2 OW-V system are summarized in Table B.2-2 below. The detailed channelized frequency plan is given in the associated Schedule S. The V-band user link spectrum is spatially re-used up to ten times in each Phase 2 OW-V satellite. Four times frequency re-use of the V-band gateway spectrum is achieved by the use of dual orthogonal polarizations on these gateway links and spatial re-use between the two simultaneously active gateway beams. The E-band gateway spectrum is reused once using polarization diversity. V-band spectrum that is used for both gateway and user links is also re-used between these gateway and user links by spatial separation of the respective gateway and user beams.

Table B.2-2: Frequency bands used by the Phase 2 OW-V non-GSO satellite system

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 81.0 – 86.0 GHz
Satellite-to-Gateway	37.5 – 42.0 GHz 71.0 – 76.0 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 B.2-3 below.

Table B.2-3: Frequency re-use of the V-band spectrum by the Phase 2 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 (32 beams with 10-fold spatial re-use)
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 (32 beams with 10-fold spatial re-use)
50.4 – 51.4 GHz (1.0 GHz)	Gateway-to-Satellite (dual polarization)
71.0 – 76.0 GHz (5 GHz)	Satellite-to-Gateway (dual polarization)
81.0 – 86.0 GHz (5 GHz)	Gateway-to-Satellite (dual polarization)

The Phase 2 OW-V system provides broadband communications services between the user terminals and the gateway earth stations located on the global fiber network. Typically, between 10 and 20 OW-V gateway earth station antennas will be collocated at a gateway site in order to access a number of visible Phase 2 OW-V satellites simultaneously from that location. These gateway sites will include those used for the Phase 1 OW-V system, augmented by additional gateway antennas at each site as required.[5] The Phase 2 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 number and locations of the gateway earth stations have yet to be determined.

As the OW-V satellites (both Phase 1 and Phase 2) will be shared between Ku/Ka-, V-, and E-band payloads, the TT&C functions will be performed as part of the core OneWeb system using Ka-band frequencies.

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[5] OneWeb is either licensed for or has applications pending for five gateway earth stations in Ka-band frequencies in the United States. OneWeb plans to seek authority for at least one additional gateway earth station in the United States.

The Phase 2 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 is implemented using terrestrial leased circuits and secure Internet virtual private networks.

Each Phase 2 OW-V satellite will have up to 32 identical circular *user* beams, generated by a mechanically fixed flat-plate phased-array satellite antenna, with each beam 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. This user service area will correspond to a range of Earth locations where the elevation angle is generally greater than 45°, although there may be circumstances where the minimum elevation angle reduces to 25°, which is considered to be the minimum operational elevation angle.

By using the full user beam bandwidth (2 GHz in each direction) each Phase 2 OW-V satellite can provide up to 2 GHz of user bandwidth to a single Earth location. This can be augmented further by using additional visible Phase 2 OW-V satellites to serve that same location.

The Phase 2 OW-V satellites will use on-board processing techniques to allow flexible channelization and hence varying amounts of capacity to each of the 32 user beams.[6] This also provides for full flexibility to interconnect any of the uplink channels to any of the downlink channels, in both forward and return transmission directions.

The Phase 2 OW-V satellites have three identical V-band *gateway* antennas, allowing simultaneous gateway links to operate to two visible gateway earth stations. In E-band there will be two identical satellite gateway antennas for service to a single E-band gateway site at a time.

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[6] Schedule S is not capable of representing this channelization flexibility. For simplicity, the channelization for the user beams in the Schedule S shows fixed channelization with 500 MHz bandwidth channels.

The third V-band gateway antenna, and second E-band gateway antenna, are used for handover purposes as the satellites move in their orbit and transition to different visible gateway earth stations. Dual polarization is used for the gateway links to allow for 20 channels in the forward direction (gateway-to-satellite), each of nominal 500 MHz bandwidth, both in V-band and E-band. In the reverse direction (satellite-to-gateway) there will be 18 channels in V- and 20 in E-band. Spatial frequency re-use will also be used between the two geographically separated V-band gateways that are communicating with each Phase 2 OW-V satellite.

The satellite gateway antennas of the Phase 2 OW-V system can be pointed to any part of the visible Earth but will operate at elevation angles greater than 15° in most cases. In some very limited cases gateway service is needed to a point on the Earth that is at a lower elevation angle than 15°, for instance when satellites fly over oceans and need to reach far-away land areas.

As mentioned above, the Phase 2 OW-V system uses multiple steerable user beams within the designated service areas for each satellite. As the Phase 2 OW-V satellites move in their orbits the electronically steerable user beams will continually be pointed towards the designated service points. As each satellite moves beyond the reach of each service point, handover will occur to the next satellite so there is no service interruption to the users. The Phase 2 OW-V satellite phased array antenna will implement additional beams during the instant of handover of each user beam. Similarly, handover of the two Phase 2 OW-V satellite gateway links from one gateway earth station to another will also occur as the satellites move in their orbits using the additional satellite gateway antenna.

For each Phase 2 OW-V satellite full frequency re-use will occur between the user beams and the gateway beams in V-band. This necessitates ensuring spatial separation between the V-band gateway beams and any of the user beams on each Phase 2 OW-V satellite. This will be achieved by the following techniques:

(1) The user beams will generally operate above an elevation angle of 45°. Therefore, any V-band gateway beam operating at lower elevation angles will have sufficient isolation to permit spatial re-use of the user beam frequencies; and

(2) V-band 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 Phase 2 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.

Based on the frequency re-use schemes described above, the requirements of §25.210(f) are more than met when applied to the V- and E-band frequencies.

The transmission schemes in the Phase 2 OW-V system are similar to the core OneWeb System, as far as the Earth-to-space and space-to-Earth links are concerned, except for the use of wider bandwidth carriers and channels in the Phase 2 OW-V system. In addition, the use of on-board processing techniques permits more flexible channel-to-beam allocation. 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 channels 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.

OneWeb will continue to operate at least two separate satellite control centers each backing up the other. These will be used to control the satellites on which the Phase 2 OW-V payloads will operate. The centers, along with network operation centers, are located in Tysons Corner, Virginia and London, UK. Connectivity between these control centers and the TT&C and gateway earth stations is implemented using terrestrial leased circuits and secure Internet virtual private networks.

B.3 Predicted Space Station Antenna Gain Contours (§25.114(c)(4)(vi)(B))

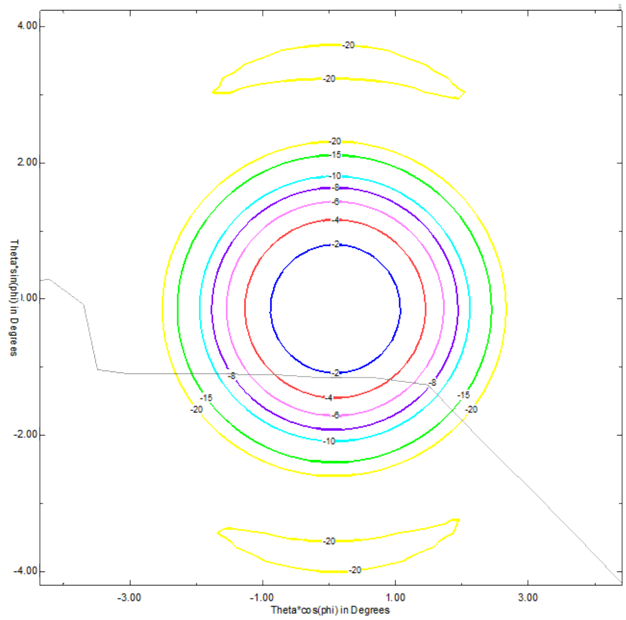
Data for the satellite antenna gain contours are embedded in the associated Schedule S submission. The Schedule S data is provided in the form of GXT files of the required contours plotted with the beam peak pointed to nadir, as required by §25.114(c)(4)(vi)(B). The satellite beams used in the Phase 2 OW-V system are the same for all satellites in the constellation, regardless of orbital plane.

For the links between the Phase 2 OW-V satellites and the users, the satellite beams are generated by satellite phased array antennas and, although they are nominally circular, the beam distorts as the scan angle increases as shown below. The satellite user beams can also be adjusted in terms of their size, and hence gain, over a range of values. To account for this adjustability in gain, the Schedule S includes both maximum and minimum gain values for these user beams.

Figure B.3-1 below provides examples of the beam contours for the user beam transmit antennas for the highest gain user beam, in order to illustrate the effect of the beam distortion as the beam is steered away from nadir. 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 25° elevation contour). The beams are plotted in satellite-centered angles relative to nadir. Figure B.3-2 below provides the same information for the user beam receive antennas.

Figure B.3-1: User beam transmit antenna gain contours

(a) Beam pointed to nadir



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

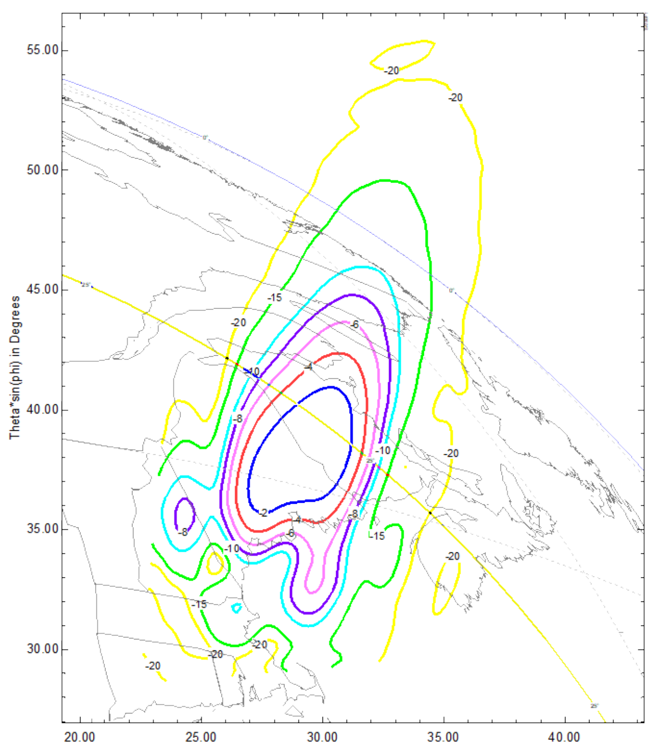
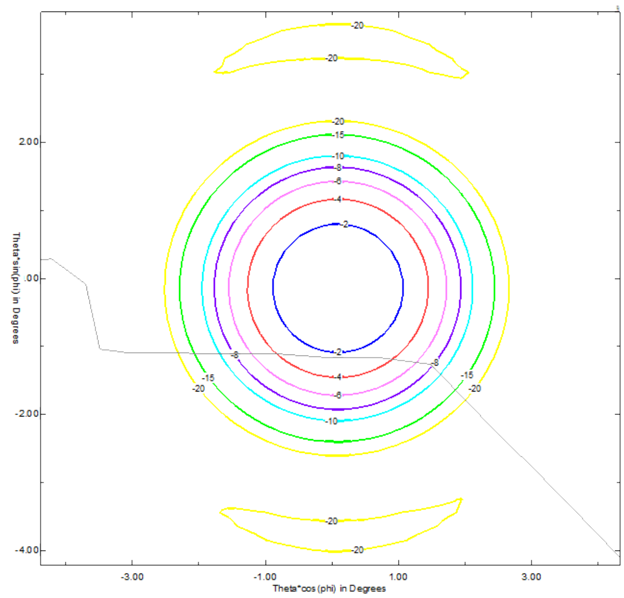
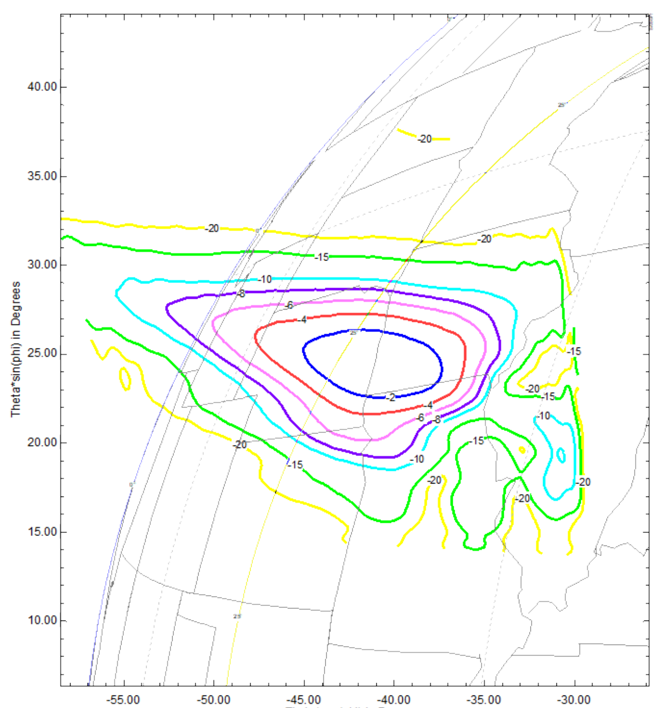


Figure B.3-2: User beam receive antenna gain contours

(a) Beam pointed to nadir



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



B.4 TT&C AND PAYLOAD CONTROL CHARACTERISTICS (§25.202(G))

The Phase 2 OW-V satellites will not have TT&C or payload control functions operating in the V-band or E-band frequencies that are the subject of this modification request. The TT&C and payload control functions will be performed in the Ka-band frequency ranges already authorized. Therefore, no additional information is required in this application concerning the TT&C or payload control for the Phase 2 OW-V system.

B.5 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.

B.6 COMPLIANCE WITH PFD LIMITS (§25.208)

There are ITU Power Flux Density ("PFD") limits in all parts of the V-band downlink frequency bands proposed to be used by the Phase 2 OW-V system, which is 37.5-42.0 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 this downlink band. However, the FCC PFD limits are not consistent in all cases with the ITU PFD limits. Both ITU and FCC PFD limits across the 37.5-42.0 GHz band are summarized in Table B.6-1 below.

Table B.6-1: ITU and FCC Power Flux Density Limits in the 37.5-42.0 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

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.

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.

There are no PFD limits, either in the ITU Radio Regulations or the FCC rules, for the E-band downlink frequency ranges proposed for the Phase 2 OW-V system. The actual maximum PFD levels are, however, given in the associated Schedule S.

For V-band, the predicted worst-case PFD levels from the Phase 2 OW-V system in the relevant portions of the 37.5-42.0 GHz downlink band are shown in Figures B.6-1 and B.6-2, respectively, for the user beams and the gateway beams. This analysis assumes the maximum EIRP density levels (given in the associated Schedule S) and computes the PFD based on the spreading loss to the point on the Earth corresponding to the elevation angle. It also factors in the limitation of the minimum elevation angle of the satellite transmit beam (15° for gateway beams and 25° for user beams) and the gain roll-off of the satellite transmit beam for elevation angles below these minima.

Also shown in these diagrams are the various ITU and FCC PFD limits referred to above, with color coding where appropriate to identify the frequency ranges in which they apply. From these diagrams, and noting that the Phase 2 OW-V system uses the 37.5-40.0 GHz band only for gateway links, it is clear that all links of the Phase 2 OW-V system meet all of the ITU and FCC PFD limits.

In practice, downlink power control may be used for the user and gateway downlinks, but the maximum power will correspond to the maximum EIRP density levels stated in the Schedule S. Downlink power control used in this way would therefore have the effect of reducing the PFD levels at the higher elevation angles, providing additional margin compared to the PFD limits at these higher elevation angles compared to those shown below. Also, the downlink power control in the gateway links will be used to further reduce the maximum EIRP density in the rare instances where operation is required at elevation angles below 15°, as explained in Section B.2 above, in order to comply with the PFD limits shown in Figure B.6-2 for elevation angles below 15°.

Figure B.6-1: PFD Levels from the User Downlink Beams of the Phase 2 OW-V System in the 40.0-42.0 GHz Band compared with ITU and FCC PFD Limits

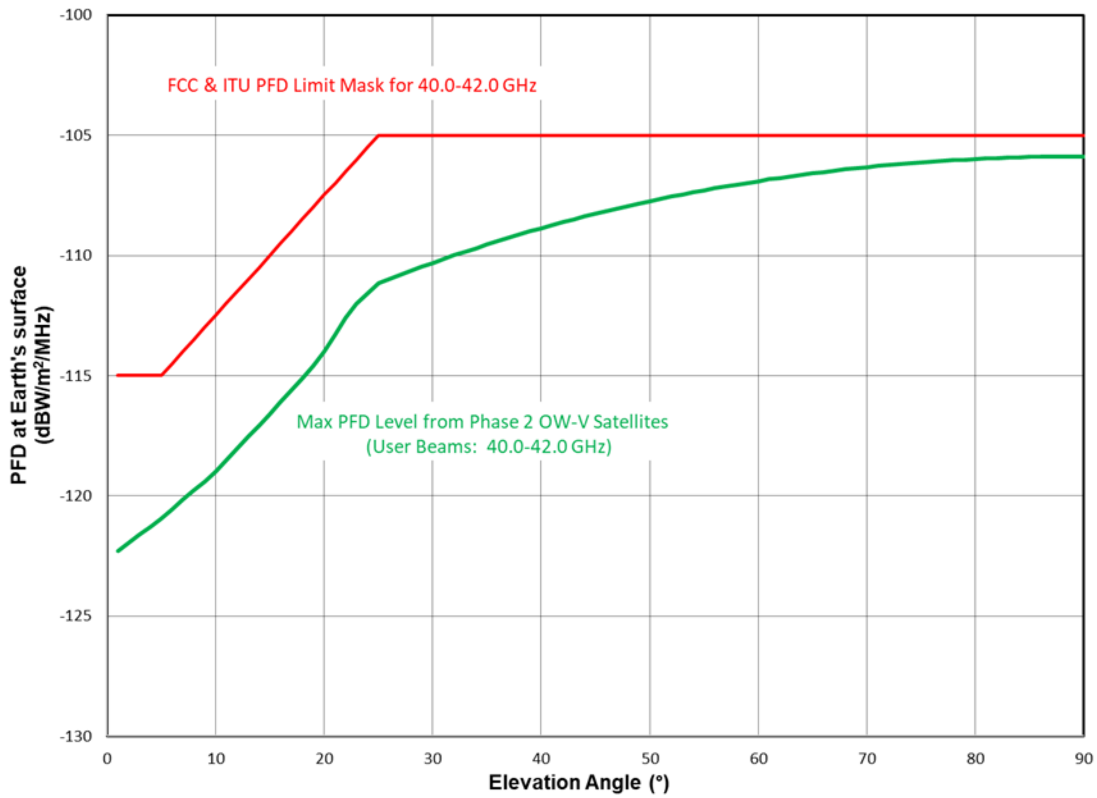
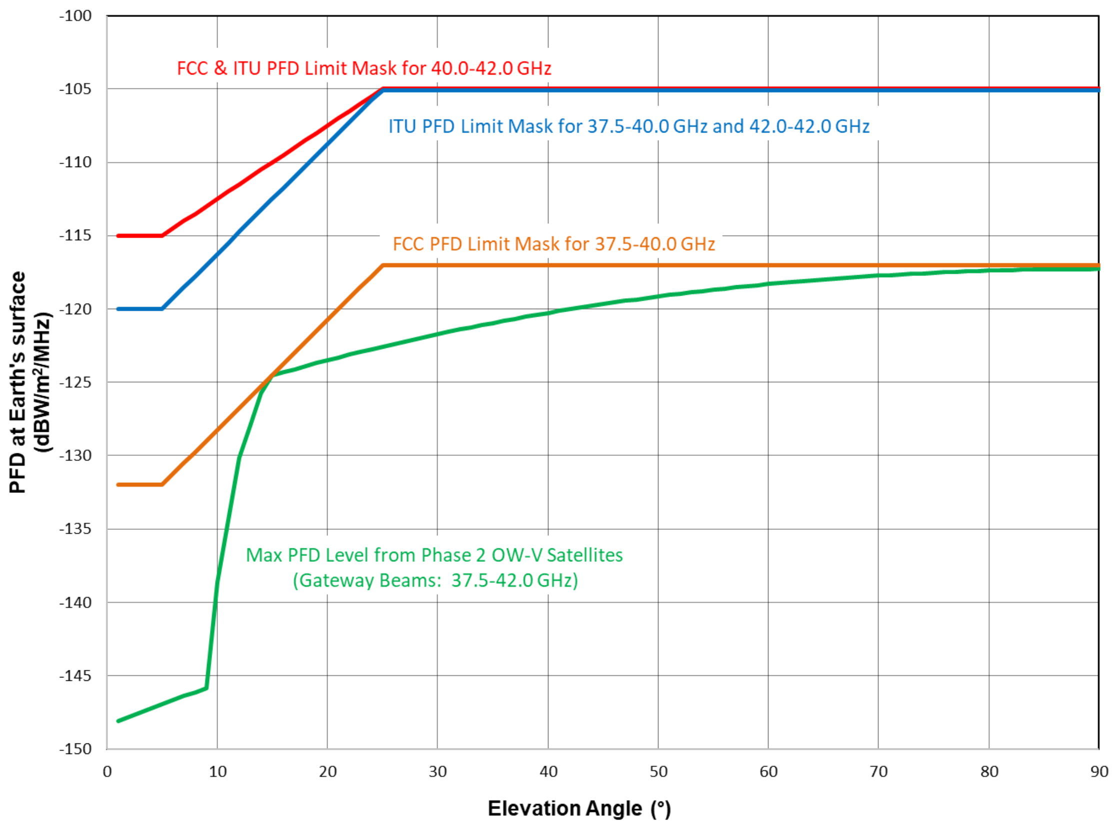


Figure B.6-2: PFD Levels from the Gateway Downlink Beams of the Phase 2 OW-V System in the 37.5-42.0 GHz Band compared with ITU and FCC PFD Limits



B.7 INTERFERENCE ANALYSES AND FREQUENCY SHARING

B.7.1 Sharing with GSO Satellite Networks

In 2018 the FCC adopted §25.289 of its rules essentially paralleling Nos. 22.2 and 22.5I of the ITU Radio Regulations. In addition, the ITU has made progress towards quantifying the protection levels for GSO satellite networks from NGSO systems. WRC-19 added two new provisions to Article 22 of the Radio Regulations which apply to the V-band frequency ranges, namely Nos. 22.5L and 22.5M, which quantify the GSO protection levels. Although the full software and methodology to implement these provisions are not yet available, OneWeb hereby commits to meeting these GSO protection levels so there will be no unacceptable interference to co-frequency

V-band GSO satellite networks from the transmissions in the Phase 2 OW-V system pursuant to Section 25.289 of the Commission's rules.

Currently there are no specific ITU rules relating to the protection of GSO satellite networks in E-band from NGSO E-band satellite systems, other than No. 22.2. OneWeb commits to meeting this requirement, and the FCC §25.289 in E-band.

The V-band GSO protection levels required by Nos. 22.5L and 22.5M will be achieved by ensuring all uplink and downlink transmissions avoid the GSO arc by a minimum GSO avoidance angle necessary to meet these requirements. The same technique will be used in E-band. Note that this GSO arc avoidance technique used to protect GSO satellite networks from interference from the Phase 2 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 for the Phase 2 OW-V user links is straightforward because of the use of overlapping service areas and dynamically steerable beams. This combination of features permits the operation of satellite diversity for these links whenever an inline or near-inline event occurs with respect to the GSO arc. Using this technique, the Phase 2 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 the network control center will instantaneously switch such links to alternate Phase 2 OW-V satellites, thereby maintaining the required GSO avoidance angle.

In the case of the Phase 2 OW-V gateway links (V- and E-band), 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.

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 (45°), there will be no possibility of a GSO alignment situation, so no interference mitigation is required. Even for the gateway links, which has 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.

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 Phase 2 OW-V system.

B.7.2 Sharing with Other NGSO Satellite Systems

Since WRC-19 there are ITU procedures relating to the coordination between NGSO satellite systems operating in the V-band frequencies proposed for the Phase 2 OW-V system, essentially the same as in the lower Ka and Ku bands, based on the principle of filing date priority. In addition, the FCC NGSO FSS processing round procedures place certain coordination requirements on operators prior to permitting a system to provide service into the United States. OneWeb is committed to working cooperatively in the coordination with all other operators of V- and E-band NGSO satellite systems, pursuant to these regulatory procedures, and is confident that the proposed Phase 2 OW-V system design is sufficiently flexible to permit frequency sharing between such systems.

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 Phase 2 OW-V system. Nevertheless, OneWeb will coordinate, as necessary, with NTIA to ensure compatible operation of the Phase 2 OW-V system with any such Federal systems.

B.7.3 Sharing with Terrestrial Networks in the Phase 2 OW-V Downlink Frequency Bands

The Phase 2 OW-V system will comply with all applicable FCC and ITU PFD limits which have been established to protect terrestrial systems from unacceptable interference resulting from the satellite downlink transmissions, as demonstrated in Section 1B.7 above. In addition, OneWeb acknowledges that its gateway operations in the 37.5-40 GHz band will be subject to the siting restrictions in §25.136 of the Commission's rules, with each gateway earth station being individually licensed.

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 the Phase 2 OW-V downlinks (37.5-42.5 GHz).

In the 40-42 GHz band, the FCC rules provide for blanket licensing of user terminals and thus the OneWeb terminals will operate without restrictions vis-à-vis terrestrial services.[7]

OneWeb will ensure that the E-band gateway downlinks of the Phase 2 OW-V system provide the necessary interference protection to co-frequency terrestrial services, although there are no specific PFD limits in place at present in either the ITU or FCC. These Phase 2 OW-V E-band downlinks will not be required to operate at high PFD levels as they are designed to communicate with relatively large gateway earth station antennas. The actual maximum PFD levels are given in the associated Schedule S.

B.7.4 Sharing with Terrestrial Networks in the Phase 2 OW-V Uplink Frequency Bands

The Federal government has various terrestrial communications systems operating in parts of the V-band frequency ranges proposed to be used for Phase 2 OW-V uplinks. OneWeb will therefore coordinate, as necessary, with NTIA to ensure compatibility with all of these Federal services as well as any that may operate in the E-band uplink frequency range of the Phase 2 OW-V system.

OneWeb acknowledges that its gateway operations in 47.2-48.2 GHz and 50.4-51.4 GHz will be subject to the siting restrictions in §25.136 of the Commission's rules, with each gateway earth station being individually licensed. In addition, OneWeb proposes to seek individual earth station licenses for its gateway operations in the 42.5-43.5 GHz band.

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[7] *See Use of Spectrum Bands Above 24 GHz for Mobile Radio Services et. al.,* Second Report and Order, Second Further Notice of Proposed Rulemaking, Order on Reconsideration, and Memorandum Opinion and Order, 32 FCC Rcd 10988 (2017).

In the 48.2-50.2 GHz band, the FCC rules provide for blanket licensing of user terminals and thus the OneWeb terminals will operate without restrictions vis-à-vis terrestrial services.[8]

B.7.5 Protection of the Radio Astronomy Service (RAS) and Earth Exploration Satellite Service

OneWeb acknowledges that since 2017, changes were made to Resolution 750 at WRC-19 regarding protection of the Earth exploration satellite service in 50.2-50.4 GHz from transmitting earth stations in the immediately adjacent frequency bands. OneWeb expects that its gateway earth station licenses will be conditioned on compliance with these revised limits.

There are also 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 US RAS sites are adequately protected from interference.

In the V-band frequency ranges the primary RAS frequency range is 42.5-43.5 GHz. There is a 500 MHz guard band between the closest Phase 2 OW-V downlink channel (up to 42.0 GHz) and the start of this RAS band (42.5 GHz) which will allow for adequate filtering of the satellite downlink signal, without undue burden on the Phase 2 OW-V satellite payload design, in order to protect the RAS. This approach, coupled with the possible implementation of geographic separation between the OneWeb gateway beams and the relevant RAS sites, allows considerable flexibility to meet the RAS requirements.

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 US territory, and the locations of these would be coordinated with the NSF to ensure that they will not cause harmful interference to the RAS.

OneWeb will also coordinate with NSF (and NTIA, as appropriate) regarding any RAS related frequency bands other than the 42.5-43.5 GHz band that might be impacted by the Phase 2 OW-V system.

OneWeb has been involved in coordination discussions with the National Science Foundation ("NSF") acting on behalf of the radio astronomy sites listed in US131 (all of which are facilities of NSF) concerning the protection of these sites in the USA arising from the Ku-band and Ka-band transmissions of the core OneWeb system. OneWeb and NSF have reached agreement on core principles of the coordination and are in the process of finalizing the agreement, which will be signed by NSF and appropriate astronomy facility directors. The coordination discussions also recognize separate work between OneWeb and NSF's NOIRLab, the entity responsible for key optical telescopes in the USA, to work together to assess and limit the impact of optical reflections from the OneWeb on astronomical observations. This coordination activity will be fully taken into account in the design of the Phase 2 OW-V satellites.

B.8 ITU FILINGS FOR THE PHASE 2 OW-V SYSTEM

The Phase 2 OW-V system will operate pursuant to French and U.K. ITU filings.

B.9 ORBITAL DEBRIS (§25.114(D)(14))

This matter is addressed in the Legal Narrative included with this Modification Application.

B.10 ADDITIONAL INFORMATION CONCERNING DATA IN THE ASSOCIATED SCHEDULE S (§25.114(C))

As a single Schedule S is being submitted with this modification request (Phases 1 and 2) the associated Schedule S includes all the data relevant to Phase 2 plus some data relevant to Phase 1 only. A detailed explanation concerning which data in the Schedule S (and the accompanying Excel spreadsheet) is unique to one or the other phases of the OW-V system is given below. Other data in the Schedule S, not mentioned below, are common to both Phase 1 and Phase 2.

- Orbit details embedded in the Schedule S provide a complete orbit constellation definition only for Phase 1 as it is not feasible to enter manually the large number of satellite phase angles required for Phase 2 into the online Schedule S software. The required orbit details for Phase 2 are being provided to the Commission in the form of an Excel spreadsheet (in PDF format) that is attached to this application which is structured in the same way as the Schedule S format for orbit data. Note, however, that the orbit data in the separate spreadsheet includes the satellites whose orbit data is embedded in the Schedule S;

- Certain satellite beams and their associated frequency ranges contained in the Schedule S are associated only with satellites in Phase 2. These frequency ranges and beams exclusive to Phase 2 are as follows:

    - 42.5-43.5 GHz (Beams VGR1 and VGR4);
    - 71.0-76.0 GHz (Beams EGTL and EGTR);
    - 81.0-86.0 GHz (Beams EGRL and EGRR).

- The following beams are exclusive to Phase 2, even though they operate in frequency ranges common to both Phase 1 and Phase 2:

    - Beams LURL, LURR, LUTL and LUTR;
    - Beams UTLH and UTRH.

- The following beams are exclusive to Phase 1, even though they operate in frequency ranges common to both Phase 1 and Phase 2:

    - Beams HUTL and HUTR.

- The following channels, all of 500 MHz bandwidth, are exclusive to Phase 2:

    - GUBA, GUBB, and GUB1 through GUB8;
    - GDB1 through GDB9;
    - EU1 through EU10;
    - ED1 through ED10;
    - UUB1 through UUB4;

- UDB1 through UDB4.

- The following channels, all of 490 MHz bandwidth, are exclusive to Phase 1:
  - GUA1 through GUA8;
  - GDA1 through GDA9;
  - UUA1 through UUA4;
  - UDA1 through UDA5.
- The following channels, all of 40 MHz bandwidth, are exclusive to Phase 1:[9]
  - GDAA and UDA5.

The associated Schedule S information for the OneWeb System was prepared using the FCC's online Schedule S software.[10] The data provided in the Schedule S is consistent with the latest available FCC instructions.[11]

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

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

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[9] The two 40 MHz channels (GDAA and UDA5) are necessary to fill in the small portion of spectrum below 42.0 GHz (41.960-42.000 GHz) which is assigned to OneWeb by the Commission, but which would otherwise have been excluded by the deletion of the previous channel that spanned 41.96-42.45 GHz which has now been deleted from both Phase 1 and Phase 2 of the OW-V system.

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

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

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

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/ *Kimberly M. Baum* .

Kimberly M. Baum
Vice President, Spectrum Engineering and Strategy
WorldVu Satellites Limited

November 4, 2021