ORCHESTRA NON-GEOSTATIONARY SATELLITE SYSTEM

Exhibit B
Technical Narrative to Supplement Schedule S

1. Scope and Purpose

The purpose of this Attachment is to provide the Commission with the technical characteristics of Inmarsat's ORCHESTRA NGSO satellite system as required by 47 C.F.R. § 25.114 and other sections of the FCC's Part 25 rules that cannot be captured by the Schedule S software.

2. Overall description of system facilities, operations and services and explanation of how uplink frequency bands would be connected to downlink frequency bands

The proposed NGSO constellation will complement the terrestrial and GSO satellite connectivity layers of the ORCHESTRA network. ORCHESTRA NGSO space segment consists of 198 manoeuvrable satellites, with ten planes of 18 satellites each in an orbit inclined at 50 degrees at an altitude of 1023.5 km, supplemented by an equatorial plane of 18 satellites at an altitude of 724 km. These orbital altitudes have been chosen to avoid the risk of collisions with spacecraft of other NGSO satellite operators. The manoeuvrability of the satellites will further reduce the risk of collision and permit maintenance of orbits within established tolerances.

Gateway and end-user communications coverage will be delivered through multiple steerable spot beams on each satellite.

Typical ORCHESTRA earth stations will consist of:

- End-user terminals which will employ antennas in the range of 10 cm to 1 m antenna diameter and will include earth stations on vessels, aircraft, vehicles, and other platforms;
- Gateway and TT&C earth stations, the locations of which have not yet been determined (beyond that TT&C will be conducted outside the United States), that will have antenna diameter in the range of 2 – 5 meters.

The minimum elevation angle for both user terminals and gateways will be 8 degrees.

The ORCHESTRA NGSO satellite system will operate in the 37.5-42 GHz band (space-to-Earth) & the 47.2-50.2 GHz and 50.4-51.4 GHz bands (Earth-to-space). The satellite will employ forward links (gateway-to-end user transmissions) and return links (end user-to-gateway transmissions) in portions of these frequency bands as described below.

Inmarsat proposes the following operations in the United States for the ORCHESTRA constellation:

Frequency Band	Use
37.5-40.0 GHz	Space-to-Earth transmissions to individually licensed gateway earth stations
40.0-42.0 GHz	Space-to-Earth transmissions to user terminals and individually licensed gateway earth stations
47.2-48.2 GHz	Earth-to-space transmissions from individually licensed gateway earth stations
48.2-50.2 GHz	Earth-to-space transmissions from user terminals and individually licensed gateway earth stations
50.4-51.4 GHz	Earth-to-space transmissions from individually licensed gateway earth stations

The TT&C subsystem for ORCHESTRA spacecraft will be extremely rugged by virtue of its redundancy, shielding, separation of components, and physical characteristics. With respect to RF characteristics, Inmarsat plans to conduct TT&C operations at the band edge with earth stations located outside of the United States, as shown in Table 1 below.

Table 1. V-band TT&C Characteristics

	Uplink	**Downlink**
Frequency range	47200-47250 MHz 51350-51400 MHz	37500-37525 MHz 41975-42000 MHz
Modulation	FM	PM
Polarization	RHCP or LHCP	RHCP or LHCP
Location	Outside the United States	Outside the United States

Exact frequencies remain undecided; TT&C channels may and likely will occupy less bandwidth than specified above. Because TT&C transmissions will not occur to or from U.S. earth stations and thus will not require U.S. market access or U.S. ground segment authorizations, Inmarsat has not included their specific technical parameters in the Schedule S. However, Inmarsat notes that the EIRP density for TT&C transmissions will not exceed the maximum level specified for gateway communications and agrees to provide additional information regarding final channelization upon Commission request.

Finally, as noted, Inmarsat's ITU Filing for ORCHESTRA covers additional frequency bands for which Inmarsat does not seek U.S. market access at this time. Accordingly, Inmarsat may conduct TT&C operations on assigned frequencies outside of V-band with earth stations located outside the United States. Inmarsat would be pleased to provide any updates the Commission requires regarding these plans as they become more definite.

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

All space stations in the ORCHESTRA constellation are identical and carry the same types of Gateway and User beams. Schedule S also shows transmitting beams for mobile-satellite service (MSS) in the 40-41 GHz band; this is the same beam as the User beam, but with a narrower frequency range defined in order to conform to the frequency band for MSS in the United States Table of Allocations. Diagrams below specify for each unique orbital plane the predicted antenna gain contours for each transmit antenna beam at nadir for one space station.

Further, Inmarsat has attached contour diagrams in GXT format to Schedule S reflect the nadir contours shown below and edge of coverage contours corresponding to an 8° elevation angle as seen from an earth station at both the 1023.5 km (orbital planes 1-10) and 724 km (orbital plane 11) altitudes. The spot beams on each satellite will be steerable between the contours shown throughout the service area for the steerable beams on each individual satellite (all visible area within an 8° elevation angle as seen from an earth station).

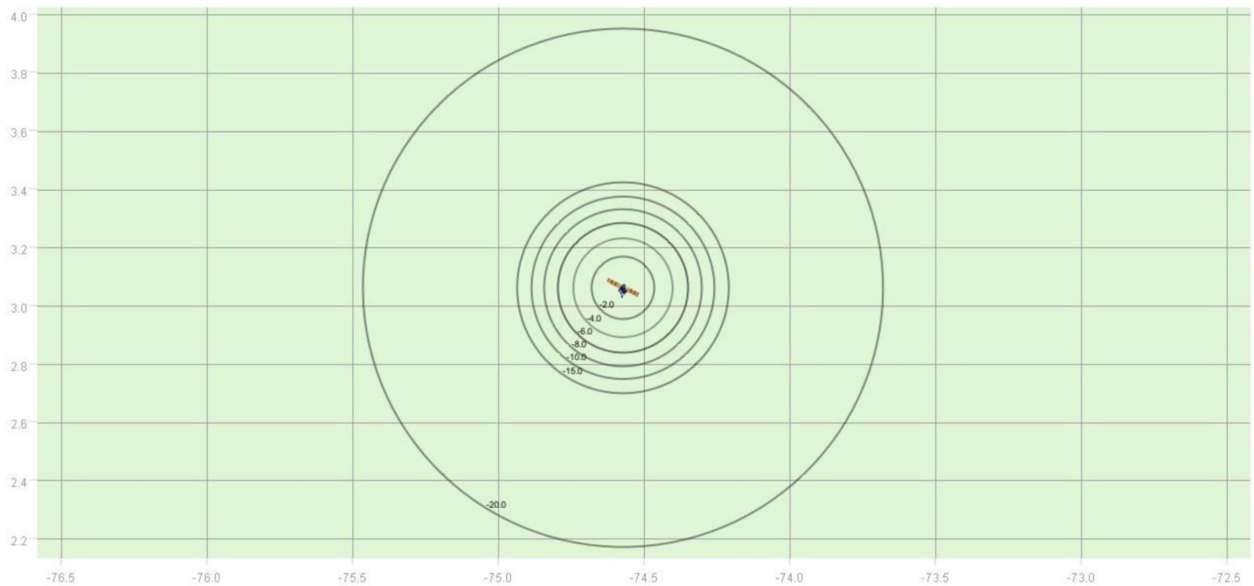

Figure 3-1. Predicted antenna gain contour at nadir of Gateway beam for orbital planes 1-10 (50° inclination at 1023.5 km orbital height). Maximum transmit gain at 40 GHz is 40.1 dBi. Representative degrees of Latitude and Longitude are shown on the y-axis and x-axis, respectively.

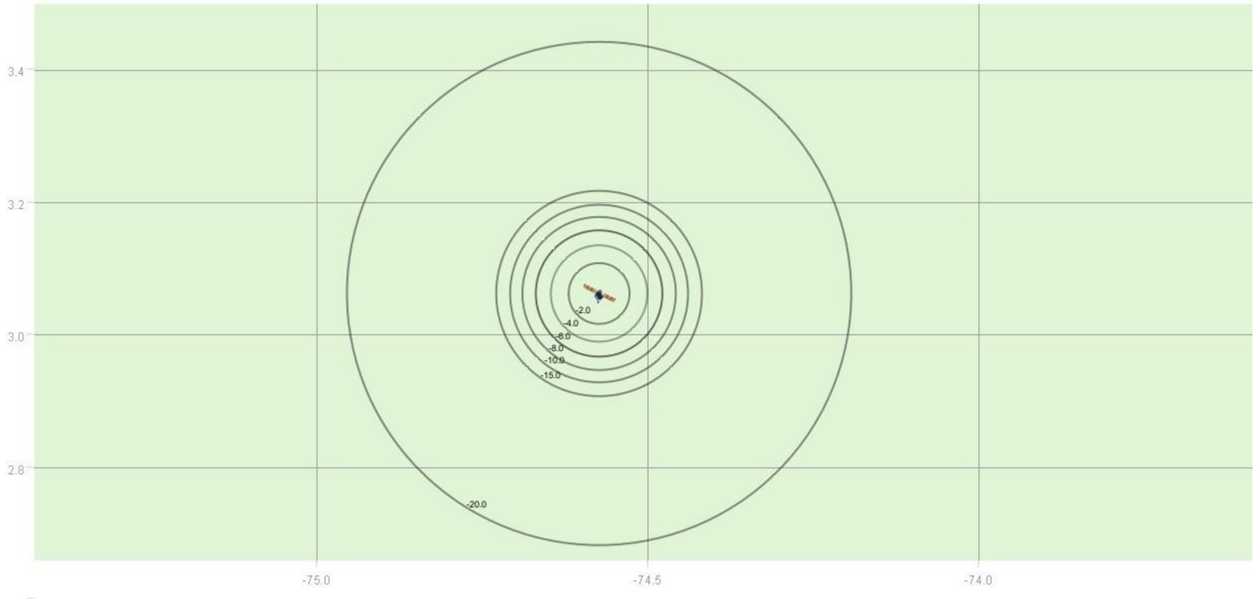

Figure 3-2. Predicted antenna gain contour at nadir of User and MSS beam for orbital planes 1-10 (50° inclination at 1023.5 km orbital height). Maximum transmit gain at 40 GHz is 47.5 dBi. Representative degrees of Latitude and Longitude are shown on the y-axis and x-axis, respectively.

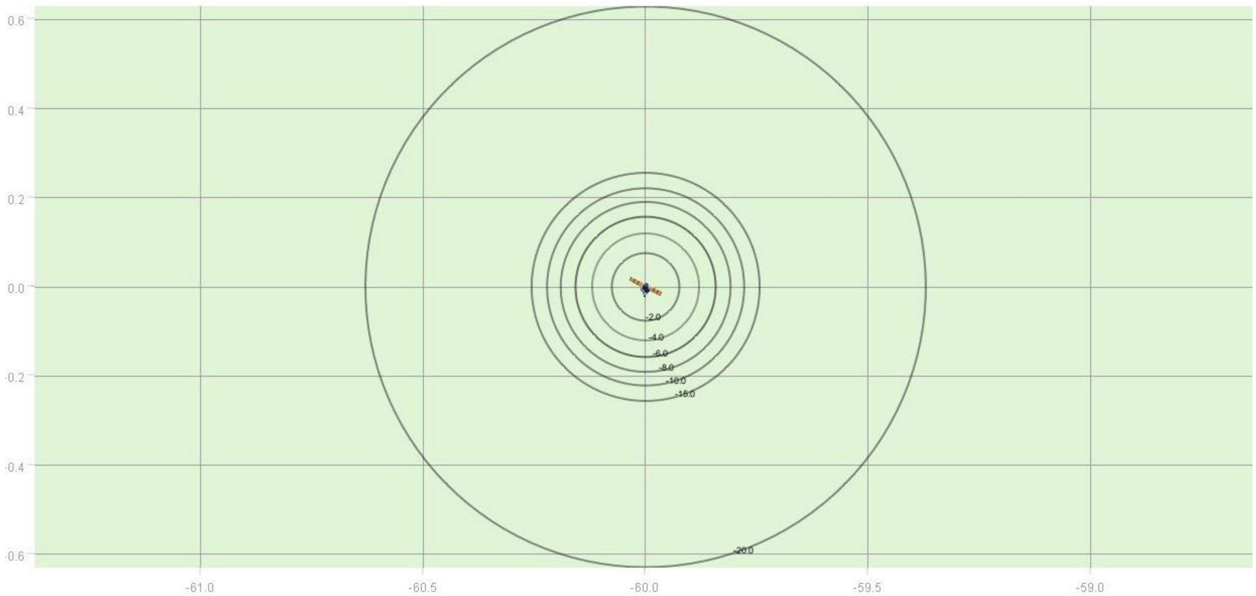

Figure 3-3. Predicted antenna gain contour at nadir of Gateway beam for orbital plane 11 (Equatorial at 724 km orbital height). Maximum transmit gain at 40 GHz is 40.1 dBi. Representative degrees of Latitude and Longitude are shown on the y-axis and x-axis, respectively.

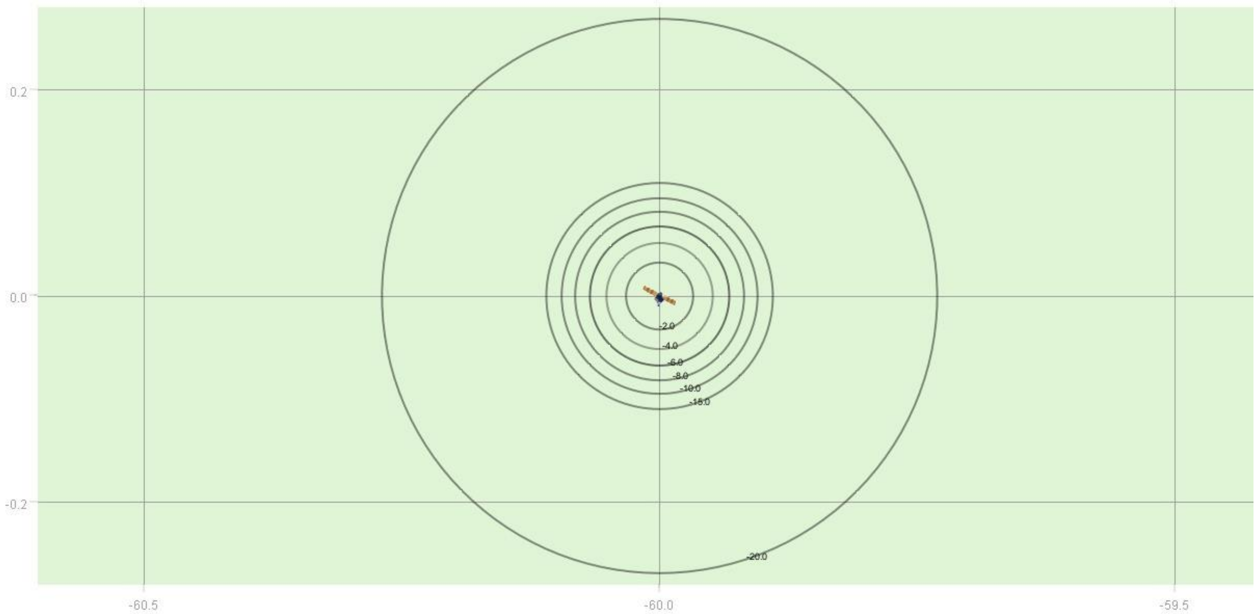

Figure 3-4. Predicted antenna gain contour of User and MSS beam for orbital plane 11 (Equatorial at 724 km orbital height). Maximum transmit gain at 40 GHz is 47.5 dBi. Representative degrees of Latitude and Longitude are shown on the y-axis and x-axis, respectively.

4. Orbital Debris Mitigation Plan (§25.114(d)(14))

The spacecraft manufacturer for the ORCHESTRA constellation has not yet been selected and therefore Inmarsat's Orbital Debris Mitigation Plan is necessarily forward looking. Inmarsat plans to reflect the material objectives of §25.114(d)(14) of the Commission's Rules in the design of the satellite through the satellite's Technical Specifications, Statement of Work and Test Plans. The Statement of Work will include provisions to address orbital debris mitigation under the scenarios described in §25.114(d)(14) as part of the preliminary design review ("PDR") and the critical design review ("CDR") and to incorporate the requirements of §25.114(d)(14), as appropriate, into its Test Plan, including a formal Failure Mode Verification Analysis ("FMVA") for orbital debris mitigation involving particularly the TT&C, propulsion and energy systems. During this process Inmarsat will provide the Commission with updated information, as appropriate.

4.1. Spacecraft Hardware Design

Although the ORCHESTRA satellites have not been completely designed, Inmarsat will ensure that the satellites do not release any debris during its operation. Furthermore, all separation and deployment mechanisms, and any other potential source of debris will be retained by the spacecraft or launch vehicle.

In conjunction with the satellite manufacturer, Inmarsat will assess and limit the probability of the satellite becoming a source of debris by collisions with small debris or meteoroids of less than one centimeter in diameter that could cause loss of control and prevent post-mission disposal. Inmarsat will take steps to limit the effects of such collisions through shielding, the placement of components, and the use of redundant systems.

The ORCHESTRA satellites will include separate TT&C and propulsion subsystems that are necessary for end-of-life disposal. The spacecraft TT&C system, vital for orbit raising, will be extremely rugged with regard to meteoroids smaller than 1 cm, by virtue of its redundancy, shielding, separation of components and physical characteristics. The TT&C subsystem will have no single points of failure.

4.2. Accidental Explosion Assessment (§25.114(d)(14)(ii))

In conjunction with satellite manufacturer, Inmarsat will assess and limit the probability of accidental explosions during and after completion of mission operations through a failure mode verification analysis. The satellite manufacturer will take steps to ensure that debris generation will not result from the conversion of energy sources on board the satellite into energy that fragments the satellite. All pressures, including those of the batteries, will be monitored by telemetry. At end-of-life and once the satellite has been placed into its final disposal orbit, Inmarsat will remove all stored energy from the spacecraft by depleting any residual fuel, leaving all fuel line valves open, venting the pressure vessels and the batteries will be left in a permanent state of discharge.

4.3. Conjunction Avoidance and Post-Mission Disposal

ORCHESTRA spacecraft will be equipped with an on-board propulsion system to actively manage collision avoidance during early orbit, operational, and disposal phases of flight. Inmarsat will share information for space situational awareness purposes and coordinate with other operators in similar orbits to avoid collisions, including at the time of disposal. As an established operator, Inmarsat has procedures in place to do this successfully. It already uses both Space Data Association and 18th SPCS collision data messages and has developed and evolved an automated system to ingest this data and ensure its use its in planning collision avoidance manoeuvres. For de-orbiting and passivation Inmarsat will follow, at a minimum, IADC guidelines and the ISO 24113 Space Debris Mitigation Requirements standard.

At the time of disposal, the orbital altitude will be lowered to 250 km or below to ensure that the spacecraft orbit degrades and the satellite burns up on entry into the atmosphere. The propellant needed to achieve the de-orbit altitude will be based on the delta-V required. Inmarsat will require the spacecraft manufacturer to include an allocation in the propellant budget to ensure that sufficient propellant is reserved to provide the required delta-V for post mission disposal. Typical lifetimes in the disposal phase are expected to last an average of 5 years, with minimum and maximum values between 2 to 8 years respectively depending on the solar cycle.

5. Cessation of Emissions (§25.207)

All downlink transmissions can be turned on and off by ground telecommand, thereby causing cessation of emissions from the satellite, as required.

6. Power Flux Density at the Earth's Surface

This section contains information on PFD limit compliance, as required by the FCC rules (§25.114(d)(12), §25.146(a)(2), §25.208(r), §25.208(s) and §25.208(t)).

6.1. Downlink PFD Limits in the band 37.5 - 40.0 GHz

The FCC's downlink PFD limits applicable in the 37.5 - 40.0 GHz frequency band as given in §25.208(r)(1) are as follows:

- -132 dB(W/m^2) in any 1 MHz band for angles of arrival between 0 and 5 degrees above the horizontal plane;
- -132 + 0.75 (δ-5) dB(W/m^2) in any 1 MHz band for angles of arrival δ (in degrees) between 5 and 25 degrees above the horizontal plane; and
- -117 dB(W/m^2) in any 1 MHz band for angles of arrival between 25 and 90 degrees above the horizontal plane;

In addition, rule §25.208(r)(2) defines maximum PFD limits during periods when the system increases power to compensate for rain-fade conditions at the earth station:

- -120 dB(W/m^2) in any 1 MHz band for angles of arrival between 0 and 5 degrees above the horizontal plane;
- -120 + 0.75(δ-5) dB(W/m^2) in any 1 MHz band for angles of arrival δ (in degrees between 5 and 25 degrees above the horizontal plane; and
- -105 dB(W/m^2) in any 1 MHz band for angles of arrival between 25 and 90 degrees above the horizontal plane.

A note is attached to the FCC's rules that states, "The conditions under which satellites may exceed these power flux-density limits for normal free space propagation described in paragraph (q)(1) to compensate for the effects of rain fading are under study and have therefore not yet been defined. Such conditions and the extent to which these limits can be exceeded will be the subject of a further rulemaking by the Commission on the satellite service rules." The PFD limits for NGSO FSS systems in 37.5 - 40.0 GHz, as defined in Table 21-4 of the ITU Radio Regulations, are the same as the limits found in §25.208(r)(2).

The following figures show the PFD limits in §25.208(r)(1) and §25.208(r)(2) along with the PFD produced in this band by an ORCHESTRA space station at a maximum EIRP density of 15 dBW/MHz for the 1023.5 km orbit (Figure 6-1a) and 12 dBW/MHz the 724 km orbit (Figure

6-1b).

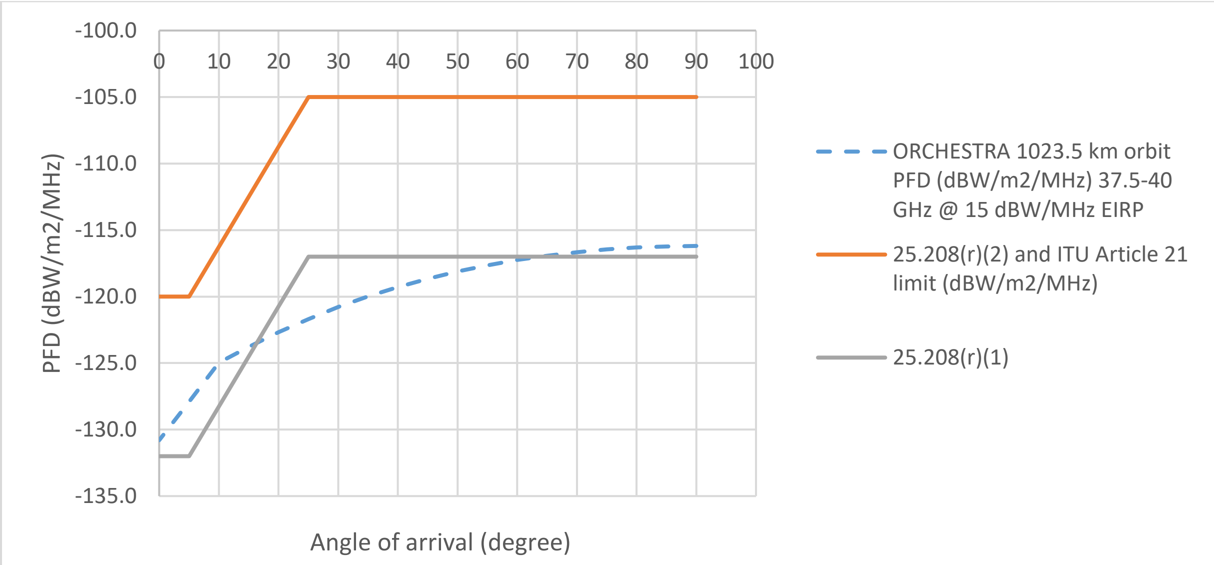

Figure 6-1a. PFD Compliance in 37.5 - 40.0 GHz for the 1023.5 km orbit

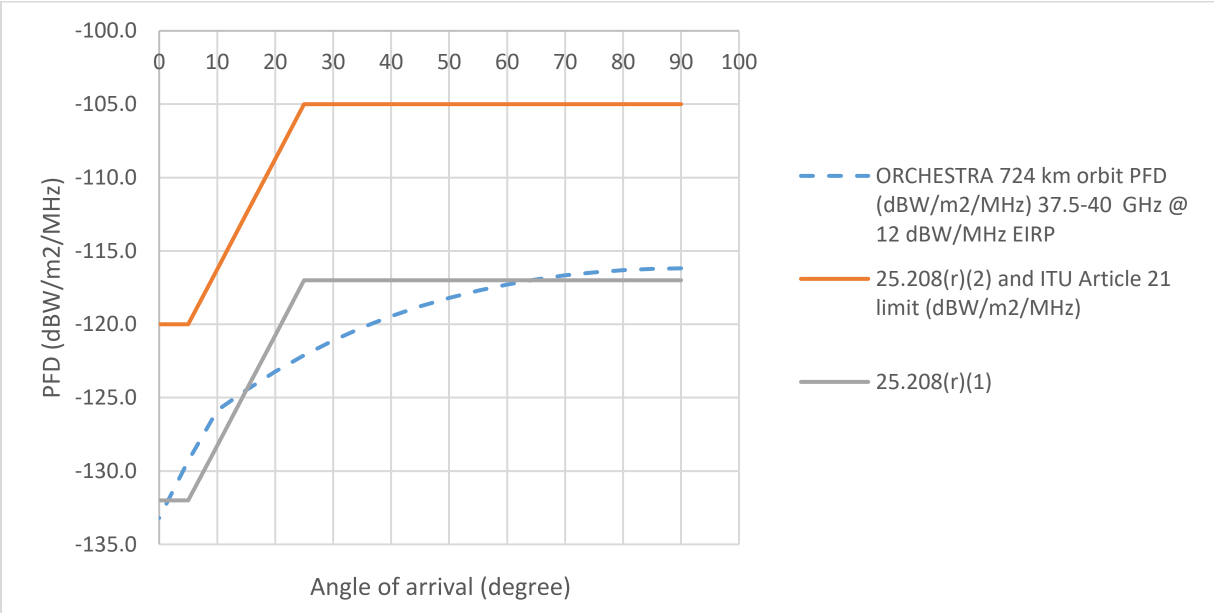

Figure 6-1b. PFD Compliance in 37.5 - 40.0 GHz for the 724 km orbit

Figures 6-1a and 6-1b show PFD compliance with the ITU and FCC §25.208(r)(2) PFD limits. To ensure compliance with §25.208(r)(1), ORCHESTRA EIRP spectral density will be lowered when transmitting in this band over the U.S as shown in Figure 6-1c and 6-1d below.

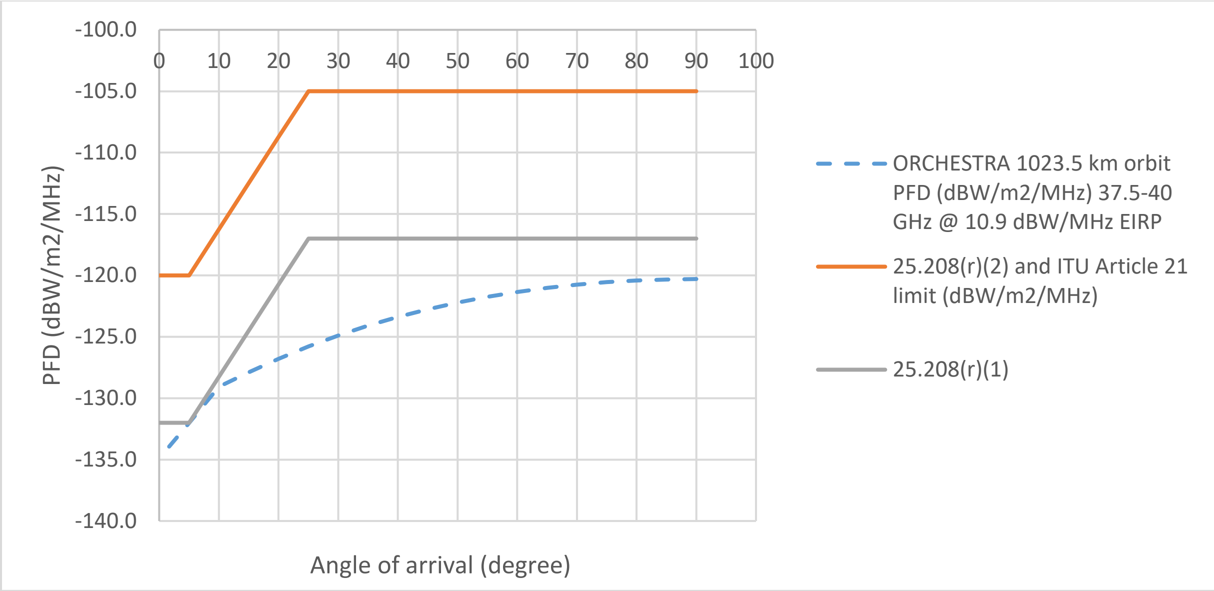

Figure 6-1c. PFD Compliance in 37.5 - 40.0 GHz for the 1023.5 km orbit (including EIRP spectral density reduction)

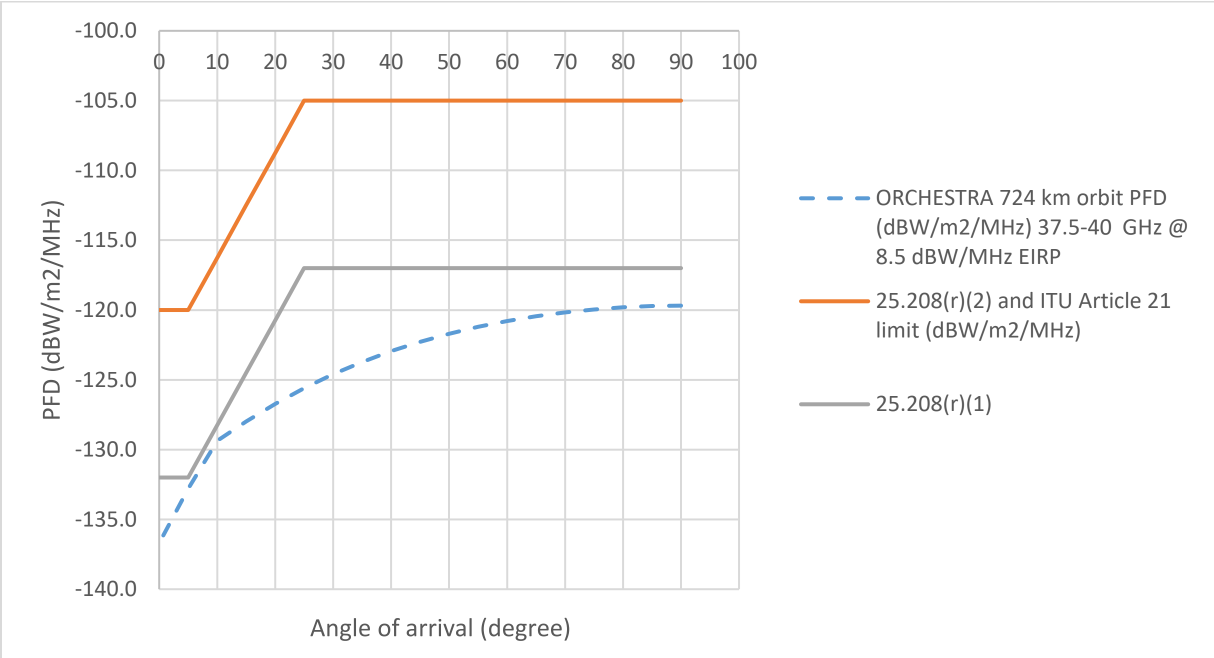

Figure 6-1d. PFD Compliance in 37.5 - 40.0 GHz for the 724 km orbit (including EIRP spectral density reduction)

6.2. Downlink PFD Limits in the band 40.0 - 40.5 GHz

The FCC's downlink PFD limits applicable in the 40.0 - 40.5 GHz frequency band as given in §25.208(s) are as follows:

- -115 dB(W/m^2) in any 1 MHz band for angles of arrival between 0 and 5 degrees above the horizontal plane;
- -115 + 0.5 (δ−5) dB(W/m^2) in any 1 MHz band for angles of arrival δ (in degrees) between 5 and 25 degrees above the horizontal plane; and
- -105 dB(W/m^2) in any 1 MHz band for angles of arrival between 25 and 90 degrees above the horizontal plane.

These limits are the same as the ITU PFD limits for 40.0 - 40.5 GHz, as defined in Table 21-4 of the Radio Regulations. The figure below shows the FCC and ITU PFD limit along with the PFD produced in this band by an ORCHESTRA space station at a maximum EIRP density of 26 dBW/MHz for the 1023.5 km orbit (Figure 6-2a) and 23 dBW/MHz the 724 km orbit (Figure 6-2b). Compliance with the FCC limit in this band is therefore achieved.

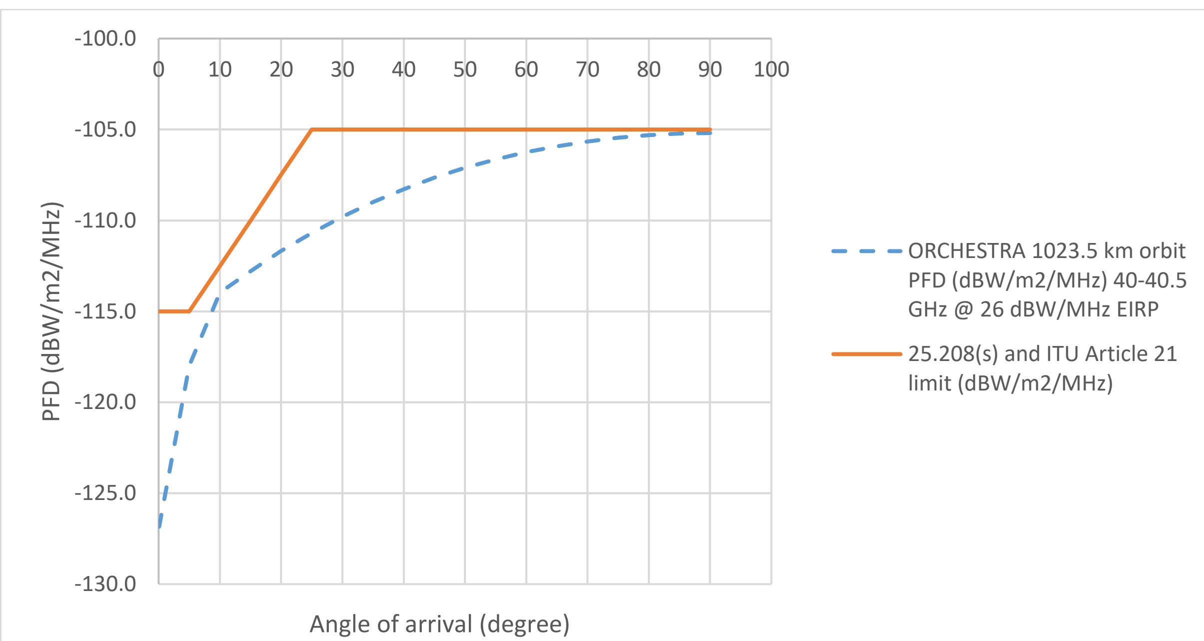

Figure 6-2a. PFD Compliance in 40.0-40.5 GHz for the 1023.5 km orbit

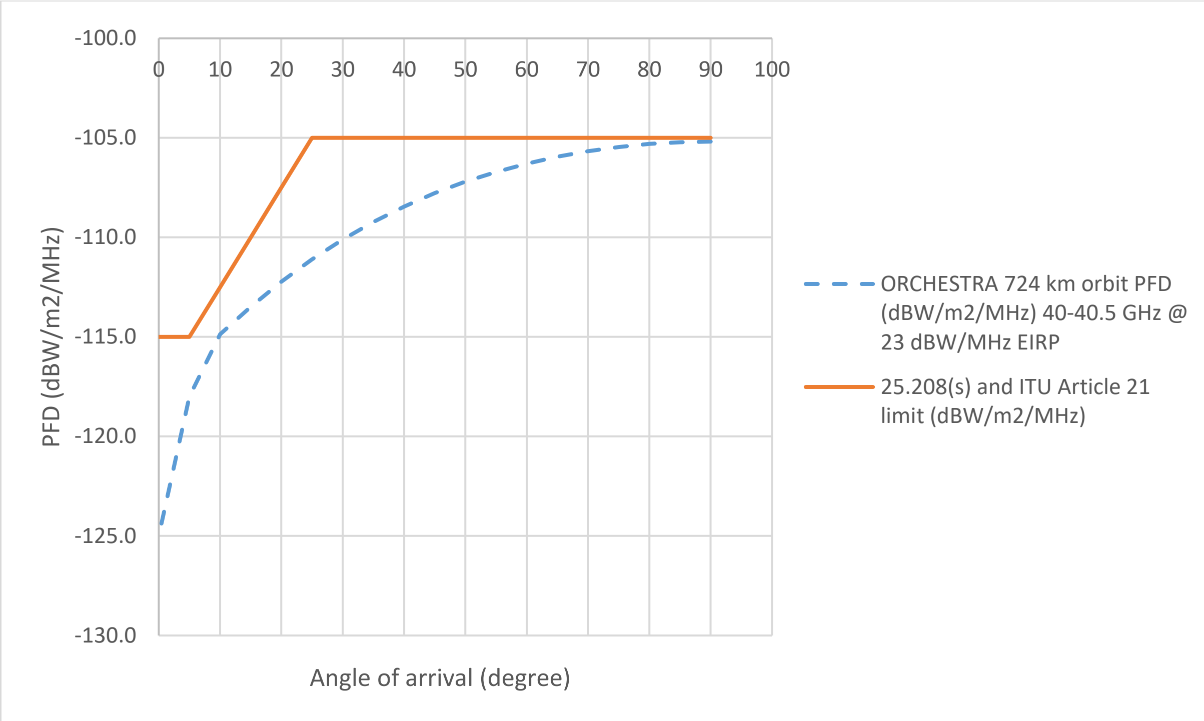

Figure 6-2b. PFD Compliance in 40.0-40.5 GHz for the 724 km orbit

6.3 Downlink PFD Limits in the band 40.5 - 42.0 GHz

The FCC's downlink PFD limits applicable in the 40.5 - 42.0 GHz frequency band as given in §25.208(t) are as follows:

- -115 dB(W/m^2) in any 1 MHz band for angles of arrival between 0 and 5 degrees above the horizontal plane;
- -115 + 0.5 (δ−5) dB(W/m^2) in any 1 MHz band for angles of arrival δ (in degrees) between 5 and 25 degrees above the horizontal plane; and
- -105 dB(W/m^2) in any 1 MHz band for angles of arrival between 25 and 90 degrees above the horizontal plane.

These limits are the same as the ITU PFD limits for 40.5 - 42.0 GHz as defined in Table 21-4 of the Radio Regulations but with footnote 11 attached which states that "the values given in this table entry shall apply to emissions of space stations of NGSO systems operating with 99 or fewer satellites. Further study concerning the applicability of these values is necessary in order to apply them to operating systems of 100 or more satellites." Despite this footnote, PFD compliance for ORCHESTRA satellites is shown against these limits in the figures below.

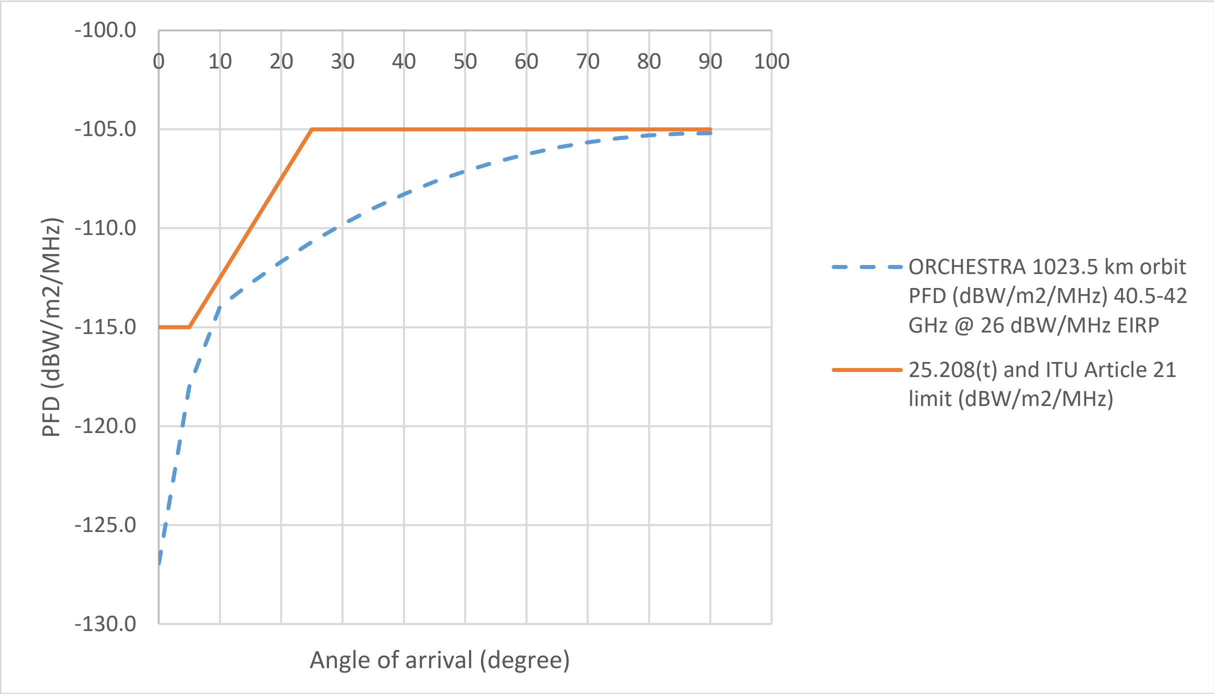

Figure 6-3a. PFD Compliance in 40.5 - 42.0 GHz for the 1023.5 km orbit

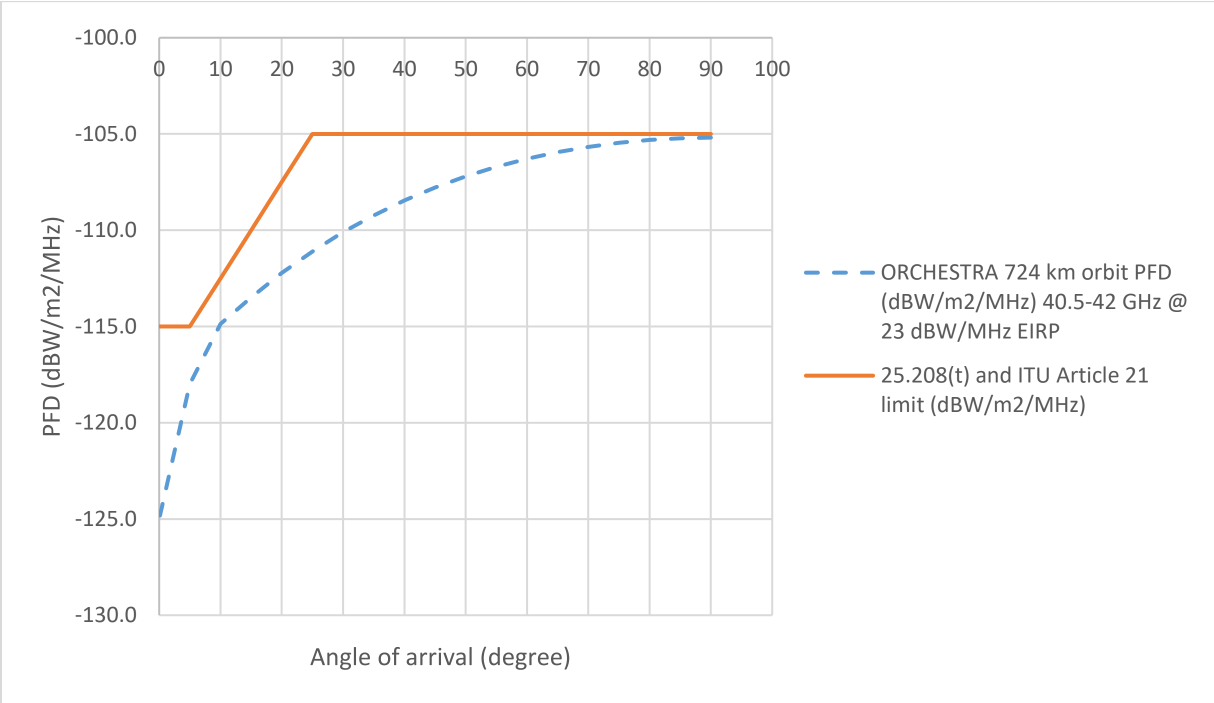

Figure 6-3b. PFD Compliance in 40.5 - 42.0 GHz for the 724 km orbit

7. Sharing among NGSO FSS Space Stations

Rule §25.261 of the Commission's rules applies to sharing among NGSO FSS space station applicants operating with earth stations using directional antennas anywhere in the world under a Commission license, or in the U.S under a grant of U.S. market access. Inmarsat will comply with §25.261(a) and coordinate the ORCHESTRA constellation in good faith with other NGSO FSS operators using overlapping frequencies. It also commits to working closely with other NGSO operators to exchange operational information and develop novel techniques for spectrum sharing as required.

In combination with good faith coordination, the use of diversity sites, steerable spot beams, and state of the art network control facilities will enable avoidance of inline interference which, in turn, would facilitate spectrum sharing between ORCHESTRA and other NGSO systems. These features and commitment to coordination will negate the necessity for band segmentation as defined in §25.261(c).

8. Schedule S Nomenclature

The Beam IDs in the associated Schedule S are named with the following system:

- First Character: E (Emission) / R (Reception)
- Second Character: U (User) / G (Gateway) / M (MSS; same beam as User but only 40-41 GHz specified)
- Third Character: L (LHCP) / R (RHCP)
- Fourth Character: Beam Number

The Channel IDs are named with the following system:

- First Character: F (Forward) / R (Return)
- Second Character: Associated beam type (U (User and MSS (same transmit channel plan within the 40-41 GHz segment only)) / G (Gateway))
- Third Characters: L (LHCP) / R (RHCP)
- Fourth Character: Channel number

ENGINEERING CERTIFICATION

I hereby certify that the following statements are true and correct to the best of my information and belief:

(i) I am the technically qualified person responsible for the engineering information contained in the foregoing Application,

(ii) I am familiar with Part 25 of the Commission's Rules, and

(iii) I have either prepared or reviewed the engineering information contained in the foregoing Application and found it to be complete and accurate.

/s/ Jonas Eneberg
Jonas Eneberg
Vice President, Regulatory Engineering

Dated: November 4, 2021