

Correspondence Reference Number: 42108

Application: 0343-EX-CN-2018

Comment: The band 401-402 MHz is not allocated for SPACE OPERATION in the uplink direction.

Therefore, you will need to provide justification and EMC analysis for the Uplink showing you can protect other operators in the band.

Response: We wish to modify our request from uplink/downlink in the 401.15-401.20 MHz band to downlink in the 401.15-401.20 MHz band, and uplink in the 402.65-402.70 MHz band.

Justification for Uplink in the 402.65 to 402.70 MHz Band

The requested uplink frequency range of 402.65 to 402.70 MHz is due to three primary factors:

- Similarity to current operations in the 402-403 MHz band & little congestion inside of the proposed 402.65-402.70 MHz uplink range ○ See Section 1: Congestion Analysis & Protection of Other Operators
- Precedent of similar uplink operations being allowed within the 401-402 MHz band ○ See Section 2: Existing Licenses for Uplink in a Similar Band
- Operational range of the GomSpace AX100UL radio ○ See Section 3: Hardware Limitations of Current Radio System

1 Congestion Analysis & Protection of Other Operators

The 402-403 MHz band permits Earth-to-space (i.e. uplink) transmissions for both Meteorological Satellite and Earth Exploration Satellite operations, as shown in Figure 1. The proposed uplink transmissions in the 402.65-402.70 MHz range will be solely for telemetry, tracking, and command (TT&C) purposes – very similar to the types of uplink transmissions used by Meteorological and Earth Exploration Satellites. [1] Most importantly, to ensure compatibility with others users, the proposed uplink will be operated on a strictly unprotected, non-interference basis such that uplink operations will be adjusted or terminated immediately if interference is reported.

To protect other operators, the FCC General Menu Reports Tool was used to conduct a survey of all current and pending FCC licenses between 402 and 403 MHz. As shown in **Error! Reference source not found.** and Table 2, the proposed uplink range of 402.65-402.70 MHz falls only within the operating range of existing licenses for Bigelow Aerospace and Spire Global, with all other operators at least 20 KHz away. Note that frequency overlap with Bigelow Aerospace and Spire Global is unavoidable, given that their licenses cover most or all of the 402-403 MHz band, but also quite feasible as demonstrated by their existing overlap with more than ten other operators. The proposed 402.65-402.70 MHz uplink range also avoids frequency bands in use by existing NOAA weather satellites, including the GOES-R series.

The proposed uplink operation further protects operators by locating the proposed ground station in Urbana, Illinois – a substantial distance from neighboring licensees. No uplink facility operating in the 402-403 MHz range currently exists in Illinois or a state neighboring it, with the nearest licensee located more than 500 miles away in Duluth, Minnesota. In addition, uplink transmission will only take place

during transmit windows averaging approximately 10 minutes, further decreasing the chance of harmful interference. In the unexpected event that another user in the band does report harmful interference in the 402.65-402.70 MHz range, the University of Illinois will immediately adjust or halt all uplink transmissions.

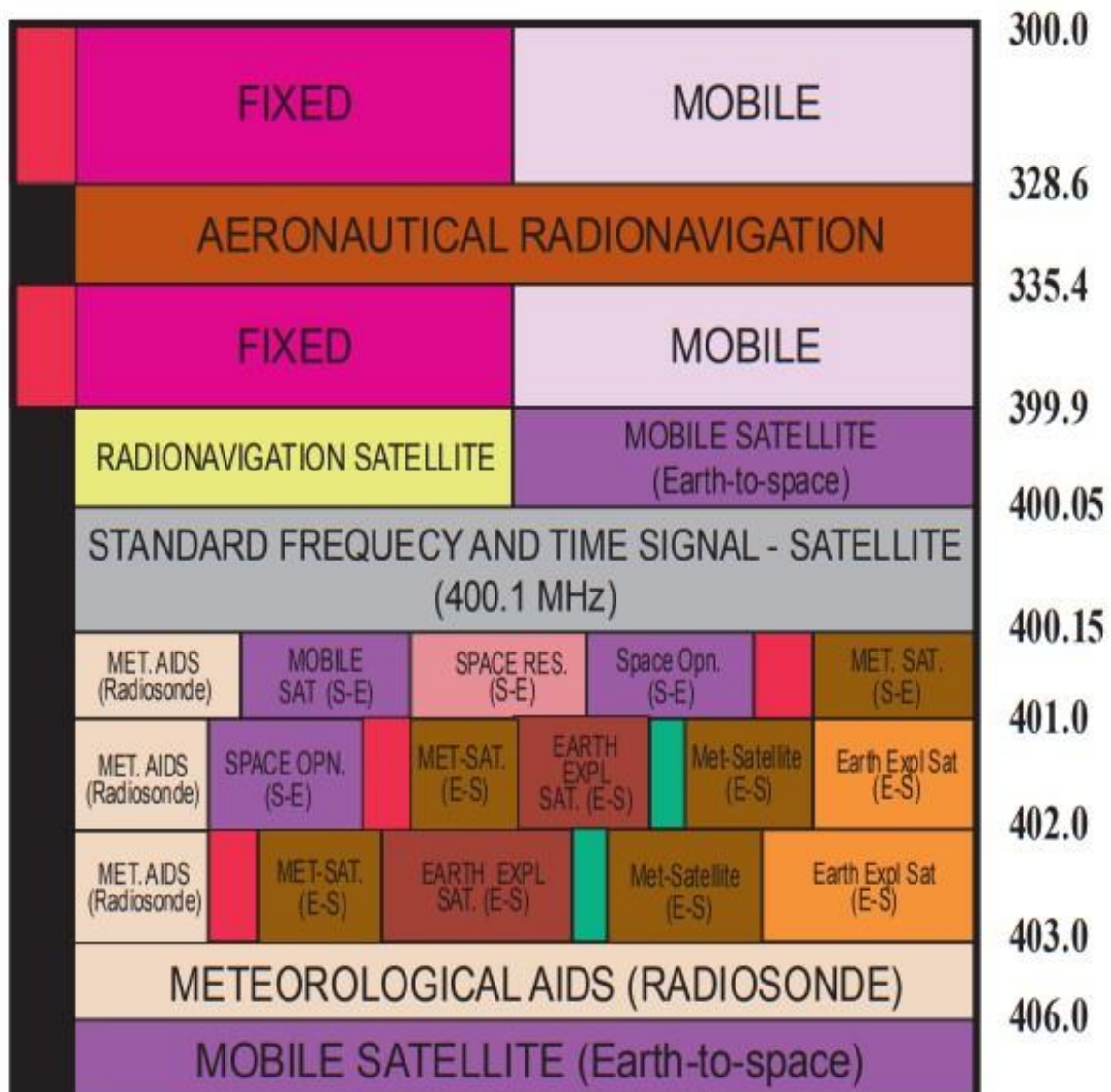


Figure 1: Frequency Allocations in the 300.0-406.0 MHz Range [2]

Table 1: Currently Licensed & Pending Facilities in the OET Experimental Licensing System Database for Frequency Range 402-403 MHz [3]

Licensee	Transmitter City	Transmitter State	Lower Frequency	Upper Frequency
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			(MHz)	(MHz)
Lockheed Martin Corporation	Owego	NY	402.000	
Lockheed Martin Corporation	Owego	NY	402.000	
Quinteccent Inc	Radium Springs	NM	402.000	406.000
Lockheed Martin Corporation	Marion	MA	402.125	
Bigelow Aerospace, LLC	North Las Vegas	NV	402.400	403.000
Bigelow Aerospace, LLC	Fairfax	VA	402.400	403.000
Bigelow Aerospace, LLC	Loring AFB	ME	402.400	403.000
Bigelow Aerospace, LLC	Naalehu	HI	402.400	403.000
Bigelow Aerospace, LLC	North Pole	AK	402.400	403.000
Lockheed Martin Corporation	Marion	MA	402.500	
Astro Digital, Incorporated	Moffett Field	CA	402.580	402.620
Astro Digital, Incorporated	Santa Clara	CA	402.600	
University of Illinois at UrbanaChampaign (Proposed)	Urbana	IL	402.650	402.700
BAE Systems Information and Electronic Systems Integration Inc.	Merrimack	NH	402.725	
BAE Systems Information and Electronic Systems Integration Inc.	Merrimack	NH	402.725	
Lockheed Martin Corporation	Marion	MA	402.875	
The Boeing Company	Ridley Park	PA	403.000	
The Boeing Company	Middletown	DE	403.000	
The Boeing Company	Crestview	FL	403.000	
The Boeing Company	Huntington Beach	CA	403.000	406.000
The Boeing Company	Rowland Heights	CA	403.000	406.000
The Boeing Company	Mt Wilson	CA	403.000	406.000
The Boeing Company	Huntington Beach	CA	403.000	406.000
The Boeing Company	Rowland Heights	CA	403.000	406.000
The Boeing Company	Mt Wilson	CA	403.000	406.000
Volvo Ocean Race	Newport	RI	403.000	449.000
The Boeing Company	Seattle	WA	403.000	608.000

Table 2: Currently Licensed & Pending Facilities in the International Bureau Filing System Database for Frequency Range 402-403 MHz [3]

Licensee	Transmitter City	Transmitter State	Lower Frequency (MHz)	Upper Frequency (MHz)
Spire Global, Inc.	Hartford	CT	402.000	403.000
Spire Global, Inc.	Ellicott	CO	402.000	403.000
Spire Global, Inc.	Anchorage	AK	402.000	403.000
Spire Global, Inc.	Boca Raton	FL	402.000	403.000
Spire Global, Inc.	Juneau	AK	402.000	403.000
Spire Global, Inc.	Naalehu	HI	402.000	403.000
Spire Global, Inc.	Naalehu	HI	402.000	403.000
Spire Global, Inc.	Piti	GU	402.000	403.000
Spire Global, Inc.	Tukwila	WA	402.000	403.000
Spire Global, Inc.	San Francisco	CA	402.000	403.000
Spire Global, Inc.	Richardson	TX	402.000	403.000
Spire Global, Inc.	West Jordan	UT	402.000	403.000
Spire Global, Inc.	San Francisco	CA	402.000	403.000
Spire Global, Inc.	Saint Croix	VI	402.000	403.000
Spire Global, Inc.	Juneau	AK	402.000	403.000
Spire Global, Inc.	Tuscon	AZ	402.000	403.000
Spire Global, Inc.	Duluth	MN	402.000	403.000
Spire Global, Inc.	Charlotte	NC	402.000	403.000
Astro Digital US, Inc.	Santa Clara	CA	402.580	402.620
Astro Digital US, Inc.	Santa Clara	CA	402.580	402.620
RBC Signals, LLC	Deadhorse	AK	402.580	402.620
RBC Signals, LLC	Deadhorse	AK	402.580	402.620
<i>University of Illinois at UrbanaChampaign (Proposed)</i>	<i>Urbana</i>	<i>IL</i>	<i>402.650</i>	<i>402.700</i>
DG Consents Sub, Inc.	DULLES	VA	402.720	402.720
Astro Digital US, Inc.	Santa Clara	CA	402.880	402.920
Astro Digital US, Inc.	Santa Clara	CA	402.880	402.920
RBC Signals, LLC	Deadhorse	AK	402.880	402.920
RBC Signals, LLC	Deadhorse	AK	402.880	402.920

2 Existing Licenses for Uplink in a Similar Band

Precedent exists within the FCC public database for granting an uplink license to experimental CubeSats in bands allocated for uplink by Meteorological and Earth Exploration Satellites. Specifically, in 2017, Astranis Space Technologies Corp. received an FCC experimental license for a TT&C uplink from 401.600-401.750 MHz for a demo telecommunications CubeSat. This uplink range falls within the 401-402 MHz band, allocated to Meteorological and Earth Exploration Satellite uplink as well as Space Operation downlink. Within their license narrative, Astranis successfully makes the case that TT&C uplink operations for CubeSats can be compatible with existing uplink operations by Meteorological and Earth Exploration Satellites:

“TT&C uplink operations in the 401 MHz band will take place intermittently and for brief periods (approximately 10 minutes) when the satellite is in view of the Fairbanks, Alaska earth station site. Through coordination with any other co-frequency operations in the area, Astranis will ensure its TT&C operations will be fully compatibility with other spectrum users and are conducted on a strictly unprotected, non-interference basis only. Nonetheless, Astranis commits to adjust or suspend earth station uplink operations in the 401.600-401.750 MHz band upon notification that such operations are causing harmful interference to other spectrum users.”⁶

⁶ The U.S. Table of Allocations includes Earth Exploration Satellite and Meteorological Satellite operations in the Earth-to-space direction in the 401 MHz band, and such operations are similar to and compatible with intermittent, temporary TT&C operations. Astranis’ proposed experimental TT&C uplink operations can be permitted in the band because they will be conducted on an unprotected, non-interference basis.” [1]

A similar case can be made for the 402-403 MHz band, namely that by careful frequency selection and a commitment to unprotected, non-interference operation, the University of Illinois’s proposed uplink between 402.65-402.70 MHz to a LEO CubeSat can and will be fully compatible with existing licenses for Meteorological and Earth Exploration Satellites.

3 Hardware Limitations of Current Radio System

The radio present on the CAPSat CubeSat is a GomSpace AX100UL radio. As shown below in Table 3, the AX100UL operates only within the 395-405 MHz band, with a noticeable gap in the 399.5-400.5 MHz range due to manufacturer limitations designed to avoid interference with the Standard Frequency and Time Signal for satellites.

Table 3: GomSpace AX100 Radio Operational Ranges [3]

Variant	Description
AX100U	UHF 430-440 MHz
AX100UL	UHF-Low 395-405 MHz (except 399.5 – 400.5 MHz) ¹
AX100V	VHF 140-150 MHz (except 143.5 – 144.5 Mhz)

¹ The hole in the range is caused by intermodulation with the reference XTAL and will cause spurs if selected closer than 500 khz to a multiple of 16.000 MHz.

Because this radio's operational range is 395-405 MHz (excluding 399.5-400.5 MHz), locating an ideal frequency is challenging. For instance, other satellite systems such as NOAA GOES/GOES-R are operated within the 400-401 MHz band, and much of the lower portion of the AX100UL operating range (395-400 MHz) is not allocated for uplink by satellites or is extremely congested. The top end of the operational range (403-406 MHz) is earmarked for meteorological aids for which this mission does not qualify.

The proposed uplink frequency range of 402.65-402.70 MHz was thus selected based on its current allocation for Earth-to-Space uplink operations, lack of congestion compared to other bands, and compatibility with the mission's existing radio system.

References

- [1] Astranis, "FCC Experimental STA Application: Narrative Summary," 8 August 2017. [Online]. Available: <https://apps.fcc.gov/els/GetAtt.html?id=196451&x=..> [Accessed 15 May 2018].
- [2] NTIA Office of Spectrum Management, "United States Frequency Allocations: The Radio Spectrum," October 2003. [Online]. Available: <https://www.ntia.doc.gov/files/ntia/publications/2003allochrt.pdf>. [Accessed 15 May 2018].
- [3] FCC, "FCC General Menu Reports 3.1.14 October 7, 2010," [Online]. Available: https://fjallfoss.fcc.gov/General_Menu_Reports/. [Accessed 3 June 2018].
- [4] GomSpace, "NanoCom AX100 Datasheet," 2016. [Online]. Available: <https://gomspace.com/UserFiles/Subsystems/datasheet/gs-ds-nanocom-ax100-33.pdf>. [Accessed 2018 May 15].