ATTACHMENT A
Technical Annex

A.1 SCOPE AND PURPOSE

This Technical Annex contains information required by 47 C.F.R. § 25.114 and other Part 25 rules with respect to a proposed technical modification of the EchoStar XXIV satellite to add frequencies at 28.6-29.1 GHz for FSS gateway uplinks. The information provided in Sections A.2 through A.7 below is intended to supplement, and not replace, prior application filings providing the technical characteristics of the EchoStar XXIV satellite. The debris mitigation plan provided in Section A.22 below, however, replaces prior debris mitigation information submitted for the EchoStar XXIV satellite.

A.2 GENERAL DESCRIPTION

The following chart shows the EchoStar XXIV frequency segments and their intended use.

#	Frequencies	Direction	Use	Coverage
1	18.3 - 18.6 GHz	space-to-Earth	User terminals	North, Central and South America
2	18.6 - 18.8 GHz	space-to-Earth	User terminals	North, Central and South America
3	18.8 - 19.3 GHz	space-to-Earth	User terminals	North,[1] Central and South America
4	19.7 - 20.2 GHz	space-to-Earth	User terminals	North, Central and South America
5	27.5 - 28.0 GHz	Earth-to-space	Gateways	North, Central and South America
6	28.1 - 28.6 GHz	Earth-to-space	Gateways	North, Central and South America
7	28.6 - 29.1 MHz	Earth-to-space	Gateways	North, Central and South America[2]
8	29.3 - 29.5 GHz	Earth-to-space	User terminals	North, Central and South America
9	29.5 - 29.9 GHz	Earth-to-space	User terminals	North, Central and South America
10	29.992 – 29.996 GHz	Earth-to-space	Command	North America
11	40.0 - 40.5 GHz	space-to-Earth	Gateways	North, Central and South America

[1] Hughes Network Systems, LLC ("Hughes") seeks to add spectrum at the 18.8-19.3 GHz band for FSS downlinks to user terminals in the United States on a secondary basis with respect to NGSO FSS operations.

[2] Hughes seeks add spectrum at the 28.6-29.1 GHz band for FSS feeder uplinks. In the United States, Hughes will provide this service on a secondary basis with respect to NGSO FSS operations.

#	Frequencies	Direction	Use	Coverage
12	40.5 – 41.0 MHz	space-to-Earth	Gateways and User terminals[3]	North, Central and South America
13	41.0 – 42.0 MHz	space-to-Earth	Gateways	North, Central and South America
14	47.2 - 50.2 GHz	Earth-to-space	Gateways	North, Central and South America
15	50.4 - 51.4 GHz	Earth-to-space	Gateways	North, Central and South America

Table 2-1. Ka and Q/V bands Frequencies.

In the 18.8-19.3 GHz and 28.6-29.1 GHz bands the Commission's rules permit GSO FSS operations on a secondary basis with respect to NGSO FSS operations.[4] Transmissions in the 28.6-29.1 GHz band (Earth-to-space) will only be made by individually licensed gateway earth stations, while transmissions in the 18.8-19.3 GHz band (space-to-Earth) will be received by user terminals. Transmissions in the 18.8-19.3 GHz and 28.6-29.1 GHz bands shall not cause harmful interference to, or claim protection from, non-geostationary satellite systems in the FSS authorized in these bands. Additionally, transmissions in the 28.6-29.1 GHz band (Earth-to-space) shall not cause harmful interference to, or claim protection from, stations in the fixed service operating under the call signs indicated in NG62 of the Table of Frequency Allocations.

A.3 SPACE STATION TRANSMIT AND RECEIVE CAPABILITY

A.3.1 Ka-band Frequencies

The EchoStar XXIV satellite beam coverage, for both transmit and receive, will consist of 301 user beams throughout the Americas, which will be served by 20 gateways located in the U.S.

A.3.2 Q/V-band Frequencies

The EchoStar XXIV satellite Q/V-band beam coverage, for both transmit and receive, will consist of 20 gateway beams and 4 user beams.

A.3.3 Antenna gain contours for typical beams and service area

As required by 47 C.F.R. §25.114(c)(4)(vii) the predicted antenna gain contours for typical transmit and receive antenna beams are provided in GXT format in a prior Schedule S filing for the satellite.

[3] Although prior application filings for the satellite indicated that the 40.5-41.0 GHz band will be used for downlinks to gateways only, this Technical Annex hereby clarifies that the spectrum will be used for downlinks to both gateways and user terminals, consistent with the terms of the Commission's license grant and its allocations rules. Accordingly, new beam and a corresponding channel are included in the accompanying Schedule S.

[4] 47 C.F.R. §§ 2.102(a), 2.106 n.NG165.

The predicted gain contours for additional typical beams are shown in the table below.

No.	Beam	Tx/Rx	Frequencies	Polarization
1	UT4L	Tx	40500-41000 MHz	LHCP
2	UT4R	Tx	40500-41000 MHz	RHCP
3	GR3L	Rx	28600-29100 MHz	LHCP
4	GR3R	Rx	28600-29100 MHz	RHCP

Table 3-1. List of gain contours for additional typical beams.

For all beams, a single isoline map showing the service area was provided in GXT format in a prior Schedule S filing.

A.4 FREQUENCY AND POLARIZATION PLAN

The EchoStar XXIV satellite Ka-band and Q/V-band frequency plans are provided in Figures 4-1 and 4-2 below.

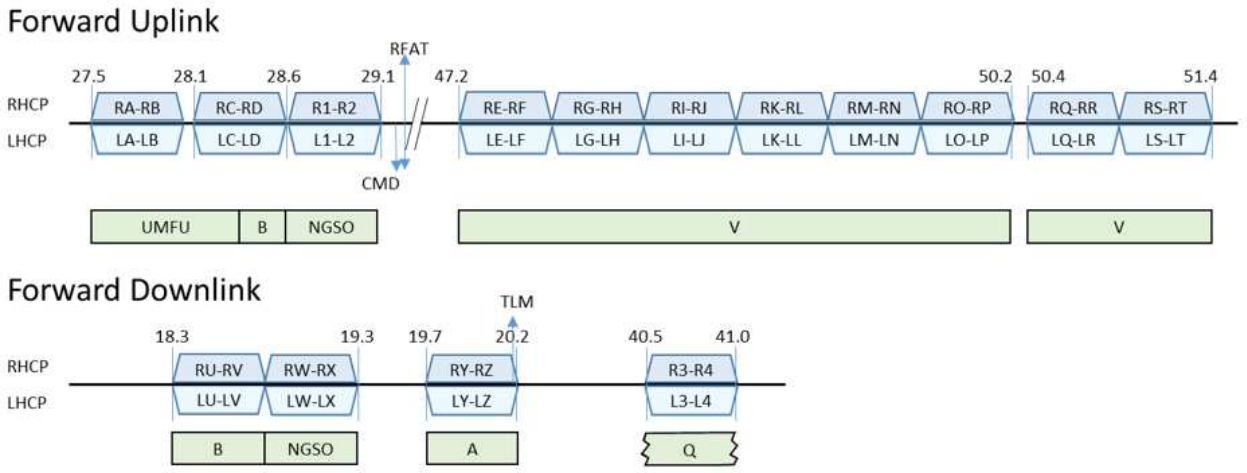

Figure 4-1. Updated frequency plan for the forward link.

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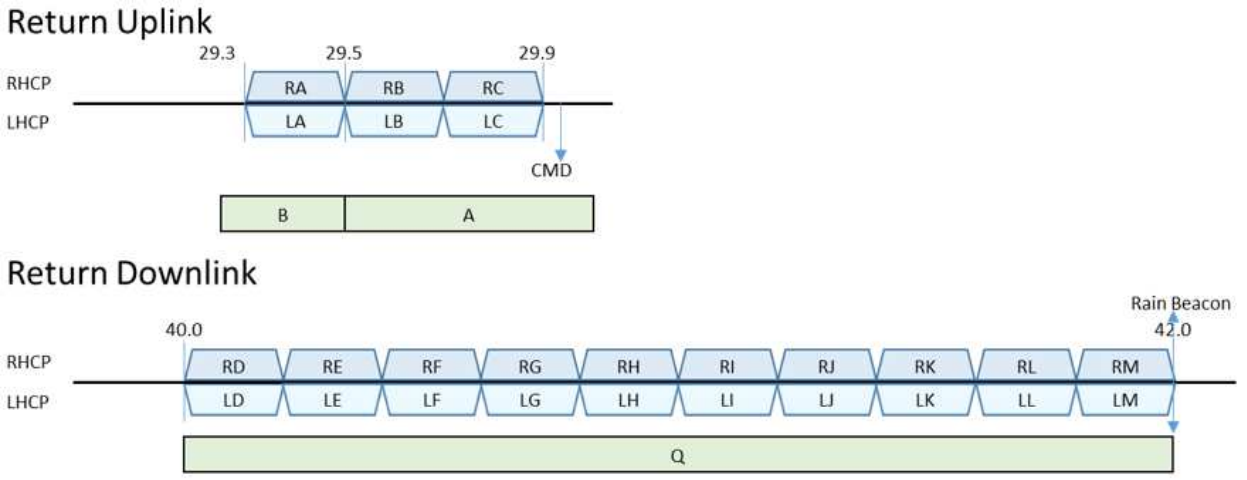

Figure 4-2. Updated frequency plan for the return link

Circular polarization will be used on both the uplink and downlink, as shown in figures 4-1 and 4-2 above, with the downlink polarization in any user beam being orthogonal to the uplink polarization.

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A.12 KA-BAND TWO-DEGREE COMPATIBILITY

The EchoStar XXIV satellite will meet the Commission's two-degree spacing requirements, as discussed below. All Ka-band frequency transmissions of the EchoStar XXIV satellite earth stations will not exceed the uplink off axis EIRP density and downlink PFD levels of 47 C.F.R. §25.138, regardless of whether the frequency band used is subject to 47 C.F.R. §25.138.

A.12.1 Frequency Bands Not Subject to 47 C.F.R. §25.138

This section demonstrates that uplink transmissions in the 27.5-28.0 GHz and 28.1-28.35 GHz band, and downlink transmissions in the 18.8-19.3 GHz band are two-degree compatible.

Currently there are no operational GSO Ka-band satellites that use the 27.5-27.85 GHz band within two degrees of the 95.2º W.L. location, and the only operational GSO Ka-band satellite that uses the 18.8-19.3 GHz, 27.85-28.35 GHz and 28.6-29.1 GHz bands within this arc is EchoStar XIX, which is licensed to Hughes.

Because, as indicated above, all Ka-band transmissions of the EchoStar XXIV satellite network will not exceed the uplink off axis EIRP density and downlink PFD levels of 47 C.F.R. §25.138, regardless of whether the frequency band used is subject to 47 C.F.R. §25.138, and because these limits ensure two-degree compatibility in the band subject to 47 C.F.R. §25.138, it is safe to conclude that they also ensure two-degree compatibility in the band immediately adjacent to the bands subject to 47 C.F.R. §25.138.

Additionally, as EchoStar XXIV will be located 1.9 degrees away from EchoStar XIX (at 97.1º W.L.), Hughes hereby certifies that EchoStar XIX operations will accommodate the operation of EchoStar XXIV to avoid interference between both satellites in order to comply with 47 C.F.R. §25.140(a)(2).[5]

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A.14 SHARING WITH NGSO FSS

[5] *See* 47 C.F.R. § 25.140(a)(2).

In the United States, the 18.8-19.3 GHz and 28.6-29.1 GHz bands are designated for non-geostationary fixed-satellite service (NGSO FSS) on a primary basis and to GSO FSS on a secondary basis.[6] Stations operating in a secondary service cannot cause harmful interference to or claim protection from harmful interference from stations of a primary service. Accordingly, EchoStar XXIV will operate in the 18.8-19.3 GHz (downlink) and 28.6-29.1 GHz (uplink) bands on a secondary basis with respect to authorized NGSO FSS systems.

Hughes' proposed U.S. operations will be consistent with the obligations of a secondary user of spectrum to avoid harmful interference into, and to accept any interference received from, primary users.

To prevent the EchoStar XXIV satellite network from causing harmful into NGSO satellite systems using the 28.6-29.1 GHz and 18.8-19.3 GHz bands, the EchoStar XXIV satellite and its associated earth stations will cease transmissions in these bands during all potential interference conditions. The highest interference levels that could occur into NGSO networks from the EchoStar XXIV network are when there is an "in-line" event. On the uplink an in-line event occurs when the NGSO satellite, the GSO satellite and the interfering GSO earth station are all in a line. As the NGSO satellite continues to move within its orbit, an angle between the NGSO satellite and the GSO satellite, subtended at the GSO earth station, is created. As long as the GSO earth station does not transmit when the NGSO satellite is within a certain angle, no harmful interference to the NGSO satellite will occur. A similar situation exists on the downlink.

Determining the amount of angular separation required, as well as implementing any required interference avoidance measures, will depend upon the technical parameters of each NGSO FSS network.

Several NGSO operators have been licensed in the U.S. for the use of the 18.8-19.3 GHz and 28.6-29.1 GHz bands. Currently, Hughes has in place coordination agreements with a number of authorized NGSO FSS operators. Such coordination agreements ensure that EchoStar XXIV operations will comply with the obligations of a secondary user, avoiding harmful interference into, and accepting any interference received from, NGSO systems, as primary users. Based on the principles Hughes has already used to achieve technical compatibility with a number of authorized NGSO FSS operators, Hughes will continue to work with other authorized NGSO FSS operators to reach similar coordination or other arrangements to ensure no harmful interference to those systems.

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A.22 ORBITAL DEBRIS MITIGATION PLAN

[6] *See* 47 C.F.R. § 2.106 n.NG165; *see also Update to Parts 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, ¶ 14 (2017).

The spacecraft manufacturer for the EchoStar XXIV satellite is Space Systems/Loral ("SS/L"). Hughes has ensured that the material objectives of Section 25.114(d)(14) are incorporated into its satellite Technical Specifications, Statement of Work and Test Plans.

A.22.1 Spacecraft Hardware Design

Hughes confirms that the satellite will not undergo any planned release of 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.

Hughes does not expect that the satellite will undergo any release of 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 SS/L, Hughes has assessed and limited 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 can cause loss of control and prevent post-mission disposal. Hughes has taken steps to limit the effects of such collisions through shielding, the placement of components, and the use of redundant systems.

Hughes will incorporate a rugged TT&C system with regard to meteoroids smaller than 1 cm through redundancy, shielding, and appropriate physical separation of components. The TT&C subsystem will have no single points of failure. The TT&C system will be equipped with near omni-directional antennas mounted on opposite sides of the spacecraft. These antennas, each providing greater than hemispherical coverage patterns, are extremely rugged and capable of providing adequate coverage even if struck, bent or otherwise damaged by a small or medium sized particle. Either one of the two omni-directional antennas, for both command and telemetry, will be sufficient to enable orbit raising. The command receivers and decoders and telemetry encoders and transmitters will be located within a shielded area and will be totally redundant and physically separated. A single rugged thruster and shielded propellant tank provide the energy for orbit-raising.

The propulsion subsystem is designed such that it will not be separated from the spacecraft after de-orbit maneuvers. It will be protected from the effects of collisions with small debris through shielding. Moreover, propulsion subsystem components critical to disposal (e.g. propellant tanks) will be located deep inside the satellite, while other components, such as the thrusters, externally placed, are redundant to allow for de-orbit despite a collision with debris.

A.22.2 Minimizing Accidental Explosions

In conjunction with SS/L, Hughes has assessed and limited the probability of accidental explosions during and after completion of mission operations. The satellite is designed to ensure that debris generation will not result from the conversion of energy sources on board the satellite into energy that fragments the satellite. The propulsion subsystem pressure vessels are designed with high safety margins. Bipropellant mixing will be prevented by the use of valves that avoid backwards flow in propellant lines and pressurization lines. 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, Hughes will ensure removal of all stored energy from the spacecraft

by depleting any residual fuel, leaving all fuel line valves open, venting the pressure vessels, and leaving the batteries in a permanent state of discharge.

A.22.3 Safe Flight Profiles

In considering current and planned satellites that may have a station-keeping volume that overlaps the EchoStar XXIV satellite, Hughes has reviewed the lists of Commission licensed satellite networks, as well as those that are currently under consideration by the Commission. In addition, non-U.S.-licensed networks for which a request for coordination has been published by the ITU within ±0.15° of 95.2° W.L. have also been reviewed.

There are no pending applications before the Commission to use an orbital location ±0.15° from 95.2° W.L., and Hughes is not aware of any satellite, besides the satellite Spaceway 3 operated by Hughes, with an overlapping station-keeping volume with the EchoStar XXIV satellite that is the subject of an ITU filing that is either in orbit or progressing towards launch.

Hughes therefore concludes that physical coordination of the EchoStar XXIV satellite with another party is not required at the present time.

A.22.4 Post-Mission Disposal

At the end of the operational life of the EchoStar XXIV satellite, Hughes will maneuver the satellite to a disposal orbit with a minimum perigee of 300 km above the normal GSO operational orbit. The post-mission disposal orbit altitude is based on the following calculation, according to 47 C.F.R. § 25.283:

Total Solar Pressure Area "A" = 155 m2
"M" = Dry Mass of Satellite = 5817 kg
"CR" = Solar Pressure Radiation Coefficient = 1.3

Therefore, the Minimum Disposal Orbit Perigee Altitude is calculated as:

= 36,021 km + 1000 x CR x A/m
= 36,021 km + 1000 x 1.3 x 155/5817
= 36055.6 km
= 267 km above GSO (35,786 km)

To provide adequate margin, the disposal orbit will be increased to 300 km. This will require approximately 4 kg of xenon propellant, taking account of all fuel measurement uncertainties, which will be allocated and reserved in order to perform the final orbit raising maneuver.