TECHNICAL APPENDIX

Application of Kuiper Systems LLC
for Authority to Launch and Operate a
Non-Geostationary Satellite Orbit System
in Ka-band Frequencies

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TECHINCAL APPENDIX

Pursuant to Section 25.114 and other relevant provisions of the Federal Communications Commission's ("FCC" or "Commission") rules,[1] this Technical Appendix provides an overall description of the Kuiper System's facilities, operations, and services. In addition, annexes are attached addressing compatibility with co-frequency terrestrial fixed services ("FS"), geostationary satellite orbit ("GSO") and non-geostationary satellite orbit ("NGSO") fixed-satellite service ("FSS") operations, and clarification of certain Schedule S references.

I. NGSO SYSTEM DESCRIPTION

Amazon's Kuiper System will provide high-speed, low-latency satellite broadband services via a fleet of 3,236 Ka-band satellites at orbital altitudes of 590 km, 610 km, and 630 km. The Kuiper System uses advanced communication antennas, sub-systems and semiconductor technology to provide cost effective consumer and enterprise broadband service, IP transit, carrier grade Ethernet, and wireless backhaul traffic. The Kuiper System is designed to maximize spectrum reuse and efficiency and can flexibly steer capacity to match regional customer demand. In addition, the Kuiper System leverages Amazon's terrestrial networking infrastructure to deliver secure, high speed, low latency broadband services for customers.

The Kuiper System space segment and ground segment will be made up of five primary components:

1. Fleet of 3,236 advanced NGSO satellites with an innovative satellite design, orbital architecture and implementation plan.
2. A range of customer terminals, including enterprise, consumer, and mobility terminals.
3. Gateway earth station sites distributed throughout the Kuiper System's service area.

[1] 47 C.F.R. § 25.114(d)(1).

4. Kuiper software-defined network ("SDN") and operational / business support systems.

5. Kuiper satellite control functionality, including satellite operation centers and secure telemetry, tracking, and command ("TT&C") network.

A. Kuiper System Space Segment

1. Constellation Design

a. Orbital Characteristics

The Kuiper System space segment comprises 3,236 advanced NGSO satellites in three orbital "shells," at different altitudes and inclinations. Table 1 describes how the Kuiper satellites are distributed within the planes of each of the three orbital shells.[2]

Table 1. Constellation Design Showing Altitudes and Inclinations

Altitude (km)	Inclination	Planes	Number of Satellites per Plane	Number of Satellites
630	51.9	34	34	1156
610	42	36	36	1296
590	33	28	28	784

The constellation design is based on the following considerations:

- Lowest number of satellites to achieve maximum and evenly spread terrain overlap coverage between 56 degrees north and south of the Equator.
- Rapid planned active deorbit timeframe (< 1 year) and a maximum passive deorbit timeframe (<10 years) well below international standards in case active deorbit is not possible.
- Small satellite spot beams on the ground, enhancing spectrum efficiency and frequency re-use.
- Low payload power requirements due to lower altitudes.
- Reduced radiation hazard to the satellite, enabling use of high-performance COTS hardware.

[2] For example, the 610 km shell has 36 satellites in each of 36 planes with 42° inclination equally spaced 10° apart in ascending node.

The Kuiper System's orbital architecture is designed to maximize capacity and coverage for customers at full constellation deployment. By using overlapping altitude shells at different inclinations the constellation design minimizes total number of satellites required to spread coverage evenly across geographic latitudes and provide link diversity even when one satellite experiences an inline interference event with other systems.

An orbital shell of multiple satellites in multiple planes creates a moving satellite field of view (FOV) honeycomb pattern over the Earth's surface.[3] The satellite footprints are "tiled" by staggering satellite positions in neighboring orbital planes so that the footprints fit together as shown in Figure 1 below.

Figure 1. Satellite Positioning for Best Alignment of Coverage Footprints

[3] Because the full Kuiper system constellation consists of 3,236 satellites, Amazon did not include the mean anomaly for every satellite in every plane of the three orbital shells in the Schedule S form. Instead, only the first orbital plane of each of the three orbital shells was provided in the form. The information for the complete set of orbital planes, including mean anomaly for each satellite within each plane, is provided in a spreadsheet attached to the Schedule S form, as a more efficient way to provide this information.

b. System Implementation and Geographic Coverage

The Kuiper System deployment plan will proceed in five phases as shown in the table below. The cumulative number of planes launched to each inclination is shown in each row, along with the total number of launched satellites.

Table 2. Constellation Deployment Launch Plan

Constellation Deployment Sequence					
Phase	**Shell (Alt/Inclination)**	**Added Planes**	**Satellites/ Plane**	**Deployed Satellites**	**Total Satellites**
1	630 km/51.9°	17	34	578	578
2	610 km/42.0°	18	36	648	1226
3	630 km/51.9°	17	34	578	1804
4	590 km/33.0°	28	28	784	2588
5	610 km/42.0°	18	36	648	3236

When fully deployed, the Kuiper System will provide continuous coverage of the United States and its territories, with the exception of Alaska.[4]

The Kuiper System will commence commercial operations after the first launch phase of 578 satellites. This initial deployment enables continuous service within certain latitude range, while mitigating the potential impact of inline interference events with other GSO and NGSO satellite systems. More limited service outside the latitude range may be possible depending on spectrum requirements, spectrum access limitation, customer type, and service application. During deployment, full-time commercial service will initially be available between 39°N-56°N and 39°S-56°S latitudes. Additional deployments will expand full-time commercial service towards the equator until the Kuiper System has full-service coverage throughout the 56°N-56°S latitude range.

[4] Alaska's high latitude makes it effectively impossible to serve using the Kuiper System and Amazon is requesting an appropriate waiver to reflect this limitation.

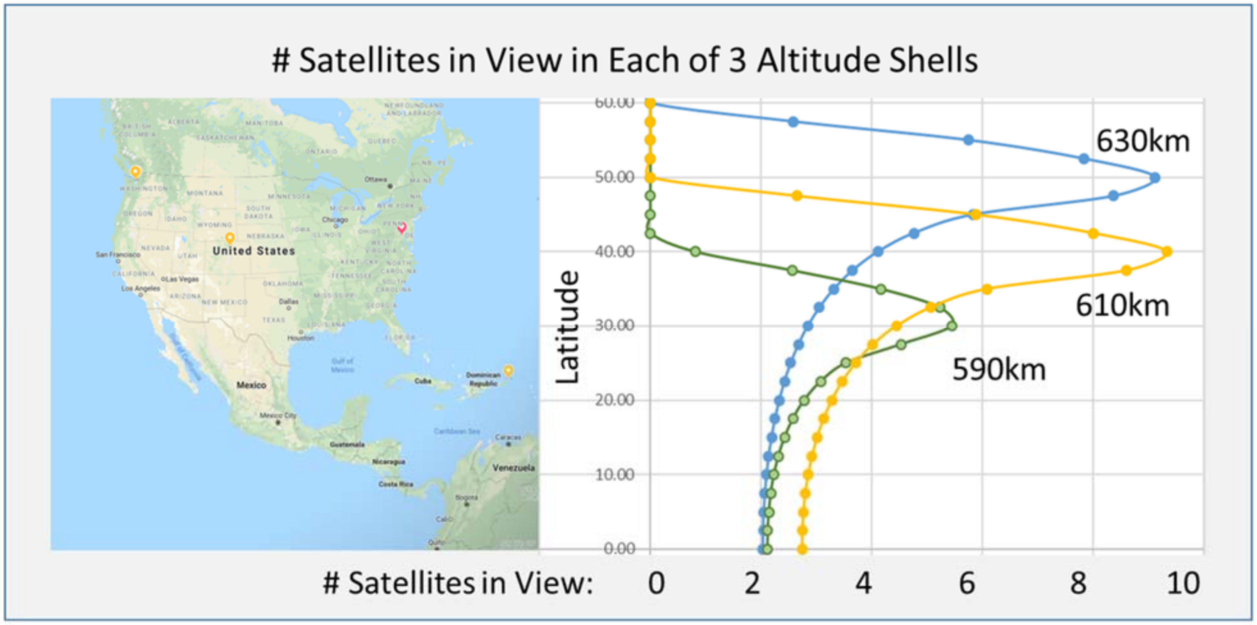

Figure 2. Service Coverage in the United States with Three Orbital Shells

2. Kuiper System Satellites

The Kuiper System consists of 3,236 advanced, high-performance satellites. The Kuiper satellites use advanced phased array antennas with multiple user beams. The antenna technology and software-defined control functionality allow flexible frequency and capacity allocation depending on the needs of customers within a given region.

A separate set of antennas on the Kuiper satellites communicate with gateway earth stations. All traffic within the satellites is fully routable between multiple user and gateway modem banks providing full packet regeneration, repacking and reprioritization. Typically, on-orbit TT&C communications are conducted using Kuiper System gateway links.[5] Separate TT&C links are used during launch and early orbit phase ("LEOP") operations, deorbit procedures, and in situations when gateway links might not be available.

[5] This allows Amazon to continuously monitor and command any and all satellites in the Kuiper System rather than relying on intermittent access to a smaller number of dedicated TT&C earth stations.

a. Communications Payload Architecture

The Kuiper satellite payload architecture is supported by a satellite bus which provides orbital control, power generation and storage, flight control, and satellite pointing. The Kuiper satellite communications payload includes multiple types of antennas, modems, and a packet routing and switching engine. The Kuiper satellite communications payload will become operational once the satellite is in its intended orbital slot, nadir pointing, and set up by network operations.

The communications payload is regularly reprogrammed to deliver capacity based on customer needs within areas being served. The payload networking and routing sub-system is configured by the Kuiper System's ground network operations to pre-programmed beams to appropriate virtual spots[6] on the ground. All uplink and downlink traffic is fully regenerated on the satellite and routing / switching / repacking activities are performed between beams.

Modems support a wide range of modulation and coding options for the communications payload, including the latest generation low density parity-check code ("LDPC") forward error correction. Each modem supports adaptive coding and modulation per user link and supports quality of service queues to buffer data appropriately. The networking and routing sub-system supports multiple quality of service levels allowing enforcement of service level agreements and best effort networking solutions, as shown in Figure 3, below.

[6] Virtual spots refer to an Earth-fixed hexagonal grid defining user beam serving areas.

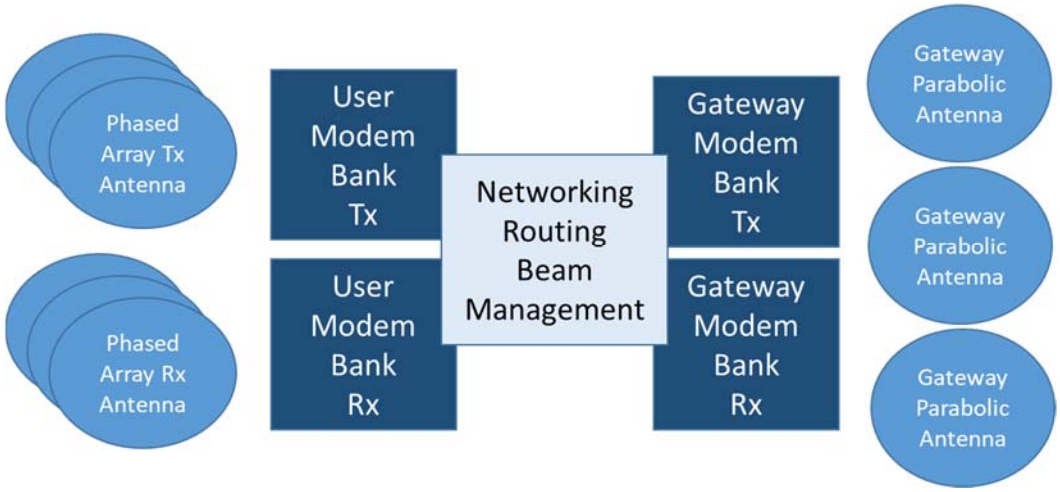

Figure 3. Kuiper Satellite Communications Payload Overview

(1) User Beams

The Kuiper satellite user beams provide connectivity for multiple active customers in virtual spots around the world. The use of high gain, steerable and shapeable phased array antennas, operation at low orbital altitudes, supports virtual spots of approximately 300 km^2 (or a radius of just under 10 km). A larger user beam of approximately 500 km^2 (~2dB reduced in directivity) may be used in cases where larger spot-beam sizes are needed for coverage. The user beams maintain continuous service to assigned virtual spots by constantly updating their coefficients to compensate for satellite motion. Additionally, when user beams are switched between satellites, the communications payload supports near seamless handoff and switching to maintain customer connectivity.

Figure 4 shows a multi-frequency-colored / multi-virtual-spot example superimposed on a map of Washington State. Each virtual spot can be served by any satellite in view, but only one satellite may serve the same spot at a specific frequency at any one time.

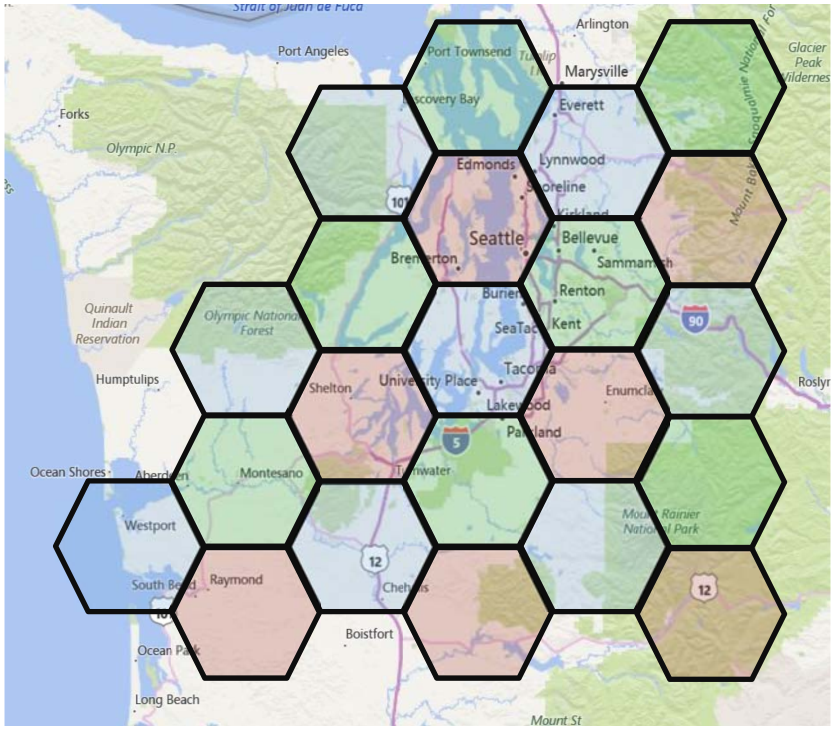

Figure 4. Representative Spot Beam Frequency Reuse (300 km^2 Spot Area)

Spot beams are allocated by the Kuiper System SDN and support reassignment to other satellites to account for GSO exclusion angles, grazing (users on edge of service coverage), and inline interference events. When alternate satellites are available in view of a virtual spot, the Kuiper System beam planning SDN optimally assigns a satellite to that virtual spot for best throughput, adherence to coordination agreements and compliance with international, regional, and country-specific regulations. The beam planning SDN switches satellite resources rapidly to allow fast resource reassignment while limiting control traffic. In cases where alternate satellites cannot be assigned, the system also supports spectrum splitting when needed.

While user beams will generally be centered on each virtual spot, the system can point beams away from the spot center to optimize throughput (especially if the majority of traffic is intended for customers away from the center) using more advanced self-interference management.

Customers will always see a persistent connection to Internet applications, enterprise links, and Amazon services and will be unaware of the switching of satellites, gateways, or routes through the Kuiper System network. Customers will experience a standard Ethernet interface and will not see any of the lower level radio resource, routing, or control plane layers.

(a) Gain Contours

Each Kuiper satellite user beam antenna produces several independent, steerable and shapeable Ka-band beams with variable channel bandwidth, enhancing the efficient use of spectrum to serve customers in proportion to their number and bandwidth demands. The user transmit beams and user receive beams on Kuiper satellites are dynamically shaped to produce almost identical spot contours on the ground. The beams from the satellites in the 590 km and 610 km shells will be adjusted to approximately match the beams from satellites in the 630 km shell. This allows all Kuiper satellites to have approximately the same spot beam footprint and support customers interchangeably.

The user beam transmit antenna contours are supplied in the GIMS database attached to the associated Schedule S.[7] The intended maximum transmit power, gain and EIRP values are supplied in Schedule S Beam Gain Contours for 300 km^2 spots at minimum elevation of 35 degrees. Transmission does not occur until a beam has been assigned to a specific location by Kuiper's beam controller and beams follow specific virtual spots on the ground until the service of a virtual spot is reassigned to another satellite. Beams on a satellite may be reassigned to new frequencies to avoid inline interference events or resource constraints. The transmit antenna panel uses power control management to adjust transmit power for slant range and phased array cosine

[7] Annex D of the Technical Appendix contains more detailed information on beam definitions supplied in Schedule S.

loss. Annex A contains detailed explanations of the transmitted PFD levels and how power control is applied to achieve the same PFD when possible.

User beams from the satellite are only supported for customer terminal elevation angles above 35°. The satellite will not assign any user beams that require a customer terminal to point and operate below 35° elevation angle. Potential interference is generally reduced by using high gain / narrow beams and prioritizing higher elevation angles as part of the beam planning process. Additionally, the phased array antennas use tapering to shape beams to reduce overall sidelobes and self-interference to the primary beam.

The user beam receive antenna gain contours will generally match each transmit beam in shape. Differences in beam shape are primarily due to differences in transmit and receive frequencies. The receive beam gains and G/T values are described in Schedule S. Representative antenna gain contours for the transmit and receive beams for a representative Kuiper satellite operating in the 630 km shell are included in Schedule S, as required by Section 25.114(c)(4)(vi)(B) of the Commission's rules.

The uplink and downlink beam contours are circular at nadir. However, several factors cause the beam contour to widen and become elliptical as the slant angle increases: (i) the phased array antenna beam widens in the direction of steering (the width remains almost the same perpendicular to the direction of steering); (ii) the projection of the beam on the surface of the Earth elongates as it moves away from nadir; and (iii) the curvature of the Earth further elongates the beam in one dimension.

To partially counter this effect, the circular beam at nadir will be slightly widened (while maintaining the circular shape). As the beam is steered off-nadir, the beam will be tightened to keep the spot shape as close to circular as possible. The effect of the beam widening at nadir is shown in the GIMS database. To represent a worst-case condition, this widened beam is used to generate the scan and nadir contours.

Figures 5a and 5b show the gain contours for the user beams at Nadir illuminating 300 km^2 and 500 km^2 coverage areas, respectively. Likewise, Figures 6a and 6b show the gain contours for the user beams at minimum elevation angle illuminating 300 km^2 and 500 km^2 coverage areas.

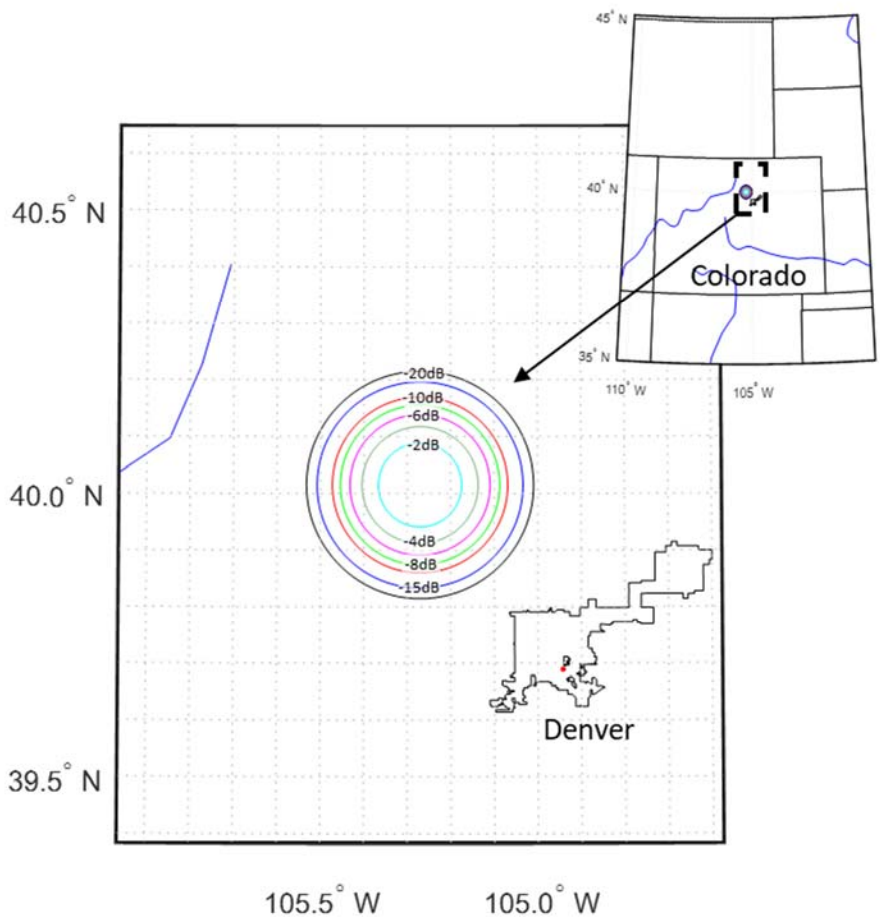

Figure 5a. Beam Gain Contours for 300 km^2 Spots at Nadir

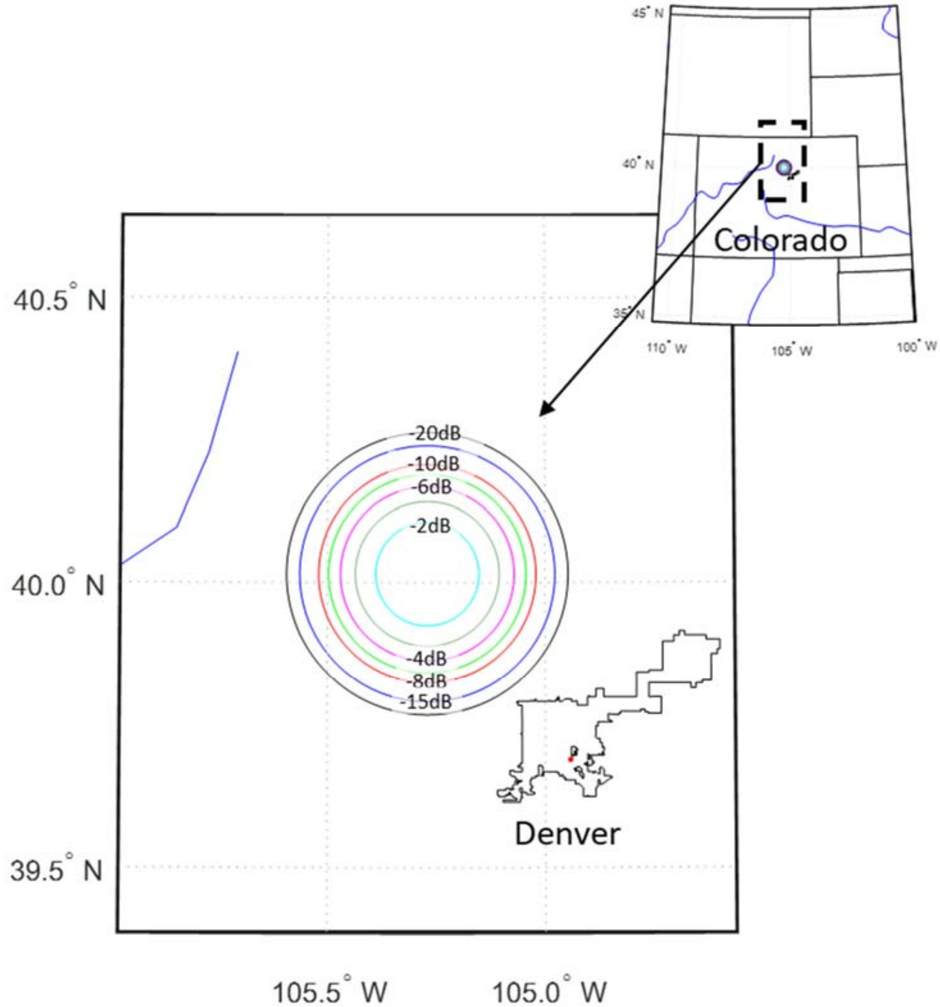

Figure 5b. Beam Gain Contours for 500 km^2 Spots at Nadir

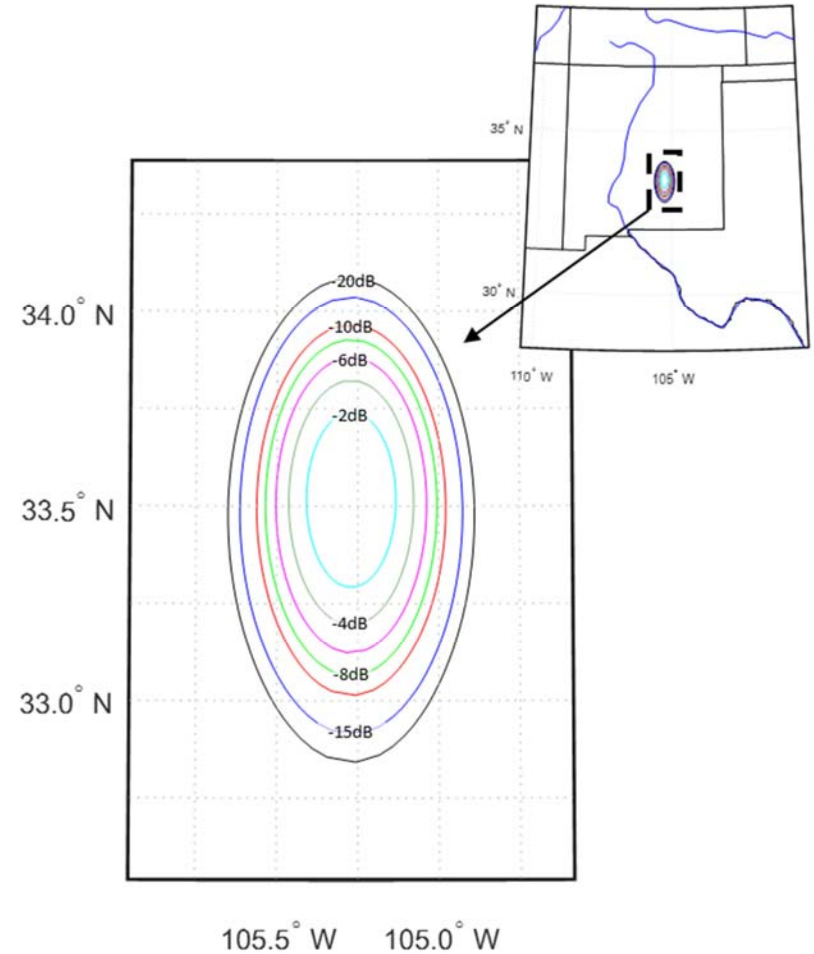

Figure 6a. Beam Gain Contours for 300 km^2 Spots at Minimum Elevation of 35 Degrees

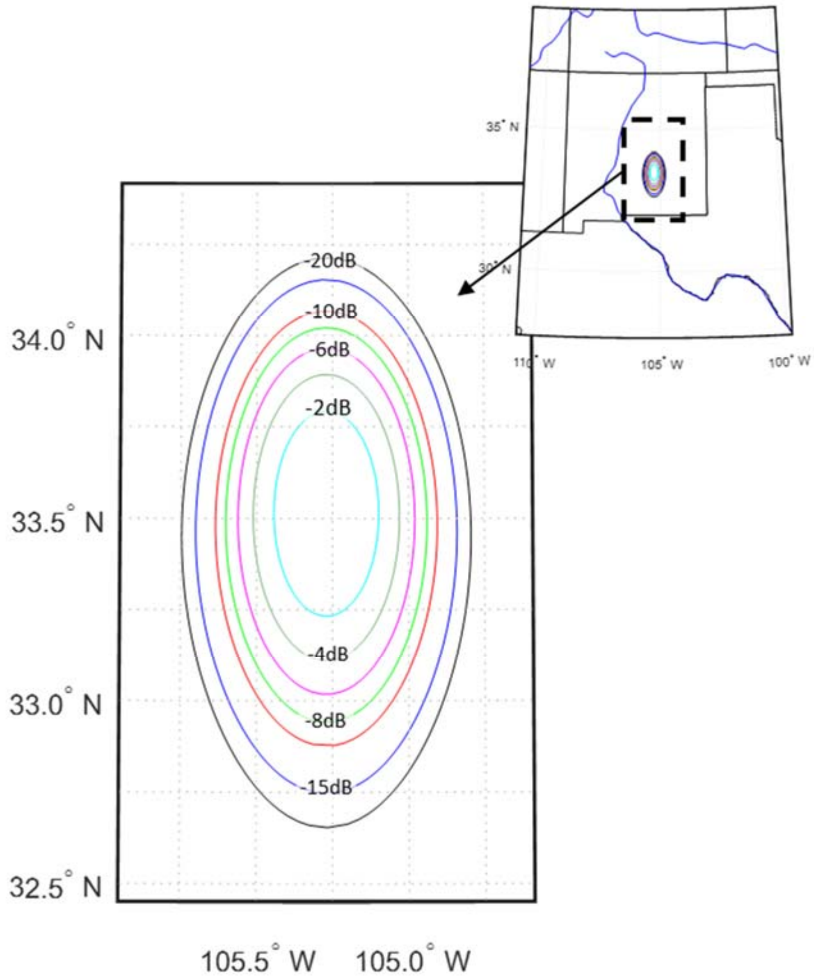

Figure 6b. Beam Gain Contours for 500 km^2 Spots at Minimum Elevation of 35 Degrees

(b) Coverage Areas

The phased array antennas on each Kuiper satellite are capable of serving up to 48.2° from nadir as shown in Figure 7. This angular range corresponds to a 1,560,000 km^2 coverage area below each satellite in the 630 km shell. This coverage area corresponds to minimum elevation angles of approximately 35°, 35.2°, and 35.4° for customer terminal communications with Kuiper satellites in the 590 km, 610 km, and 630 km shells, respectively. An example of the coverage area under a satellite is shown in Figure 8.

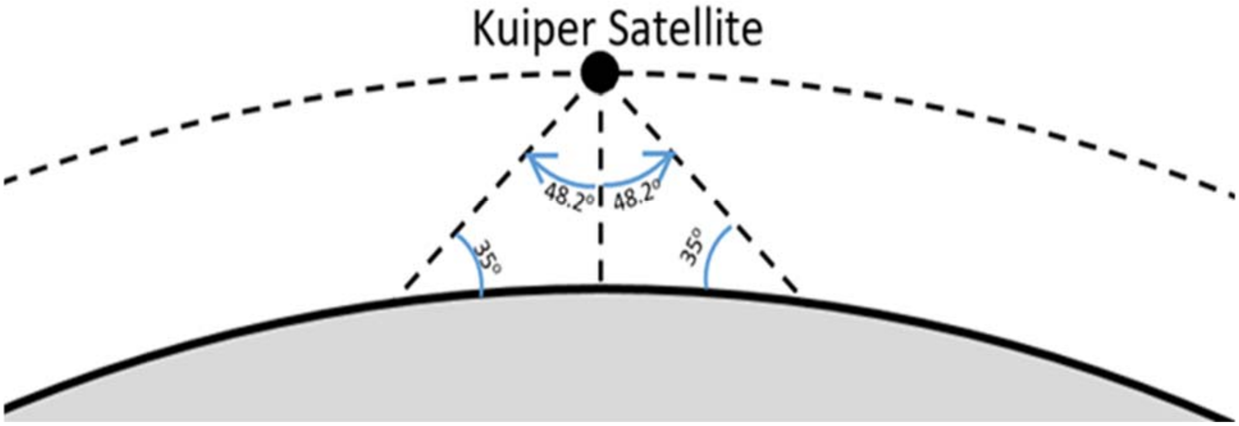

Figure 7. Steering Range of User Beams

Figure 8. Coverage Area for a User Beam

(2) Gateway Beams

Gateway links are always point-to-point connections, and satellites and gateways point directly at each other using coordinated system control information transferred through gateway links. Throughout the duration of a link connection, the pointing of both antennas is updated in milliseconds to maximize gateway link throughput. Both gateways and satellites use an additional antenna to support handoff to the next gateway link. This avoids any loss of signal when moving between sites and provides a seamless handover as satellites move through multiple gateways per orbit. Each gateway site will have up to four active antennas per site and all antennas can make use of all gateway frequencies and both polarizations.

The number of United States gateways sites will be approximately equal to the number of active satellites serving U.S. territory. The initial gateway deployments start with a minimum number based on initial coverage latitudes, and grows based on the number of satellites that have been brought into service. The gateway sites will be selected to support satellite orbital paths, extending service to offshore areas, Amazon network infrastructure, and access to backhaul fiber. Additionally, gateway site selections will address meeting GSO exclusion angles, inline events, or ground outages. Lastly, the number of gateway locations will increase in regions where higher rain fade is present to allow site diversity during high propagation loss conditions with a specific gateway site. Higher densities of gateway locations may also be installed along coasts to support offshore customers. Site location selection will consider FCC rules for proposed use of the 27.5-28.35 GHz band.

(a) Gain Contours

Mechanically steered, reflector antennas will be used for satellite communications with gateway earth stations for uplink and downlink beams. Similar to user beams, the gateway beam projection widens as the beam is steered away from nadir (albeit only as a result of slant angle and curvature of the Earth). Figures 9 and 10 present the beam contours for gateway uplink and downlink beams at nadir and Figures 11 and 12 show the same beams at maximum slant angle.

Downlink 17.7 GHz @ Nadir, 0.45 m, 2.8 Degree HPBW

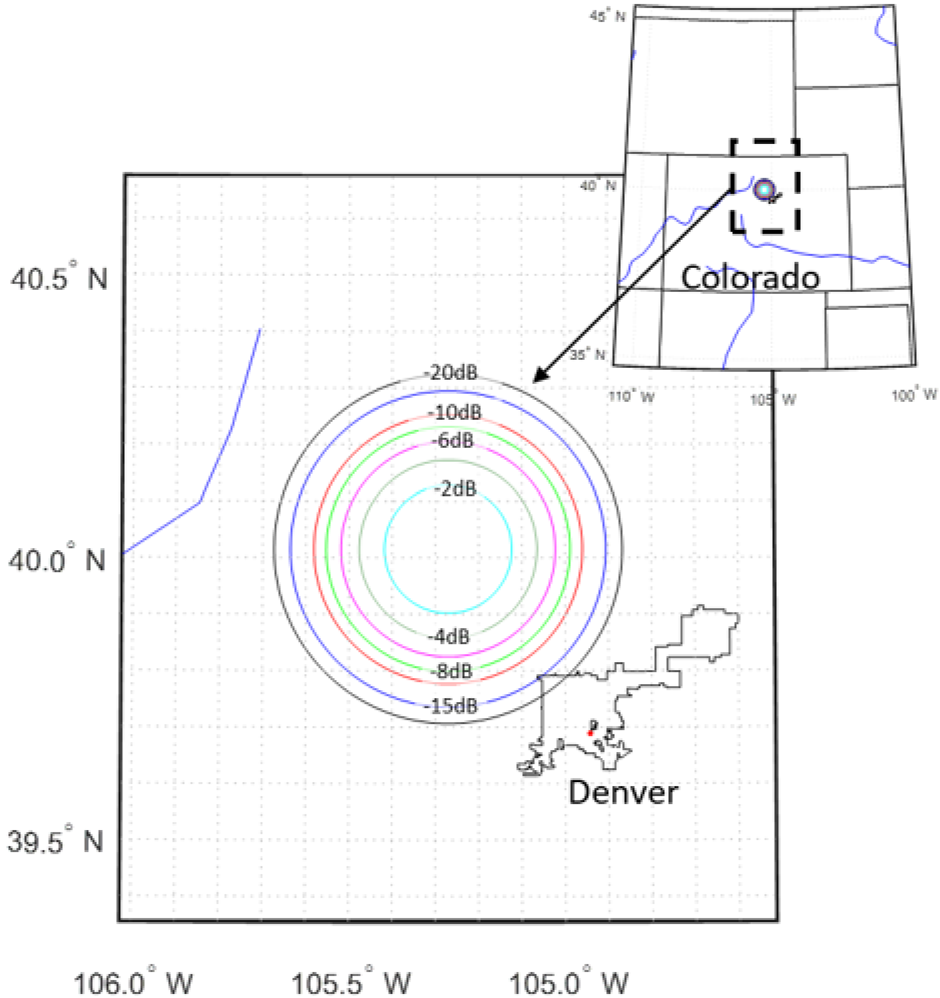

Figure 9. Contour for Downlink Gateway Beams at Nadir

Uplink 27.5 GHz @ Nadir, 0.45 m, 1.8 Degree HPBW

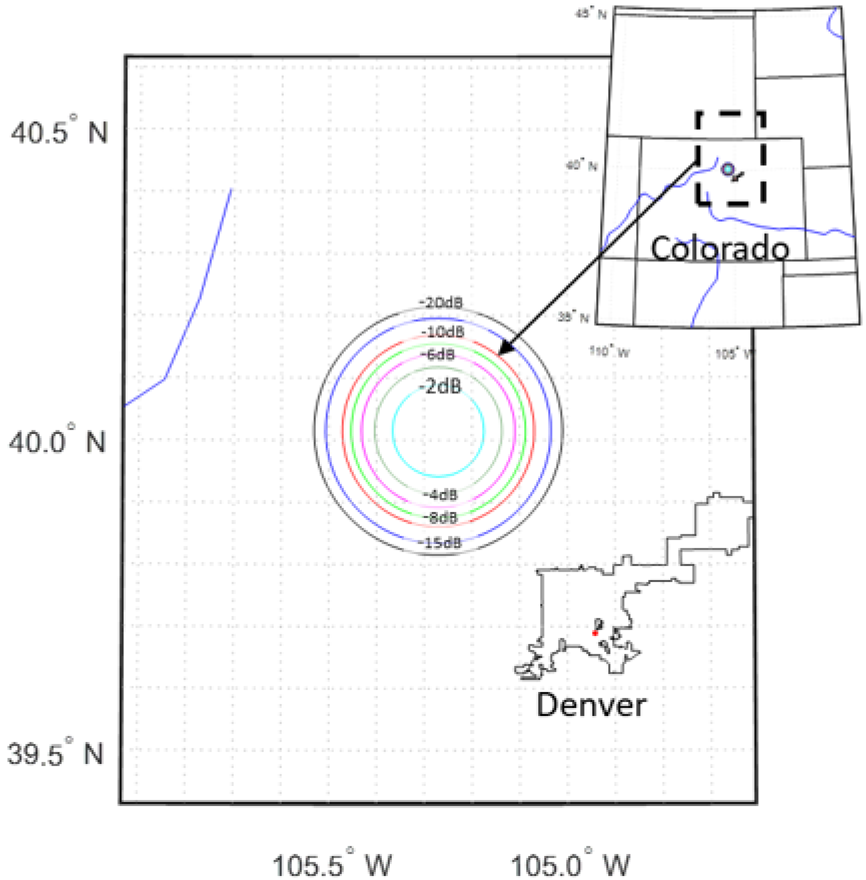

Figure 10. Contour for Uplink Gateway Beams at Nadir

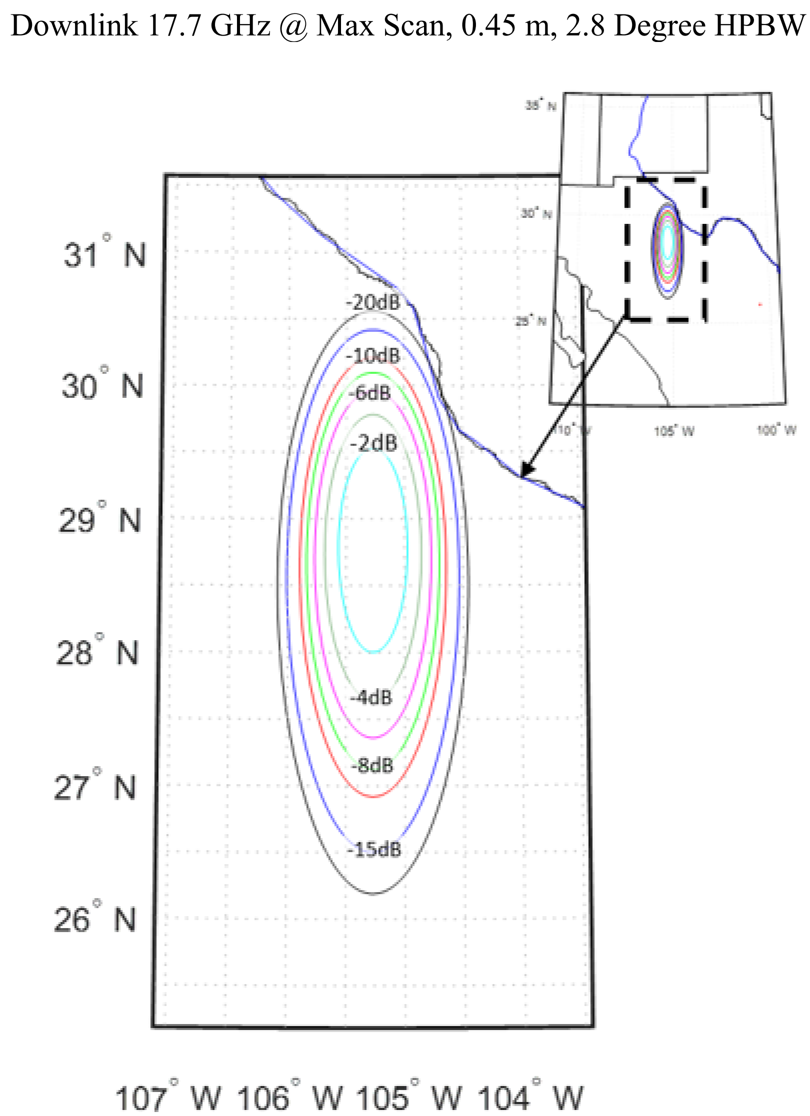

Figure 11. Contour for Downlink Gateway Beams at Maximum Slant Angle

Uplink 27.5 GHz @ Max Scan, 0.45 m, 1.8 Degree HPBW

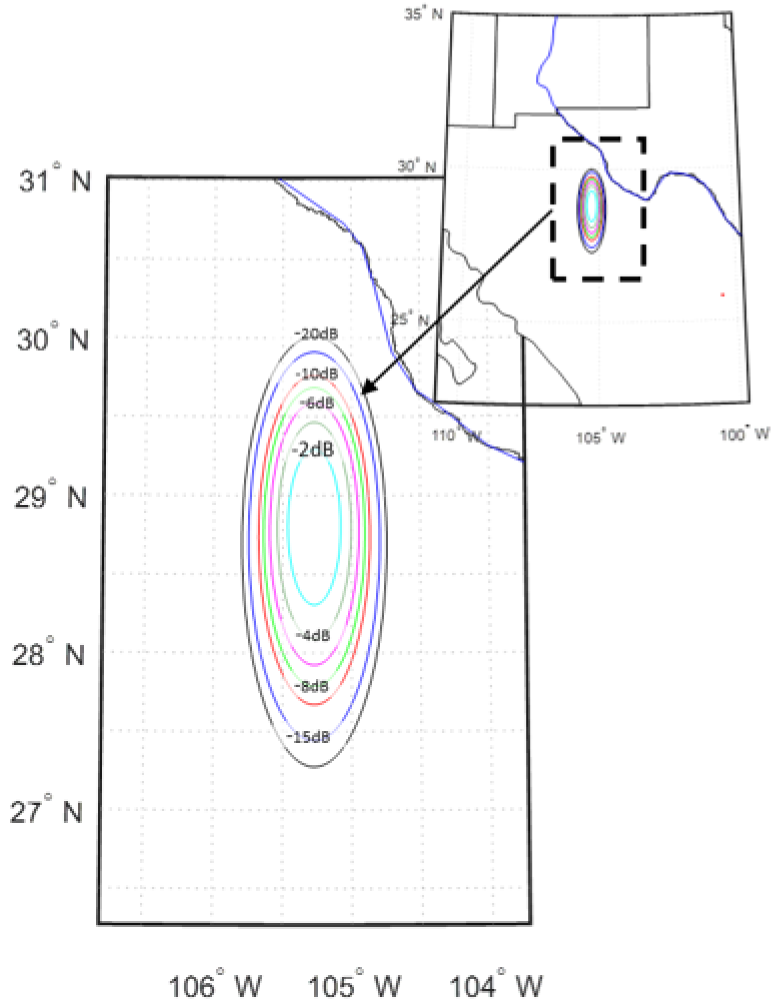

Figure 12. Contour for Uplink Gateway Beams at Maximum Slant Angle

(b) Coverage Area

The coverage area for Kuiper satellite gateway beams extends further than that for user beams. Each satellite operating in the 630 km shell can connect to any gateway earth station (subject to availability and traffic constraints) within 58° from nadir corresponding to 3,200,000 km^2 gateway coverage area below each satellite. Figure 13 shows the coverage area for gateway beams under a satellite.

Figure 13. Coverage Area for Gateway Beams

(3) TT&C Beams

Fixed beam antennas with wide half-power beam width are used for TT&C connectivity. Multiple patch antennas are installed on the Kuiper satellite to ensure broad coverage at any satellite attitude. The beam contour for TT&C antenna is shown in Figure 14.

(a) Coverage Areas

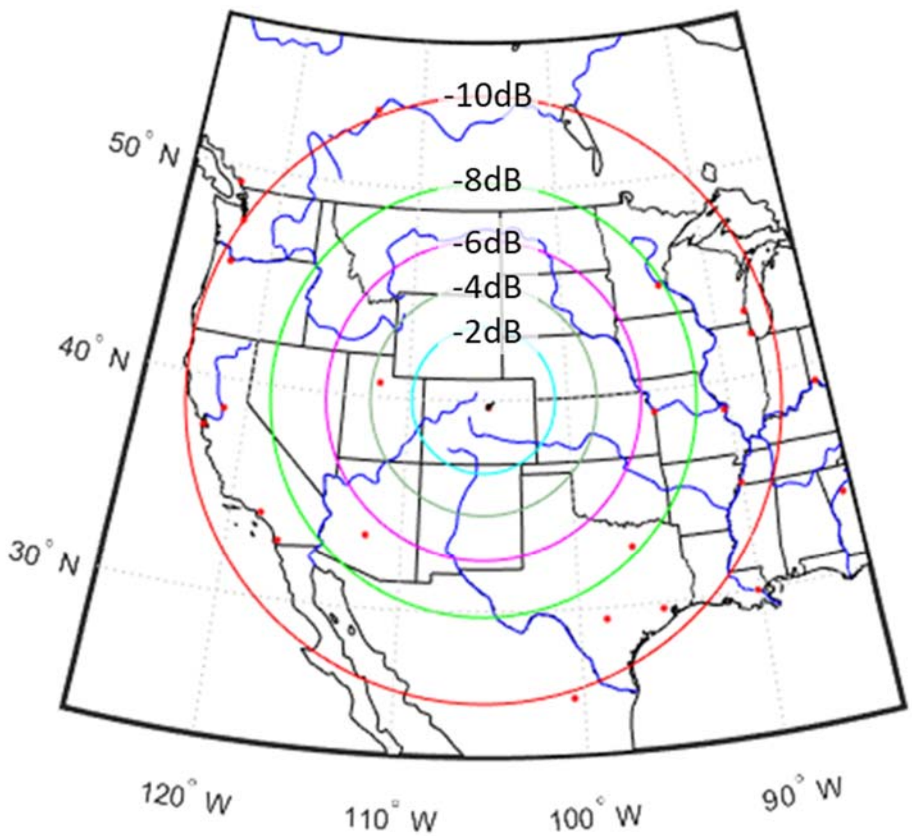

Figure 14. Coverage Area for TT&C Beams

3. Frequency and Polarization Plan

a. User Links

All Kuiper customer terminal, gateway, and TT&C communications are conducted in Ka-band frequencies. The following spectrum are proposed for user links.

Table 3: Customer Terminal Uplink and Downlink Frequencies

User Uplink Frequencies		
Uplink Frequencies	Satellite Antenna Type	Link Polarization
28.35-28.6	Phased Array	RHCP/LHCP
28.6-29.1	Phased Array	RHCP/LHCP
29.5-30.0	Phased Array	RHCP/LHCP

User Downlink Frequencies		
Downlink Frequencies	Satellite Antenna Type	Link Polarization
17.7-18.6	Phased Array	RHCP/LHCP
18.8-19.3	Phased Array	RHCP/LHCP
19.3-19.4	Phased Array	RHCP/LHCP
19.7-20.2	Phased Array	RHCP/LHCP

User downlinks take advantage of phased array solutions on the satellite, with steerable and shapeable beams to customer terminals (with peak gains ranging between 30 and 45 dBi) supporting either customer phased array or parabolic dish antennas. Each user downlink beam can deliver gigabit class throughputs (downlink), depending on the available spectrum, customer antenna gain, and operational conditions.

The user downlink spectrum is divided into 100 MHz channels (as declared in the associated Schedule S). The 100 MHz channels can be aggregated into wider channels ranging from 200 to 500 MHz in bandwidth. Each of the phased array panels on the satellite can use one of the three principal band spectrum designations, each consisting of 4 to 5 channels.[8]

The user beam antennas can support multiple beams (co-frequency) to spots in different locations within the service area. All user beams can be operated in left, right, or left + right circular polarization, providing operational flexibility to address coordination needs and for regional and country specific regulations. The proposed user principal downlink spectrum designations are defined as follows:

[8] These principal spectrum aggregations are allocated for initial service deployment in the U.S. The remaining bands are considered alternative spectrum designations and have been included in Schedule S to provide flexibility to address region and country specific regulations.

Table 4. User Downlink Channelization

Downlink Spectrum Designations	Starting Frequency	Ending Frequency	Bandwidth
Primary Spectrum Designation - 1	17.7 GHz (External to U.S.) or 17.8 GHz (Within U.S.)	18.2 GHz	500 MHz (External to U.S.) or 400 MHz (Within U.S.)
Primary Spectrum Designation - 2	18.2 GHz	18.6 GHz	400 MHz
Primary Spectrum Designation - 3	18.8 GHz	19.3 GHz	500 MHz

The proposed principal[9] user uplink spectrum is in the 28.5-29.1 GHz band. This band is divided into 50 MHz channels (as declared in the associated Schedule S) which similarly to the downlink channels can be aggregated into wider band segments in multiples of 50 MHz up to 200 MHz.

The aggregate of uplink spectrum is smaller compared to the downlink aggregate due to the asymmetric nature of the majority of customer internet traffic. User channels are shared between multiple uplink terminals using a combination of FDMA (frequency allocation), TDMA (portions of time allocated by the satellite per user), and potentially CDMA (allocation by code) or TDMA for random access channel requests.

The payload architecture supports sub-dividing band segments within a beam into smaller frequency units (FDMA) that can also be steered to a new location. This resource allocation method is well suited to address the variability in the traffic needs of each service area and allows the system to adapt from a small number of users to larger customer bases after more satellites are deployed.

[9] These principal spectrum designations are intended for initial service deployment in the U.S. The remaining bands are considered alternative spectrum designations and have been included in Schedule S to provide flexibility to address region specific regulations.

b. Gateway Links

Gateway links are enabled using satellite parabolic and ground parabolic antennas with sizes between 1.0 meter and 2.4 meters. The frequency bands intended for gateway links are shown in Table 5. The channelization for listed gateway frequencies is similar to the user bands in that the uplink bands are divided into 50 MHz channels and the downlink bands are divided into 100 MHz channels. Furthermore, these channels can also be aggregated into wider band segments. Each satellite parabolic antenna can operate at all of the listed frequencies and leverage both left and right polarizations.

Table 5. Gateway Link Frequencies

Gateway Uplink Frequencies		
Uplink Frequencies	Satellite Antenna Type	Link Polarization
27.5-28.6	Parabolic	RHCP/LHCP
28.6-29.1	Parabolic	RHCP/LHCP
29.1-29.5	Parabolic	RHCP/LHCP
29.5-30.0	Parabolic	RHCP/LHCP

Gateway Downlink Frequencies		
Downlink Frequencies	Satellite Antenna Type	Link Polarization
17.7-18.6	Parabolic	RHCP/LHCP
18.8-19.3	Parabolic	RHCP/LHCP
19.3-19.7	Parabolic	RHCP/LHCP
19.7-20.2	Parabolic	RHCP/LHCP

c. TT&C Links

TT&C links are enabled via a limited set of high gain (2 to 3 meter) earth station antennas and patch antennas placed on different satellite surfaces to allow connectivity even when the satellite is not nadir aligned. On-orbit TT&C links can also be operated using gateway antennas on the satellite and gateway earth stations. The proposed bands for operating the TT&C links are shown in Table 6. The actual occupied channel bandwidths for TT&C communication can be 1, 5, 10, 20, or 50 MHz. To the extent possible, the intended channels have been designed to correspond to band edges. The current plan of operation calls for using one channel to communicate with any one satellite simultaneously, but multiple frequencies may be used from one TT&C ground site. The center frequencies for three uplink and three downlink TT&C channels have been declared in Schedule S and can also be found in Annex D of this document.

Table 6. TT&C Frequencies

TT&C Uplink Frequencies		
Uplink Frequencies	Satellite Antenna Type	Link Polarization
27.5-28.05	Multiple Low Gain	RHCP/LHCP

TT&C Downlink Frequencies		
Downlink Frequencies	Satellite Antenna Type	Link Polarization
19.25-19.4	Multiple Low Gain	RHCP/LHCP

d. Cessation of Emissions

To meet Section 25.207 requirements,[10] the control of all antenna beams (sub-system and power amplifier) can be enabled or disabled individually via ground control commands sent over TT&C links under both on-orbit and deorbit conditions. If all communications to ground stations cease for a pre-determined wait period, the satellite executes an automatic cease transmission to prevent the possibility of a satellite failing in a transmitting state.

B. Kuiper System Ground Segment

Each Kuiper ground terminal follows a set of rules for operation. Other than initial network entry ("INE") or TT&C operations, all ground terminals follow coordinated hand-off control messages such that they will only transmit or receive when they have been assigned a specific satellite and set of frequencies. This avoids any uncoordinated traffic that may interfere with another GSO or NGSO system. During the INE process, customer terminals follow a specific sequence to determine if a satellite is in view, and only transmit their desire to enter the network after they have received an authenticated message, slot, and frequency for INE.

[10] *See* 47 C.F.R. § 25.207.

Each type of Kuiper ground terminal is only allowed to operate after reaching the minimum elevation angle described in the following table. Ground terminals cannot access Kuiper's network below these angles, and satellites will never direct any beams to elevation angles below the values in Table 7.

Table 7: Network Minimum Elevation Angles

	Polarization	**Elevation Angle [deg]**	**Satellite Angle [deg]**
Gateways	LHCP/RHCP	20	58.8
High Gain User Links	LHCP/RHCP	35	48.2
Low Gain User Links	LHCP/RHCP	39	45
TT&C Links	LHCP/RHCP	5	65

An initial set of ground antennas are defined in the ITU filings USASAT-NGSO-8A, USASAT-NGSO-8B, and USASAT-NGSO-8C. The Kuiper System design allows for two types of antennas (phased array and parabolic) supporting a range of gains (customer terminal receive gains from 30 to 41 dBi and transmit gains from 29.5 to 45.2 dBi, and gateway receive gains from 39 to 49 dBi and transmit gains from 40 to 52.8 dBi). Adaptive coding and modulation schemes in all modems allow for both high throughput / high gain terminals and low cost / low gain terminals.

1. Customer Terminals

Kuiper customer terminals will allow residential, enterprise and mobile (transportation) customers to access Kuiper satellite services using either electronically steered phased array antennas or mechanically steered parabolic antennas. The customer terminal modem enables high-speed service within a single spot beam, link optimization, customer terminal beam-pointing, and secure customer communications.

2. Gateway Terminals

Gateway sites will be distributed throughout the service area, to enable each Kuiper satellite to access two different gateway earth stations to achieve system throughput and reduce inline interference events. Traffic from multiple gateway sites is aggregated via terrestrial fiber backhaul links to an Internet Exchange Point ("IXP") or Point-of-Presence ("PoP") site. At each IXP or PoP site, the Kuiper System interfaces with content distribution caches, enterprise and telecommunication network peering, connections to the Internet backbone, or direct connect into Amazon backbone infrastructure and data centers, as shown in Figure 15.

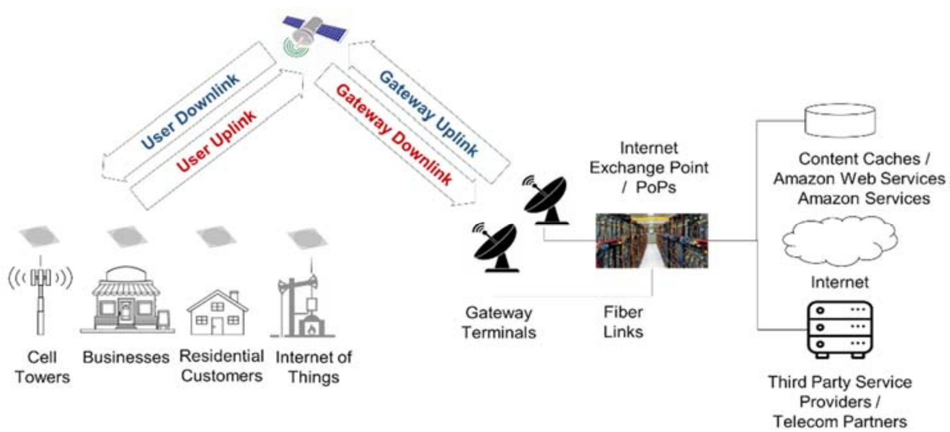

Figure 15. Kuiper System Network Architecture

3. Kuiper System Network Control

The Kuiper System network is managed via a global software defined networking ("SDN") controller (the "Kuiper SDN"). The Kuiper SDN is responsible for optimal allocation of beams for customers and gateways across the system and does a long-term allocation of resources based on customer demand and service type, including performing short-term adjustment of resources based on time of day or peak capacity needs. The Kuiper SDN optimizes the network among multiple satellites if resources become unavailable due to exclusion angles implemented to protect geostationary satellite orbit ("GSO") satellites, coordination agreement constraints, or satellite operational limitations. Traffic control within an assignment period, including uplink channel allocation of users, is done within each Kuiper satellite for each beam and gateway links communicate Kuiper SDN command and control information to the satellite constellation.

4. Kuiper Satellite Control

The Kuiper System employs an independent network of TT&C earth stations, separate antennas and radios onboard the satellite, and multiple satellite operations centers. The TT&C network is primarily used during launch operations, de-orbit operations, and during any anomaly situation. Since most nominal satellite control operations use Kuiper's gateway network, only a few TT&C sites are needed around the world, and only a few satellites actively communicate with TT&C earth stations at any given time.

Consistent with Section 25.202(g) of the Commission's rules, Kuiper System typical, on-orbit TT&C links would cause no more interference and require no more protection than gateway links in the relevant spectrum. TT&C channels can vary in bandwidth with 1, 5, 10, 20, or 50 MHz[11] channel sizes, and different channels are selected for different antennas allowing access to multiple satellites from a common site if desired. The TT&C links will use single carrier modulation or may also be spread when larger channel sizes are used. TT&C communications will contain satellite status and position data and allow uploading for task lists. The link will also be used for satellite data collection when necessary.

[11] The actual transmission bandwidths will be typically much smaller than 50 MHz In certain circumstances, including during LEOP, larger TT&C channel bandwidths may be required to enable simultaneous communications with Kuiper satellites that are in close proximity.

II. ORBITAL DEBRIS MITIGATION/SATTELITE END-OF-LIFE PLAN

A. Kuiper System Orbital Debris Mitigation

The Kuiper System constellation was designed with space safety foremost in mind. Amazon is working with the Combined Space Operations Center as well as multiple commercial Space Situational Awareness enterprises, to jointly conduct analyses and studies to determine safety levels, elements of constellation design, and maneuver plans. The following sections explain how Amazon's design of and operational strategies for the Kuiper System will mitigate orbital debris risks, as required by Section 25.114(d)(14) of the Commission's rules.[12]

1. Debris Release

Amazon has designed the Kuiper satellites and the processes for deployment and operation of the Kuiper System so that no debris will be released during normal deployment and operations. Amazon also has assessed and limited the probability of a Kuiper satellite becoming a source of debris by collisions with small debris or meteoroids that could cause loss of control and prevent post-mission disposal. Design approaches will be employed to minimize risk of lethal, not-trackable ("LNT") debris initiating a significant debris release event.

2. Accidental Explosion

Amazon has assessed and limited the probability of accidental explosions during and after completion of mission operations. The satellite design goal is to use unpressurized non-explosive propellant storage. No hypergolics or explosive actuation devices will be used and the propellant will be chemically inert. In addition, the tank will be externally protected against debris impact by satellite structural panels. Kuiper satellite design will ensure there are no design flaws that can accidentally create significant energy release or debris events under the influence of any single

[12] *Pursuant to* 47 C.F.R. § 25.114(d)(14).

failure. Kuiper satellites can be deactivated (decommissioned) by signal from the ground or will be deactivated automatically if all communications to ground stations cease for a pre-determined wait period.

The deactivation process involves passivation of the satellite, including de-energizing of all energy reservoirs and leaving all fuel lines open. Energy reservoirs include propellant tanks, battery cells, and momentum storage devices. Charging circuits also will be permanently switched off or fused, to preclude any potential recharge. This deactivation process will be conducted after a satellite's orbit has been lowered as described in Section II.A.4 below. Propellant budget and power system lifetimes are designed to allow the orbit lowering. Satellites then will be deorbited as described below.

3. Collision Risks with Large Debris and Other Space Stations

Amazon has assessed and limited the probability of the Kuiper satellite systems becoming a source of debris through collision with large debris or other operational space stations. Amazon has reviewed the catalog of active space stations and debris objects in our proposed orbits and finds the collision risk probability to be low and will further abate any residual risk by active conjunction avoidance as explained below. The cumulative lifetime conjunction risk will be held below 0.001 for every satellite, by active conjunction assessment and maneuvering.

A comprehensive space debris avoidance program will be put in place including: effective, timely response to conjunction data message ("CDM") advice of conjunction risk; third-party assistance in tracking orbital threats to improve conjunction warning response; low-risk maneuver trigger thresholds to avoid satellite and debris of all kinds; a statically safe constellation with large satellite separation at orbit intersections; and "full lifecycle" conjunction avoidance from early operations after dispensing to re-entry.

Kuiper satellite launch and early operation procedures will be especially sensitive to space debris concerns. When the satellites separate from the launch vehicle, debris release concerns will be paramount, as discussed above. The production satellite will be dispensed into an orbit safely below the International Space Station ("ISS") and individually checked out to validate nominal performance of all systems. Any aberrant satellite will be deorbited. After successful checkout, collision avoidance procedures will be initiated before and continue throughout orbit raise, thus protecting all previously launched space vehicles through active conjunction assessment and maneuvering as necessary. Kuiper satellites will maneuver to assure better than the NASA-recommended standard 1 in 10,000 P(hazard) for every conjunction throughout mission life, including this early phase.[13]

On-orbit, the satellite constellation is designed to be intrinsically safe, with buffer zones between all satellites throughout the constellation. In-track separation is the first parameter critical to space safety. Across the entire Kuiper System constellation, at every potential intra-system conjunction, the design assures a minimum 50 km separation at closest approach.

The natural motion imposed by Earth's oblateness, plus eccentricity mean and variance, and including the largest maneuvers, result cumulatively no more than 9 km of altitude deviation of Kuiper satellites. The Kuiper System's three orbital shells will be 20 km apart. Thus, there is no possibility of collision between Kuiper satellites deployed in different planes.

In addition, the Kuiper System's lowest orbital shell will be 40 km from the nearest known large proposed NGSO system. Inter-constellation spacing of 40 km between constellations allows for potential variability in orbital station keeping control techniques that may exist between

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[13] *See Mitigation of Orbital Debris*, Second Report and Order, 19 FCC Rcd 11567, 11603 ¶ 88 (2004); *NASA Technical Standard, Process for Limiting Orbital Debris*, NASA-STD-8719.14 Revision A with Change 1, at 44-45, Requirement 4.7.3 (May 25, 2012) ("NASA Standard").

different satellite operators. The long-term control tolerances for apogee and perigee are each 2 km and the tolerances for inclination and right ascension of the ascending node ("RAAN") are each 0.1 degree.

Amazon has reviewed the catalog of active space stations and debris objects in our proposed orbits and finds the collision risk probability to be low and will further abate any residual risk by active conjunction avoidance as explained above. The cumulative lifetime conjunction risk will be held below 0.001 for every satellite, by active conjunction assessment and maneuvering.

B. Kuiper Satellite Post-Mission Disposal

Kuiper satellites will actively decommission and deorbit within one year after the active mission lifetime[14]. While decommissioning, all satellites will continue to perform avoidance maneuvers in consequence of ongoing conjunction assessment plans, maintaining the same high standards as during the mission operations phase. Own-ship ephemerides will also be made available throughout the lifecycle, to the 18th Space Control Squadron (SpCS) and civilian SSA clearinghouse organizations.

During active deorbit, a Kuiper satellite's perigee will be lowered to below ISS to assure rapid demise. The satellite's apogee will then also be lowered below ISS. During these orbit-lowering maneuvers, conjunction avoidance will be active. After the final orbit-lowering stage, de-energization of onboard systems will be initiated, followed by reentry and demise. Total duration of active deorbit will be less than one year.

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[14] The end of the mission's lifetime is assumed to be when propellant reaches reserve levels.

Amazon has also considered the Commission's Notice of Proposed Rulemaking on Mitigation of Orbital Debris in the New Space Age[15] in selecting the Kuiper System's constellation altitudes to ensure that satellites will passively deorbit in under 10 years (typically 5-7 years). At the densest projected ballistic coefficient, and average sunspot activity, the following trajectory predicts 6 years decay time for satellites in the 630 km shell.

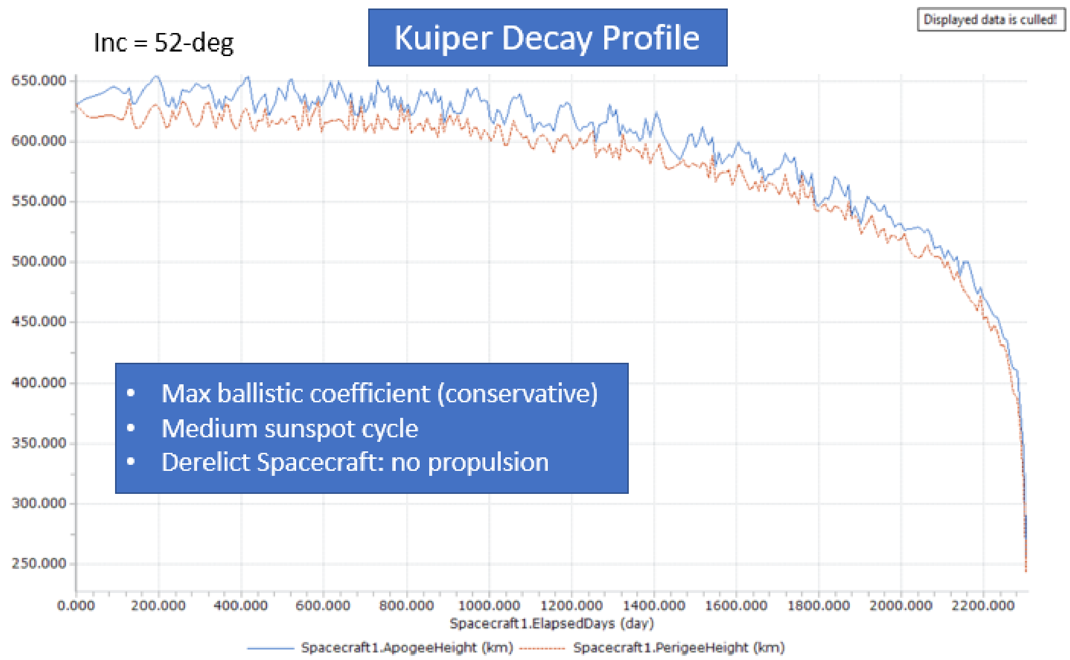

Figure 16. Kuiper Decay Profile

The certain and timely deorbit provided by the natural drag environment, without recourse to any satellite systems or functions, is a substantial enhancement to overall space safety.

As described earlier, Amazon will place satellites in variable inclinations. This is done to require the fewest satellites needed for effective coverage. In addition, Amazon will comply with the NASA limit for > 15 Joule hazard to humans, per NASA-STD-8719.14.[16] Amazon will use

[15] *See Mitigation of Orbital Debris in the New Space Age*, Notice of Proposed Rulemaking and Order on Reconsideration, 33 FCC Rcd 11352 (2018).

[16] *See NASA Standard*, at 44, Requirement 4.7.2.

the approved DAS software techniques to verify < 1:10,000 chance of harm by casualty to any person. In view of the foregoing, the Kuiper System's planned deorbit processes comply fully with the FCC's rules.

ENGINEERING CERTIFICATION

I hereby certify that I am the technically qualified person responsible for preparation of the engineering information contained in this Application of Kuiper Systems LLC for Authority to Launch and Operate a Non-Geostationary Satellite Orbit System in Ka-band Frequencies, 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/ Rod Fleck
Rod Fleck
Director of Payload Architecture
Kuiper Systems LLC

Date: July 4, 2019

ANNEX A. INTERFERENCE PROTECTION AND SHARING WITH CO-FREQUENCY FIXED SERVICES

A1. Sharing with FS Services

The Kuiper System is designed to co-exist with terrestrial fixed service ("FS") operations. The minimum elevation angle at which the Kuiper customer terminals operate is 35˚. The large elevation angle of these terminals, in addition to the typically low elevation angle of FS antennas, results in sufficiently large sidelobe isolation to protect FS operations from harmful interference. The Kuiper System's downlink EIRP levels also comply with all applicable FCC and ITU power flux density ("PFD") limits designed to protect the FS operations from downlink interference.

Amazon demonstrates compliance with the provisions of Sections 25.208 and 25.146(a)(1), and the limits set forth in Article 21 of the ITU Radio Regulations, below. The maximum PFD value for each downlink beam has been included in the Schedule S. The discussion below and the demonstrations in Sections A2, and A3 are provided for completeness and the convenience of the Commission.

The limits as shown in Table 21-4 of Article 21applicable to Kuiper satellites operating in the 17.7-19.3 GHz band are:

Angles of Arrival (δ) Above the Horizontal Plane	0°-5°	5°-25°	25°-90°
PFD Limit in dB[W/m2/MHz]	−115 − X	−115 − X + ((10 + X)/20)(δ − 5)	−105

Where X is a constant defined as a function of N, the number of satellites in the Constellation, and is calculated as follows:

Number of Satellites N	N ≤ 50	50 < N ≤ 288	N>288
X [dB]	0	(5/119)*(N - 50)	(1/69)*(N + 402)

The limits as shown in ITU RR Table 21-4 applicable to Kuiper satellites operating in the 19.3-19.7 GHz band are:

Angles of Arrival (δ) Above the Horizontal Plane	0°-5°	5°-25°	25°-90°
PFD Limit in [dB(W/m2/MHz)]	−115	−115 + 0.5(δ − 5)	−105

The maximum downlink PFD levels produced by each Kuiper satellite beam type transmitting from each of the three constellation shells at 630 km, 610 km, and 590 km have been evaluated to demonstrate compliance with the limits.

While there are no PFD limits in the 19.7-20.2 GHz band, the expected maximum PFDs for Kuiper System gateway beams in this band are the same as those shown for the other bands. The PFD level for Kuiper System user beams operating in the 19.7-20.2 GHz band will be 10 dB lower to ensure EPFD regulations are met. Also, as noted in the "Service Area Description" of Schedule S, no beams will operate in the 17.7–17.8 GHz band in the United States. The beam "Service Area Descriptions" included in Schedule S reflect operations only outside the United States.

A2. PFD Compliance for Gateway Downlink Beams

Figures A1 through A3 show the maximum PFD produced by the satellite transmit downlink beams serving Kuiper System gateway earth stations.[17]

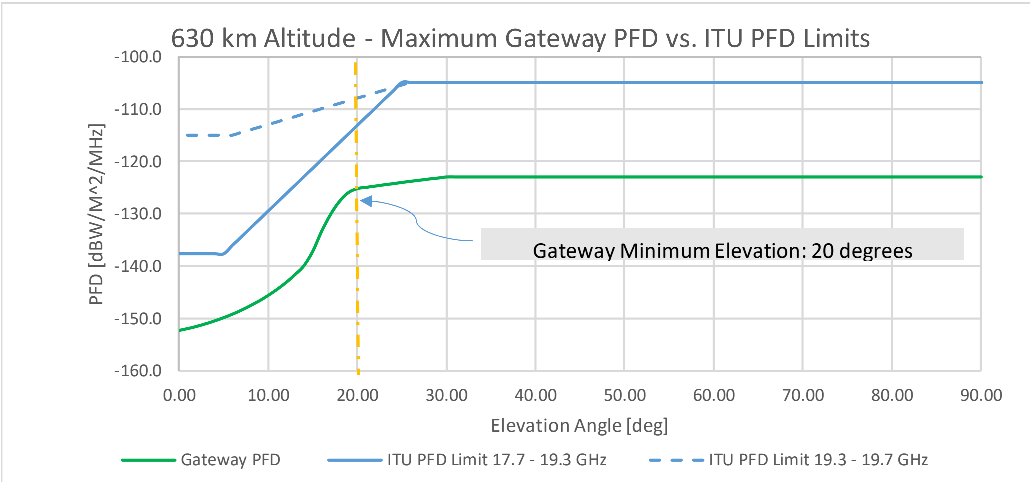

Figure A1. Maximum Downlink PFD from Gateway Beams from the 630 km Shell

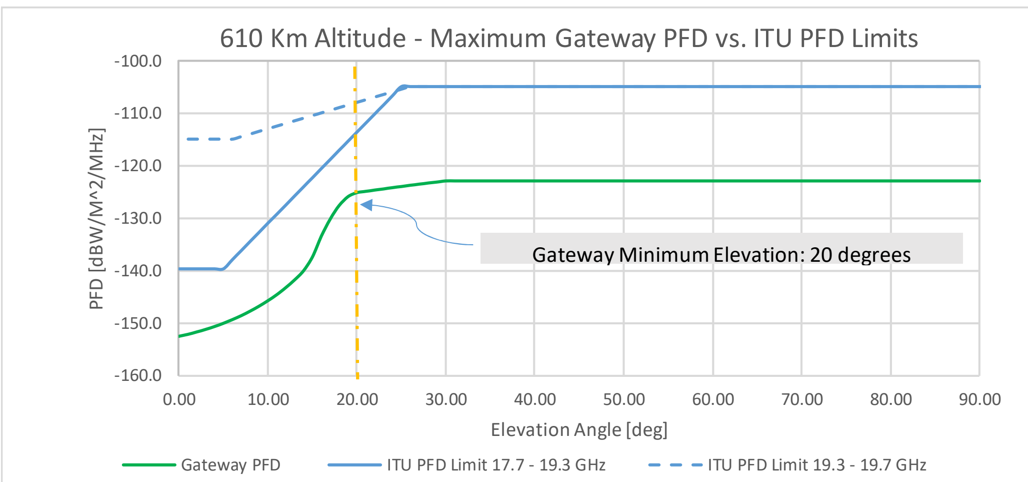

Figure A2. Maximum Downlink PFD from Gateway Beams from the 610 km Shell

[17] The PFD levels between 20˚ and 90˚ of elevation correspond to main beam transmissions and the PFD levels shown below 20˚ correspond to sidelobe antenna patterns of a beam pointing to 20˚.

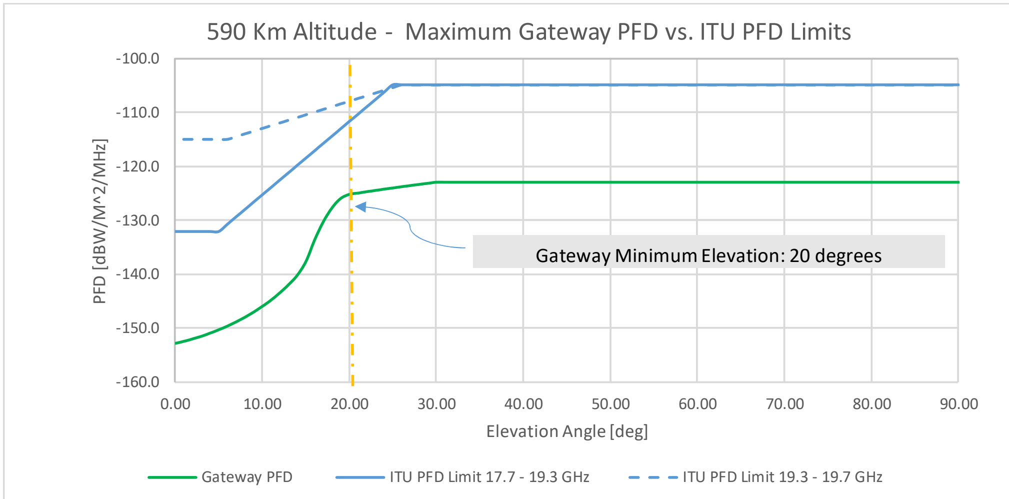

Figure A2. Maximum Downlink PFD from Gateway Beams from the 590 km Shell

The calculated maximum PFD levels of gateway beams (shown in green) are all well below the limits imposed by the ITU (shown in blue). These beams will operate with gateway earth station elevation angles down to 20˚ regardless of Kuiper satellite altitude. At gateway earth station elevation angles from 20˚ to 30˚, the PFD levels will decrease since each beam's transmit power is constant and the PFD decreases as a consequence of the increasing path loss. At gateway earth station elevation angles from 30˚ to 90˚, the beams maintain a constant PFD level of -123 dBW/m^2/MHz by adjusting the beam transmit power to compensate for differences in path loss as they are steered.

The transmit antenna pattern assumptions per beam are shown in Table A1. The assumed antenna pattern is more conservative than that suggested by ITU Recommendation S.672-4 and results in PFD levels well below the specified limits.

Gateway Transmit Antenna Radiation Pattern	
Off-Axis Angles [deg]	Gain Equation [dB]
0.0 - 2.92	G_{max} - $3(\theta/1.46)^2$
2.92 - 20.0	34 - 25Log10(θ)
20.0 - 180.0	1.5

Table A1. Assumed Satellite Gateway Antenna Pattern

A3. PFD Compliance for User Downlink Beams

Figures A4 through A6 show the maximum PFD produced by the transmit beams serving the Kuiper customer terminals.[18]

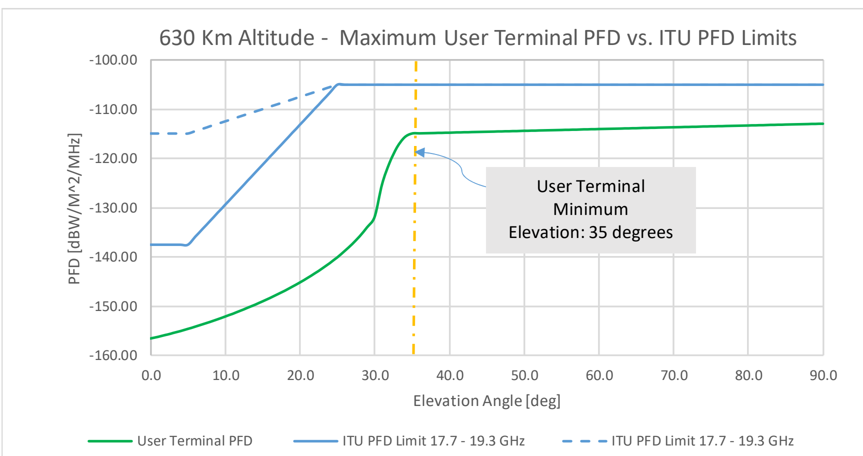

Figure A3. Maximum Downlink PFD from User Beams from the 630 km Shell

[18] The maximum PFD levels for customer terminal elevation angles between 35˚ and 90˚ correspond to main beam transmissions and the PFD levels shown below 35˚ correspond to sidelobe patterns of a customer terminal at a 35˚ elevation angle.

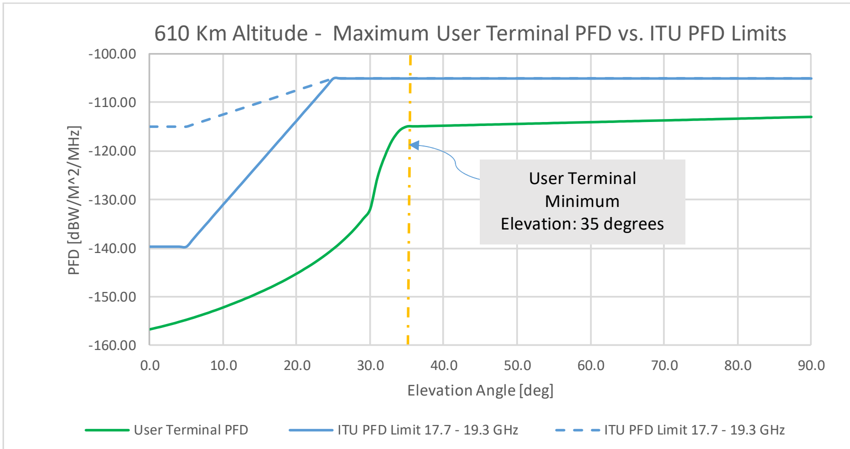

Figure A4. Maximum Downlink PFD from User Beams from the 610 km Shell

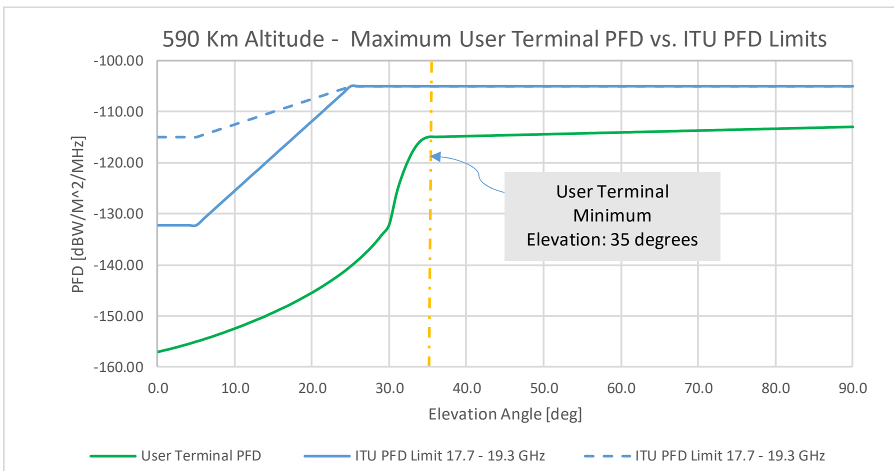

Figure A5. Maximum Downlink PFD from User Beams from the 590 km Shell

As shown, the calculated maximum PFD produced by user beams (shown in green) are all also well below the limits imposed by the ITU (shown in blue) for the17.7-19.3 GHz and 19.3-19.7 GHz bands. These beams will operate with customer terminals at a minimum elevation angle of 35˚ regardless of satellite altitude. The user downlink beam maintains a log-linearly decreasing PFD of -113 dBW/m^2/MHz at nadir to -115 dBW/m^2/MHz at 35˚customer terminal elevation angle. Since these beams are produced by phased array antennas, the transmit gain reduces as the antenna scans from nadir to the edge of coverage and the corresponding scan loss is assumed to be equal to cos^2 (beam scan angle). The transmit power levels of these beams continuously adjust to compensate for most losses due to antenna scan and the slant range path associated with the serving beam's scan angle.

The assumed transmit user beam antenna pattern assumptions are shown in Table A2.

User Link Antenna Pattern at Minimum Elevation Angle (35 degrees)	
Off-Axis Angles [deg]	**Gain Equation [dB]**
0.0 - 3.44	$G_{max} - 3(\theta/1.72)^2$
3.44 - 20.0	34 - 25Log10(θ)
20.0 - 180.0	1.5

Table A2. Assumed Satellite User Beam Antenna Pattern

A4. PFD Compliance for TT&C Downlink Beams

Figures A7 through A9 show the maximum PFD produced by the TT&C beams from satellites operating in the 630 km, 610 km, and 590 km shells, respectively.

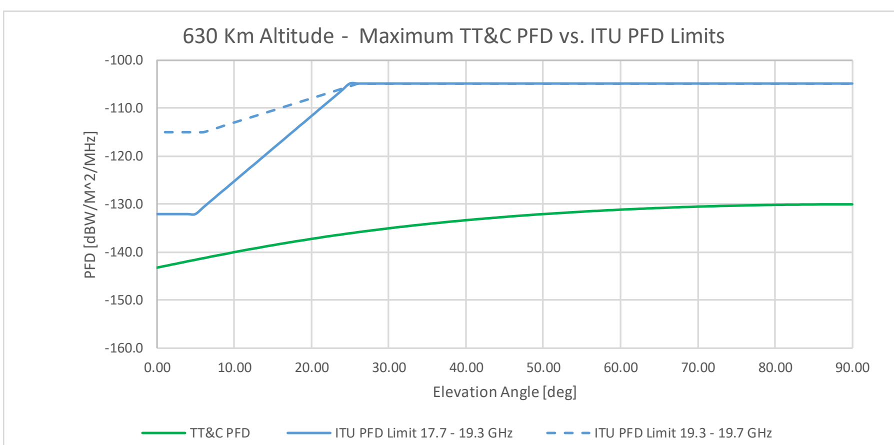

Figure A7. Maximum Downlink PFD from TT&C Beams from the 630 km Shell

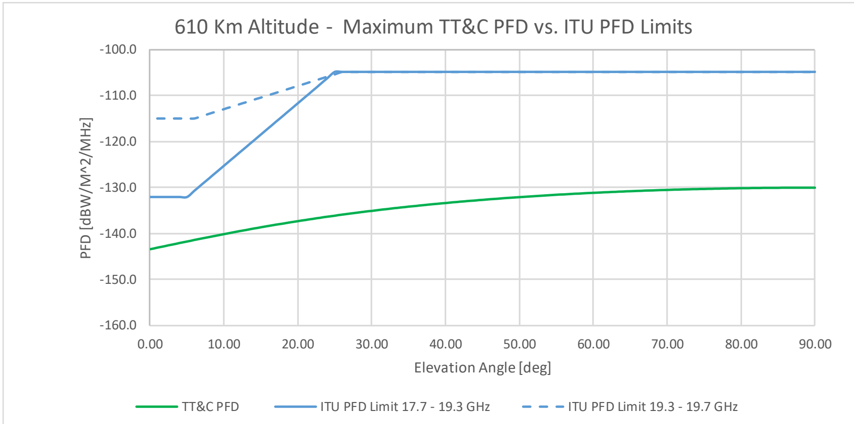

Figure A8. Maximum Downlink PFD from TT&C Beams from the 610 km Shell

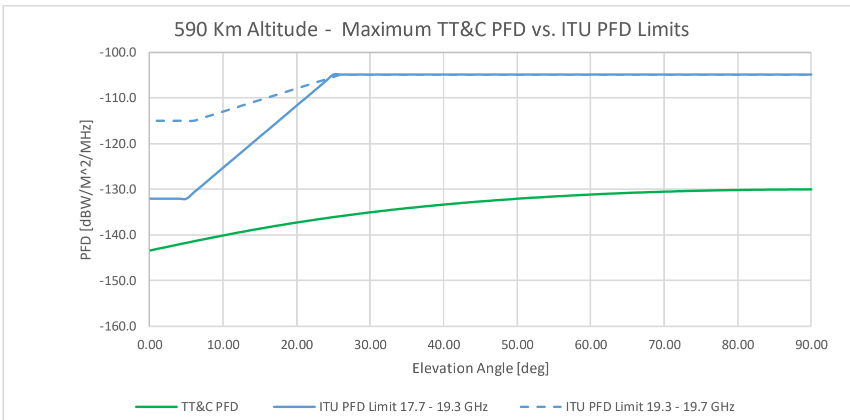

Figure A9. Maximum Downlink PFD from TT&C Beams from the 590 km Shell

As shown, the calculated maximum PFD levels produced by TT&C beams (shown in green) are well below the limits imposed by the ITU (shown in blue) in the 19.25-19.4 GHz band. These beams will operate with TT&C earth stations at a minimum elevation angle of 5˚ regardless of satellite altitude and produce a maximum EIRP density of -63.0 dBW/Hz; consequently, the PFD on the ground will not exceed -130 dBW/m^2/MHz. A conservative approach of assuming the maximum EIRP density for all angles of arrival has been made for the shown PFD levels. Even with these conservative assumptions, the transmitted PFDs satisfy the ITU PFD limits by a minimum margin of 10 dB.

ANNEX B. INTERFERENCE PROTECTION AND SHARING WITH CO-FREQUENCY GSO FSS SYSTEMS

The Kuiper System is fully compliant with the requirements in Article 22 of the ITU Radio Regulations and 47 CFR §25.146(c) of the Commissions' rules and will, therefore, adequately protect GSO FSS satellite networks operating in the Ka-band from harmful interference. The Kuiper System is also compliant with Resolution 85 (WRC-03) regarding aggregate EPFD in case the number of NGSO systems results in a measured aggregate EPFD level that exceeds the specified level in Resolution 85.

Kuiper System earth stations reduce EIRP density levels as their elevation angle increases and mute transmissions entirely within a specified angular range from the GSO arc[1] to minimize PFD levels towards GSO satellites. Likewise, the Kuiper System satellites will mute their transmission towards GSO earth stations within the same angular range to ensure EPFD compliance. The Kuiper System uses only one user beam in any one frequency channel to serve customers at any one geographical location (*i.e.,* Nco = 1) regardless of the number of satellites in view. The Kuiper System also limits the maximum number of co-frequency gateway beams to serve each gateway site to four (*i.e.,* Nco = 4).

As more satellites are deployed, the Kuiper System will employ logic to increase the GSO arc avoidance angle and to allocate gateway earth stations to Kuiper satellites that maintain compliance with EPFD levels. These operational concepts will apply throughout all stages of the constellation deployment. Gateway beam operations in the 18.8-19.7 GHz band will comply with the EPFD levels and operational concepts applicable to the 17.8-18.6 GHz band.

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[1] In this context, the angular separation or exclusion angle from the GSO arc is known as the α (alpha) angle.

The EPFD levels from satellites and earth stations based on the foregoing interference protection schemes for all three orbital shells of the Kuiper System constellation have been evaluated to assess compliance with the specifications in Tables 22-1B, 22-1C, 22-2, and 22-3 of Article 22 of the ITU Radio Regulations. A complete set of EPFD space radio communications stations ("SRS") databases, mask databases and results databases have been prepared and is being submitted to the ITU. For clarity and completeness of this application, some selected sample EPFD results, representing the worst-case interference conditions and geometry, have also been included in this report in Sections B1 to B3.

B1. EPFD Compliance for Downlink Operations

Kuiper System downlinks will be operated to protect GSO earth stations operating in FSS bands from harmful interference. This section details the methodology employed by the Kuiper System to manage interference into these earth stations and provides EPFD statistics for representative interference scenarios. As shown, the Kuiper System fully complies with all single-entry EPFD↓ validation limits stated in 47 CFR §25.146 and Article 22 of the ITU Radio Regulations.

The Kuiper System satellite constellation consists of three shells that will operate at altitudes of 630 km, 610 km, and 590 km. The deployment of these shells will be achieved in multiple phases. Downlink interference from satellites in each of the three shells in the Kuiper System into victim GSO earth station types has been evaluated, the worst-case geometries[2] have been defined, and the resulting EPFD↓ interference statistics have been calculated.

[2] Pursuant to the definition in Recommendation ITU-R S.1503-2, the worst-case geometry is a location of the GSO earth station and GSO satellite that analysis suggests would experience the highest single-entry EPFD values for the given inputs.

GSO earth station sizes and antenna patterns used in the EPFD calculations are those specified in Tables 22-1B and 22-1C of Article 22 of the ITU Radio Regulations. Specifically, Table 22-1B addresses EPFD↓ limits of interference into GSO earth stations operating in the 17.8-18.6 GHz band with aperture diameters of 1.0 m, 2.0 m, and 5.0 m. Table 22-1C addresses limits of interference into GSO earth stations operating in the 19.7-20.2 GHz band and contains EPFD↓ limits into four sizes of reference earth stations at 70 cm, 90 cm, 2.5 m, and 5.0 m. Because there are more than 50 EPFD scenario evaluations required by the ITU, in the interest of brevity, a complete set of EPFD results have been provided for the shell with the least EPFD margin thus requiring the use of the largest exclusion angle of 18°. Also included are the EPFD results from the satellites in the early deployment sequence into the worst-case victim GSO earth stations, highlighting the impact of αangle increases until the final α angle of 18° is reached.

As previewed previously, regardless of constellation deployment stage, the Kuiper System will be operated such that no more than a single user beam from a single satellite will ever simultaneously serve customer terminal in any one geographic location in the same frequency channel (*i.e.,* N_{co}=1). Likewise, the Kuiper gateway earth station locations will at most be serviced by four simultaneous, co-frequency satellite downlink beams (*i.e.,* $N_{co} = 4$). These beams can be produced by satellites from one or more shells, but the total number of beams will always be limited to four as shown in the gateway beams EPFD analysis.

By using an α angle (GSO arc avoidance), the Kuiper System avoids downlink transmissions into a GSO earth station's main beam and, therefore, benefits from sidelobe isolation. For user beams, the GSO exclusion angle α is 12° at all operational latitudes during the initial phase of constellation deployment. This allows maximum user coverage while still meeting the EPFD limits. In the second phase of constellation deployment, the α angle is increased to 15°

due to the increasing number of satellites in view and increasing coverage. Starting in the third phase of constellation deployment and beyond, the α angle is increased to 18˚ for downlink user beams.[3] See Figures B1 through B3.

The exclusion angle for the gateway beams will typically be 18˚ throughout all phases of constellation deployment.[4] The minimum elevation angle for the gateway earth stations is 20˚ at all latitudes. See Figures B4 through B6.

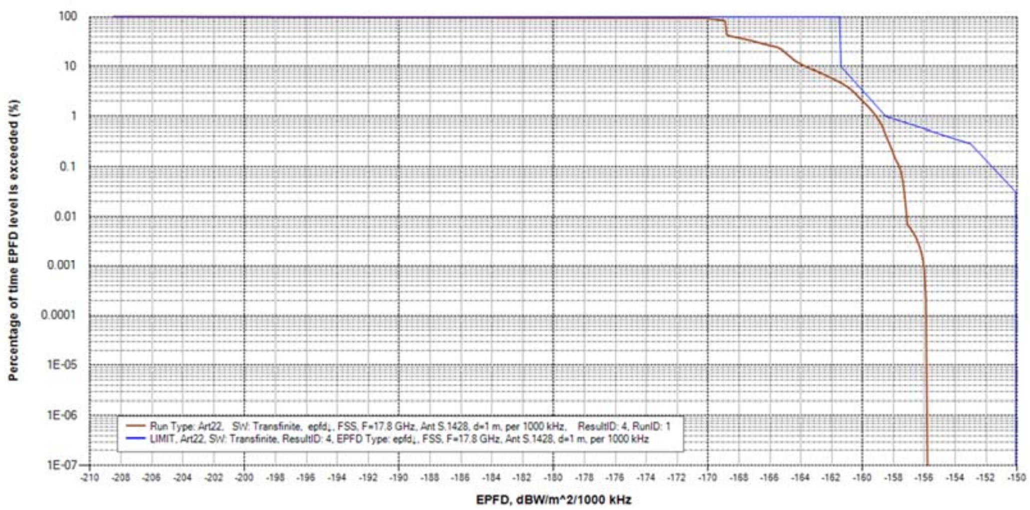

Figure B1. EPFD↓ Launch Phase 1, Freq=17.8 GHz, α=12˚, ES Diam=1.0 m

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[3] As noted, the Kuiper System limits the maximum number of user beams operating in any frequency band in any geographical location to one (*i.e.*, N_{co}=1), and limits the number of gateway beams to four (*i.e.*, N_{co} = 4).

[4] In some cases near the equator, gateway beams are operated with lower exclusion angles and reduced PFD to guarantee sufficient coverage while still meeting applicable EPFD limits.

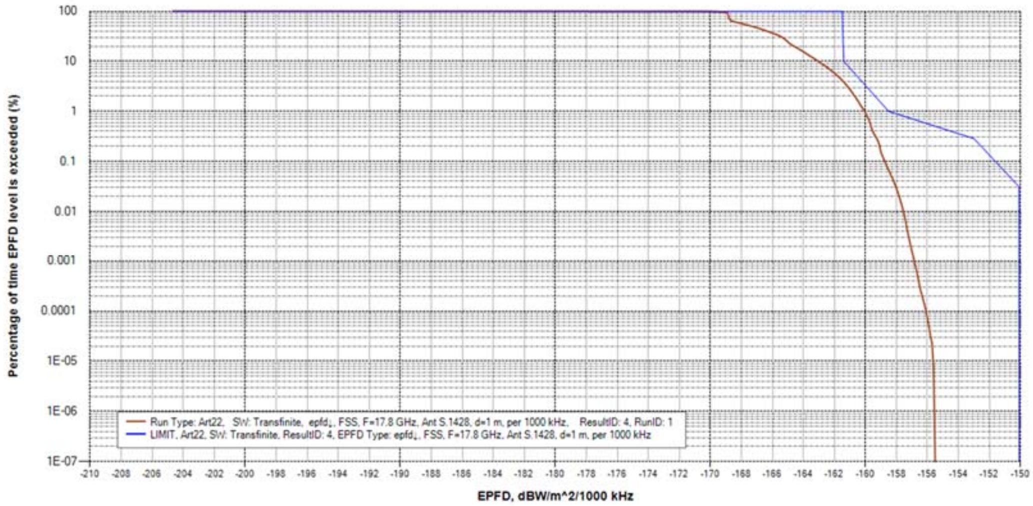

Figure B2. EPFD↓ Launch Phase 2, Freq=17.8 GHz, α=15˚, ES Diam=1.0 m

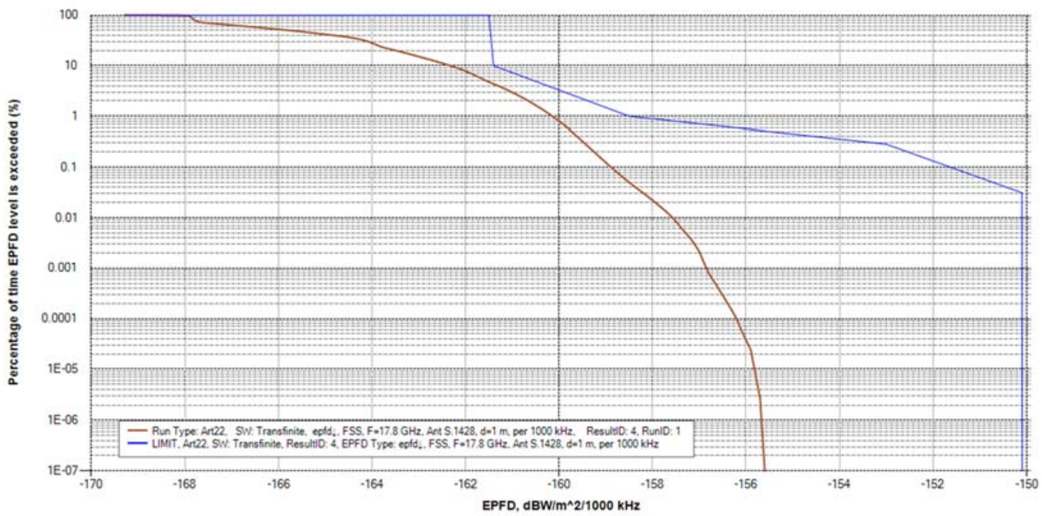

Figure B3. EPFD↓ Launch Phase 3, Freq=17.8 GHz, α=18˚, ES Diam=1.0 m

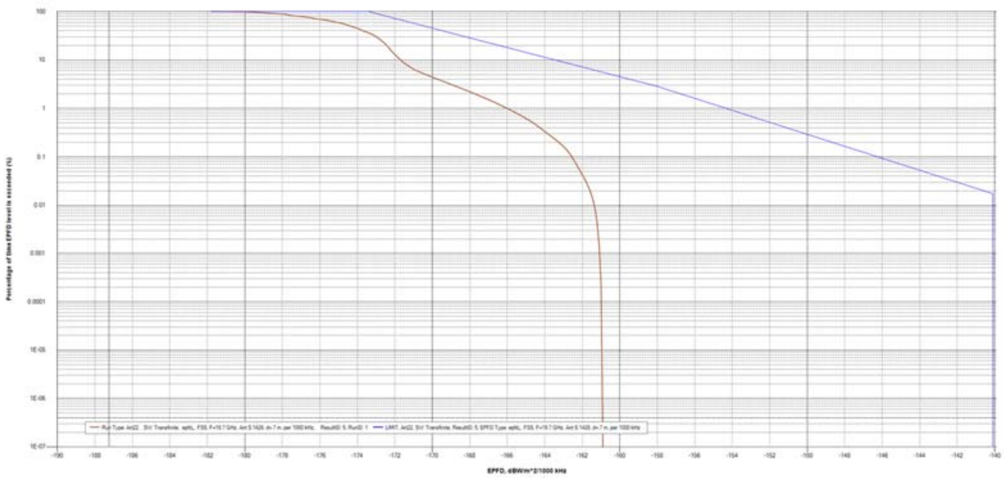

Figure B4. EPFD↓ Launch Phase 1, Freq=19.7 GHz, α=18˚, ES Diam=0.7 m

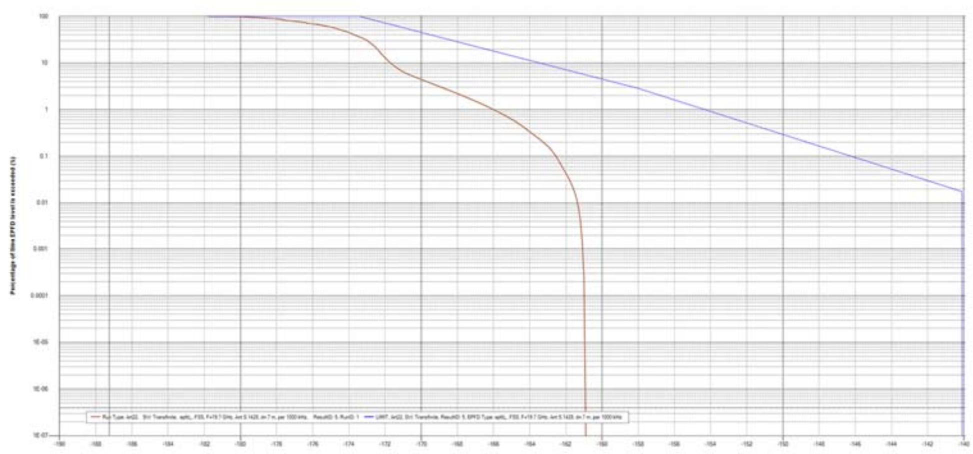

Figure B5. EPFD↓ Launch Phase 2, Freq=19.7 GHz, α=18˚, ES Diam=0.7 m

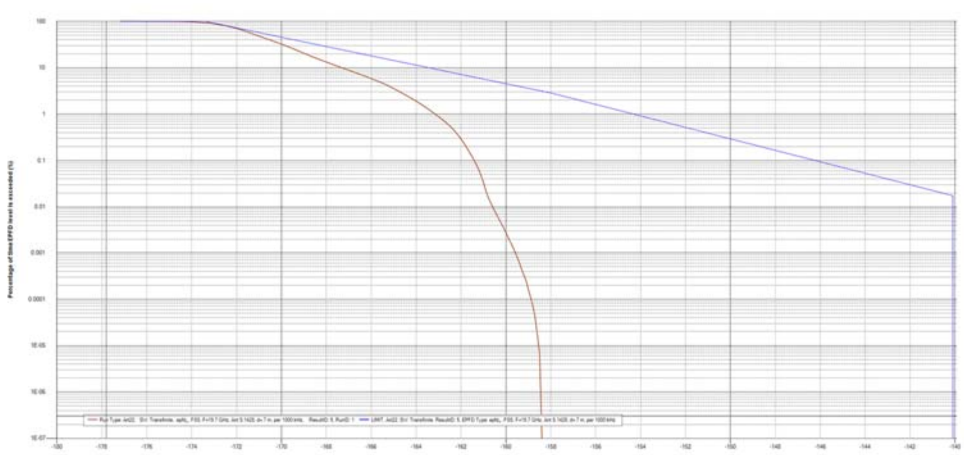

Figure B6. EPFD↓ Launch Phase 3, Freq=19.7 GHz, α=18˚, ES Diam=0.7 m

The EPFD↓ data for the fully deployed 610 km shell (containing the most Kuiper satellites) operated with α = 18° is illustrated in Figures B7 through B14.

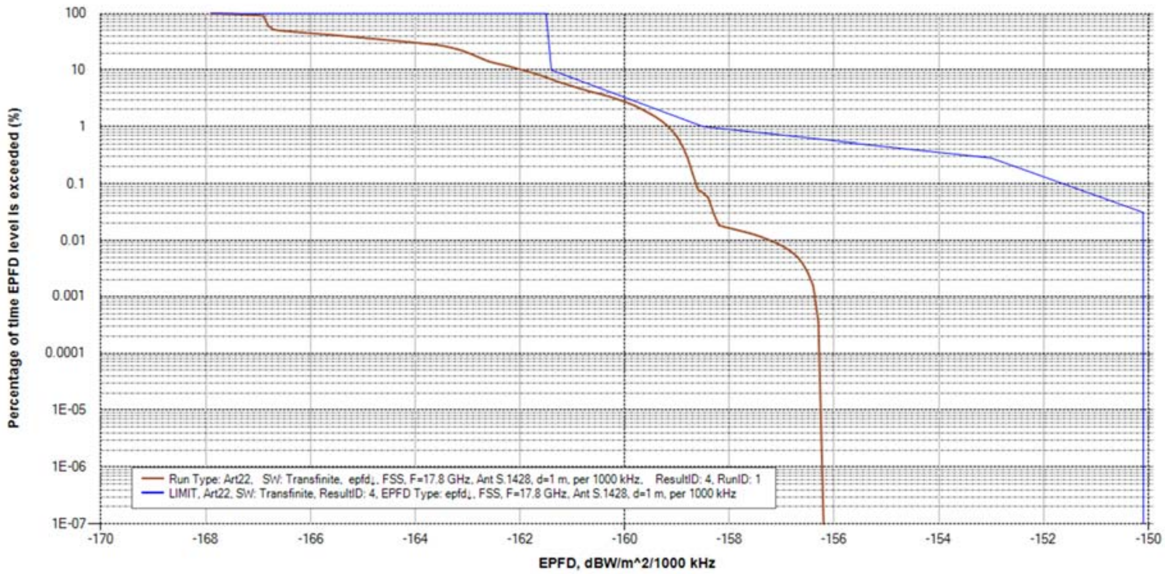

Figure B7. EPFD↓ Fully Deployed Shell 2, Freq=17.8 GHz, α=18° ES Diam=1.0 m

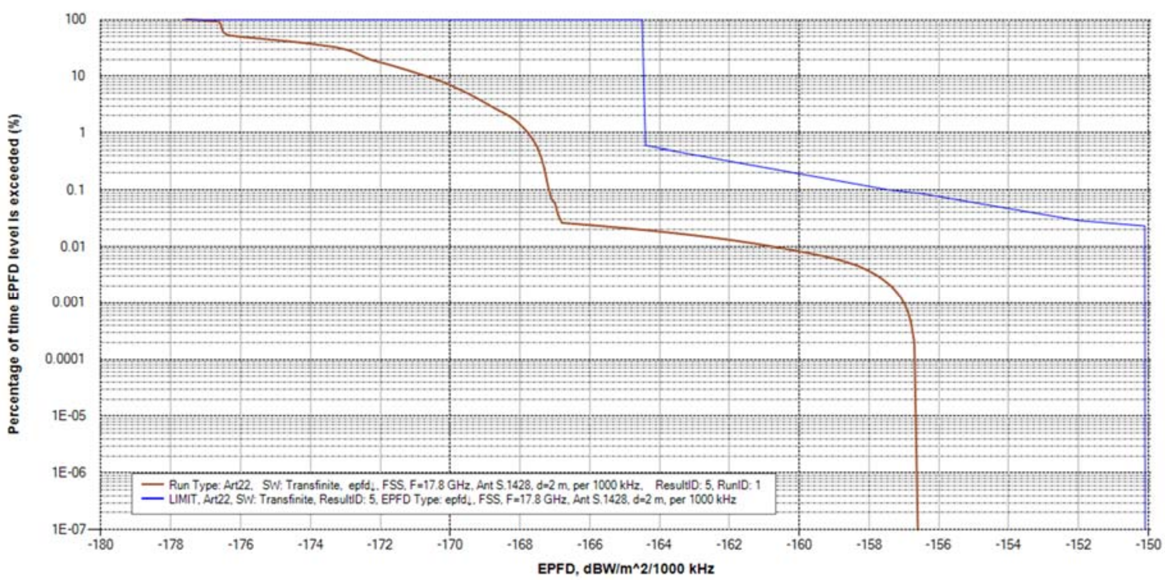

Figure B8. EPFD↓ Fully Deployed Shell 2, Freq=17.8 GHz, α=18°, ES Diam=2.0 m

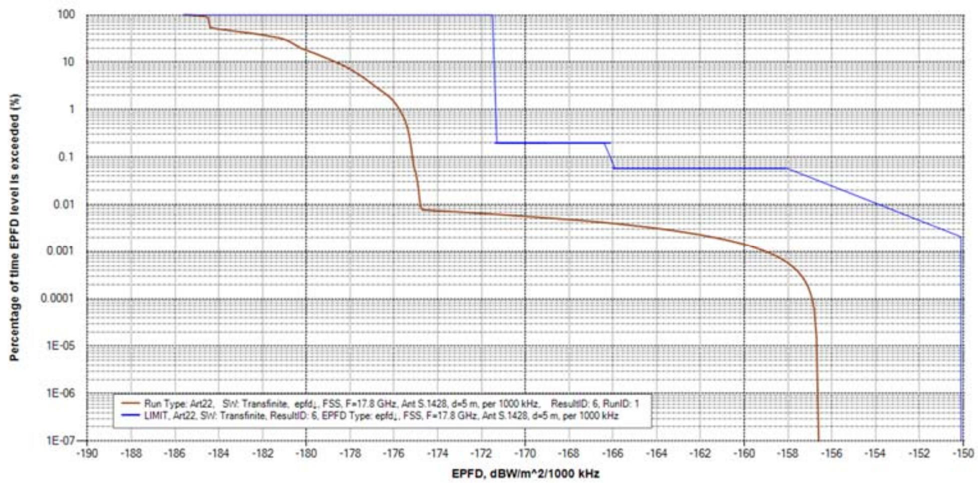

Figure B9. EPFD↓ Fully Deployed Shell 2, Freq=17.8 GHz, α=18˚, ES Diam=5.0 m

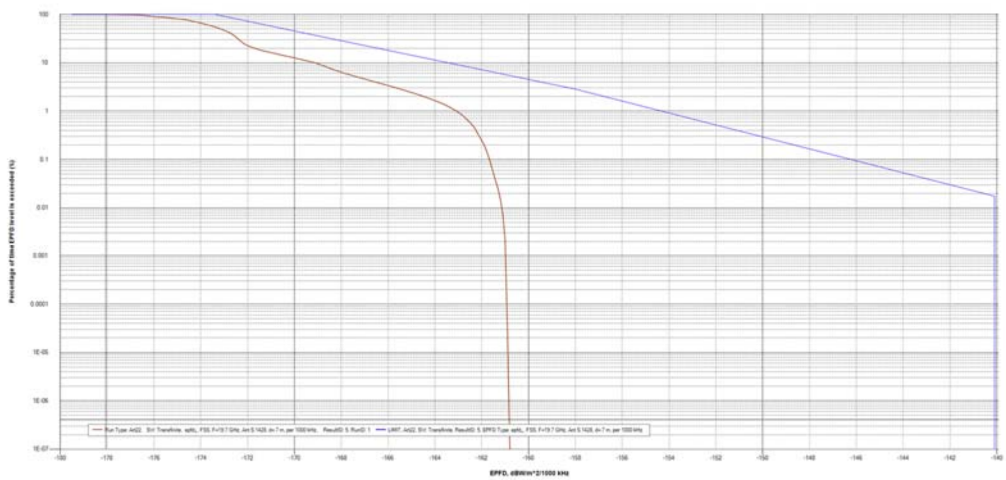

Figure B10. EPFD↓ Fully Deployed Shell 2, Freq=19.7 GHz, α=18˚, ES Diam=0.7 m

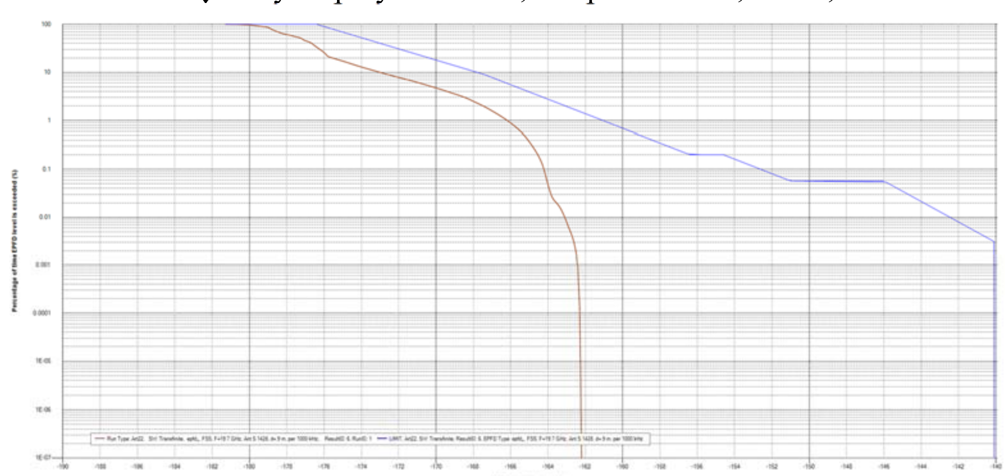

Figure B11. EPFD↓ Fully Deployed Shell 2, Freq=19.7 GHz, α=18˚, ES Diam=0.9 m

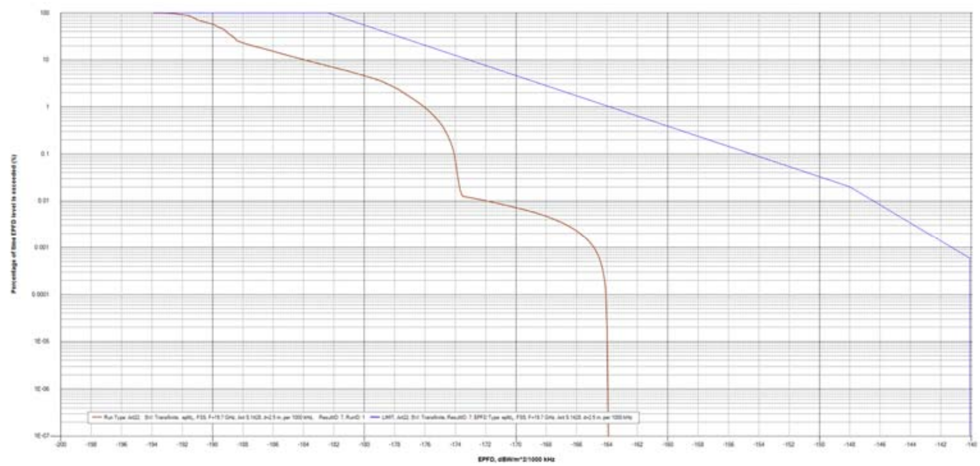

Figure B12. EPFD↓ Fully Deployed Shell 2, Freq=19.7 GHz, α=18˚, ES Diam=2.5 m

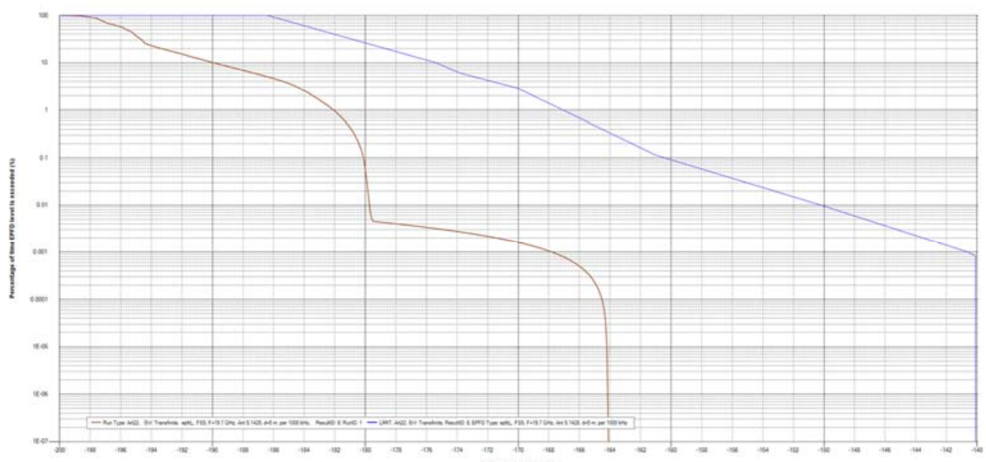

Figure B13. EPFD↓ Fully Deployed Shell 2, Freq=19.7 GHz, α=18˚, ES Diam=5.0 m

The foregoing EPFD↓ results reflect the anticipated operational configuration of the Kuiper System. Because Kuiper System satellites can adjust the transmit power levels of each beam according to the beam's scan angle, expected path loss, and antenna gain, they can compensate for any adjustment to operations to maintain compliance with EPFD↓ levels. To the extent necessary, updated EPFD↓ analyses for any alternative operational concepts, such as those in Annex A for PFD computations, will be developed and submitted to the ITU (and made available to the FCC) prior to service initiation.

B2. EPFD Compliance for Uplink Operations

The concept of operation for Kuiper System uplink beams is similar to that of the downlink beams. This section details the methodology employed by the Kuiper System to protect GSO satellites and provides EPFD statistics representing the worst-case interference scenarios. As shown, the Kuiper System fully complies with all single-entry EPFD↑ validation limits stated in 47 CFR §25.146(c) and Article 22 of the ITU Radio Regulations.

Transmit power towards GSO satellites from Kuiper System earth stations has been evaluated and the resulting EPFD↑ interference statistics have been calculated. The assumed GSO satellite antenna patterns in the EPFD calculations are specified in Tables 22-2 of Article 22 and are contained in Table B1.

Frequency Band	EPFD [dB(W/m2)]	% of time EPFD May not be Exceeded	Reference bandwidth [kHz]	Reference Antenna Beamwidth [deg]	Reference Antenna Radiation Pattern
27.5-28.6 GHz	-162	100	40	1.55°	S.672-4, Ls= −10
29.5-30 GHz	-162	100	40	1.55°	Recommendation ITU-R S.672-4, Ls= −10

Table B1. Uplink EPFD Calculations Assumption

The Kuiper uplink EPFD compliance techniques are similar to those used for downlink operations. For example, only one user beam will serve customers in any one geographic location in the same frequency band (*i.e.,* N_{co}=1). The uplink reuse is limited to a maximum use of the same channel once every 100 km (which translates into the use of the same frequency channel once per 10,000 km^2 in large areas).[5]

Similarly, because no more than four Kuiper gateway beams will serve a single gateway site (*i.e.,* N_{co} = 4), the uplink EPFD analysis assumes transmission from four gateway earth station

[5] Of course, multiple customers per beam will be provided access.

antennas pointed at four simultaneously operating co-channel Kuiper satellite beams and no more than four co-channel gateways will operate every 250 km.[6] Thus, there will never be more than four co-channel gateways in any 62,500 km^2 area.

EPFD compliance is also achieved through GSO arc avoidance, *i.e.*, observing an exclusion angle or α angle with respect to the Kuiper earth station's boresight angle, and that all emissions into GSO space stations are from earth station sidelobes. In the initial phase of constellation deployment, the GSO exclusion angle α for customer terminals (which operate at a 35˚ minimum elevation angle) is 12° at all operational latitudes. This α angle allows maximum user coverage while still meeting the EPFD limits. In the second phase of constellation deployment, due to the increasing number of satellites in view, the exclusion angle is increased to 15˚. Starting in the third phase of constellation deployment and beyond, the α angle is increased to 18˚ for all customer terminals. The impact on EPFD↑ from increasing the customer terminal α angle with the deployment of additional Kuiper satellites is shown in Figures B14 – B16.

The gateway EPFD↑ limits are met in all phases of constellation deployment by operating at an exclusion angle of 6˚.[7] Because there is no difference in the exclusion angle between the three phases, the EPFD↑ from the gateways to the three fully deployed orbital shells instead is shown in figures B17 – B19. All the gateway EPFD satisfy the ITU PFD limits by a minimum margin of 11 dB.

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[6] There are circumstances in which the distance between co-channel gateways may be smaller, *e.g.*, to take advantage of site diversity to provide greater availability.

[7] The gateway uplink EPFD analysis uses 6˚ everywhere because the uplink simulation permits only a single α angle to be chosen for all latitude ranges. Amazon has chosen the 6˚ as the lowest (worst-case) α angle.

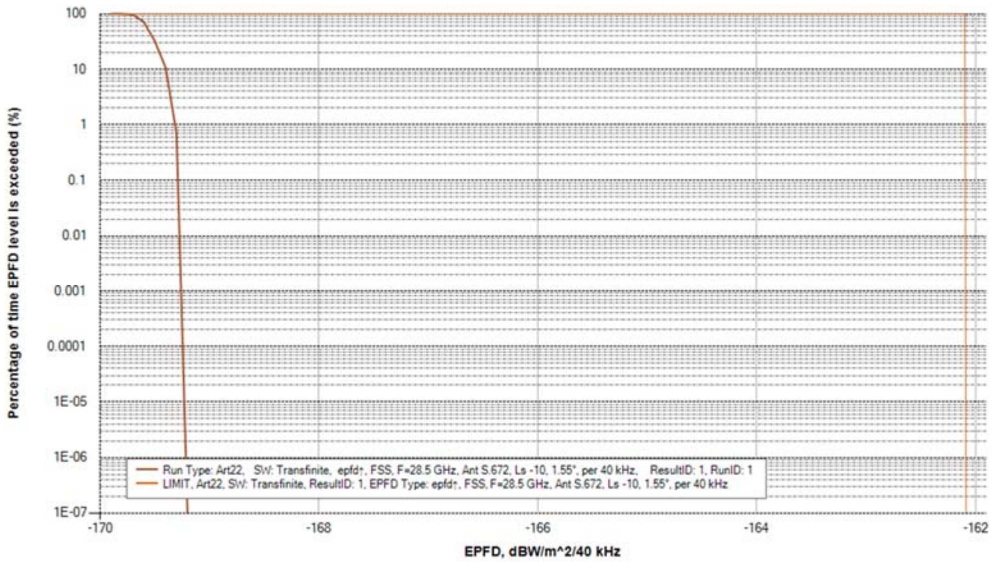

Figure B14. EPFD↑ – Launch Phase 1: Customer Terminals

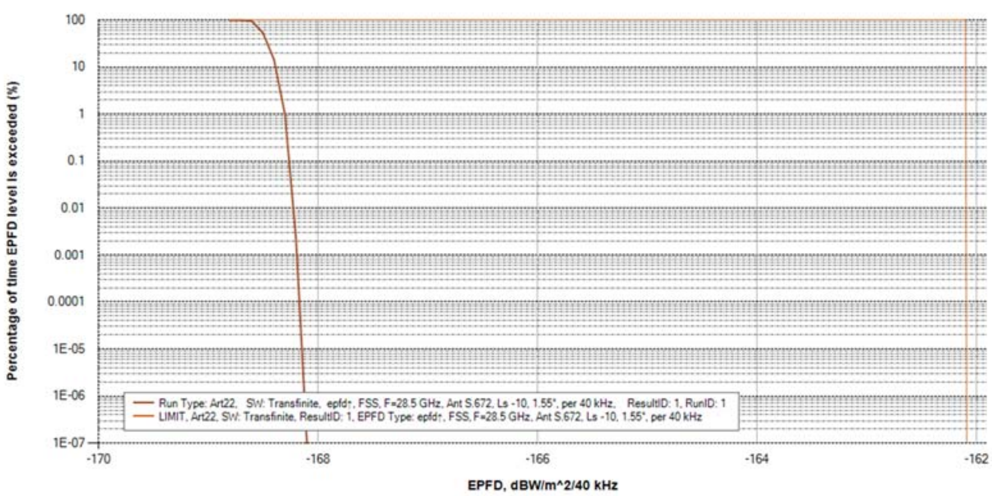

Figure B15. EPFD↑– Launch Phase 2: Customer Terminals

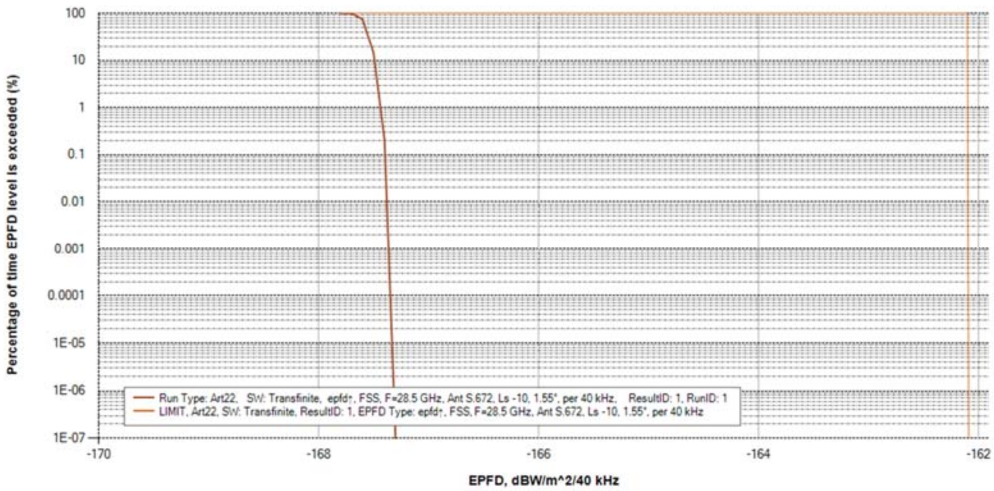

Figure B16. EPFD↑ – Launch Phase 3: Customer Terminals

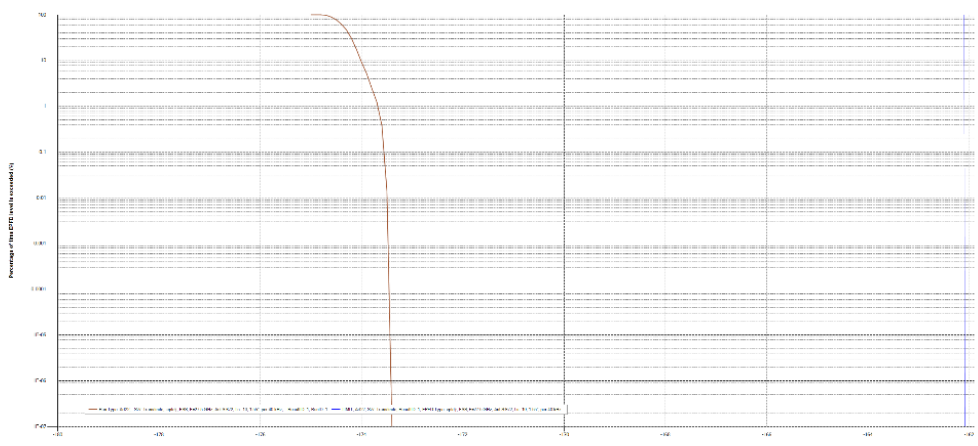

Figure B17. EPFD↑ – Fully Deployed 630 km Shell Gateway Antennas

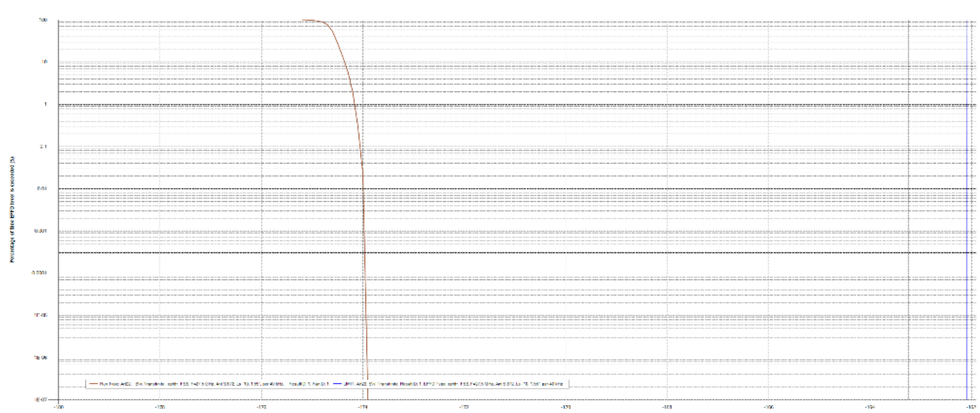

Figure B18. EPFD↑ – Fully Deployed 610 km Shell Gateway Antennas

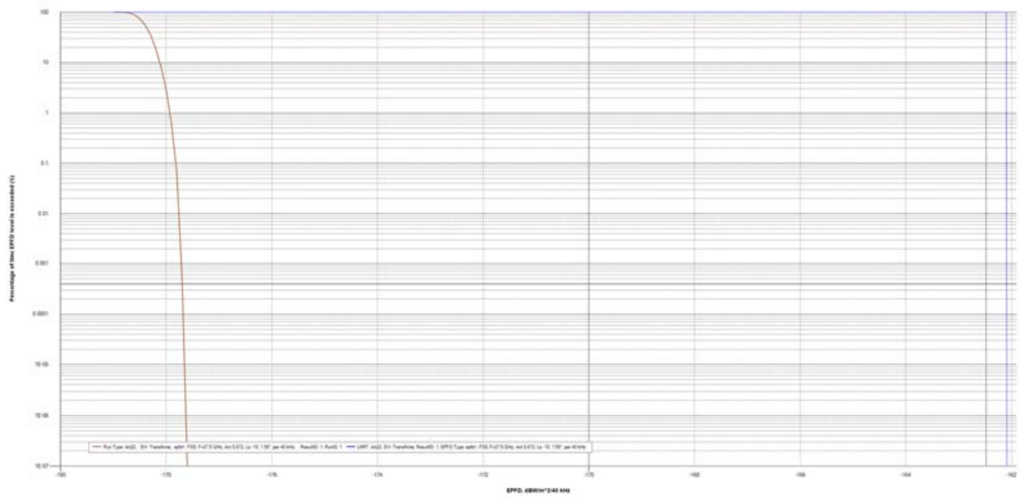

Figure B19. EPFD↑ – Fully Deployed 590 km Shell Gateway Antennas

The foregoing EPFD↑ results reflect the anticipated operational configuration of the Kuiper System. Future adjustments to operational concepts may involve trades such as EIRP density for earth station density to optimize service delivery while maintaining compliance with EPFD↑ levels. To the extent necessary, updated EPFD↑ analyses for any alternative operational concepts will be proposed and submitted to the ITU (and made available to the FCC) prior to service initiation.

B3. Compliance with Inter-Satellite EPFD Limits

The ITU has adopted EPFD limits to protect GSO space station receivers operating in the 17.8-18.4 GHz band from interference due to NGSO satellite downlink operations (“$EPFD_{is}$”). These limits are specified in Table 22-3 of Article 22 of the ITU Radio Regulations, and the Kuiper System fully complies with the limits. $EPFD_{is}$ from Kuiper System downlink transmissions from satellites in each of the three shells has been evaluated and the resulting $EPFD_{is}$ interference statistics have been calculated.

The computed $EPFD_{is}$ accounts for the contribution of emissions from all co-frequency satellite downlink (user and gateway) beams within radio line of sight of any given GSO space station. These emissions are based on a conservative estimate of blockage of satellite antennas and the specified downlink emission levels. The remainder of applicable assumptions are from Table 22-3 and are shown in Table B2.

Table B2. Limits to the $EPFD_{is}$ is Radiated by NGSO Satellite Systems

Frequency Band	EPFD [dB(W/m2)]	% of time EPFD May not be Exceeded	Reference bandwidth [kHz]	Reference Antenna Beamwidth [deg]	Reference Antenna Radiation Pattern
17.8-18.4 GHz	-160	100	40	4°	Recommendation ITU-R S.672-4, Ls= −20

Selected interference statistics from the ITU filings that represent the worst case $EPFD_{is}$ interference scenarios, *i.e.*, interference from each fully deployed shell, are shown in Figures B20 through B22.

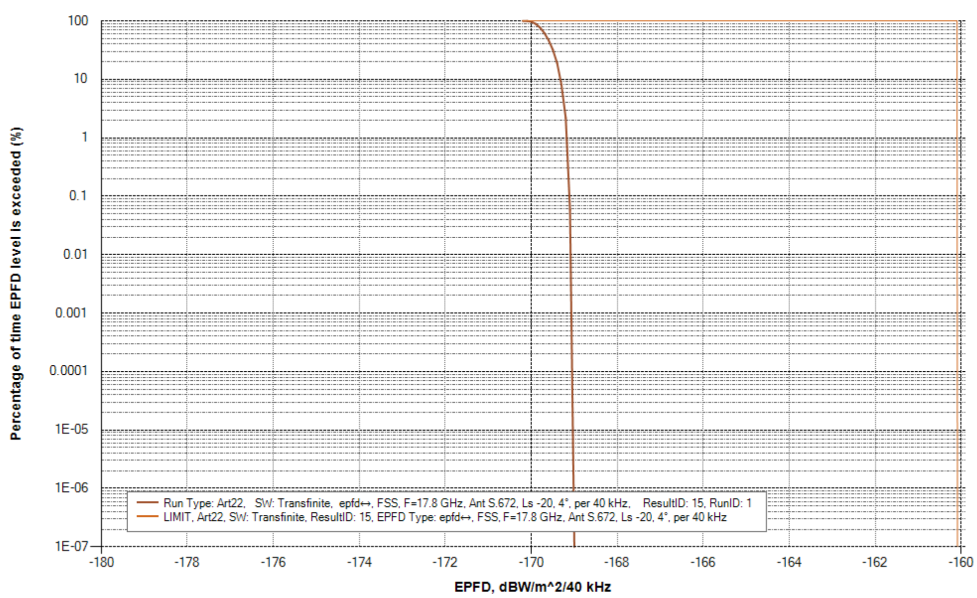

Figure B20. $EPFD_{is}$ is Due to Fully Deployed 630 km Shell

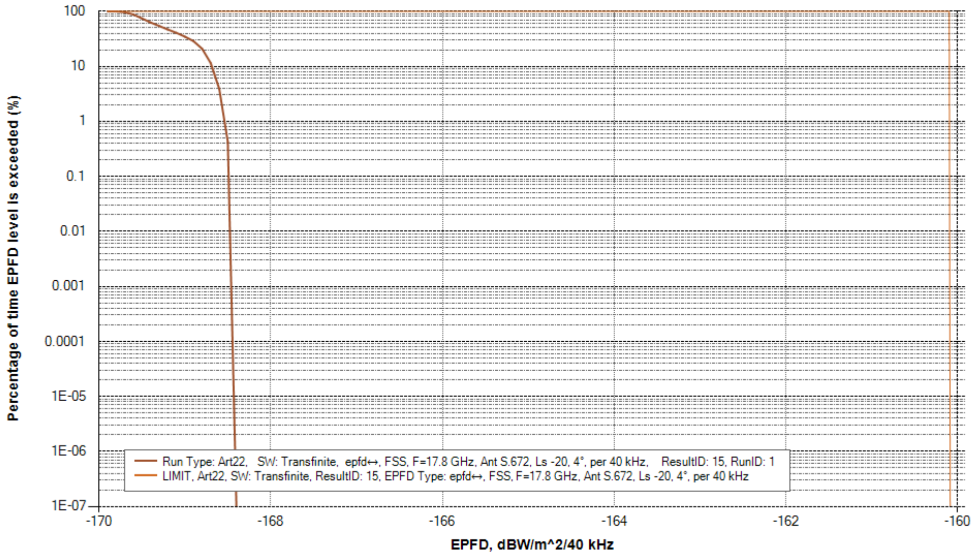

Figure B21. $EPFD_{is}$ is Due to Fully Deployed 610 km Shell

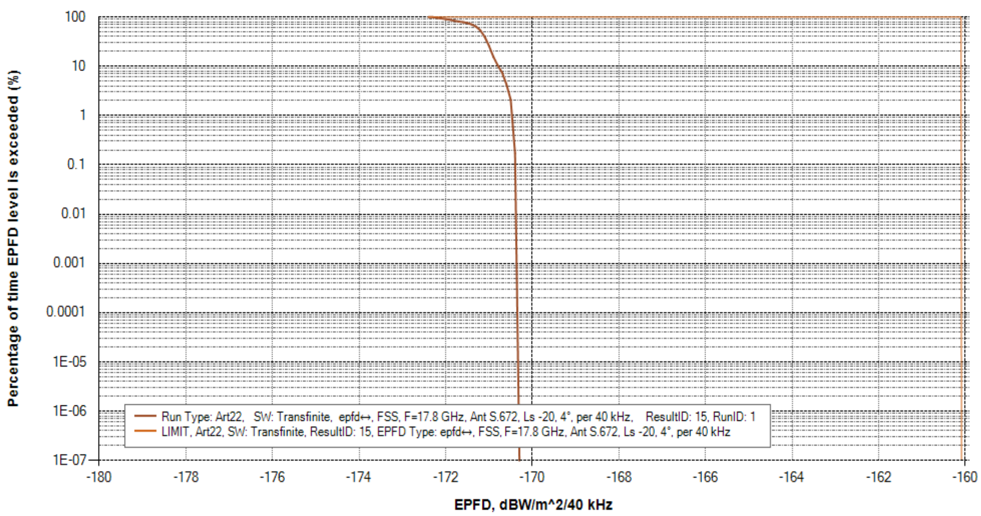

Figure B22. $EPFD_{is}$ is Due to Fully Deployed 590 km Shell

ANNEX C. SPECTRUM SHARING WITH CO-FREQUENCY NGSO SYSTEMS

In this Annex, Amazon highlights the Kuiper System's ability to share spectrum with co-frequency NGSO systems and to operate pursuant to Section 25.261 of the Commission's rules. Specifically, this Annex examines the following issues:

1. The spectrum access and sharing regime established by Section 25.261.
2. The spectrum sharing capabilities of the Kuiper System.
3. Ka-band NGSO FSS coordination and spectrum sharing considerations under Section 25.261.
4. Implications of authorizing the Kuiper System to operate pursuant to Section 25.261.
5. Interference protection and spectrum sharing considerations regarding MSS feeder links in the 19.3-19.7 GHz and 29.1-29.5 GHz bands.

C1. Section 25.261 Spectrum Access and Sharing Regime

Section 25.261 of the Commission's rules essentially provides that: (i) NGSO FSS operators must coordinate in good faith the use of commonly authorized frequencies; and (ii) absent coordination, whenever the increase in system noise temperature exceeds 6% ΔT/T in a commonly authorized frequency band, such frequency band must be divided among the affected satellite systems.[1] In the *NGSO FSS Order*, the Commission concluded that new NGSO system applicants could be permitted to operate pursuant to Section 25.261, subject to a case-by-case analysis "based on the situation at the time, and considering both the need to protect existing

[1] 47 C.F.R. §25.261. This default procedure also includes a provision for frequency band selection based on the launch date of the initial satellite in an authorized NGSO system. *See* 47 C.F.R. §25.261(c)(1) ("The selection order for each satellite network will be determined by the date that the first space station in each satellite system is launched and capable of operating in the frequency band under consideration…").

expectations and investments and provide for additional entry as well as any comments filed by incumbent operators and reasoning presented by the new applicant."[2]

C2. Ka-band NGSO FSS Spectrum Sharing Capabilities

The Kuiper System is designed to facilitate coordination and spectrum sharing on par with other Ka-band NGSO FSS systems. Through the use of small spot beams, satellite diversity, and flexible network control functionality, the Kuiper System is able to avoid inline interference events where necessary through good faith coordination, including changing the satellite serving a particular location (possible with overlapping satellite coverage areas), dynamic channel reassignment, and spectrum sub-channelization. Figures C1 and C2, below, depict a notional user beam projection area relative to coverage area for a single Kuiper satellite.[3]

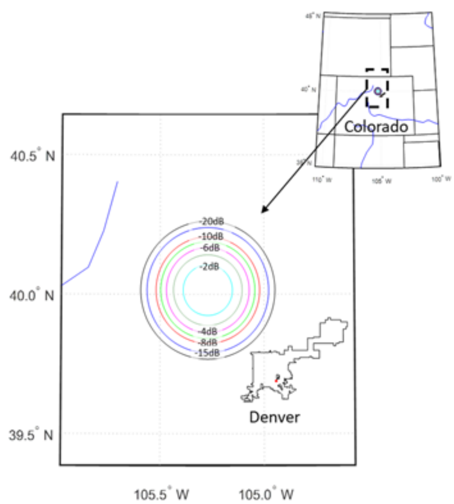

Figure C1. User Beam Gain Contour (Nadir)

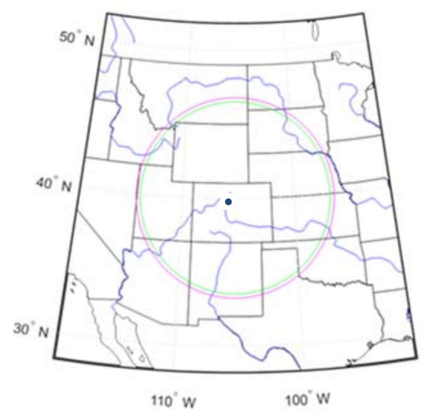

Figure C2. Coverage Area for a User Beam

[2] *See Update to Parts 2 and 25 Concerning Non-Geostationary, Fixed-Satellite Service Systems and Related Matters*, Report and Order and Further Notice of Proposed Rulemaking, 32 FCC Rcd 7809, ¶ 61 (2017) ("*NGSO FSS Order*").

[3] The use of small spot beams throughout a large coverage area significantly reduces the potential for interference into and from the Kuiper System given the potential for geographic and frequency diversity, as well as a larger number of possible transmission paths that may afford angular separation from NGSO systems operating at different orbit altitudes.

The Kuiper System will also employ a constellation design that affords overlapping coverage from multiple satellites. This satellite diversity will enable Amazon and other Ka-band NGSO system operators, through coordination, to employ algorithms that reduce the number of inline interference events through selection of an alternative satellite. Figure C3 identifies the number of satellites in view by latitude in the United States.

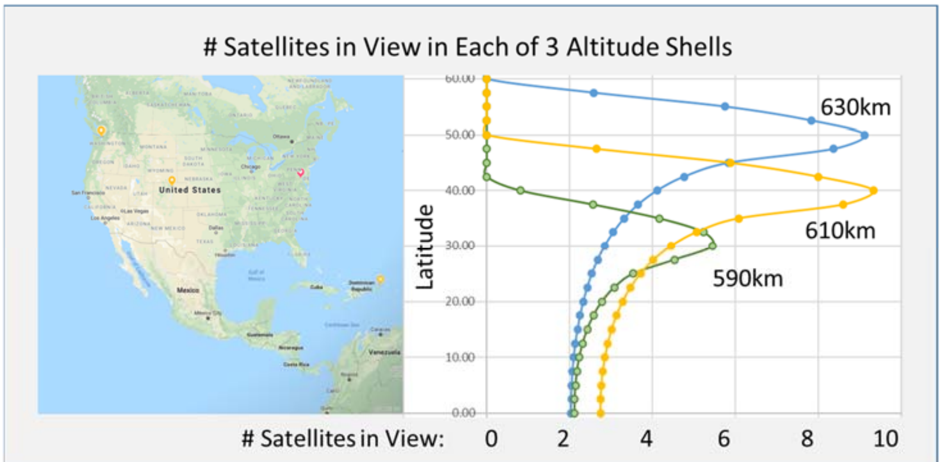

Figure C3. Satellites in View in the United States with Three Orbital Shells

In appropriate circumstances, the Kuiper System is capable of reassigning the channel used in that user beam (i.e., change the frequencies or "color" in the figure above) transmitted from an aligned satellite to address frequency overlap with another system.

Figure C4 depicts the Kuiper System's user beam and three-color frequency reuse pattern.

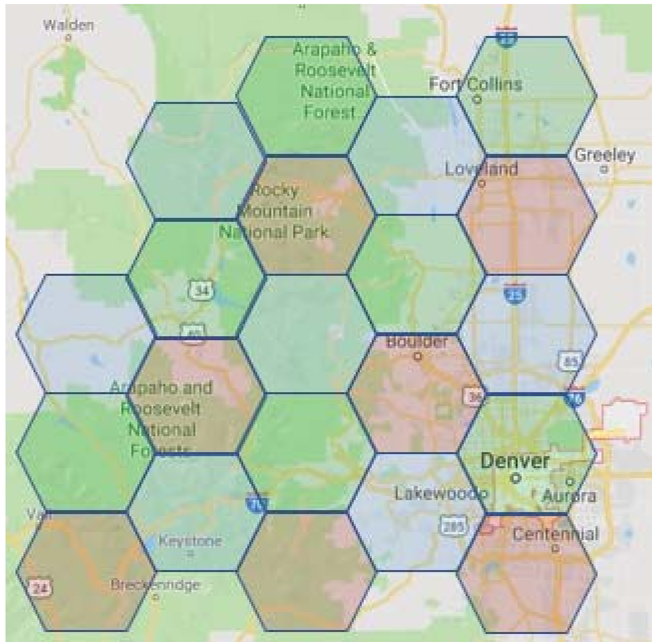

Figure C4. Representative User Beam and 3-Color Frequency Reuse

The Kuiper System's ability to dynamically sub-channelize its user beam channels also will enable Amazon to share spectrum with other NGSO systems. All other authorized Ka-band NGSO FSS systems must comply with Section 25.261.[4] Although their system characteristics and spectrum sharing techniques may be different, Ka-band NGSO systems authorized pursuant to this provision must abide by its basic spectrum access and sharing principles: good faith coordination or, absent coordination, spectrum splitting pursuant to the rule's default procedure.[5] Amazon looks forward to working with system operators via good faith coordination, information exchange, and

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4 *See, e.g.*, *Audacy Corporation Application for Authority to Launch and Operate a Non-Geostationary Medium Earth Orbit Satellite System in the Fixed- and Inter-Satellite Services*, Order and Authorization, 33 FCC Rcd 5554, ¶ 31 (2018) ("…we include a condition requiring Audacy, like all other NGSO FSS operators, to comply with the spectrum sharing requirements specified in Section 25.261.")

5 To facilitate compatible operation of NGSO FSS constellations, operators also must ensure that ephemeris data regarding their constellation is available to all authorized, co-frequency satellite operators in a manner that is mutually acceptable to the parties. *See NGSO FSS Order*, ¶¶ 57-58.

otherwise to ensure compatible operations and maximize the use of Ka-band spectrum and orbital resources.

Four elements must be present to experience an actual inline interference event: (i) geometric alignment of satellites, which can be evaluated using the orbital characteristics and number of satellites in authorized NGSO systems (but consideration of this factor alone leads to many false positives); (ii) aligned satellites from involved systems operating co-frequency;[6] (iii) aligned satellites operating at the same time;[7] and (iv) geographic proximity of the earth stations communicating with the aligned satellites.[8] These considerations could be addressed through information sharing or by employing alternative sharing mechanisms, including use of a higher $\Delta T/T$ threshold or a β (beta) angle between NGSO satellites (an avoidance/separation angle similar to the α angle for GSO arc avoidance). These and other approaches can facilitate good faith coordination among Ka-band NGSO system operators.

Additionally, given satellite power resources, planned frequency reuse, beam sizes, and coverage areas, Amazon estimates that a single Ka-band NGSO satellite can operate in all available spectrum in less than 1% of its total coverage area. Given the small percentage of potential spectrum use at any point in time within an individual satellite's coverage area, the potential for

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[6] Because many authorized systems use emissions bandwidths smaller than the entire authorized band in each direction of transmission, it is possible that there will be no frequency overlap during an alignment event. Even with frequency overlap, systems operating with different polarizations may not experience harmful interference.

[7] It is possible that the satellites or earth station may not be operating simultaneously on the same frequencies depending on service application or other factors. For example, applications with buffering and intermittent transmission requirements may not operate at all during a temporary alignment event.

[8] If the earth stations are sufficiently separated, it is possible there will be no beam overlap or sufficient angular separation of the transmission paths to permit co-frequency operation.

co-frequency, contemporaneous operations to a specific geographic location during a satellite alignment event is extraordinarily low.[9]

The Commission adopted a default procedure, absent coordination, for dividing authorized spectrum among systems involved in an interference event:

> (1) Each of n (number of) satellite networks involved must select 1/n of the assigned spectrum available in each of these frequency bands. The selection order for each satellite network will be determined by the date that the first space station in each satellite system is launched and capable of operating in the frequency band under consideration;
>
> (2) The affected station(s) of the respective satellite systems may operate in only the selected (1/n) spectrum associated with its satellite system while the $\Delta T/T$ of 6 percent threshold is exceeded;
>
> (3) All affected station(s) may resume operations throughout the assigned frequency bands once the threshold is no longer exceeded.[10]

The Commission also adopted a specific order of spectrum selection based on satellite launch date because "this approach provides the proper incentive to bring spectrum into use while adequately protecting all systems from interference."[11]

C3. Authorizing the Kuiper System to Operate Pursuant to Section 25.261

In addition to the significant public interest benefits of granting Amazon's application to operate a Ka-band NGSO FSS system discussed in the Legal Narrative, there are specific benefits

[9] Amazon has conducted extensive NGSO system compatibility simulations and believes real inline interference events would occur only a small fraction of the time. The potential for multi-system alignments involving more than two NGSO systems is even more remote.

[10] 47 CFR § 25.261(c).

[11] *See The Establishment of Policies and Service Rules for the Non-Geostationary Satellite Orbit, Fixed Satellite Service in the Ka-band,* Report and Order, 18 FCC Rcd 14708, ¶ 25 (2003) ("*Ka-band NGSO Order*"). There can be material benefits associated with choosing earlier in the spectrum selection process and that the Commission intended to confer those benefits to promote early system implementation. For example, for an NGSO system operating user links in only half of the authorized spectrum at a given location during an inline interference event, selecting first would ensure that no adjustment to its operations would be necessary.

associated with authorizing the Kuiper System under Section 25.261. Operating pursuant to the same spectrum access and coordination rules as other Ka-band NGSO systems will facilitate the earliest possible introduction of Kuiper System service. Amazon estimates, however, that the Kuiper System could lose a substantial portion of its initial geographic coverage and service expansion would slow dramatically if it is required to "protect" other systems rather than coordinate and operate under Section 25.261. This would unnecessarily delay the availability of new satellite-based broadband connectivity to unserved and underserved communities in the United States and worldwide. The Commission has indicated that its "treatment of later applicants to approved systems must necessarily be case-by-case based on the situation at the time, and considering both the need to protect existing expectations and investments and provide for additional entry as well as any comments filed by incumbent operators and reasoning presented by the new applicant."[12] Amazon submits that there would be no material adverse impact on the investment-backed expectations of previously approved NGSO systems for a number of reasons. Notably, at the time of license grant, all Ka-band NGSO system operators were aware that the spectrum access and sharing regime in Section 25.261 would be applied to them and potential new entrants subject to the Commission's case-by-case analysis. In addition, the number and duration of inline interference events may be limited and can be addressed through good faith coordination.[13] Finally, the impact of dividing authorized spectrum during intermittent, temporary inline events not resolved through good faith coordination also may be limited.[14]

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[12] *NGSO FSS Order*, ¶ 61.

[13] Actual inline interference between the Kuiper System and another NGSO Ka-band system that would require resolution via good faith coordination would occur an extremely small percentage of the time.

[14] In many cases, NGSO systems will use emissions that are smaller than the full authorized band, as well as adaptive coding and modulation ("ACM"), intermittent and temporary reduction in

C4. Interference Protection and Sharing with MSS Feeder Links in the 19.3-19.7 GHz and 29.1-29.5 GHz Bands

Iridium LCC is currently licensed and operating MSS feeder links in the 19.4-19.6 GHz downlink band and 29.1-29.3 GHz uplink band in support of their 66-satellite low earth orbit (LEO) constellation L-band MSS user links. Iridium operates only gateway sites to support its constellation in Tempe, Arizona; Oahu, Hawaii; Punta Arenas, Chile; Fairbanks, Alaska; and Svalbard, Norway. Only the gateway sites in Arizona, Hawaii and Chile are within the latitude range served by the Kuiper System. The Kuiper System gateway links will employ a combination of site diversity and angular avoidance of inline interference events to ensure protection of Iridium gateway links.

Both the Kuiper and the Iridium constellations employ high gain antennas with narrow beams on both their satellites and the gateway earth stations that employ the MSS feeder link spectrum. Consequently, gateway sites that are placed more than a few hundred km apart will benefit from sufficient antenna off-boresight isolation to assure that unacceptable levels of interference are avoided. As a first step, Kuiper will not collocate their gateway earth station sites with any existing or planned Iridium gateway earth station sites. Furthermore, any Kuiper gateway earth station sites that are placed within sufficient proximity of any Iridium gateway earth station site to produce occasional levels of unacceptable interference, will be operated to avoid co-frequency / co-polarization operations during any times when the potential for interference has been predicted. When an unavoidable inline interference event is predicted, the Kuiper System

potentially available spectrum may have no material impact on customers. Brief and intermittent spectrum constraints would not necessarily cause disruption of service given the adaptive nature of these networks and associated applications, and any associated throughput reductions would be managed like any others (*e.g.*, rain fade, network congestion, etc.) by the system.

will either reduce its EIRP in the appropriate bands/polarizations or temporarily cease transmissions in the applicable bands/polarizations for the duration of the inline interference event.

Special consideration will be provided for the Iridium TT&C links since satellite antenna discrimination is limited. Any Kuiper gateway sites that might be collocated or operate in proximity of an Iridium TT&C site will avoid the bands that Iridium employs for their TT&C operations. The Kuiper System intends to initiate discussion with Iridium to formalize the operating constraints.

ANNEX D. SCHEDULE S REFERENCES

D1. Beam Id

The following tables contain the Beam IDs for each antenna type as they appear in the associated Schedule S. The Beam IDs were named according to the following guidelines:

- Beam Id First Letter R/T --> Receive/Transit
- Beam Id Second Letter U/G/T --> User/Gateway/TT&C
- Beam Id Third Letter --> R/L --> Right/Left Polarization
- Beam Id Fourth Letter --> A through Z → Letter Identifier

User Downlink Beams	
500 km^2 Beam Coverage Area	300 km^2 Beam Coverage Area
37dBi TX Gain	39dBi TX Gain
-46 dBW Max EIRP Density	
TULA	TULG
TURA	TURG
TULB	TULH
TURB	TURH
TULC	TULI
TURC	TURI
TULD	TULJ
TURD	TURJ
TULE	TULK
TURE	TURK
TULF	TULL

Gateway Downlink Beams	
34.4dBi TX Gain	36.9dBi TX Gain
-56 dBW Max EIRP Density	
TGRA	TGRI
TGLA	TGLI
TGRB	TGRJ
TGLB	TGLJ
TGRC	TGRK
TGLC	TGLK
TGRD	TGRL
TGLD	TGLL
TGRE	TGRM
TGLE	TGLM
TGRF	TGRN
TGLF	TGLN
TGRG	TGRO
TGLG	TGLO
TGRH	TGRP
TGLH	TGLP

TT&C Downlink	TT&C Downlink
RHCP	LHCP
9 dBi Rx Gain	9 dBi Rx Gain
TTR1, TTR2	TTL1, TTL2

User Uplink Beams	
500 km^2 Beam Coverage Area	300 km^2 Beam Coverage Area
37dBi RX Gain	39dBi RX Gain
RURA	RURE
RULA	RULE
RURB	RURF
RULB	RULF
RURC	RURG
RULC	RULG
RURD	RURH
RULD	RULH

TT&C Uplink	TT&C Uplink
RHCP	LHCP
9 dBi Rx Gain	9 dBi Rx Gain
RTRA	RTLA

Gateway Uplink Beams	
38.2dBi RX Gain	40.7dBi RX Gain
RGRA	RGRH
RGLA	RGLH
RGRB	RGRI
RGLB	RGLI
RGRC	RGRJ
RGLC	RGLJ
RGRD	RGRK
RGLD	RGLK
RGRE	RGRL
RGLE	RGLL
RGRF	RGRM
RGLF	RGLM
RGRG	RGRN
RGLG	RGLN

D2. TT&C Channelization

D/L TT&C Channels			
LHCP Channel	RHCP Channel	Bandwidth [MHz]	Center Frequency [MHz]
TL01	TR01	50.0	19,275.0
TL02	TR02	20.0	19,290.0
TL03	TR03	10.0	19,295.0
TL04	TR04	5.0	19,297.5
TL05	TR05	1.0	19,299.5
TL06	TR06	50.0	19,325.0
TL07	TR07	20.0	19,310.0
TL08	TR08	10.0	19,305.0
TL09	TR09	5.0	19,302.5
TL10	TR10	1.0	19,300.5
TL11	TR11	50.0	19,375.0
TL12	TR12	20.0	19,390.0
TL13	TR13	10.0	19,395.0
TL14	TR14	5.0	19,397.5
TL15	TR15	1.0	19,399.5

U/L TT&C Channels			
LHCP Channel	RHCP Channel	Bandwidth [MHz]	Center Frequency [MHz]
TL41	TR41	50.0	27,525.0
TL42	TR42	20.0	27,510.0
TL43	TR43	10.0	27,505.0
TL44	TR44	5.0	27,502.5
TL45	TR45	1.0	27,500.5
TL46	TR46	50.0	27,975.0
TL47	TR47	20.0	27,990.0
TL48	TR48	10.0	27,995.0
TL49	TR49	5.0	27,997.5
TL50	TR50	1.0	27,999.5
TL51	TR51	50.0	28,025.0
TL52	TR52	20.0	28,010.0
TL53	TR53	10.0	28,005.0
TL54	TR54	5.0	28,002.5
TL55	TR55	1.0	28,000.5

D3. GIMS – Schedule S Cross Reference Table

GIMS Beam Name	Link	Antenna	Pattern	Antenna Size	Schedule S Beam Id
GLRXC63	Uplink	Gateway	Coverage	Large	RGR(H-N), RGL(H-N)
GLRXN63	Uplink	Gateway	Nadir	Large	RGR(H-N), RGL(H-N)
GLRXS63	Uplink	Gateway	Max Scan	Large	RGR(H-N), RGL(H-N)
GMRXC63	Uplink	Gateway	Coverage	Medium	RGR(A-G), RGL(A-G)
GMRXN63	Uplink	Gateway	Nadir	Medium	RGR(A-G), RGL(A-G)
GMRXS63	Uplink	Gateway	Max Scan	Medium	RGR(A-G), RGL(A-G)
ULRXC63	Uplink	User	Coverage	Large	RUL(E-H), RUR(E-H)
ULRXN63	Uplink	User	Nadir	Large	RUL(E-H), RUR(E-H)
ULRXS63	Uplink	User	Max Scan	Large	RUL(E-H), RUR(E-H)
UMRXC63	Uplink	User	Coverage	Medium	RUL(A-D), RUR(A-D)
UMRXN63	Uplink	User	Nadir	Medium	RUL(A-D), RUR(A-D)
UMRXS63	Uplink	User	Max Scan	Medium	RUL(A-D), RUR(A-D)
TTCRX63	Uplink	TT&C	Nadir	N/A	RTRA, RTLA
GLTXC63	Downlink	Gateway	Coverage	Large	TGR(I-P),TGL(I-P)
GLTXN63	Downlink	Gateway	Nadir	Large	TGR(I-P),TGL(I-P)
GLTTXS63	Downlink	Gateway	Max Scan	Large	TGR(I-P),TGL(I-P)
GMTXC63	Downlink	Gateway	Coverage	Medium	TGR(A-H), TGL(A-H)
GMTXN63	Downlink	Gateway	Nadir	Medium	TGR(A-H), TGL(A-H)
GMTXS63	Downlink	Gateway	Max Scan	Medium	TGR(A-H), TGL(A-H)
ULTXC63	Downlink	User	Coverage	Large	TUL(G-L), TUR(G-L)
ULTXN63	Downlink	User	Nadir	Large	TUL(G-L), TUR(G-L)
ULTXS63	Downlink	User	Max Scan	Large	TUL(G-L), TUR(G-L)
UMTXC63	Downlink	User	Coverage	Medium	TUL(A-F), TUR(A-F)
UMTXN63	Downlink	User	Nadir	Medium	TUL(A-F), TUR(A-F)
UMTXS63	Downlink	User	Max Scan	Medium	TUL(A-F), TUR(A-F)
TTCTX63	Downlink	TT&C	Nadir	N/A	TTR1, TTL1,TTR2 TTL2

D4. Clarifications

- In the Schedule S Frequency Channel definitions, the “Feeder Link Channels” refer to Kuiper “Gateway” Channels.