BRIO Satellite

Exhibit 2

File #: 0220-EX-CN-2018

Technical Information

March 7, 2018

Submitted By

SpaceQuest, Ltd.
3554 Chain Bridge Road
Suite 400
Fairfax, VA 22030

Table of Contents

List of Figures

1 Ownership, Operations and Construction.

SpaceQuest, Ltd. is a small business concern, and the owner, manufacturer and operator of the BRIO satellite. SpaceQuest has selected Spaceflight Industries of Seattle, Washington as the launch provider. BRIO will be launched on a SpaceX Falcon 9 launch vehicle from Vandenberg, AFB in California (geographic coordinates 34.5762°N; 4.2803°W) in July 2018. Pursuant to Part 5 §5.64 of the Commission's Rules, construction of the proposed experimental satellite and associated facilities has begun prior to the Commission's grant of an authorization. This is necessary given the nature of satellite construction and technical requirements over long lead times. Such construction is entirely at SpaceQuest's risk without any assurances that its proposed experiment will be subsequently approved.

- Space Station Name: BRIO
- BRIO Estimated Construction Completion Date: May 2018
- Spaceflight Final Certification of Licenses (Go/NoGo): May 31, 2018
- Purpose: Experimental, non-Common Carrier basis
- Orbital Type: NGSO

2 Orbital Requirements.

The satellite is designed to operate in a circular sun-synchronous orbit as described in Figure 1. The satellites are based on COTS technology that allows for small, lightweight and low-cost spacecraft.

BRIO	Value
Total Number of Orbital Planes:	1
Celestial Reference Body:	Earth
Inclination Angle (degrees):	97.52
Orbital Period (seconds)	5760
Apogee	575 km
Perigee	575 km

Figure 1 Orbital Parameters

3 Service Area.

United States

4 Satellite Payload.

The primary satellite mission of BRIO is to investigate, identify and resolve potential technical and implementation issues with its advanced satellite SDR radio design. Another important objective is to demonstrate the ability to upload and run new firmware that can introduce new features to the SDR Radio after it is on orbit. The results of this three-phase experiment will (1) demonstrate and validate the ability to uplink large numbers of messages to a satellite using a single channel, (2) demonstrate the ability to downlink messages to different ground devices on a single channel, and (3) implement an advanced signal processing algorithm on board a satellite to provide highly spectrally efficient bidirectional communications.

The secondary satellite mission of BRIO is to test a backup receiver developed by SpaceQuest to send executive commands, to reboot the satellite flight computer, or to cycle the spacecraft power bus in the event of a system failure. As a components manufacturer, it is expected that the outcome of this testing will result in a significant advancement in satellite radio equipment technology.

The BRIO UHF frequency assignment will be used for satellite telemetry, command and control. The S-Band assignment will be used to download selected mission data from the Myriota payload and upload new computer firmware to improve performance and correct any software deficiencies.

5 Principle Specifications.

BRIO is a 3U CubeSat whose outside envelope measures 100 x 100 x 340.5mm. The satellite's total mass is 5 kg. It has four deployable solar arrays, which deploy from the short edges of the spacecraft. The LiIon battery consists of eight cells wired as 4-series and 2 parallel. The expected mission lifetime is 5 years in a 575-km orbit due to battery life and deorbit analysis. SpaceQuest will own and operate the experimental CubeSat throughout its mission lifetime. The BRIO satellite will not be sold or transferred to another party.

6 System Block Diagram.

Figure 2 below shows the major components of the spacecraft and their interfaces. The flight computer is responsible for TT&C and payload scheduling. The attitude determination and control system orients the solar panels to the sun, except when the satellite is re-oriented to communicate with a ground station. The Software Defined Radio shown below is for an S-Band transceiver. The deployed array and antenna configuration is shown in Figure 3.

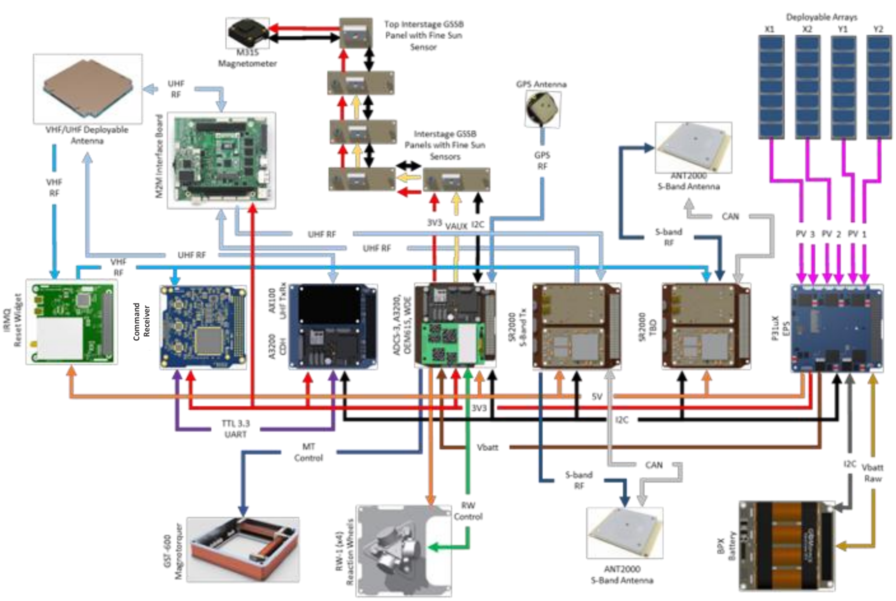


Figure 2 System Block Diagram

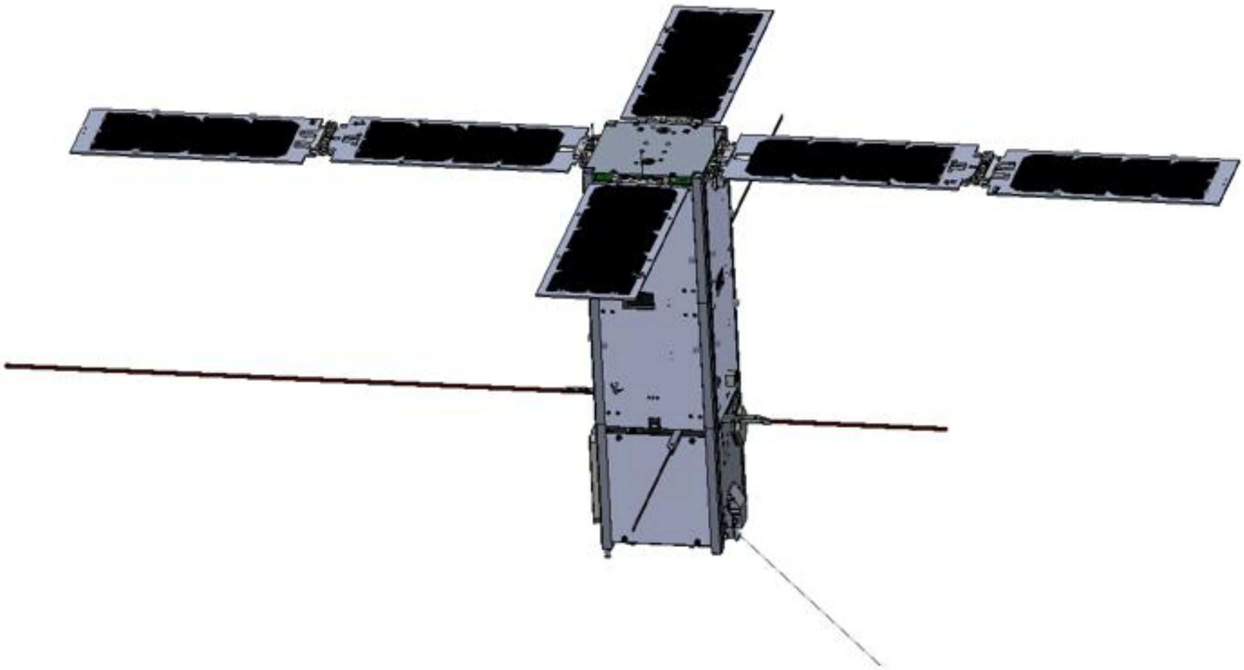


Figure 3 Isometric view of deployed configuration.

This configuration allows for two VHF and two UHF monopole antennas deployed from the body of the spacecraft. One UHF antenna is used for TT&C communication. The second UHF antenna is grounded. A third UHF antenna that is deployed from the side of the satellite when the solar panels are deployed is for a UHF SDR transceiver, which is a part of the experimental communications payload being evaluated for the hosted Myriota payload.

The receive-only VHF monopole antennas are used to test a new backup receiver design to send executive commands to reboot the satellite flight computer in the event of a system failure.

7 Telemetry, Tracking & Command and Payload Operations

The space-to-Earth downlink frequency band of 400.50-400.65 MHz and the Earth-to-space uplink frequency band of 399.90-400.05 MHz for TT&C communications will communicate with SpaceQuest's Earth stations in Fairfax, Virginia, Naalehu, Hawaii, North Pole, Alaska, and Limestone, Maine. The SpaceQuest TT&C Earth stations will also have the capability to uplink executive commands to a backdoor command receiver at 145.92 MHz.

The second UHF Transceiver used to evaluate Myriota's advanced communications processor will also operate in the space-to-Earth downlink frequency band of 400.50-400.65 MHz and the Earth-to-space uplink frequency band of 399.90-400.05 MHz.

The space-to-Earth frequency band of 2288-2289 MHz will be used to downlink experimental test data to SpaceQuest's Earth stations in North Pole, Alaska and Limestone, Maine. The Earth-to-space uplink frequency band of 2045-2046 MHz from LimeStone, Maine will be used occasionally to upload new firmware to the Myriota payload.

8 Radio Equipment.

8.1 UHF TT&C Transceiver

- NanoComm AX100 UHF Transceiver manufactured by GomSpace.
- Primary transceiver capability for telecommand, telemetry, and schedule uploads.
- The transceiver can operate between 390 and 406 MHz at 9600 bps. modulation.

8.1.1 Downlink: UHF Transmit

- Operating Frequency 400.60 MHz
- Output Power: 3 Watts
- EIRP: 3.3 dBW
- Channels: 400.50-400.65 MHz
- Frequency Deviation: 16 kHz

8.1.2 Uplink: UHF Receive

- Operating Frequency 399.95 MHz
- Sensitivity: -110 dBm
- Channels: 399.90-400.05 MHz
- Frequency Stability: ±10 ppm.

8.2 VHF Receiver:

- CERX-145 Narrowband FM Receiver manufactured by SpaceQuest
- Experimental backup VHF Receiver for emergency reboot or power cycle
- 145.92 MHz fixed receive frequency
- GMSK modulation at 9600bps.
- Sensitivity: -119 dBm

8.3 S-Band Transceiver:

- GomSpace TR600 S-Band SDR Transceiver
- Primary transceiver for mission data and commands to primary payload.
- Space-to-Earth downlink operates from 2220 to 2290 MHz
- Earth-to-space uplink operated from 2025 to 2110 MHz
- 700 Kbps data rate with QPSK modulation.

8.3.1 Downlink: S-Band Transmit

- Requested Frequency 2288-2289 MHz
- Output Power: 1 Watts
- Peak antenna Gain: 7 dBi
- EIRP: 3.3 dBW
- Data Rate: 700 kbps

- Channels: Tunable SDR Transmitter from 2220-2291MHz
- Necessary Bandwidth: 1,000 kHz.

8.3.2 Uplink: S-Band Receive

- Operating Frequency 2045-2046 MHz
- Sensitivity: -100 dBm
- Data Rate: 700 kbps
- Channels: Tunable SDR Receiver from 2025-2110 MHz
- Frequency Stability: ±10 ppm

8.4 UHF Experimental Payload Transceiver

- ERP-100 UHF Transceiver manufactured by SpaceQuest.
- UHF transceiver to be used with Myriota's experimental payload processor.
- The transceiver can operate between 390 MHz and 406 MHz at 9600 bps.
- Modulation is FM/GMSK

8.4.1 Downlink: UHF Transmit

- Operating Frequency 400.60 MHz
- Output Power: 4 Watts
- EIRP: 4.5 dBW
- Channels: 400.50-400.65 MHz
- Frequency Deviation: 16 kHz

8.4.2 Uplink: UHF Receive

- Operating Frequency 399.95 MHz
- Sensitivity: -112 dBm
- Channels: Tunable SDR
- Frequency Stability: ±10 ppm.

A summary of the BRIO Transmitter and Receiver parameters are provided in Figure 4.

Description	Transmitter 1	Transmitter 2	Transmitter 3	Receiver 1	Receiver 2	Receiver 3	Receiver 4
Radio Name	UTX	SBTX	EXTX	URX	SBRX	EXRX	VRX
Carrier Frequency, MHz	400.6	2288.5	400.6	399.95	2045.5	399.95	145.92
3 dB Bandwidth, MHz	0.015	0.75	0.015	0.015	0.75	0.015	0.015
Necessary Bandwidth, MHz	0.035	1.0	0.035	0.035	1.0	0.035	0.035
20 dB Bandwidth, MHz	0.020	0.80	0.020	NA	NA	NA	NA
60 dB Bandwidth, MHz	0.035	0.90	0.035	NA	NA	NA	NA
Receiver Sensitivity, dBm	NA	NA	NA	-110	-100	-110	-119
Antenna Gain, dBi	0.0	7.0	0.0	0.0	7.0	0.0	0.0
Modulation Type	GMSK	QPSK	GMSK	GMSK	QPSK	GMSK	GMSK
Total Data Rate (KHz)	9.6	700	9.6	9.6	700	9.6	9.6
Receiver Span (MHz)	NA	NA	NA	0.15	1.0	0.15	0.05
EIRP, dBW	3.3	3.4	4.5	NA	NA	NA	NA
Antenna Polarization	Linear	Circular	Linear	Linear	Circular	Linear	Linear

Figure 4 Summary of BRIO Transmitter and Receiver parameters.

9 Antenna Systems

The antenna frequency parameters for the BRIO Satellite are provided in Figure 5.

Beam	Lower Frequency	Upper Frequency	Freq. Units	Power	Power Units	Output Power/ERP	ERP Units	Mean/ Peak	Frequency Tolerance	Station Class
SBTX	2288.0	2289.0	MHz	1.0	W	3.4	dBW	Peak	+/-10 ppm	Mobile
UTX	400.50	400.65	MHz	3.0	W	3.3	dBW	Peak	+/-10 ppm	Mobile
EXTX	400.50	400.65	MHz	4.0	W	4.5	dBW	Peak	+/-10 ppm	Mobile

Figure 5 Antenna Frequency Registration

The antenna emission parameters for the BRIO Satellite are provided in Figure 6.

Beam	Lower Frequency	Upper Frequency	Units	Emission	Modulating Signal	Necessary Bandwidth
SBTX	2288.0	2289.0	MHz	1M00G1D	QPSK	1,000 KHz
UTX	400.50	400.65	MHz	35K0F1D	GMSK	35KHz
EXTX	400.50	400.65	MHz	35K0F1D	GMSK	35KHz

Figure 6 Frequency Emissions Registration

10 Satellite Link Budgets

The UHF TT&C uplink budget is shown in Figure 7. Figure 8 shows the TT&C downlink budget.

UHF	Uplink Budget						2/26/18	
ELEVATION ANGLE TO SATELLITE (Deg)	**5**	**10**	**20**	**30**	**45**	**60**	**75**	**90**
ORBITAL ALTITUDE (km)	575	575	575	575	575	575	575	575
EARTH'S RADIUS (km)	6378	6378	6378	6378	6378	6378	6378	6378
COVERAGE HALF ANGLE TO HORIZON (Deg)	67	67	67	67	67	67	67	67
SLANT RANGE TO SATELLITE (km)	2268	1874	1343	1034	782	655	594	575
SURFACE DISTANCE FROM RECEIVER TO SSP (km)	2111	1714	1164	824	508	301	141	0
Ground Transmitter								
TRANSMITTER FREQUENCY (MHz)	**399.95**	**399.95**	**399.95**	**399.95**	**399.95**	**399.95**	**399.95**	**399.95**
GROUND TRANSMITTER POWER (Watts)	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
GROUND TRANSMITTER POWER (dB)	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
TRANSMISSION LINE LOSS (dB)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
ANTENNA GAIN (dBi)	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5
GROUND TRANSMITTER EIRP (dBw)	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0
Satellite Receiver								
FREE SPACE LOSS (dB)	151.6	149.9	147.0	144.7	142.3	140.8	139.9	139.6
ISOTROPIC POWER AT SATELLITE ANTENNA (dB)	-129.6	-127.9	-125.0	-122.7	-120.3	-118.8	-117.9	-117.6
SATELLITE RECEIVER ANTENNA GAIN (dBi)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
POLARIZATION LOSS (dB)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
IMPLEMENTATION LOSS (dB)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
SYSTEM NOISE TEMPERATURE (K)	400	400	400	400	400	400	400	400
FRONT END GAIN (Ant Gain-Losses) (dB)	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0
FRONT END G/T (dB/K)	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0
BOLTZMAN'S CONSTANT (dB)	-228.6	-228.6	-228.6	-228.6	-228.6	-228.6	-228.6	-228.6
UPLINK C/No (dB-Hz)	69.0	70.7	73.6	75.8	78.3	79.8	80.7	80.9
DATA RATE (bps)	9600	9600	9600	9600	9600	9600	9600	9600
Eb/No (dB)	29.2	30.9	33.8	36.0	38.5	40.0	40.8	41.1
Eb/No REQUIRED FOR BER OF 10^{-5} (dB)	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5
UPLINK MARGIN (dB)	**17.7**	**19.4**	**22.3**	**24.5**	**27.0**	**28.5**	**29.3**	**29.6**

Figure 7 Satellite UHF TT&C Uplink Budget

UHF	Downlink Budget						2/26/18	
ELEVATION ANGLE TO SATELLITE (Deg)	**5**	**10**	**20**	**30**	**45**	**60**	**75**	**90**
ORBITAL ALTITUDE (km)	575	575	575	575	575	575	575	575
EARTH'S RADIUS (km)	6378	6378	6378	6378	6378	6378	6378	6378
COVERAGE HALF ANGLE TO HORIZON (Deg)	67	67	67	67	67	67	67	67
SLANT RANGE TO SATELLITE (Km)	2268	1874	1343	1034	782	655	594	575
SURFACE DISTANCE FROM RECEIVER TO SSP (km)	2111	1714	1164	824	508	301	141	0
Satellite Transmitter								
SATELLITE DOWNLINK FREQUENCY (MHz)	**400.60**	**400.60**	**400.60**	**400.60**	**400.60**	**400.60**	**400.60**	**400.60**
TRANSMITTER OUTPUT POWER (Watts)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
TRANSMITTER OUTPUT POWER (dBw)	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8
IMPLEMENTATION LOSS (dB)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
SATELLITE TRANSMIT ANTENNA GAIN (dB)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SATELLITE DOWNLINK EIRP (Watts)	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
SATELLITE DOWNLINK EIRP (dBw)	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3
Ground Receiver								
FREE SPACE LOSS (dB)	151.6	149.9	147.0	144.7	142.3	140.8	139.9	139.6
ISOTROPIC POWER AT MOBILE ANTENNA (dBw)	-148.3	-146.6	-143.7	-141.5	-139.0	-137.5	-136.7	-136.4
GROUND ANTENNA GAIN (dB)	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5
POLARIZATION LOSS (dB)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
TRANSMISSION LINE LOSS (dB)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
SYSTEM NOISE TEMPERATURE (K)	290	290	290	290	290	290	290	290
FRONT END GAIN (Ant Gain-Losses) (dB)	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5
FRONT END G/T (dB/K)	-15.1	-15.1	-15.1	-15.1	-15.1	-15.1	-15.1	-15.1
BOLTZMAN'S CONSTANT (dB)	-228.6	-228.6	-228.6	-228.6	-228.6	-228.6	-228.6	-228.6
DOWNLINK C/No (dB-Hz)	65.2	66.8	69.7	72.0	74.4	76.0	76.8	77.1
DATA RATE (bps)	9600	9600	9600	9600	9600	9600	9600	9600
Eb/No (dB)	25.4	27.0	29.9	32.2	34.6	36.1	37.0	37.3
Eb/No REQUIRED FOR GMSK BER of 10^{-5} (dB)	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5
DOWNLINK MARGIN (dB)	**13.9**	**15.5**	**18.4**	**20.7**	**23.1**	**24.6**	**25.5**	**25.8**

Figure 8 Satellite UHF TT&C Downlink Budget

The S-Band uplink budget is shown in Figure 9. Figure 10 shows the S-Band downlink budget.

S-Band	Uplink Budget							3/7/18
ELEVATION ANGLE TO SATELLITE (Deg)	1	5	15	25	40	60	75	90
ORBITAL ALTITUDE (km)	575	575	575	575	575	575	575	575
EARTH'S RADIUS (km)	6378	6378	6378	6378	6378	6378	6378	6378
COVERAGE HALF ANGLE TO HORIZON (Deg)	67	67	67	67	67	67	67	67
SLANT RANGE TO SATELLITE (km)	2660	2268	1573	1169	847	655	594	575
SURFACE DISTANCE to SSP (km)	2503	2111	1405	975	596	301	141	0
		0.0						
Ground Transmitter		0						
TRANSMITTER FREQUENCY (MHz)	2045.5	2045.5	2045.5	2045.5	2045.5	2045.5	2045.5	2045.5
GROUND TRANSMITTER POWER (Watts)	10	10	10	10	10	10	10	10
GROUND TRANSMITTER POWER (dB)	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
TRANSMISSION LINE LOSS (dB)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
ANTENNA GAIN (dBi) (10-ft dish @ 50% efficiency)	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
GROUND TRANSMITTER EIRP (dBw)	48.5	48.5	48.5	48.5	48.5	48.5	48.5	48.5
Satellite Receiver								
FREE SPACE LOSS (dB)	167.1	165.7	162.5	160.0	157.2	154.9	154.1	153.8
ISOTROPIC POWER AT SAT ANTENNA (dB)	-119	-117	-114	-111	-109	-106	-106	-105
SATELLITE RECEIVER ANTENNA GAIN (dBi)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
POLARIZATION LOSS (dB)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
IMPLEMENTATION LOSS (dB)	1.5	1.5	0.5	0.5	0.5	0.5	0.5	0.5
SYSTEM NOISE TEMPERATURE (K)	400	400	400	400	400	400	400	400
FRONT END GAIN (Ant Gain-Losses) (dB)	-1.5	-1.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
FRONT END G/T (dB/K)	-27.5	-27.5	-26.5	-26.5	-26.5	-26.5	-26.5	-26.5
BOLTZMAN'S CONSTANT (dB)	-228.6	-228.6	-228.6	-228.6	-228.6	-228.6	-228.6	-228.6
UPLINK C/No (dB-Hz)	82.5	83.9	88.0	90.6	93.4	95.6	96.5	96.8
DATA RATE (bps)	700000	700000	700000	700000	700000	700000	700000	700000
Eb/No (dB)	24.0	25.4	29.6	32.2	35.0	37.2	38.0	38.3
Eb/No REQUIRED FOR BER OF 10^{-6} (dB)	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
UPLINK MARGIN (dB)	**11.0**	**12.4**	**16.6**	**19.2**	**22.0**	**24.2**	**25.0**	**25.3**

Figure 9 Satellite S-Band Uplink Budget

S-Band	Downlink Budget							3/7/18
ELEVATION ANGLE TO SATELLITE (Deg)	1	5	15	25	40	60	75	90
ORBITAL ALTITUDE (km)	575	575	575	575	575	575	575	575
EARTH'S RADIUS (km)	6378	6378	6378	6378	6378	6378	6378	6378
COVERAGE HALF ANGLE TO HORIZON (Deg)	67	67	67	67	67	67	67	67
SLANT RANGE TO SATELLITE (Km)	2660	2268	1573	1169	847	655	594	575
SURFACE DISTANCE to SSP (km)	2503	2111	1405	975	596	301	141	0
Satellite Transmitter								
SATELLITE DOWNLINK FREQUENCY (MHz)	2288.5	2288.5	2288.5	2288.5	2288.5	2288.5	2288.5	2288.5
TRANSMITTER OUTPUT POWER (Watts)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
TRANSMITTER OUTPUT POWER (dBw)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TRANSMISSION LINE LOSS	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
IMPLEMENTATION LOSS (dB)	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
SATELLITE TRANSMIT ANTENNA GAIN (dB)	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
SATELLITE DOWNLINK EIRP (Watts)	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
SATELLITE DOWNLINK EIRP (dBw)	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4
Ground Receiver	1	5	15	25	40	60	75	90
FREE SPACE LOSS (dB)	168.1	166.7	163.5	160.9	158.2	155.9	155.1	154.8
ISOTROPIC POWER AT MOBILE ANTENNA (dBw)	-164.7	-163.3	-160.1	-157.5	-154.8	-152.5	-151.7	-151.4
GROUND ANTENNA GAIN (dB)	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
POLARIZATION LOSS (dB)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
TRANSMISSION LINE LOSS (dB)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
SYSTEM NOISE TEMPERATURE (K)	290	290	290	290	290	290	290	290
FRONT END GAIN (Ant Gain-Losses) (dB)	35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5
FRONT END G/T (dB/K)	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
BOLTZMAN'S CONSTANT (dB)	-228.6	-228.6	-228.6	-228.6	-228.6	-228.6	-228.6	-228.6
DOWNLINK C/No (dB-Hz)	74.8	76.2	79.4	81.9	84.7	87.0	87.8	88.1
DATA RATE (bps)	######	700,000	700,000	700,000	700,000	700,000	700,000	700,000
Eb/No (dB)	16.3	17.7	20.9	23.5	26.3	28.5	29.4	29.6
Eb/No REQUIRED FOR GMSK BER of 10^{-6} (dB)	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
DOWNLINK MARGIN (dB)	**3.3**	**4.7**	**7.9**	**10.5**	**13.3**	**15.5**	**16.4**	**16.6**

Figure 10 Satellite S-Band Downlink Budget

The UHF Experimental Payload uplink budget is shown in Figure 11.

UHF	Uplink Budget						3/6/18	
ELEVATION ANGLE TO SATELLITE (Deg)	**5**	**10**	**20**	**30**	**45**	**60**	**75**	**90**
ORBITAL ALTITUDE (km)	575	575	575	575	575	575	575	575
EARTH'S RADIUS (km)	6378	6378	6378	6378	6378	6378	6378	6378
COVERAGE HALF ANGLE TO HORIZON (Deg)	67	67	67	67	67	67	67	67
SLANT RANGE TO SATELLITE (km)	2268	1874	1343	1034	782	655	594	575
SURFACE DISTANCE TO SSP (km)	2111	1714	1164	824	508	301	141	0
Ground Transmitter								
TRANSMITTER FREQUENCY (MHz)	**399.95**	**399.95**	**399.95**	**399.95**	**399.95**	**399.95**	**399.95**	**399.95**
GROUND TRANSMITTER POWER (Watts)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
GROUND TRANSMITTER POWER (dB)	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8
TRANSMISSION LINE LOSS (dB)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
ANTENNA GAIN (dBi)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GROUND TRANSMITTER EIRP (dBw)	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3
Satellite Receiver								
FREE SPACE LOSS (dB)	151.6	149.9	147.0	144.7	142.3	140.8	139.9	139.6
ISOTROPIC POWER AT SAT ANTENNA (dB)	-148.3	-146.6	-143.7	-141.5	-139.0	-137.5	-136.6	-136.4
SATELLITE RECEIVER ANTENNA GAIN (dBi)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
POLARIZATION LOSS (dB)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
IMPLEMENTATION LOSS (dB)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
SYSTEM NOISE TEMPERATURE (K)	400	400	400	400	400	400	400	400
FRONT END GAIN (Ant Gain-Losses) (dB)	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0
FRONT END G/T (dB/K)	-28.0	-28.0	-28.0	-28.0	-28.0	-28.0	-28.0	-28.0
BOLTZMAN'S CONSTANT (dB)	-228.6	-228.6	-228.6	-228.6	-228.6	-228.6	-228.6	-228.6
UPLINK C/No (dB-Hz)	52.3	54.0	56.8	59.1	61.5	63.1	63.9	64.2
DATA RATE (bps)	9600	9600	9600	9600	9600	9600	9600	9600
Eb/No (dB)	12.5	14.1	17.0	19.3	21.7	23.3	24.1	24.4
Eb/No REQUIRED FOR BER OF 10^{-5} (dB)	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5
UPLINK MARGIN (dB)	**1.0**	**2.6**	**5.5**	**7.8**	**10.2**	**11.8**	**12.6**	**12.9**

Figure 11 Satellite Experimental UHF Uplink Budget

The UHF Experimental Payload downlink budget is shown in Figure 12.

UHF	Downlink Budget						3/6/18	
ELEVATION ANGLE TO SATELLITE (Deg)	**5**	**10**	**20**	**30**	**45**	**60**	**75**	**90**
ORBITAL ALTITUDE (km)	575	575	575	575	575	575	575	575
EARTH'S RADIUS (km)	6378	6378	6378	6378	6378	6378	6378	6378
COVERAGE HALF ANGLE TO HORIZON (Deg)	67	67	67	67	67	67	67	67
SLANT RANGE TO SATELLITE (Km)	2268	1874	1343	1034	782	655	594	575
SURFACE DISTANCE TO SSP (km)	2111	1714	1164	824	508	301	141	0
Satellite Transmitter								
SATELLITE DOWNLINK FREQUENCY (MHz)	**400.60**	**400.60**	**400.60**	**400.60**	**400.60**	**400.60**	**400.60**	**400.60**
TRANSMITTER OUTPUT POWER (Watts)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
TRANSMITTER OUTPUT POWER (dBw)	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
IMPLEMENTATION LOSS (dB)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
SATELLITE TRANSMIT ANTENNA GAIN (dB)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SATELLITE DOWNLINK EIRP (Watts)	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8
SATELLITE DOWNLINK EIRP (dBw)	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
Ground Receiver								
FREE SPACE LOSS (dB)	151.6	149.9	147.0	144.7	142.3	140.8	139.9	139.6
ISOTROPIC POWER AT ANTENNA (dBw)	-147.0	-145.4	-142.5	-140.2	-137.8	-136.3	-135.4	-135.1
GROUND ANTENNA GAIN (dB)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
POLARIZATION LOSS (dB)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
TRANSMISSION LINE LOSS (dB)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
SYSTEM NOISE TEMPERATURE (K)	290	290	290	290	290	290	290	290
FRONT END GAIN (Ant Gain-Losses) (dB)	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0
FRONT END G/T (dB/K)	-28.6	-28.6	-28.6	-28.6	-28.6	-28.6	-28.6	-28.6
BOLTZMAN'S CONSTANT (dB)	-228.6	-228.6	-228.6	-228.6	-228.6	-228.6	-228.6	-228.6
DOWNLINK C/No (dB-Hz)	52.9	54.6	57.5	59.8	62.2	63.7	64.6	64.9
DATA RATE (bps)	9600	9600	9600	9600	9600	9600	9600	9600
Eb/No (dB)	13.1	14.8	17.7	19.9	22.4	23.9	24.8	25.0
Eb/No REQUIRED FOR GMSK BER of 10^{-5} (dB)	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5
DOWNLINK MARGIN (dB)	**1.6**	**3.3**	**6.2**	**8.4**	**10.9**	**12.4**	**13.3**	**13.5**

Figure 12 Satellite Experimental UHF Downlink Budget

The VHF uplink budget is shown in Figure 13. The VHF Uplink Margin is plotted in Figure 14.

VHF	Uplink Budget							2/26/18
ELEVATION ANGLE TO SATELLITE (Deg)	**5**	**10**	**20**	**30**	**45**	**60**	**75**	**90**
ORBITAL ALTITUDE (km)	575	575	575	575	575	575	575	575
EARTH'S RADIUS (km)	6378	6378	6378	6378	6378	6378	6378	6378
COVERAGE HALF ANGLE TO HORIZON (Deg)	67	67	67	67	67	67	67	67
SLANT RANGE TO SATELLITE (km)	2268	1874	1343	1034	782	655	594	575
SURFACE DISTANCE FROM RECEIVER TO SSP (km)	2111	1714	1164	824	508	301	141	0
Ground Transmitter								
TRANSMITTER FREQUENCY (MHz)	**145.9**	**145.9**	**145.9**	**145.9**	**145.9**	**145.9**	**145.9**	**145.9**
GROUND TRANSMITTER POWER (Watts)	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
GROUND TRANSMITTER POWER (dB)	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
TRANSMISSION LINE LOSS (dB)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
ANTENNA GAIN (dBi)	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
GROUND TRANSMITTER EIRP (dBw)	16.5	16.5	16.5	16.5	16.5	16.5	16.5	16.5
Satellite Receiver								
FREE SPACE LOSS (dB)	142.8	141.1	138.2	136.0	133.5	132.0	131.1	130.9
ISOTROPIC POWER AT SATELLITE ANTENNA (dB)	-126.3	-124.6	-121.7	-119.5	-117.0	-115.5	-114.6	-114.4
SATELLITE RECEIVER ANTENNA GAIN (dBi)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
POLARIZATION LOSS (dB)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
IMPLEMENTATION LOSS (dB)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
SYSTEM NOISE TEMPERATURE (K)	400	400	400	400	400	400	400	400
FRONT END GAIN (Ant Gain-Losses) (dB)	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0
FRONT END G/T (dB/K)	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0
BOLTZMAN'S CONSTANT (dB)	-228.6	-228.6	-228.6	-228.6	-228.6	-228.6	-228.6	-228.6
UPLINK C/No (dB-Hz)	72.3	73.9	76.8	79.1	81.5	83.1	83.9	84.2
DATA RATE (bps)	9600	9600	9600	9600	9600	9600	9600	9600
Eb/No (dB)	32.5	34.1	37.0	39.3	41.7	43.3	44.1	44.4
Eb/No REQUIRED FOR BER OF 10^{-5} (dB)	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5
UPLINK MARGIN (dB)	**21.0**	**22.6**	**25.5**	**27.8**	**30.2**	**31.8**	**32.6**	**32.9**

Figure 13 Satellite VHF Uplink Budget

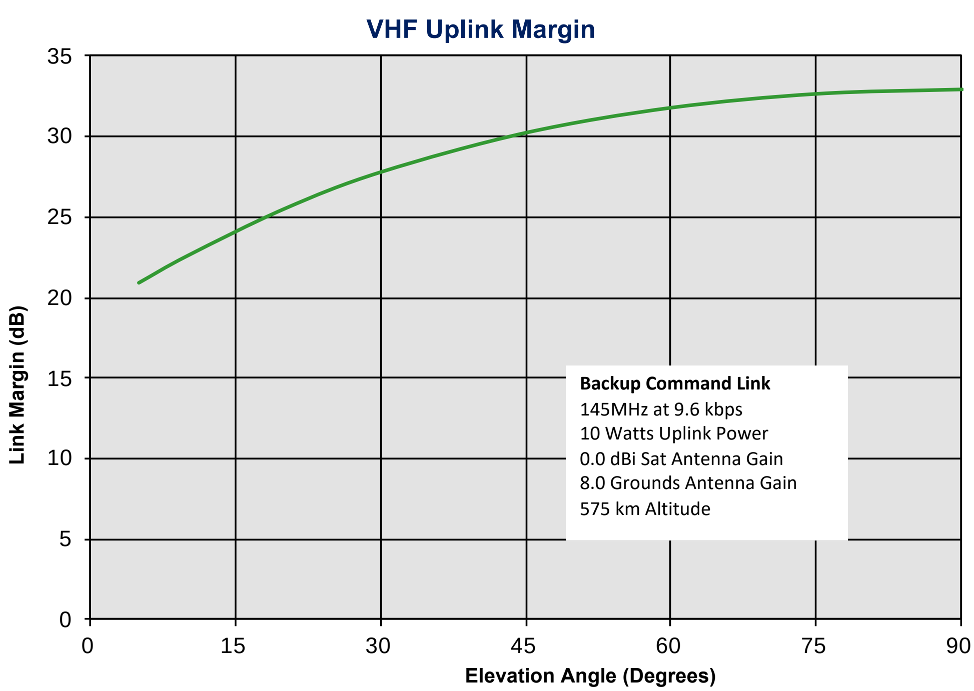


Figure 14 Satellite VHF Link Margins Vs. Elevation Angle

The satellite link margins for the UHF TT&C radio are plotted in *Figure 15*.

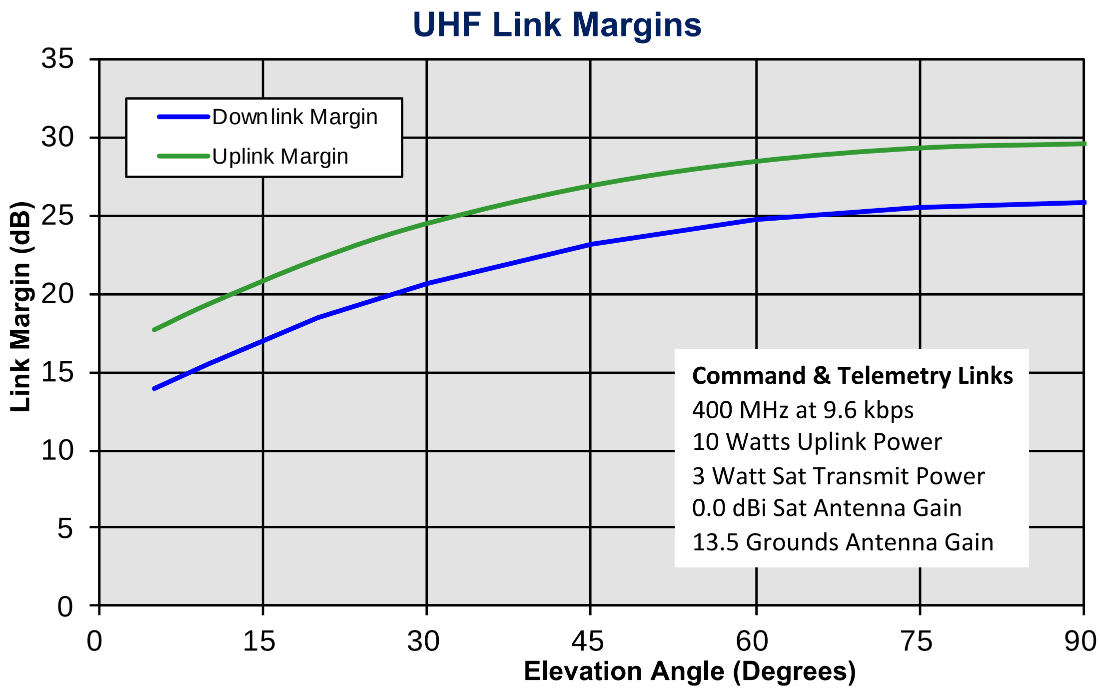


Figure 15 Satellite UHF TT&C Link Margins Vs. Elevation Angle

The satellite link margins for the S-Band radio are plotted in *Figure 16*.

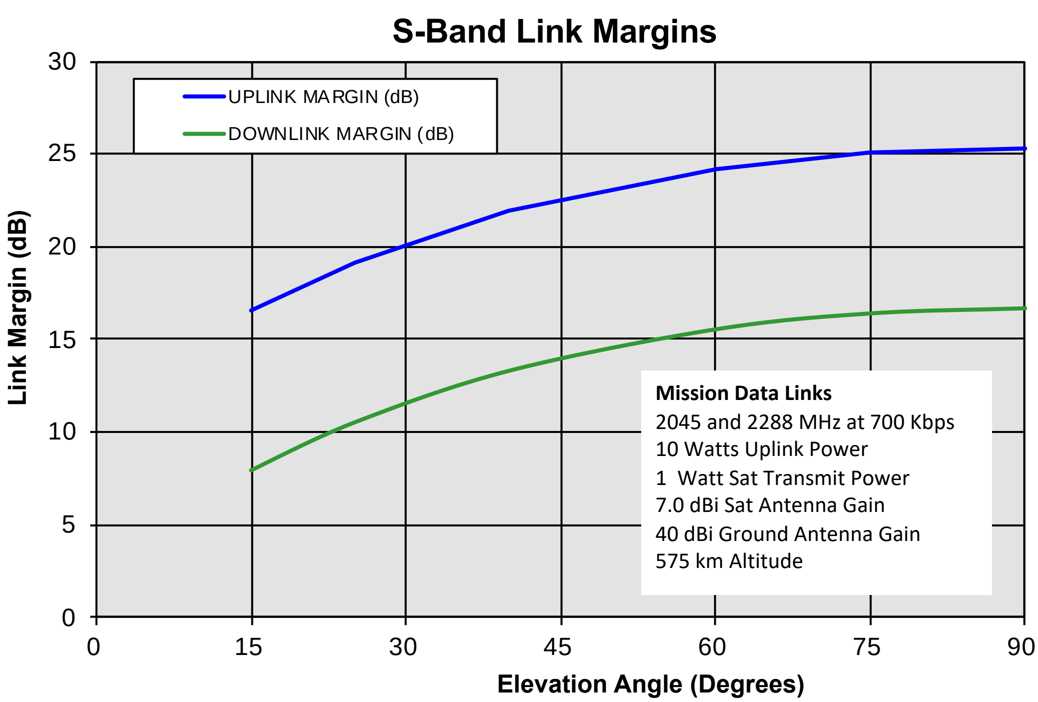


Figure 16 Satellite S-Band Link Margins Vs. Elevation Angle

The satellite link margins for the UHF Experimental Transceiver is plotted in *Figure 17*.

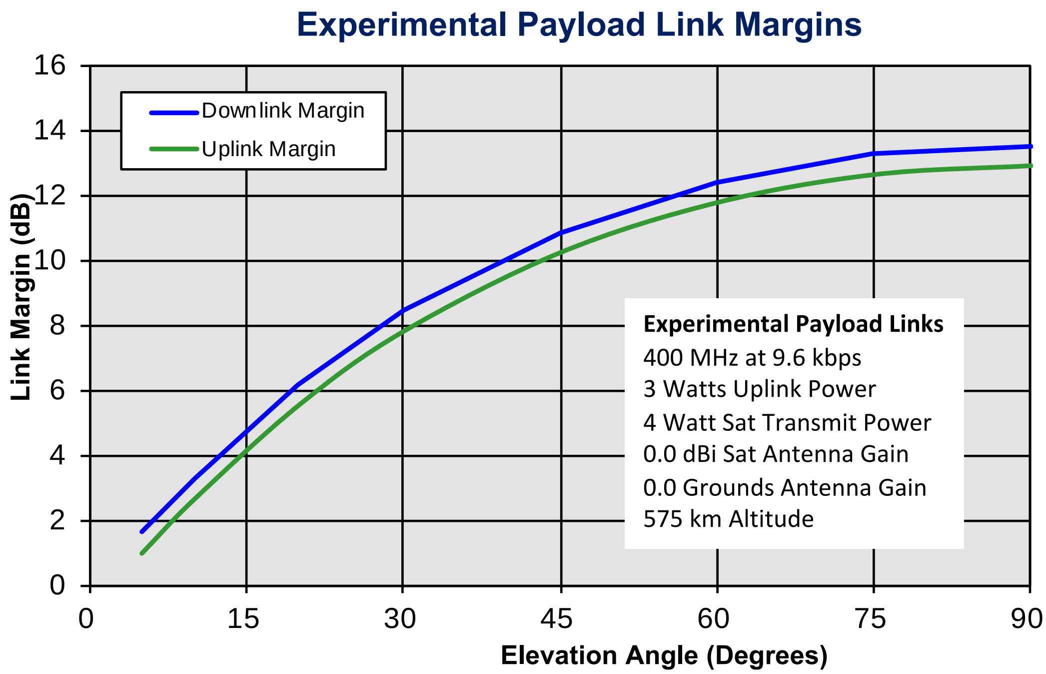


Figure 17 Satellite UHF Experimental Radio Link Margins Vs. Elevation Angle

11 Interference Analysis

11.1 400.50-400.65 MHz (TT&C and Experimental Downlink)

Interference with U.S. federal and commercial assignments in the 400.50-400.65 MHz band is unlikely as transmissions will only occur while over the SpaceQuest TT&C ground stations. The 400.50 to 400.65 MHz space-to-Earth band is allocated for UHF Little LEO data services.

11.2 399.90 -400.05 MHz (TT&C and Experimental Uplink)

Interference with U.S. federal and commercial assignments in the 399.00-400.05 MHz band is unlikely as uplink transmissions will only occur while over the SpaceQuest TT&C ground stations. The 399.0-400.05 MHz Earth-to-space band is allocated for UHF Little LEO data services.

11.3 2288-2289 MHz (Payload Downlink)

The GomSpace S-Band SDR transmitter is designed to operate in the 2220-2290 MHz band, but can operate slightly higher with some performance loss. Operation above 2292 MHz is not possible.

The 2288-2289 MHz downlink band was chosen for the BRIO satellite, but any other 1.0 MHz channel in the 2220-2291 MHz band would be acceptable. S-Band downlink operations will occur several times each day at either North Pole, AK or Limestone, ME.

Transmissions will be restricted as necessary to eliminate interference with other users of the band.

11.4 2045-2046 MHz (Payload Uplink)

SpaceQuest's S-Band satellite receiver is designed to operate in the 2025-2110 MHz band. A 1.0 MHz channel between 2045-2046 MHz was chosen because it appears to have the fewest number of license assignments. Infrequent S-Band uplink transmissions from Limestone, ME will be used to load new firmware to the BRIO satellite and to send confirmations of successful data packet downloads. Any 1.0 MHz channel within the 2025-2010 MHz band would be acceptable for the BRIO experiment.

12 Power Flux Density Analysis

12.1 400.50-400.65 MHz (TT&C Downlink)

The Power Flux Density for the UHF TT&C downlink is shown in Figure 18.

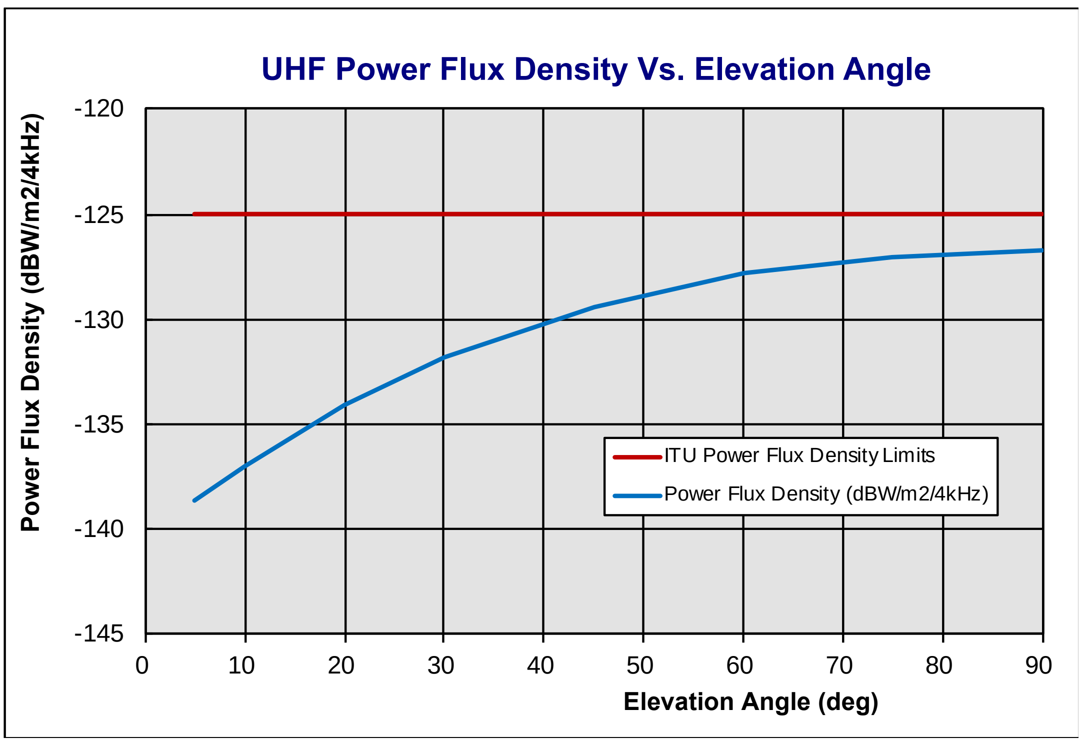


Figure 18 PFD at the Surface of the Earth for the UHF Transmitter

12.2 2288-2289 MHz (S-Band Downlink)

The PFD for the S-Band downlink satisfies the ITU PFD limits as shown in Figure 19.

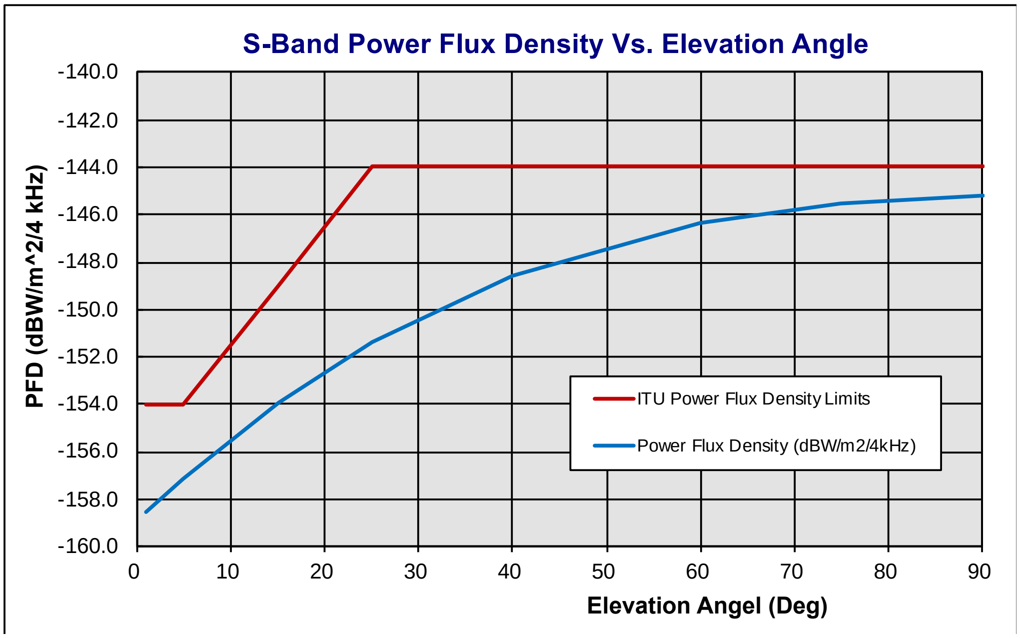


Figure 19 PFD at the Surface of the Earth for the S-Band Transmitter

12.3 400.50-400.65 MHz (Experimental Payload Downlink)

The Power Flux Density for the UHF Experimental Payload downlink is shown in Figure 20.

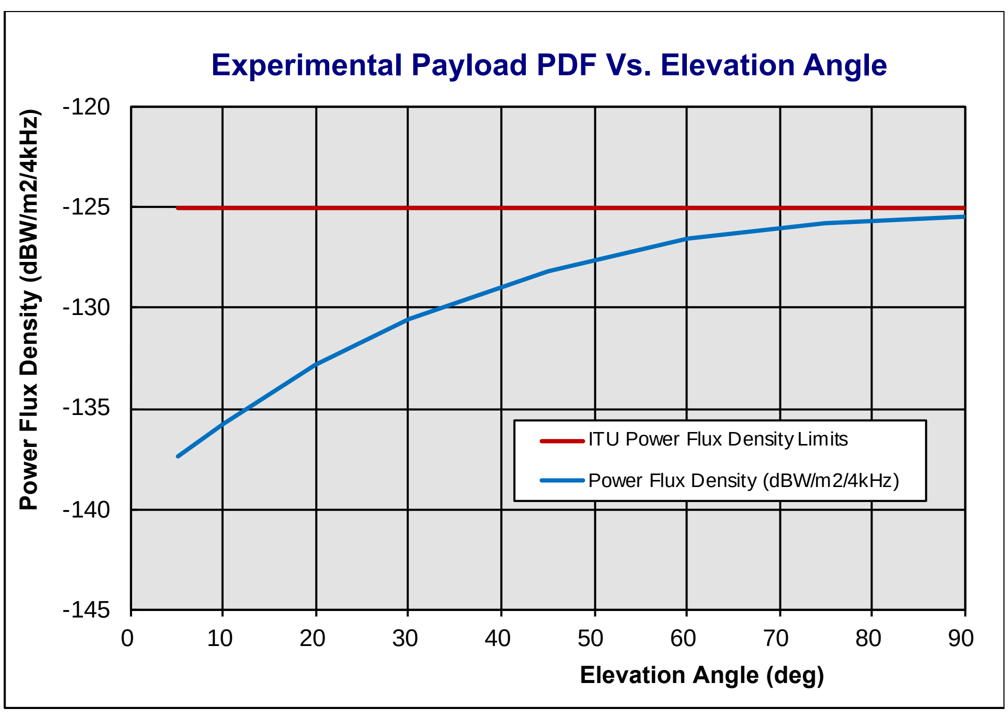


Figure 20 PFD at the Surface of the Earth for the UHF Payload Transmitter

13 Space Station Antenna Radiation Patterns

13.1 S-Band: BRIO Space Station Transmit/Receive Antenna

The GomSpace NanoCom ANT2150 side-mounted S-Band Patch Antenna is used to downlink the BRIO mission data. This circularly-polarized antenna incorporates an LNA designed to receive in the 2025-2110 MHz frequency band, and a Power Amplifier designed to transmit in the 2200-2290 MHz frequency band. The radiation pattern is shown in Figure 21.

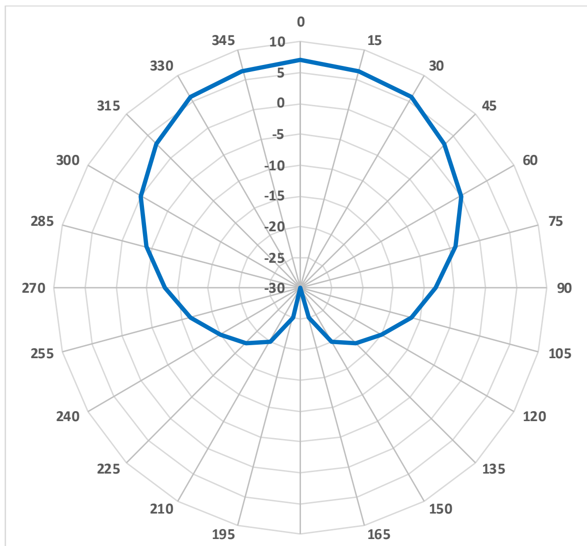


Figure 21 S-Band Satellite Transmit/Receive Antenna Radiation Pattern

13.2 UHF: BRIO Space Station TT&C Transmit/Receive Antenna

An ISIS Deployable Omnidirectional UHF Monopole Antenna System is used to uplink and downlink TT&C data. It has a 0 dBi average gain and a radiation pattern shown in Figure 22.

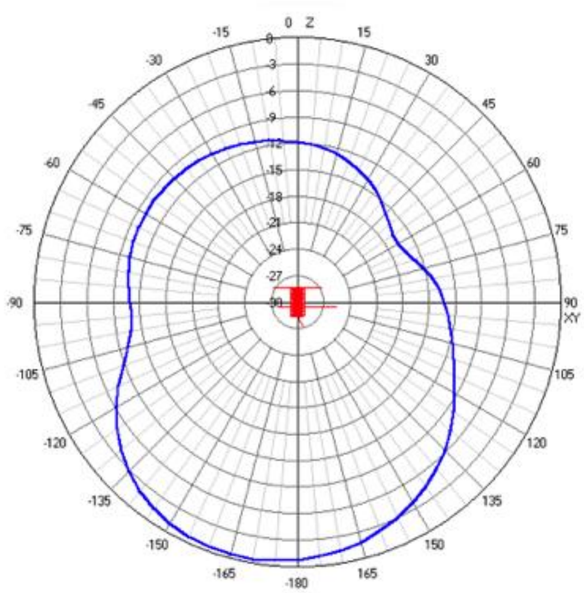


Figure 22 TT&C UHF Satellite Transmit/Receive Antenna Radiation Pattern.

13.3 VHF: BRIO Space Station Receive Antenna

The same ISIS Deployable Omnidirectional Antenna has a VHF monopole element, which is used to receive emergency commands to reboot the flight computer or to power cycle the spacecraft in the event of a single event latch up. This small, sensitive, very low-power receiver design that operates at a different, fixed frequency than the primary UHF TT&C receiver, can save a mission. SpaceQuest will perform sensitivity tests of the receiver in order to characterize its performance in the space environment. The omni-directional radiation pattern is shown in *Figure 23*.

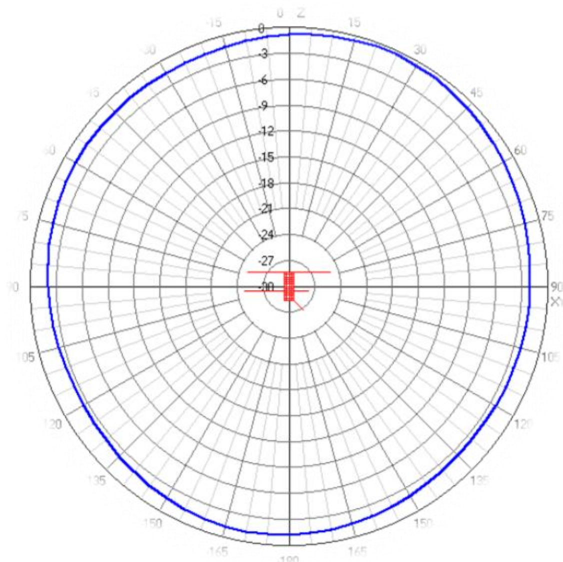


Figure 23 VHF Satellite Receive Antenna Radiation Pattern

13.4 UHF: BRIO Space Station Experimental UHF Receive/Transmit Antenna

An UHF Experimental Transceiver developed by SpaceQuest to investigate the performance of Myriota's novel protocol and processing algorithms is shown in **Error! Reference source not found.**.

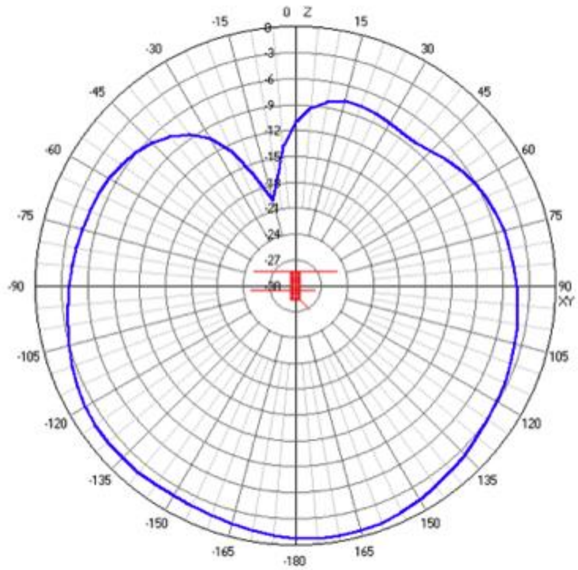


Figure 24 Experimental UHF Satellite Transmit/Receive Antenna Radiation Pattern

13.5 Summary of BRIO Antenna Characteristics

Figure 25 lists the antenna parameters for the four BRIO antennas.

Antenna Parameter	***S-Band***	***UHF***	***VHF***	***UHF Payload***
Frequency Range:	2025-2291 MHz	399.9-400.6 MHz	145.92 MHz	399.9-400.6 MHz
Bandwidth Required:	900 KHz	100 KHz	25 KHz	100 KHz
Emission Designator:	1M00G1D	35K0F1D	20K0F1D	35K0F1D
Number of Channels:	1	1	1	1
Space Station Class:	EH	ET	ED	EH
Beam Name:	SBTX and SBRX	UTX and URX	VRX	EXTX and EXRX
Emission/Receive	E/R	E/R	R	E/R
Max ISO. Gain	7.0 dBi	0.0 dBi	0.0 dBi	0.0 dBi
Antenna Type:	Patch	Monopole	Monopole	Monopole
Polarization:	Circular	Linear	Linear	Linear
Peak Power:	1.0 Watts	3.0 Watts	Receive Only	4.0 Watts
Antenna Pattern:	See Figure 21	See Figure 22	See Figure 23	See **Error! Reference source not found.**
Link Margin:	See Figure 16	See Figure 15	Receive Only	See Figure 17
Power Flux Density:	Within ITU limits. See Figure 19	Within ITU limits. See Figure 18	Receive Only	Within ITU limits. See Figure 20

Figure 25 BRIO Antenna Characteristics

14 Earth Station Antenna Radiation Patterns

The antenna pattern for SpaceQuest's UHF Earth Stations are provided in Figure 26.

14.1 UHF TT&C Antennas in Fairfax, VA, North Pole, AK and Naalehu, HI and Limestone, ME

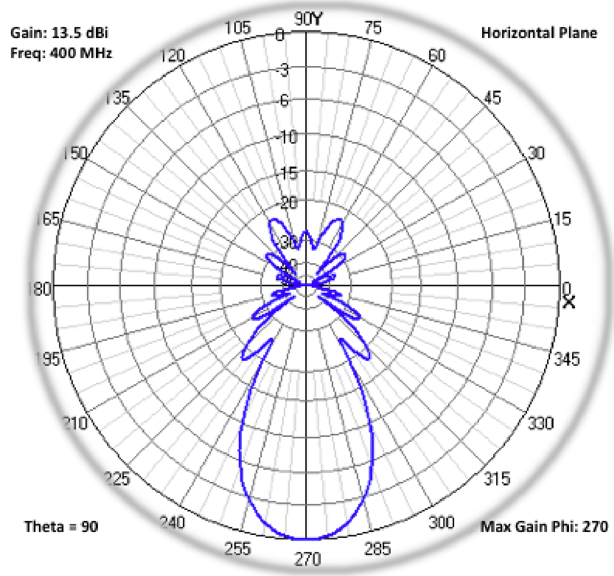


Figure 26 UHF Earth Station Antenna Radiation Pattern.

14.2 VHF Backup Antennas in Fairfax, VA, North Pole, AK and Naalehu, HI and Limestone, ME

The antenna patterns for SpaceQuest's VHF Earth Stations are provided in Figure 27.

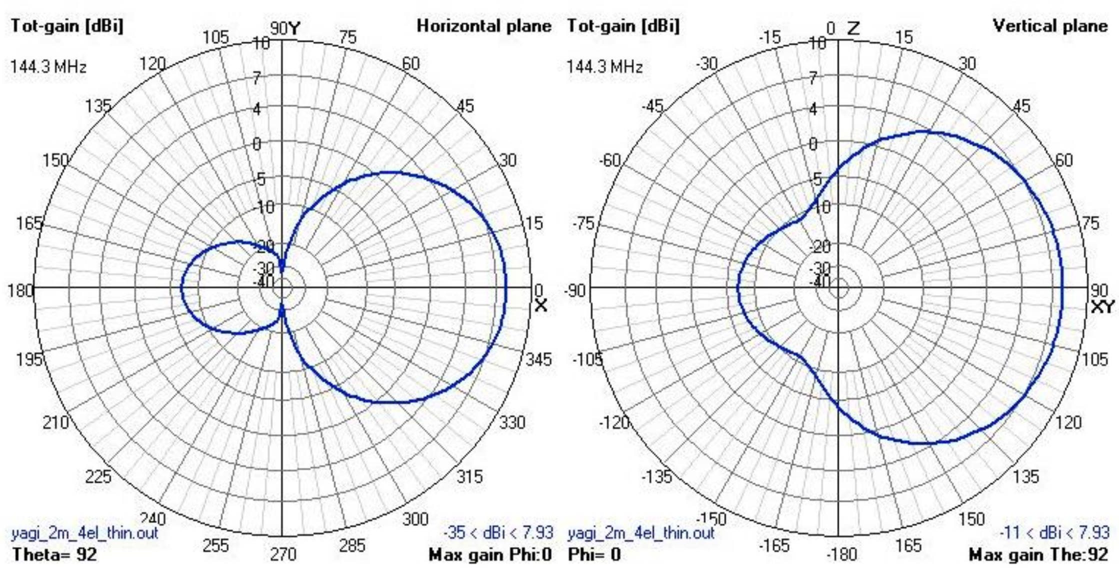
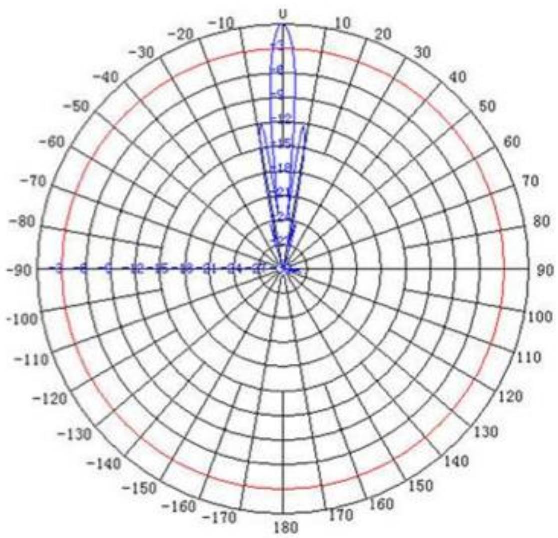


Figure 27 VHF Earth Station Antenna Radiation Pattern.

14.3 S-Band Earth Station Antenna in North Pole Alaska and Limestone, Maine.

SpaceQuest's S-Band antennas in Alaska and Maine are for downloading the spectrum data captured by the Myriota payload. Only the Maine S-Band uplink will be used to upload new firmware to the satellite. An S-Band radiation pattern for these antennas is shown in **Error! Reference source not found.**



Vertical Pattern Horizontal Pattern

Figure 28 S-Band Earth Station Antenna Radiation Pattern

14.4 UHF Experimental Antenna in Fairfax, VA

The radiation pattern for the omni-directional transceiver antenna that communicates with the UHF experimental payload on BRIO is depicted in Figure 29.

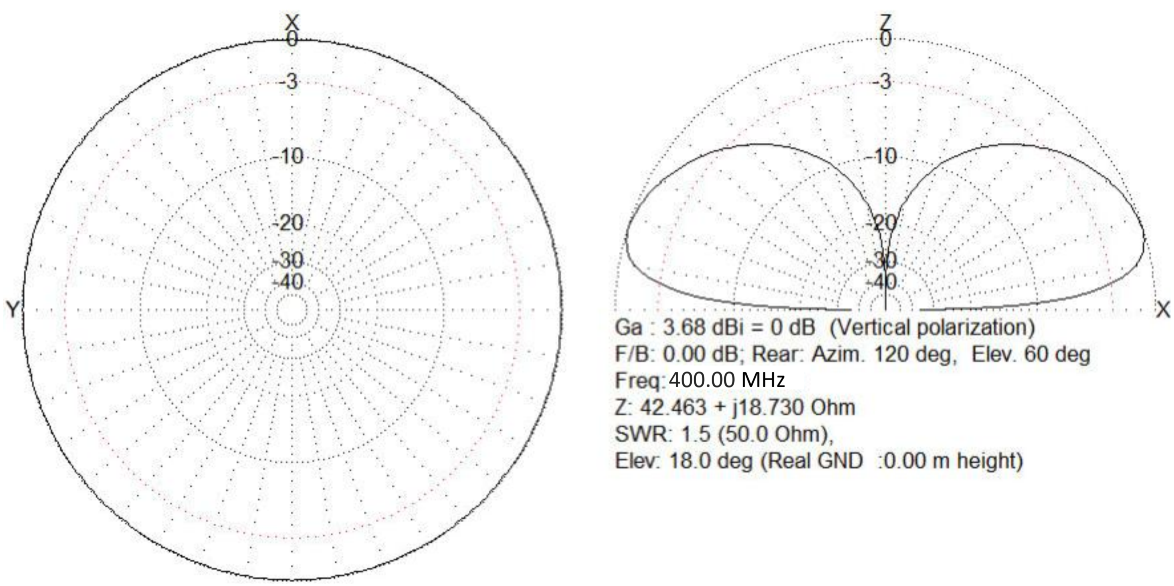


Figure 29 UHF Experimental Earth Station Antenna Radiation Pattern

15 Stop Buzzer POC

The 24-hour SpaceQuest contact for interference issues is provided below:

Name: Glenn Richardson
Email: glenn@spacequest.com
Tel: 703-424-7806