HSAT-1

Exhibit 1: Experiment Description Document for FCC Application

Stephen T. Gillespie, P.E.

Harris Corporation

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1.0 Introduction

Harris Corporation is requesting a 24 month experimental license from the Federal Communication Commission's (FCC) Office of Engineering and Technology (OET) in order to complete the objectives of the HSAT-1 mission. The HSAT-1 cubesat is an orbital experimental testbed being developed by Harris Corporation for launch in Q2 2017. The following objectives of the HSAT-1 orbital experiment will improve the radio state-of-the-art:

- Assess the effectiveness of radiation mitigation techniques of the payload in the actual environment with continual performance and event monitoring
- Assess the performance of a broad-bandwidth deployable antenna (BBDA) specifically designed for cubesats through on-orbit measurement
- Assess the effective coverage of Harris' earth-to-space and space-to-earth Tracking, Telemetry, and Control (TT&C) and payload experiment data communications through on-orbit demonstration of an S-band radio

In order to assess payload performance in a radiation environment, the HSAT-1 orbital testbed must continually receive and process, which requires a signal-rich environment. Initially, HSAT-1 will receive and process maritime Automatic Identification System (AIS) signals using a TRL-9 commercially available cubesat antenna, hereafter referred to as the "AIS monopole antenna". TT&C and payload experiment data communications will be performed during the first phase through the Globalstar constellation & network.

Approximately 60 days after launch, HSAT-1 will disable the AIS monopole antenna and deploy a broad-bandwidth deployable antenna (hereafter referred to as the "BBDA"). This begins the second phase of the payload experiment. The payload will receive VHF broadcast signals in addition to AIS signals to determine the low band performance. Solar noise will also be received to determine performance of the BBDA's mid and upper band. During this time, TT&C and payload experiment data communications through the S-band radio to a Harris ground terminal will be demonstrated. Since the BBDA receives in a much wider bandwidth, a higher data rate modem than the Globalstar is required to transmit the payload experiment data to satisfactorily characterize the performance of the antenna. The S-band radio meets this need with a higher data rate downlink capability.

Specific frequency bands requested are listed in Section 2.2. Usage of the requested RF spectrum for this flight experiment is critical to the success of the flight experiment. The requested RF communications implementation provides both the ability to successfully command the spacecraft and the ability to receive critical engineering telemetry and experiment data. Harris Corporation is requesting a 24 month experimental license from the Federal Communication Commission's (FCC) Office of Engineering and Technology (OET) in order to complete the objectives of the HSAT-1 mission.

Harris Corporation will be the sole owner and operator of the HSAT-1 satellite.

2.0 Technical Details

2.1 Physical Description and Experiment

The HSAT-1 orbital testbed is a 6U cubesat with two deployable solar array panels and two deployable antennas as depicted in Figure 2-1. Harris Corporation has signed a Launch Services Agreement (LSA) with Spaceflight, Inc, to launch HSAT-1 on an Indian Polar Satellite Launch Vehicle (PSLV) in May 2017 through the Indian Space Research Organization (ISRO) at the SHAR (Sriharikota) Spaceport (Satish Dhawan Space Center). The satellite will fly in a sun-synchronous orbit at 500 km altitude, 97.4° inclination, and 9:30 AM Local Time Descending Node (LTDN). Table 2-1 details other technical parameters of HSAT-1.

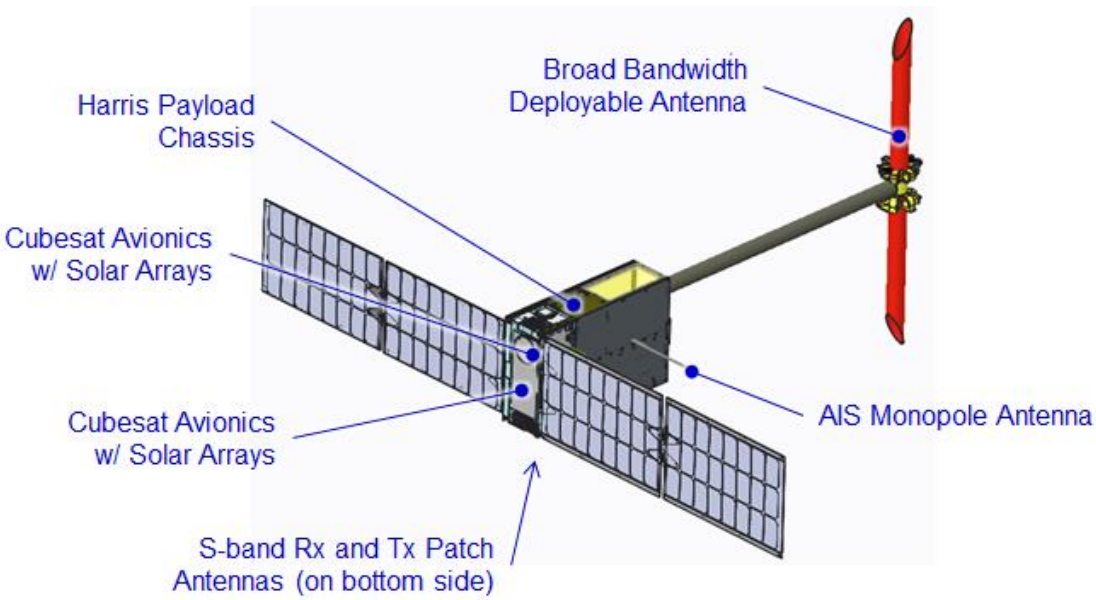

Figure 2-1: HSAT-1 Physical Description

Table 2-1: HSAT-1 Technical Description

Parameter	Value / Description
Mission Life	2 years minimum
Mass	< 13.2 kg
Size	6U
Propulsion	None
Attitude Control	Reaction wheels & torque rods
Batteries	Nine 2.8 amp-hour lithium ion cells
Primary TT&C Link	Globalstar Network
Redundant TT&C Link	S-band Radio

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HSAT-1 will be launched in a powered off state within its dispenser. Upon orbital insertion, HSAT-1 will be ejected from its dispenser and begin a power-on and boot sequence followed by orientation into a sun-safe mode (solar panels oriented towards sun). No radio communications will occur for a minimum of 30 minutes after ejection from the launch dispenser. After the radio blackout period has ended, the satellite will transmit state-of-health telemetry to Harris through the Globalstar constellation and network using Globalstar's GSP-1720 modem. Once the data has been reviewed, Harris will command the satellite to deploy the AIS monopole antenna. This antenna is manufactured by Innovative Solutions in Space and is fully qualified with flight history (TRL-9). The AIS monopole antenna is fed to a Harris-manufactured AIS receiver, which has qualification-by-similarity history. Once deployed, Harris will upload specific mission decks that will command the payload to begin receiving and processing AIS signals. Telemetry will be recorded indicating specific payload performance as well as any radiation-induced events. During this time the telemetry and corresponding mission data will be communicated to the Harris Satellite Operations Center (HSOC) through the Globalstar network.

After the primary payload objectives have been demonstrated (up to 2 months after launch), Harris will command the satellite to deploy the BBDA. Once deployed, Harris will review the deployment telemetry and then switch the payload receiver from the AIS monopole antenna to the BBDA. Payload processing will continue as before, but now utilizing four separate bands over the BBDA range instead of one. This presents the opportunity to continue to monitor payload performance and radiation effects over mission life while utilizing several discrete regions across the BBDA to evaluate specific antenna performance

Testing will conclude 24 months after launch, at which time the spacecraft will be passivated and decommissioned. Deorbit will occur naturally through atmospheric drag. Based on an analysis utilizing NASA's DAS 2.0.2 software with specific HSAT-1 inputs (mass, size, form, initial orbit, material types, etc), HSAT-1 is anticipated to remain in orbit less than 4.3 years total. In addition, the HSAT-1 design passed all other requirements of debris and deorbit in accordance with NPR 8715.6A, which addresses breakups and other debris-producing events. Reference Exhibit 2 Document 7052742 for the complete Orbital Debris and Deorbit Assessment.

2.2 Radio Frequency Spectrum Utilized

Table 2-2 summarizes the requested radio frequency spectrum for the HSAT-1 satellite. These bands were selected for various reasons:

1) Reducing cost through high reuse and utilization of existing designs (the hardware has been previously designed for these frequencies and some long lead components were already available in inventory);
2) Four separate bands spaced over the BBDA design band is necessary for evaluating antenna performance;

These bands already contain an abundance of continuous signals such as AIS and VHF broadcasting which allow the payload to continually receive and process in order to monitor and detect radiation events.

2.2.1 Requested Emitter Frequency Allocations

Harris Corporation specifically requests to utilize the following allocations for the HSAT-1 satellite system:

- Two emitters on the HSAT-1 mobile satellite
  - Globalstar: Space-to-space (1610-1626.5 MHz)
  - Downlink: Space-to-earth (2180-2185 MHz)
- One ground terminal owned by Harris Corporation
  - Uplink: Earth-to-space (2005-2006.25 MHz)

Harris Corporation requests the above specific frequency allocations to meet the current ground terminal design capabilities, there is flexibility to modify the request to nearby bands in case of coordination issues with other users.

2.3 Antenna Details

2.3.1 Space Segment Emitting Antennas

2.3.1.1 Globalstar Patch Antenna

HSAT-1 initial and primary TT&C and payload experiment communications link is through the Globalstar GAT-17PP patch antenna in conjunction with the Globalstar GSP-1720 modem aboard the satellite. The transmit element provides +4.5 dBic gain within the operating frequency band of 1610-1626.5 MHz. The receive element provides +0.2 dBic gain at 2483.5-2500.0 MHz. Figure 2-2 details the radiating pattern of the patch antenna for transmit, and Figure 2-3 details the pattern for receive.

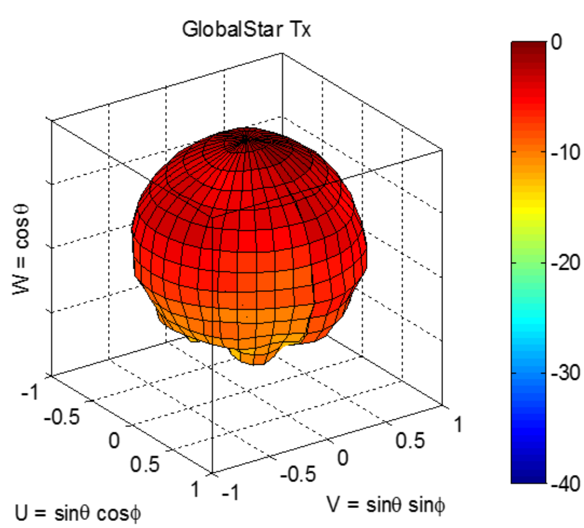

Figure 2-2: Globalstar GAT-17PP Tx Antenna Pattern

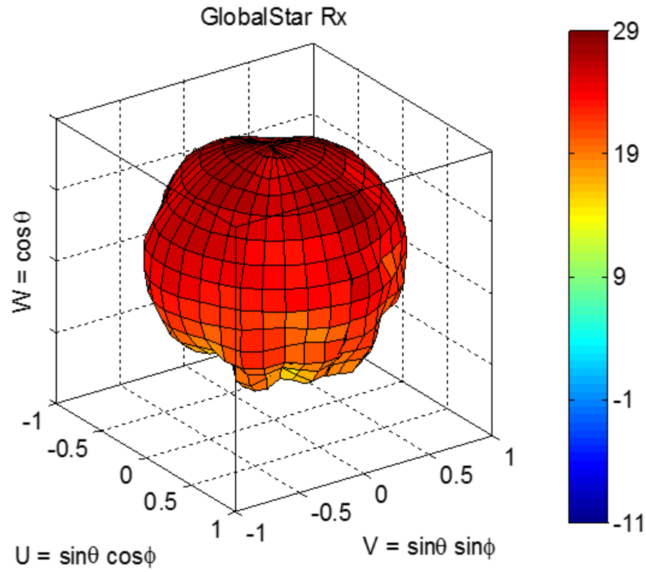

Figure 2-3: Globalstar GAT-17PP Rx Antenna Pattern

Figure 2-4: Globalstar GAT-17PP Antenna

2.3.1.2 S-band Passive Patch Antenna

HSAT-1 secondary TT&C and payload experiment communications link is through a custom passive patch antenna in conjunction with a Tethers Unlimited S-band radio aboard the satellite. This patch antenna will transmit signals containing TT&C and payload experiment data to the Harris Ground Terminal at 2180-2185 MHz. Figure 2-6 details the radiating pattern of the antenna at the center of the requested band.

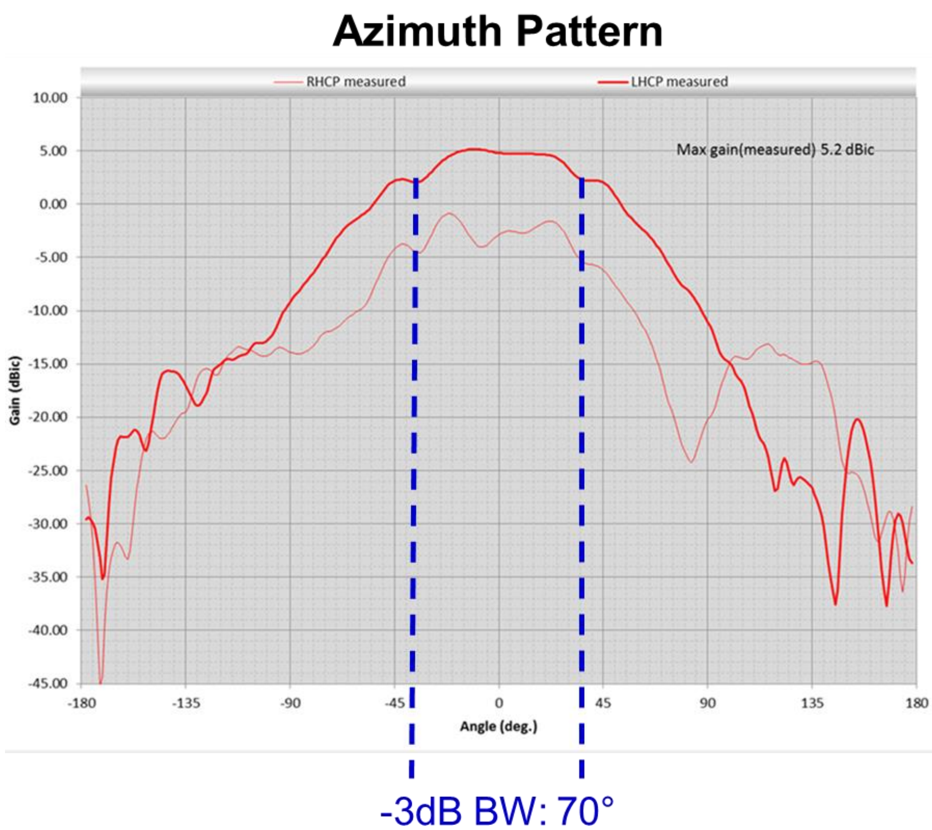

Figure 2-5: Measured S-band Patch Azimuth Pattern

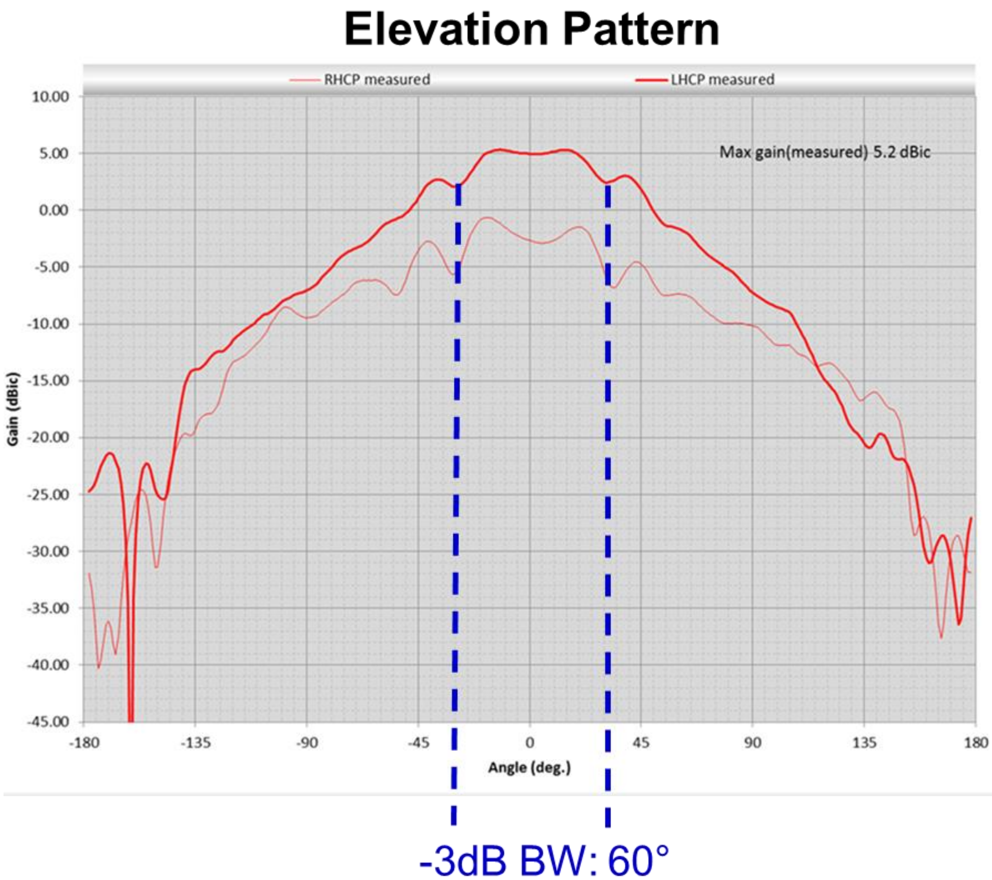

Figure 2-6: Measured S-band Patch Elevation Pattern

2.3.2 Space Segment Receive-Only Antennas

2.3.2.1 S-band Receive Patch Antenna

HSAT-1 will utilize a custom passive patch antenna in conjunction with a Tethers Unlimited S-band radio aboard the satellite. This antenna is separate from the patch antenna described in Section 2.3.1.2, and will receive TT&C signals from the Harris Ground Terminal at 2005-2006.25 MHz. The patch antenna receive pattern is identical to the radiating pattern depicted in Figure 2-6.

2.3.2.2 Payload AIS Monopole Antenna

HSAT-1 will utilize a deployable monopole whip antenna manufactured by Innovative Solutions in Space to receive AIS signals as part of the payload experiment. The antenna will receive AIS signals between 159.0125-161.025 MHz. Figure 2-7 details the pattern of the antenna at 159.0125 MHz.

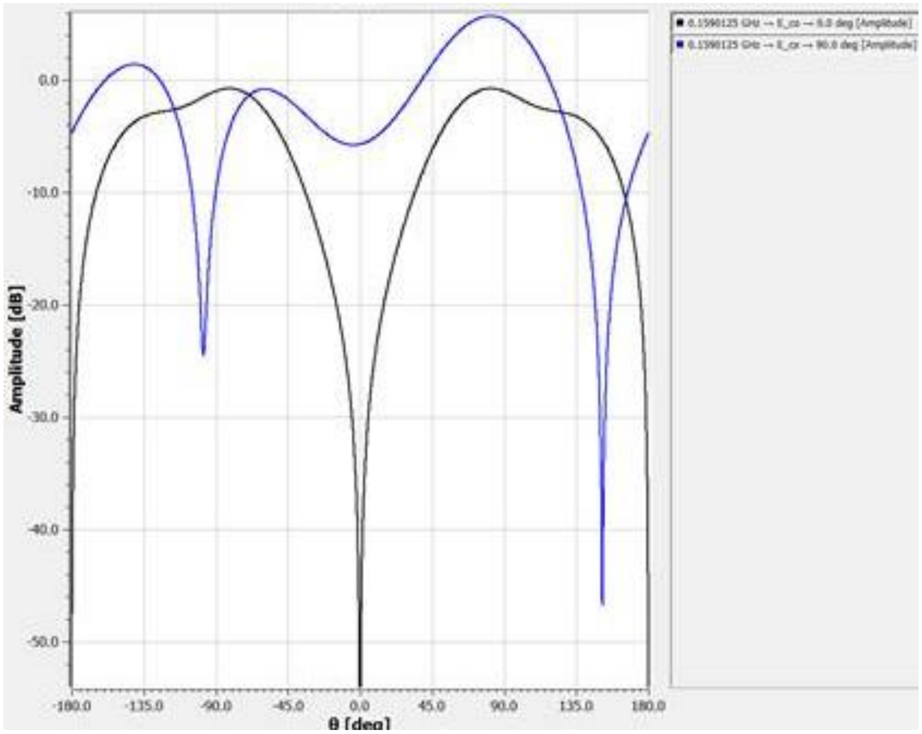

Figure 2-7: AIS Monopole Antenna Directivity

2.3.2.3 Payload Broad Bandwidth Deployable Antenna (BBDA)

HSAT-1 will utilize a custom broad bandwidth deployable antenna (BBDA) manufactured by Harris Corporation which will receive various AIS, broadcasting, and noise from 159.0125-1260.0 MHz as a part of the payload experiment. Figure 2-8, Figure 2-10, and Figure 2-11 detail the pattern of the BBDA at 159.0125 MHz, 195 MHz, 397.5 MHz, and 1260.0 MHz respectively. Specific frequency bands of the receiver are outlined in Table 2-2. Successful demonstration of this antenna technology will improve the state of the art for cubesat wideband deployable antennas.

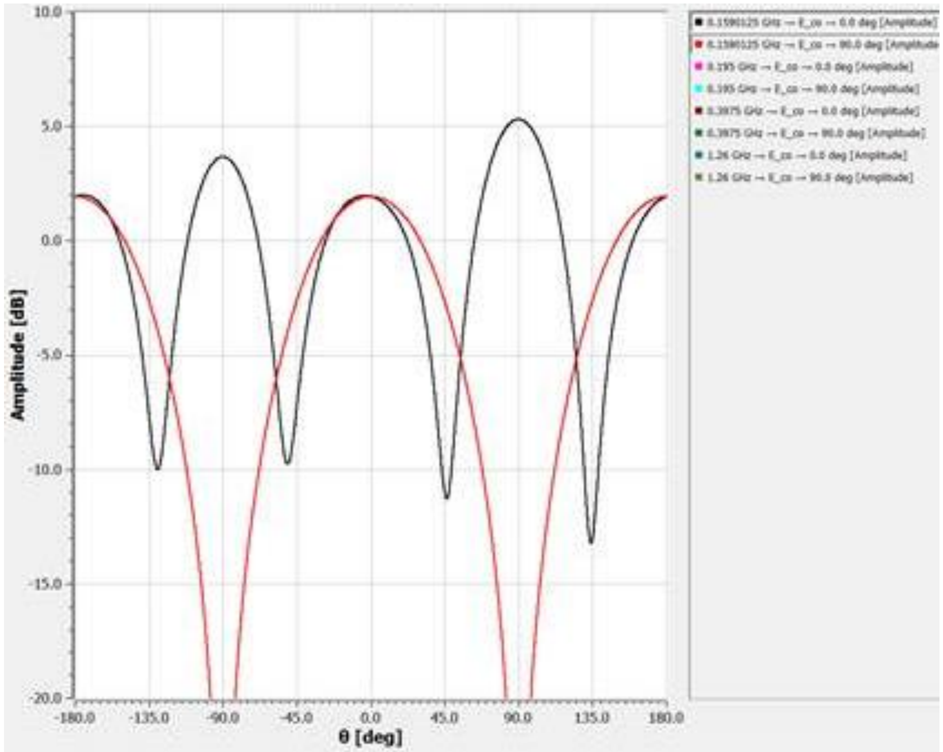

Figure 2-8: BBDA Directivity, 159.0125 MHz

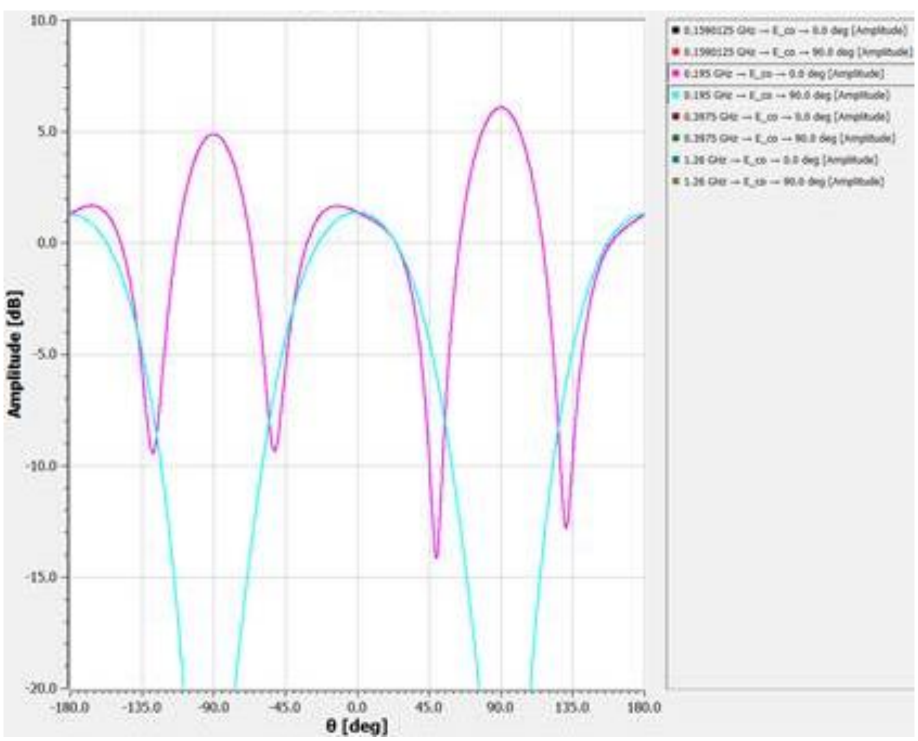

Figure 2-9: BBDA Directivity, 195 MHz

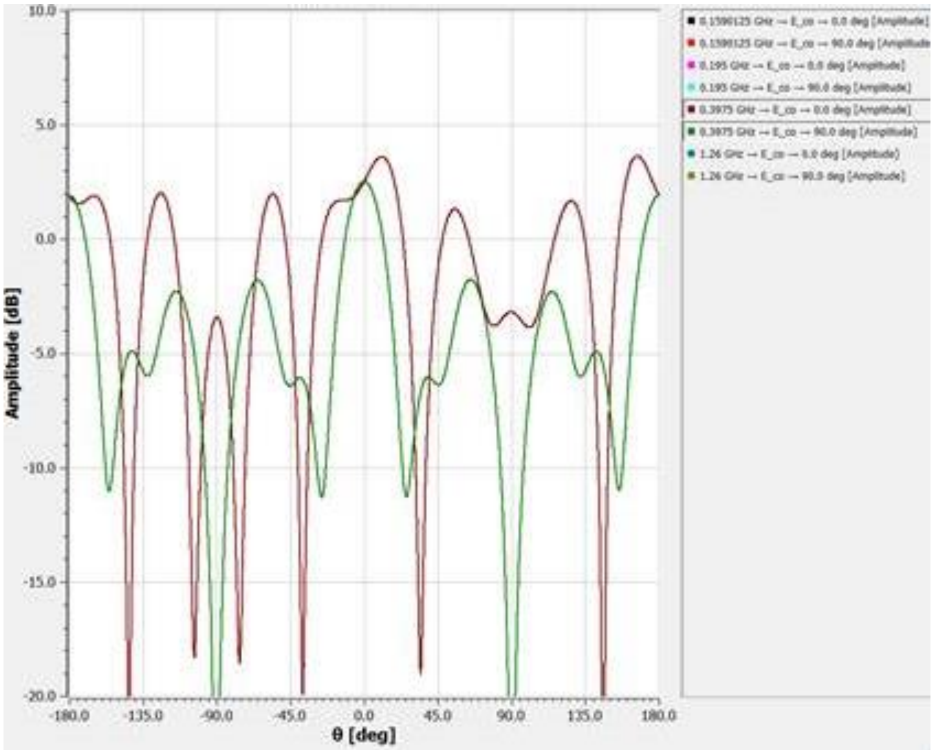

Figure 2-10: BBDA Directivity, 397.5 MHz

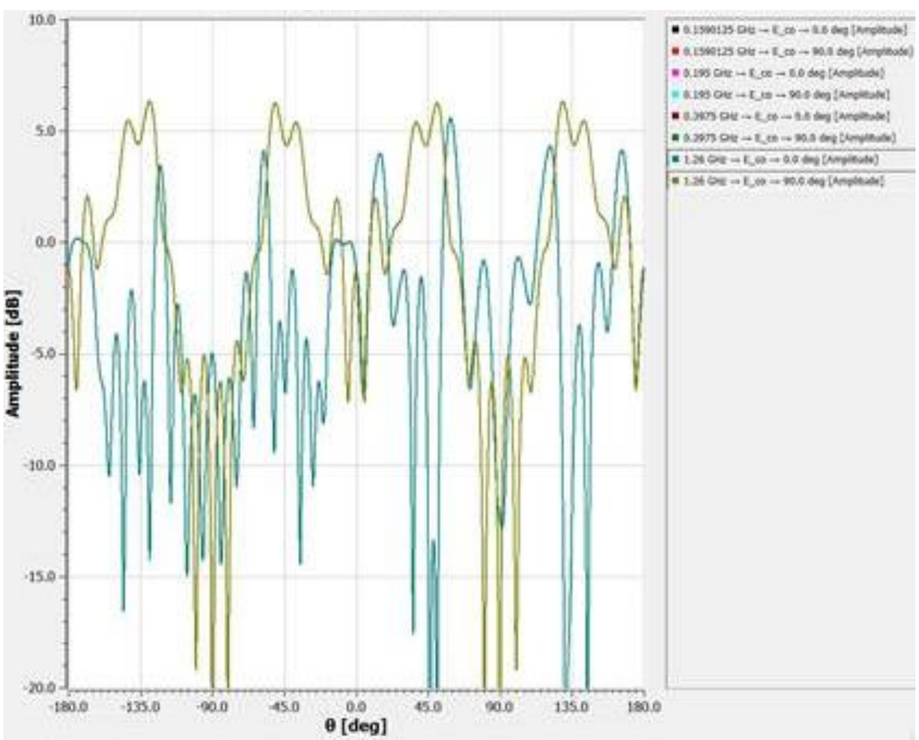

Figure 2-11: BBDA Directivity, 1260 MHz

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2.3.3 HSAT-1 Ground Terminal Antenna

HSAT-1's secondary TT&C communications uplink (the Globalstar Radio being the primary) will utilize a 4.2 meter parabolic dish antenna located at 28.026552, -80.604989 (Lat, Lon NAD83) on a rootop antenna test platform of a Harris Corporation facility in Palm Bay FL to send TT&C to the HSAT-1 spacecraft. The location and elevation of the proposed ground terminal is shown in Figure 2-13. This antenna will provide 35.1 dBic transmit gain (including radome loss) within the operating frequency band of 2005-2006.25 MHz, with 2.5° half-power beamwidth. Figure 2-12 details the radiating pattern of the antenna. No other ground stations will communicate directly with HSAT-1.

This antenna will also receive TT&C and payload experiment data transmitted by the satellite at 2180-2185 MHz.

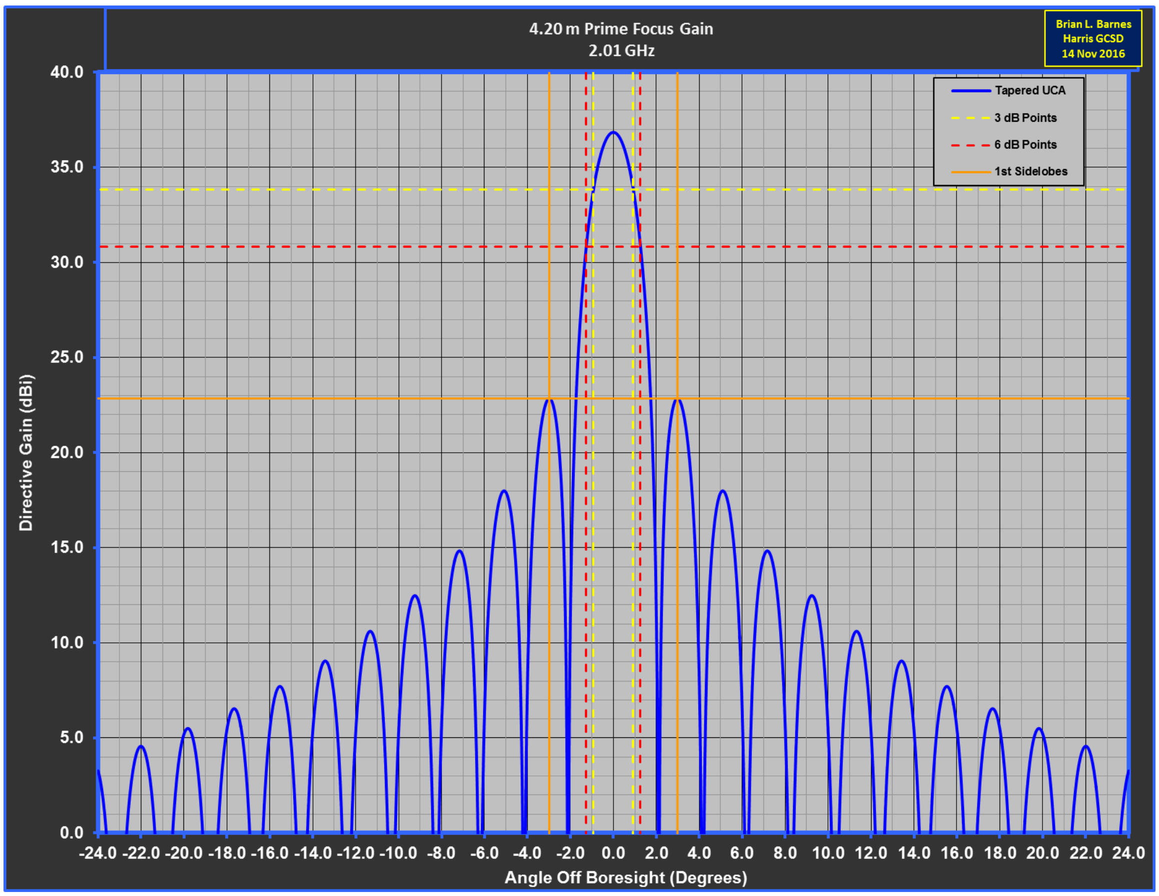

Figure 2-12: Predicted HSAT-1 Ground Terminal Antenna Pattern (not including radome loss)

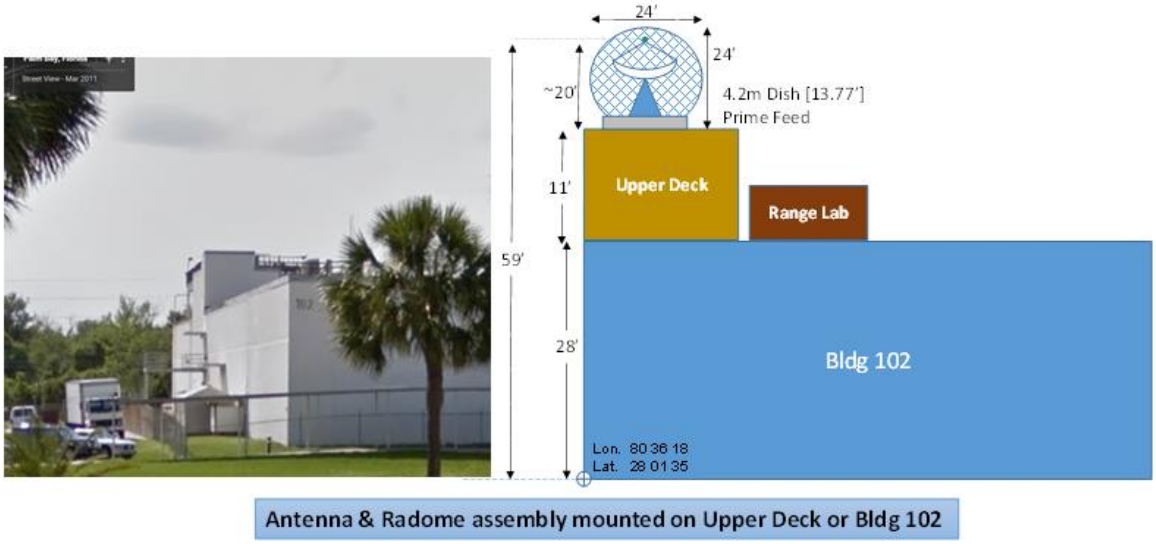

Figure 2-13: HSAT-1 Ground Terminal Location & Facility Details

2.4 Harris "Stop Buzzer" Contact

Thomas Low, Ground Segment Architect
tlow03@harris.com
Harris Corporation SIS, Palm Bay FL
321-729-2899

Table 2-2: Radio Frequency Spectrum Summary for HSAT-1

Type	Location	Function	Description	Modem / Receiver	Antenna Type	ERP (W)	Active Band (MHz)	Polarization	Modulation	Waveform & Coding
Emitters	HSAT-1 Satellite (Mobile Sat)	Comm Downlink Default/Primary	Globalstar Space-to-space	GSP-1720	GAT-17PP Patch	0.76	1610-1626.5	LHCP	QPSK/CDMA	Reference Globalstar
	HSAT-1 Satellite (Mobile Sat)	Comm Downlink Secondary	S-Band Space-to-Earth	Tethers Unlimited Swift-SLX	Passive Patch	5.72	2180-2185	LHCP	8PSK	Rolloff factor 0.25, Reed-Solomon 255/239 7-7/8 CC 5 MHz Occupied BW
	Melbourne, FL (Fixed)	Harris Ground Terminal (Uplink)	S-Band Earth-to-space	Harris	Parabolic Reflector	312.01	2005-2006.25	RHCP	Offset QPSK	Rolloff factor 0.25, 7-1/2 CC 1.25 MHz Occupied BW
Receivers	HSAT-1 Satellite (Mobile Sat)	GPS	L1 Space-to-Space	NovAtel OEM615 GPS	Passive Patch	NA	1575.42	RHCP	GPS L1 waveform, C/A coding	
	HSAT-1 Satellite (Mobile Sat)	Comm Uplink Default/Primary	Globalstar Space-to-Space	GSP-1720	GAT-17PP Patch		2483.5-2500	LHCP	QPSK/CDMA	Ref Globalstar
	HSAT-1 Satellite (Mobile Sat)	Comm Uplink Secondary	S-Band Earth-to-Space	Tethers Unlimited Swift-SLX	Passive Patch		2005-2006.25	RHCP	Offset QPSK	Rolloff factor 0.25, 7-1/2 CC; 1.25 MHz Occupied BW
	Melbourne, FL (Fixed)	Harris Ground Terminal (Downlink)	S-Band Space-to-Earth	Harris	4.2m Parabolic Reflector		2180-2185	LHCP	8PSK	Rolloff factor 0.25, Reed-Solomon 255/239, 7-7/8 CC; 5 MHz Occupied BW
	HSAT-1 Satellite (Mobile Sat)	AIS "Channel A"	AIS signal receiver	Harris Corp PN 3266638-101	AIS Monopole Antenna		155.98-162.10	Linear	AIS waveform	
	HSAT-1 Satellite (Mobile Sat)	UHF "Channel B"	VHF/UHF/L-band receiver		Broad Band Deployable Antenna Harris Corp 3266643-101		155.98-162.10 174-216 385-410 1220-1300	Linear	AIS, VHF Broadcast, Solar noise	

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