NARRATIVE DESCRIPTION

Spire Global, Inc. ("Spire") requests experimental authority to operate inter-satellite links ("ISLs") in the frequency bands 2025-2110 MHz and 2200-2290 MHz on four low-earth orbit, non-geostationary satellite orbit ("NGSO") satellites for a 3-year period.[1] The company's FCC Part 25 satellite license grant, which authorizes it to deploy 872 satellites, will cover the satellites' non-ISL links.[2] Spire respectfully requests expedited consideration and grant of this experimental license at its earliest convenience, but no later than June 15, 2020, with commencement of operations on or about August 1, 2020.

Grant of this application will contribute greatly to the radio art, serve the public interest, and support one of the FCC's primary objectives of "promoting fair and vigorous competition in the satellite communications market."[3] Spire will be able to demonstrate its ISL system's ability to deliver low-latency, low data-rate data among four satellites. The proposed experiments will prepare Spire to deploy ISLs for its full satellite constellation without interfering with terrestrial or other space operations. Reducing latency for high-priority relays of Automatic Identification System ("AIS"), Application Specific Messages, Automatic Dependent Surveillance – Broadcast ("ADS-B"), and Global Navigation Satellite System occultation and reflectometry data becomes immediately possible with such a system.

I. APPLICANT

Spire, an FCC Part 25 space and earth station licensee, manufactures cubesats; operates a cubesat constellation providing maritime, aviation, meteorological, and land surface monitoring services; and offers convenient, affordable, and on-demand access for hosted payloads.[4]

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[1] *See* 47 C.F.R. § 5.71. Spire's three-year license term request corresponds to the anticipated operational life of the satellites and accounts for manufacturing time and inevitable launch delays.
[2] *See* Stamp Grant, Spire, File No. SAT-AMD-20180102-00001 (granted in part and deferred in part Nov. 29, 2018) ("License").
[3] *Amendment of Part 25 of the Commission's Rules to Establish Rules and Policies Pertaining to the Second Processing Round of the Non-Voice, Non-Geostationary Mobile Satellite Service*, Notice of Proposed Rulemaking, 11 FCC Rcd 19841 ¶ 10 (1996); *see also* 47 C.F.R. § 5.63(c)(1).
[4] The company's offices are distributed across the United States (Boulder, Colorado; San Francisco, California; and Washington, DC), Scotland, Luxembourg, and Singapore.

II. EXPERIMENT

Expeditiously deploying radiofrequency ISLs across its commercial constellation remains Spire's immediate objective. Prior to employing such a system, however, Spire seeks authority to operate ISLs for three years on an experimental basis. Spire would deploy experimental ISLs on four 3U cubesats, each measuring 1 m x 1 m x 300 mm (envelope with the antennas and solar panels deployed), weighing 6.0 kg, and transmitting at a maximum EIRP of 7.27 dBW in 2025-2110 MHz and 7.93 dBW in 2200-2290 MHz.[5] Detailed technical and operational parameters appear in Section IV below. The satellites' non-ISL radiofrequency links do not require additional authorization because the FCC has already granted Spire this authority[6] and Spire will abide by all license conditions and U.S. Federal agency coordination agreements.[7] The company will disseminate data collected from the experimental spacecraft to the European Space Agency ("ESA") pursuant to the ESA Pioneer contract awarded to Spire and to a limited number (less than 100) of interested commercial parties.[8]

Spire will construct two batches of satellites for this experimental demonstration. Batch 1 will include two technically identical cubesats operating in the same plane (identical orbital altitudes and inclinations) and demonstrate intra-plane ISL communications.[9] The Batch 2 satellites will consist of two technically identical cubesats operating in different orbital planes from Batch 1 and demonstrate inter-plane ISL communications. Both batches will downlink data in two one-megahertz channels in

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[5] Spire's three-year license term request corresponds to the anticipated operational life of the satellites and accounts for manufacturing time and inevitable launch delays.
[6] The satellites will host pre-authorized Spire AIS and ADS-B payloads, will only communicate with Spire's ground station network, and do not raise orbital debris risks, as detailed in Section V. *See* License.
[7] *See* License.
[8] *See Pioneer for in-orbit demonstration*, ESA, https://bit.ly/33zLJAv (last visited Mar. 18, 2020). Although not required in recent NGSO experimental license grants, Spire acknowledges it may need to provide the FCC progress reports evaluating the experiment. *See* 47 C.F.R. § 5.73; *see also, e.g.*, License, Space and Sciences & Engineering, ELS File No. 0011-EX-CN-2019 (granted Feb. 19, 2020).
[9] "Technically identical" means the satellites possess the same relevant radiofrequency characteristics (*e.g.*, transmit power, out-of-band emissions, antenna patterns and gain, and transmit and receive frequencies).

2200-2290 MHz band and uplink data in two one-megahertz channels 2025-2110 MHz.[10] The four satellites will:

- test the capabilities of the ISLs;
- validate the theoretical link budget and reduce uncertainty on link budget factors with known variance;
- demonstrate the concept of operations, including scheduling ISL contacts, pointing the spacecraft at each other correctly, and initiating and closing the link;
- determine the usability of the allocated spectrum (*e.g.*, interference);
- establish realistic data rates for various link distances;
- test the ability to transmit data on designated S-band frequencies;
- evaluate the ability to receive data on designated S-band frequencies at desired link rates and ranges;
- demonstrate the ability to calibrate received power; and
- exhibit Batch 1 satellites' compatibility with Batch 2 satellites.

III. ORBITAL DEPLOYMENT PARAMETERS

The table below contains the four satellites' orbital deployment parameters.

	Number of Satellites	Altitude (km)	Inclination (deg)	Expected Launch Date
Batch 1	2	550	SSO (10:00 LTDN)	July 20, 2020
Batch 2	2	500	SSO (9:30 LTDN)	December 1, 2020

IV. ISL FREQUENCIES

Good cause exists to permit Spire's 2025-2110 MHz and 2200-2290 MHz ISL operations. The Table of Frequency Allocations authorizes Space Operations and Earth Exploration-Satellite Service ("EESS") space-to-space operators on a primary basis in all three ITU regions.[11] In the United States Table of Frequency Allocations, footnote US347 further permits non-Federal space-to-space operations for EESS operations in the 2025-2110 MHz band on a case-by-case basis. Spire's proposed operations qualify as EESS because it will be transmitting and receiving data related to the Earth's atmospheric and land surface properties. Therefore, its ISL operations in 2025-2110 MHz conform to the U.S. Table of Frequency Allocations. Because a non-Federal space-to-space allocation does not appear in the U.S. Table of Frequency Allocations for the 2200-2290 MHz band,

[10] Spire has started coordinating the specific channel selections with the U.S. Federal agency spectrum users.
[11] *See* 47 C.F.R. § 2.106 (Table of Frequency Allocations).

Spire requests a waiver to use the band for its ISL operations.[12] ISL transmissions are inherently "international" as they may transit hundreds to thousands of kilometers in space and are not limited to the orbital area directly above the United States or its territories. Considering all three ITU regions permit such "international" operations on a primary basis and Spire will coordinate this use with all Federal operators prior to use,[13] good cause exists for the FCC to waive the U.S. Table of Frequency Allocations.[14]

A. Technical Parameters

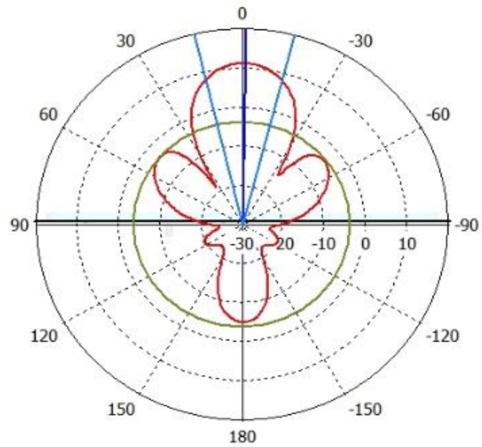
Assuming an in-plane, leader-follower configuration with an assumed range between the satellites of 1000-2000 km, Spire's ISLs in the 2025-2110 MHz (two one-megahertz channels) and 2200-2290 MHz (two one-megahertz channels) bands will possess the following characteristics.

- Beam type: Fixed
- Polarization: RHCP
- 3 dB gain: 2025-2110 MHz (8.3 dBi) and 2200-2290 MHz (8.6 dBi)
- Max transmit EIRP: 2025-2110 MHz (7.27 dBW) and 2200-2290 MHz (7.93 dBW)
- Beamwidth: vertical plane 22º (±11º), horizontal plane 65º (±32.5º)
- Bandwidth: 1 MHz
- Emission type: 1M00M1D
- Coding: QPSK DVB-S2 ¼
- Data rate: 70-300 kb/s
- Duty cycle: two 10-15 minute windows in a 90-minute orbit

The radiation patterns for the ISL antennas appear on the next page.

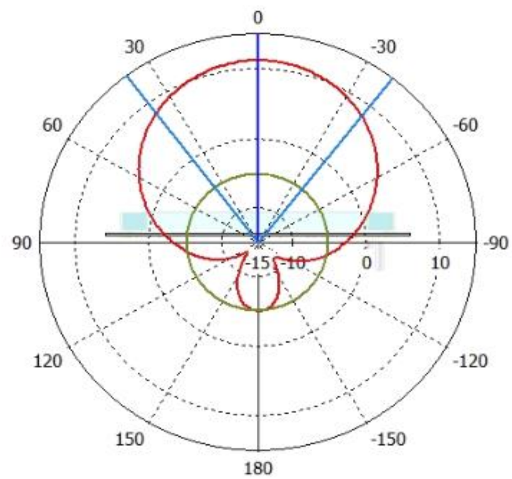
[12] *See id.*
[13] *See id.* at n.5.392 (informing NGSO ISL operators that they "shall not impose any constraints on Earth-to-space, space-to-Earth and other space-to-space transmissions of those services and in those bands between geostationary and non-geostationary satellites").
[14] The FCC may waive any of its rules for "good cause" and generally does so where—as is the case here—the relief requested would not undermine the policy objective of the rule in question and would otherwise serve the public interest. *See* 47 C.F.R. § 1.3; *Northeast Cellular Tel. Co. v. FCC*, 897 F.2d 1164, 1166 (D.C. Cir. 1990); *WAIT Radio v. FCC*, 418 F.2d 1153, 1157 (D.C. Cir. 1969).

Farfield Realized Gain Abs (Phi=0)



Theta / Degree vs. dBi

Farfield Realized Gain Abs (Phi=90)



Theta / Degree vs. dBi

B. Power Flux Density ("PFD") Limit Compliance

Section 25.208 of the FCC's rules includes no PFD limits for the 2025-2110 MHz and 2200-2290 MHz bands; however, ITU Radio Regulations Table 21-4 contains PFD limits for space-to-space operations in these bands.[15] Table 21-4 states that the PFD at the Earth's surface produced by an EESS space station's emissions in these frequency bands for all conditions and modulation methods shall not exceed the following values:

[15] *See* 47 C.F.R. § 25.208; ITU Radio Regulations Table 21-4 ("ITU Table 21-4").

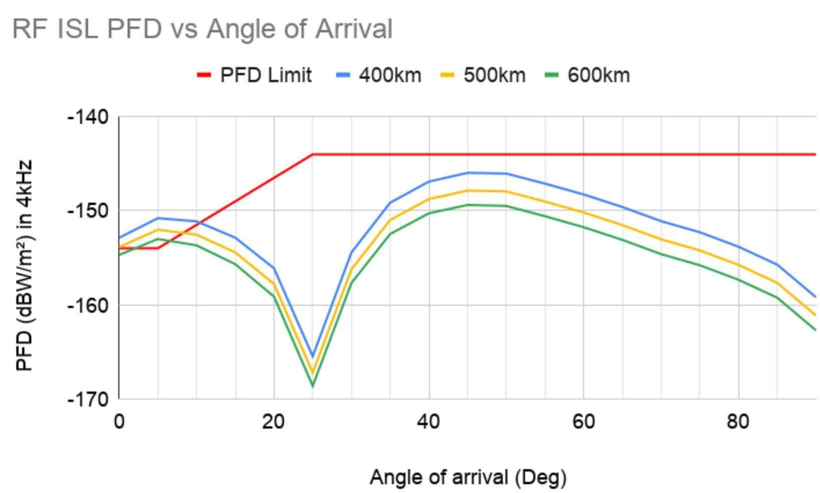
- -154 dB(W/m^2) in any 4 kHz band for angles of arrival between 0 and 5 degrees above the horizontal plane;
- -154 + 0.5(d-5) dB(W/m^2) in any 4 kHz band for angles of arrival d (in degrees) between 5 and 25 degrees above the horizontal plane; and
- -144 dB(W/m^2) in any 4 kHz band for angles of arrival between 25 and 90 degrees above the horizontal plane. [16]

Spire calculated the PFD as follows:

PFD [dBW/m^2/4 kHz] = EIRP (dBW) – 11 – 20log10(D) – 10log10(BW) + 36

where EIRP is the Maximum EIRP of the transmission, D is the distance between the satellite and affected surface area in km, and BW is the bandwidth of the transmission in MHz.

The calculations establish that Spire can comply with the applicable limits at all angles of arrival except 0-10 degrees. At these non-compliant angles, Spire will terminate operations to avoid interference concerns.



C. Protecting deep-space research earth station operations

ITU-R Recommendation SA-1157 specifies a maximum allowable interference power spectral flux-density level at the Earth's surface of -222 dB(W/Hz) to protect ground receivers in the deep-space research band operating in the 2290-2300 MHz frequencies.[17] Any Spire 2289-2290 MHz transmissions—at their worst angle of arrival directly above a receiving deep space earth station—into the 2290-2300 MHz band will possess a maximum interference power spectral density

[16] *See* ITU Table 21-4.
[17] *See* Recommendation ITU-R SA.1157-1 (2006) (deep-space research protection criteria).

of -232.74 dB(W/Hz). This value complies with the -222 dB(W/Hz) limit.[18] To assuage any remaining interference concerns, the company will implement baseband digital and hardware radiofrequency filtering and consider using transmit channels smaller than one megahertz.

D. Protecting other satellite operations

In the absence of applicable ITU and U.S. requirements protecting NGSO and geostationary-satellite orbit satellites in the 2025-2110 MHz or 2200-2290 MHz bands from ISL interference, Spire will implement modulation and channel coding techniques to reduce interference concerns. The Space Frequency Coordination Group ("SFCG"), which includes the U.S. Federal agencies, has recommended that NGSO operators reduce their ISLs' power spectral density by "using appropriate modulation techniques and channel coding in accordance with [Consultative Committee for Space Data Systems ("CCSDS")] recommendations."[19] Spire will incorporate QPSK DVB-S2 ¼ coding and consider implementing other CCSDS techniques to reduce the system's power spectral density and protect other co-channel satellites operating in these bands. The company, also as mentioned, will engage with the Federal operators to coordinate its proposed ISL use in these bands.

V. ORBITAL DEBRIS CONSIDERATIONS

The four Spire ISL satellites satisfy the applicable orbital dwell period and on-orbit collision and human casualty risk probability requirements in the FCC's rules and relevant international guidelines. Adding the ISL payload to the Spire Phase II satellite bus produces a satellite measuring 1 m x 1 m x 300 mm (envelope with the antennas and solar panels deployed) and weighing 6.0 kg. Spire's previously submitted orbital debris risk mitigation plan and assessment report—which the FCC reviewed when licensing Spire's Phase II satellites—considered satellites possessing the mentioned dimensions and operating at altitudes from 385 to 650 km and inclinations ranging from

[18] *See id.*

[19] *See, e.g.*, *Interference from Space-to-Space Links between Non-geostationary Satellites to Other Space Systems in the 2025-2110 and 2200-2290 MHz Bands*, SFCG (Oct. 20, 2005), https://bit.ly/38UT26J. CCSDS recommendations provide technology-agnostic guidance by generally noting that the specific ISL architecture requirements and mitigation techniques will vary by mission and its link characteristics. *See, e.g.*, *Space Communications Cross Support – Architecture Requirements Document*, CCSDS § 6 (May 2015), https://bit.ly/2INYVIw ("This section does not attempt to provide concrete guidance for the selection of specific modulation, coding, or link layer standards for any particular application. That is a deep technical subject that requires careful analysis of mission and communications asset characteristics and mission trajectory.").

equatorial to polar sun-synchronous (98 degrees).[20] Atmospheric reentry for nominal satellites operating between 500 km and 600 km occurs between 3.1 to 5.5 years, well before the 25-year deorbit requirement.[21] A nominal satellite's highest probability of collision with space objects greater than 10 cm in diameter equals 0.00001 (at the worst-case altitude of 650 km) and complies with the 0.001 probability requirement.[22] This collision risk probability will be lower for Spire satellites operating below 550 km and remains hundreds of times lower than legacy satellite busses' probability of collision in their worst-case orbits.[23] A nominal satellite's human casualty risk during its uncontrolled reentry equates to 0%—complying with the 1:10000 requirement—because Spire expects no objects to survive reentry.[24]

VI. ITU ADVANCED PUBLICATION INFORMATION ("API") FILING

Spire's non-ISL communications operate under the U.S. "LEMUR-2-3" API. The company will amend this filing to accommodate its experimental and future commercial ISL use.

VII. STOP BUZZER DESIGNATION

The following individuals will function as the stop buzzer contacts during experimental operations.

Name	Spire Operations Hotline	Francisca Adeuyi	Robert Sproles
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Address	251 Rhode Island Street Suite 204 San Francisco, CA 94104 United States of America	Unit 5A, Sky Park 5 45 Finnieston Street Glasgow, G3 8JU United Kingdom	1825 33rd Street Suite 100 Boulder, CO 80301 United States of America
Email	ops@spire.com	francisca.adeuyi@spire.com	robert.sproles@spire.com

[20] Spire has contemporaneously resubmitted the documents for the FCC's viewing convenience. *See generally* Spire Orbital Debris Risk Mitigation Plan ("OD Risk Plan"); Spire Orbital Debris Assessment Report ("ODAR").
[21] *See* OD Risk Plan at 2-5; ODAR at 13. The satellites naturally decay orbits.
[22] *See* OD Risk Plan at 6-9; ODAR at 7-9.
[23] *See* OD Risk Plan at 7; *see also* Darren McKnight, *et al.*, Responsible Behavior for Constellations and Clusters, Space Traffic Management Conference (2018), https://bit.ly/2WILc3G.
[24] *See* OD Risk Plan at 5; ODAR at 15.