TECHNICAL ANNEX

ASTRO DIGITAL SATELLITE SYSTEM ANTENNA PATTERNS

The antenna patterns for the Astro Digital Satellite System are provided in this attachment.

Tables C-1 and C-2 provide a summary of the antenna patterns for the space stations and ground stations.

Table C-1: Space Station Antenna Patterns

GHOSt-01 - GHOSt-06 — All Spacecraft

Pattern No.:	Antenna:	Purpose:	Emission Category:	Antenna Type:	Frequency:	Peak Gain:	Polarization:	
C-UHF-TX-GH-1	UHF TX	TLM TX-ADV	T&C	Dipole- Like	400.500 MHz	2.1 dBi	Linear	Rotating
C-UHF-TX-GH-2	UHF TX	TLM TX-TRV		Dipole- Like	400.500 MHz	2.1 dBi	Linear	Rotating
C-S-RX-GH-1	S-band RX	COMMAND		Patch	2056.0 MHz	5.5 dBi	Circular	RHCP
C-Ka-TX-GH-M1	Ka-band TX	H. S. Data (Mode 1)	Service Downlink	Horn Array	25.5-27.0 GHz	26.8 dBi	Circular	LHCP or RHCP
C-S-RX-GH-M1	S-band RX	H.S. Data Control	Service Uplink	Patch	2047.5 MHz	5.5 dBi	Circular	RHCP

Table C-2: Ground Station Antenna Patterns

GHOSt-01 - GHOSt-06 — All Earth Stations

Pattern No.:	Antenna:	Purpose:	Emission Category:	Antenna Type:	Frequency:	Peak Gain:	Polarization:		Stn. Location:	Latitude:	Longitude:	Alt. (above MSL):
C-UHF-RX-GS-1	UHF RX	TLM	T&C	2 X-Pole Yagi System	400.5	21.0 dBi	Circular	RHCP/LHCP	Santa Clara, CA	37°22'48"N	121°57'40"W	11 m
C-UHF-RX-GS-2	UHF RX	TLM		2 X-Pole Yagi System	400.5	20.5 dBi	Circular	RHCP/LHCP	Tromsø, NOR	69°39'44"N	18°56'27"E	95 m
C-S-TX-GS-3	S-band TX	CMD		1.5 m Parabola	2056.0 MHz	27.5 dBi	Circular	RHCP/LHCP	Tromsø, NOR	69°39'44"N	18°56'27"E	95 m
C-S-TX-GS-4	S-band TX	CMD		2.8 m Parabola	2056.0 MHz	33.0 dBi	Circular	RHCP/LHCP	Svalbard, NOR	78°13'55"N	15°22'23"E	479 m
C-Ka-RX-GS-5	Ka-band RX	H.S. Data	Service Downlink	2.8 m Parabola	25.5-27.0 GHz	57.0 dBi	Circular	RHCP/LHCP	Svalbard, NOR	78°13'55"N	15°22'23"E	479 m
C-Ka-TX-GS-6	Ka-band RX	H.S. Data		2.8 m Parabola	25.5-27.0 GHz	57.0 dBi	Circular	LHCP/RHCP	Troll, Antarctica	72°00'5.9"	2°31'30.8"E	1336 m
C-S-TX-GS-7	S-band TX	H.S. Data Control	Service Uplink	2.8 m Parabola	2047.5 MHz	33.0 dBi	Circular	RHCP/LHCP	Troll, Antarctica	72°00'5.9"	2°31'30.8"E	1336 m
C-S-TX-GS-8	S-band TX	H.S. Data Control	Service Uplink	2.8 m Parabola	2047.5 MHz	33.0 dBi	Circular	RHCP/LHCP	Svalbard, NOR	78°13'55"N	15°22'23"E	479 m

Space Station Antenna Patterns:

The spacecraft antenna patterns for all of the Astro Digital satellites in the constellation are the same for the two UHF monopoles and S-band patch antennas and for the high gain Ka-band horn array antennas.

While the polarization of all other spacecraft antennas is circular, the polarization of the UHF TX pattern is linear, and consequently, the terrestrially received signal polarization rotates in space, not just due to a rotation of the satellite itself but, due to:

a) The rotation of the linearly polarized wave in space due to Faraday rotation, whichalways occurs in NGSO orbits and,

b) The motion of the satellite relative to the ground station on any pass (whether the satellite is held fixed in attitude in inertial space or is pointing toward the center of theEarth or toward a ground station located on the Earth) rotates as seen by the ground station.

For this reason, a linear polarization reference (such as horizontal or vertical) cannotbe defined for the downlink UHF signal. Therefore, the technique used to receive the linear signal (or transmit a linear signal to the spacecraft) is to use a circularly polarized antenna on the Earth to receive the signal and accept at least a 3dB loss in C/N on the far end of the link, accordingly.

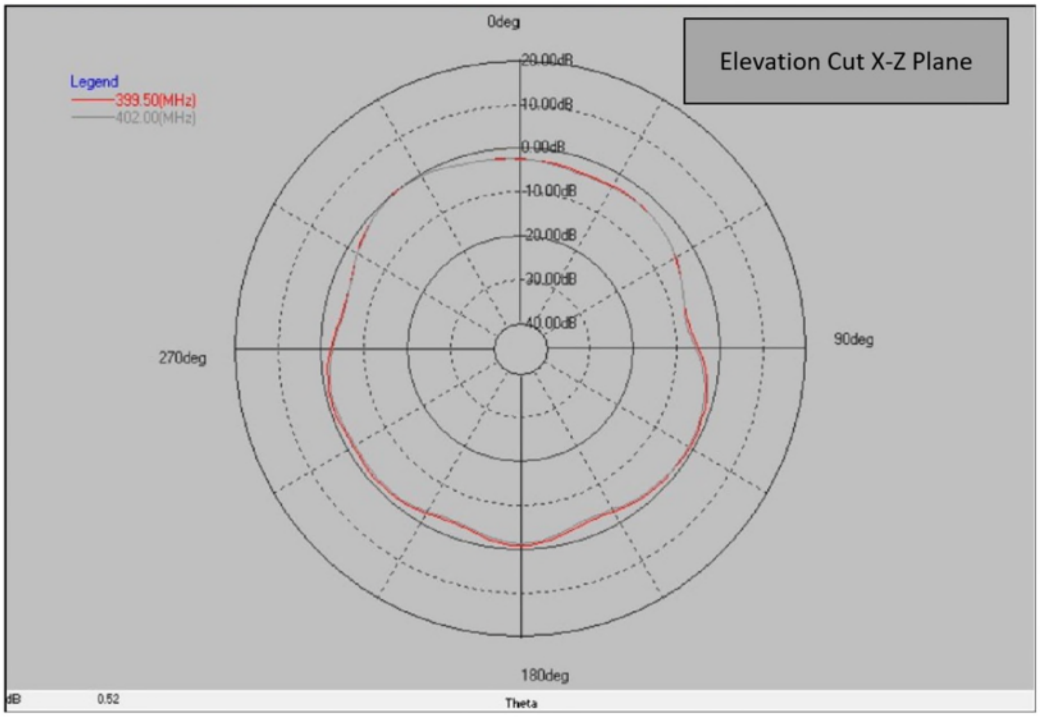


Figure C-UHF-TX-GH-1/2 A: Elevation Cut; X-Z Plane

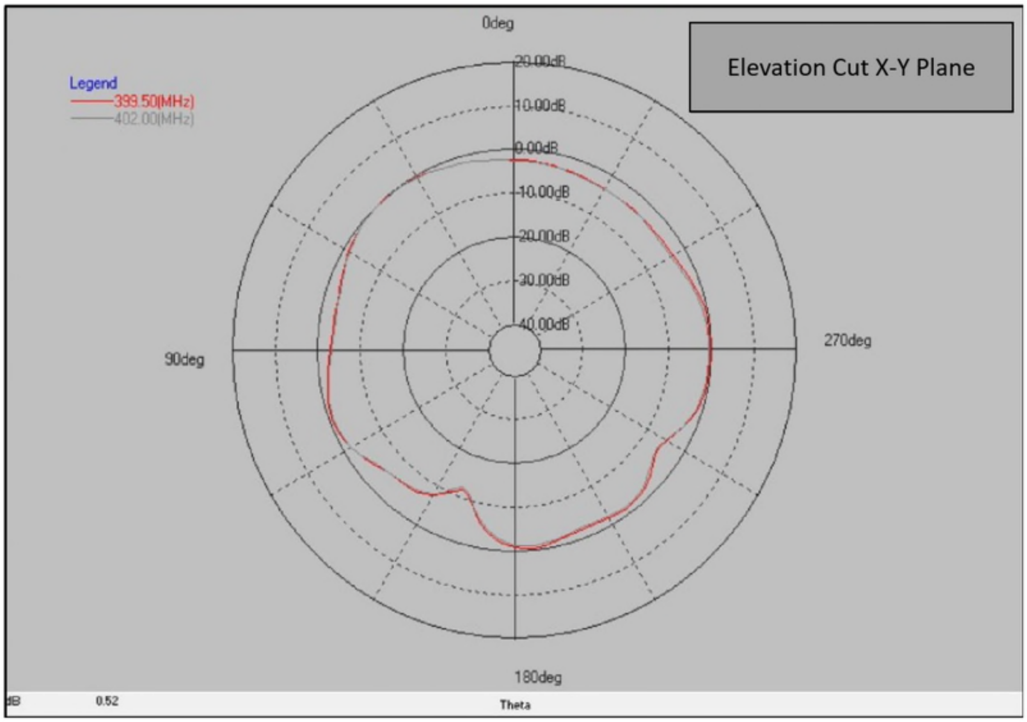


Figure C-UHF-TX-GH-1/2 B: Elevation Cut; X-Y Plane

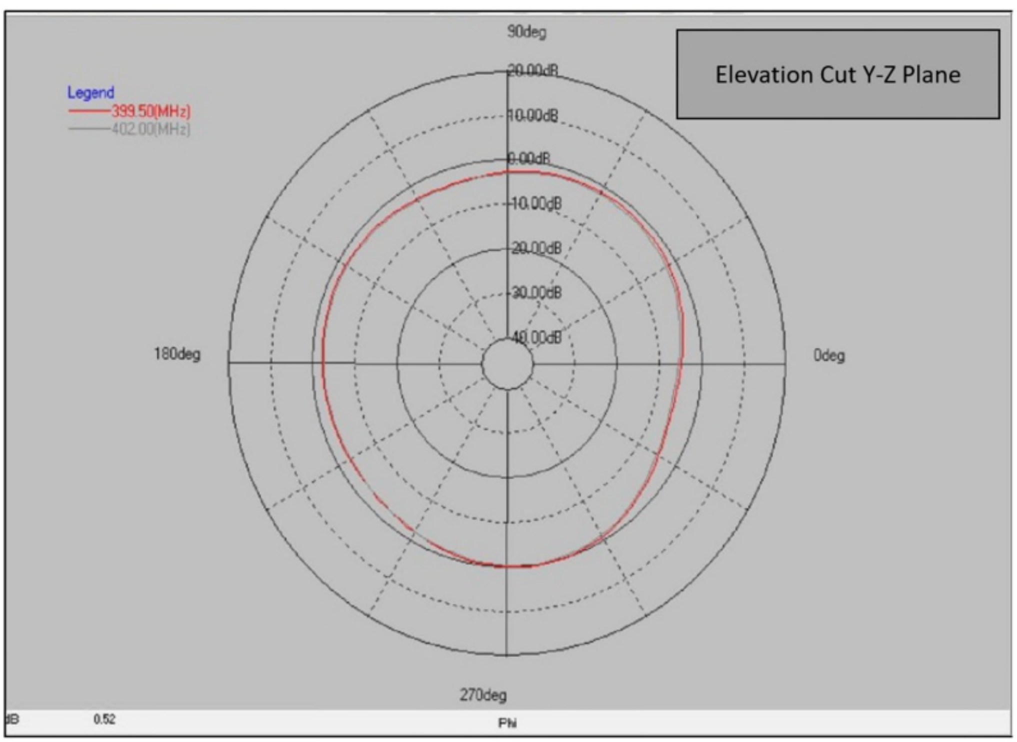


Figure C-UHF-TX-GH-1/2 C: Azimuth Cut; Y-Z Plane

There are two pairs of S-band patch antennas oriented with their boresight directions aligned with opposite axes. Two receive patches on opposite side of the satellite are CMD antennas (using 2056 MHz) and two patches, also on opposite sides are for the HSD control link (using 2047.5 MHz). Both pairs are then fed in-phase, creating a near-omnidirectional antenna pattern. The individual patterns of these antennas are presented in Figure C-S-RX-GH-1 and Figure C-S-RX-GH-M1, respectively.

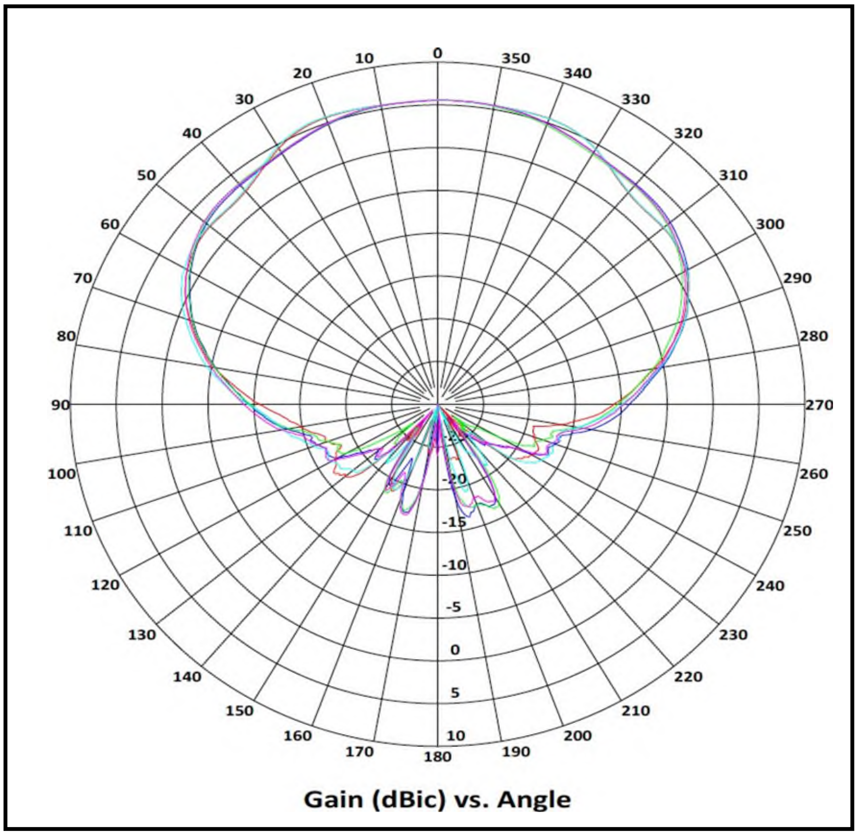


Figure C-S-RX-GH-1: Command Patch Ant. Pattern

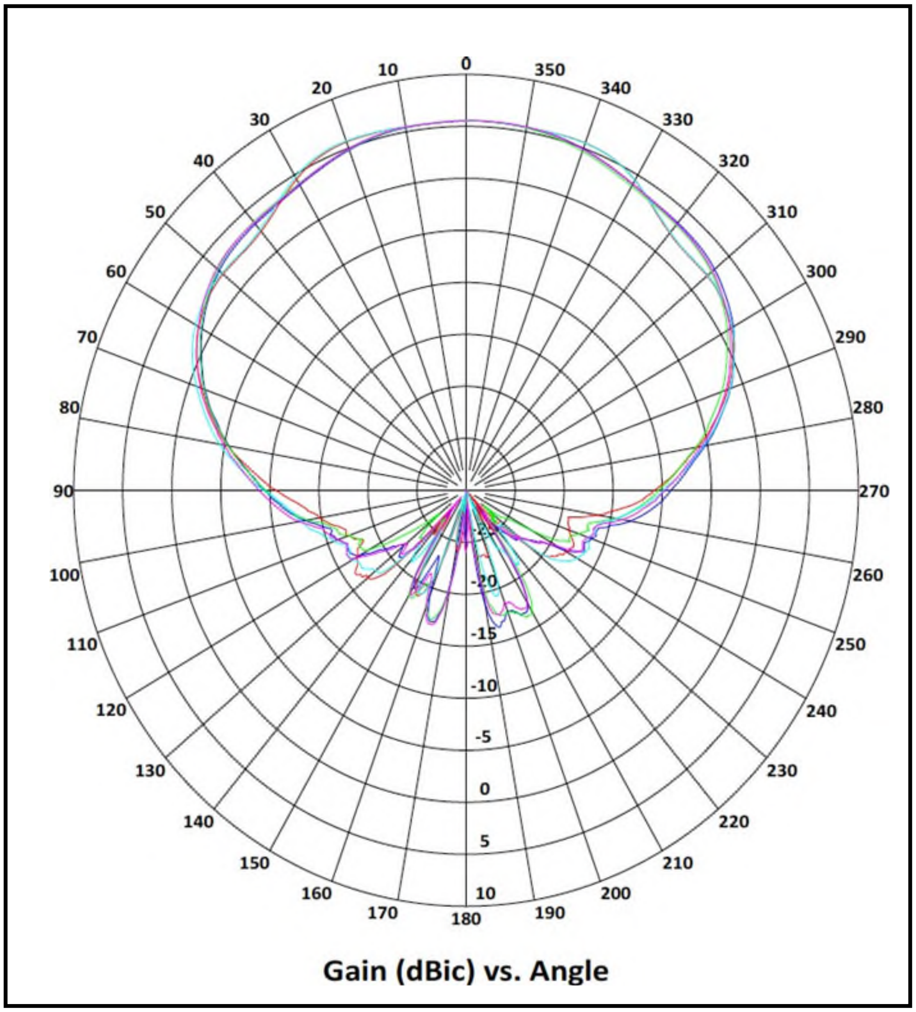
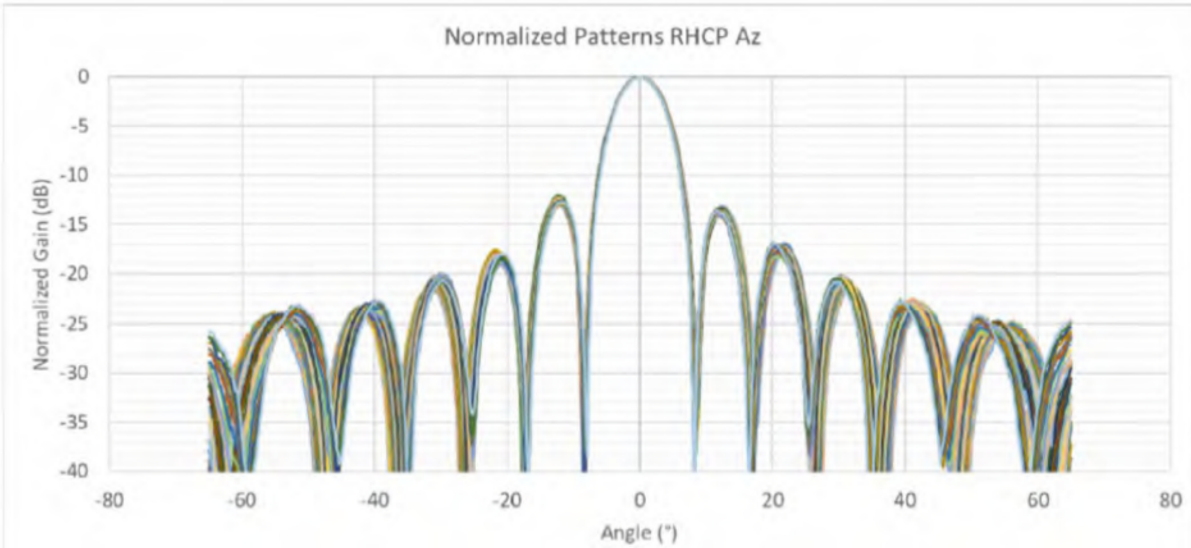
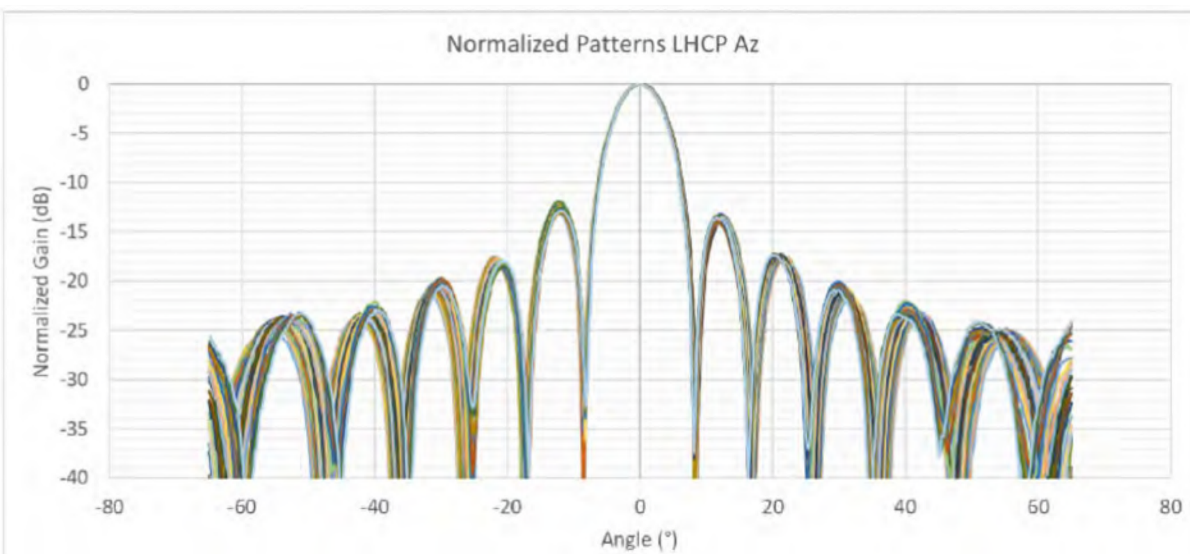


Figure C-S-RX-GH-M1: H.S. Data Control Patch antenna pattern

There will be one Ka-band transmit antenna mounted on each Astro Digital satellite for high-speed, wideband transmission of data to the earth stations located in Svalbard, Norway and Troll, Antarctica. The peak transmit antenna gain of these antennas is 27.4 dBi and the relative transmit gain pattern for these antennas is given in Figures C-Ka-TX-GH-M1-A and C-Ka-TX-GH-M1-B for RHCP and LHCP, respectively. The multiple lines represent measurements taken at several frequencies from 25.5-27.0 GHz.



<u>Figure C-Ka-TX-GH-M1 A</u>: Ka-Band transmit antenna gain pattern, RHCP



<u>Figure C-Ka-TX-GH-M1 B</u>: Ka-Band transmit antenna gain pattern, LHCP

EARTH STATION ANTENNA PATTERNS

(See Table C-2)

The antenna gain patterns for the S-band earth station transmit antennas for both the TT&C and service links can be defined by the following gain envelope pattern, which is identical to the pattern given in Recommendation ITU-R M.694-1:

$$G = G_{max} - 2.5\times10^{-3} (D/\lambda\ \varphi)^2 \qquad \text{for } 0° \le \varphi < \varphi_m$$

$$G = G_1 \qquad \text{for } \varphi_m \le \varphi < \varphi_r$$

$$G = 52 - 10 \log (D/\lambda) - 25 \log \varphi \qquad \text{for } \varphi_r \le \varphi < \varphi_b$$

$$G = 0 \qquad \text{for } \varphi_b \le \varphi \le 180°$$

where:

$$D/\lambda = 10^{\left(\frac{G_{max} - 7.7}{20}\right)}.$$

$$G_1 = 2 + 15 \log (D/\lambda).$$

$$\varphi_m = 20\ \lambda/D \sqrt{G_{max} - G_1}\ .$$

$$\varphi_r = 100\ \lambda/D.$$

$$\varphi_b = \varphi_1 = 120\ (\lambda/D)^{0.4}.$$

For the 1.5 meter antenna located in Tromsø, the maximum transmit gain is 27.5 dBi. For the 3.0 meter antennas located at Svalbard and Troll, the maximum transmit gain is 33.0 dBi. The measured antenna gain pattern for the 3.0 meter antennas is shown in Figure C-S-TX-GS-7/8.

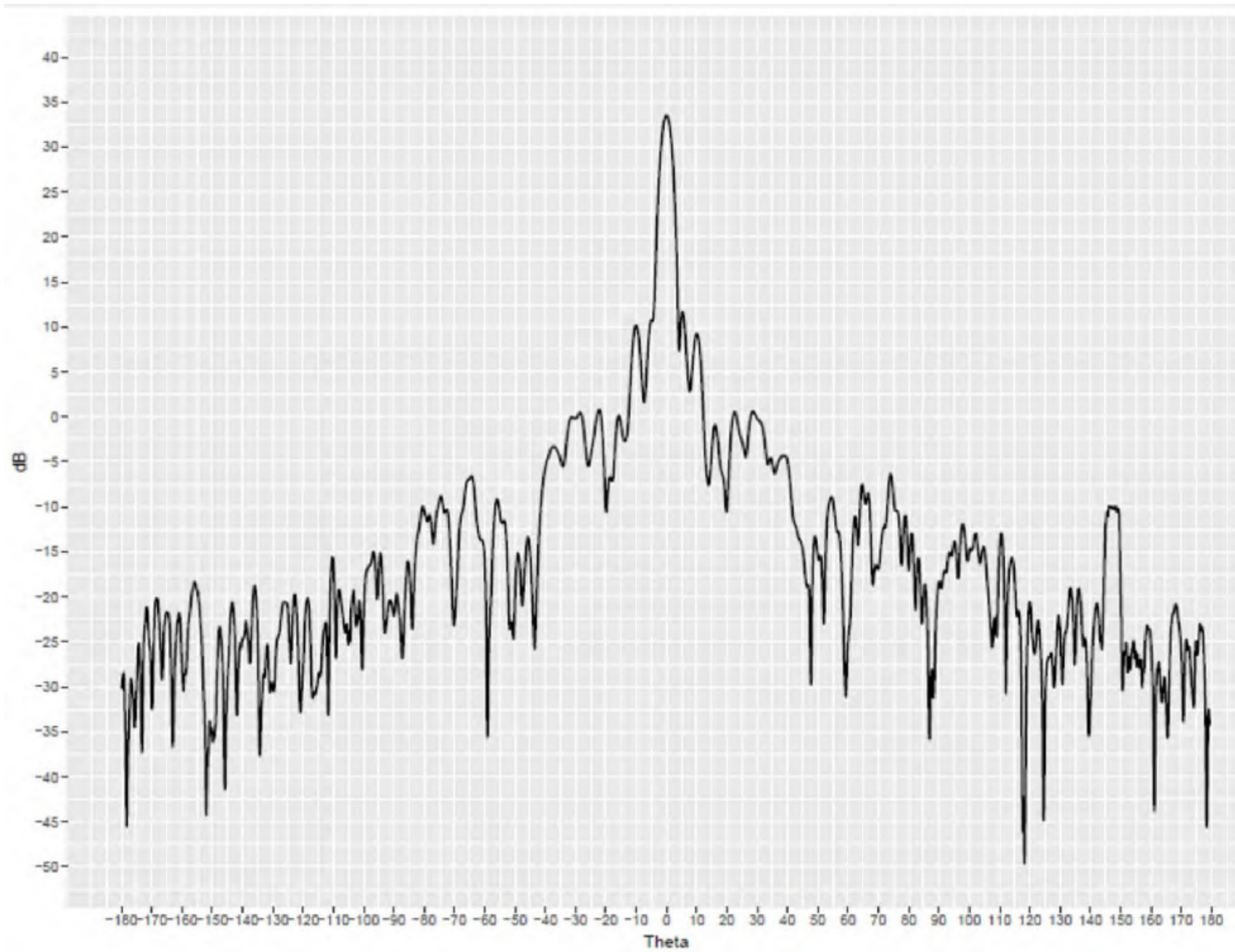
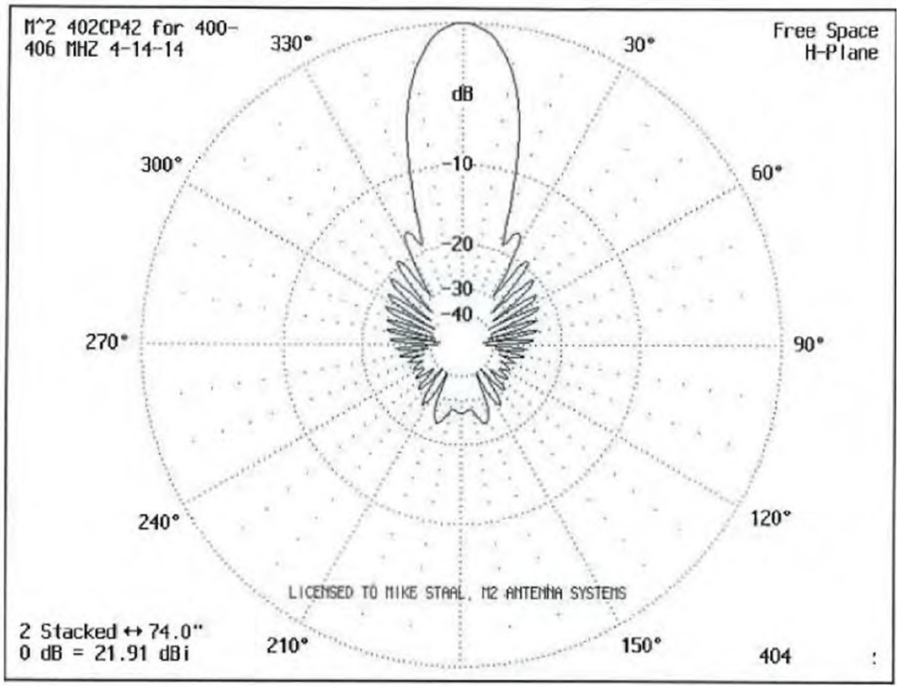
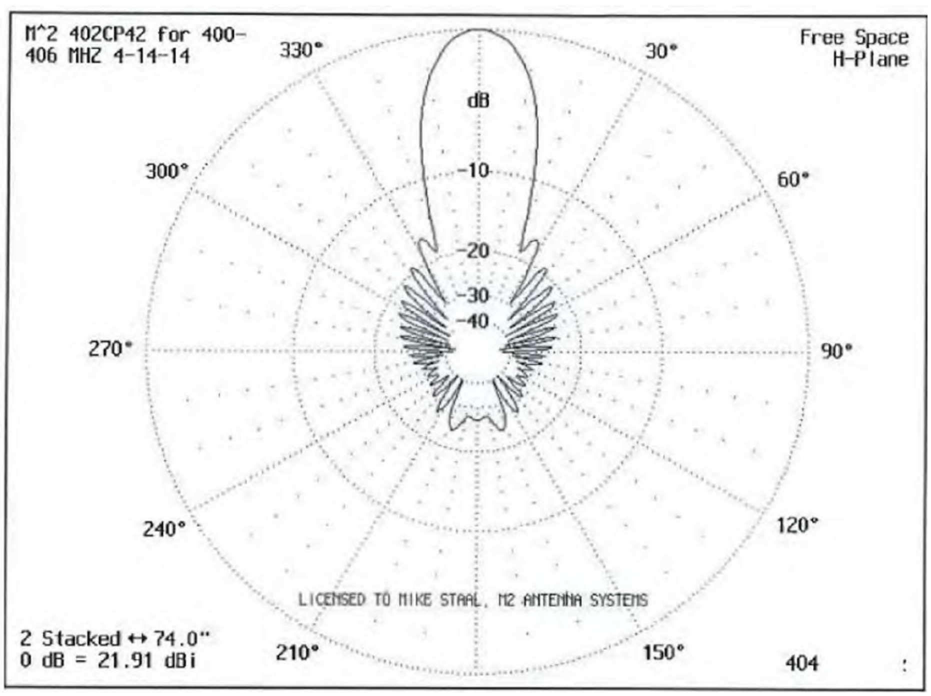


Figure C-S-TX-GS-7/8 Svalbard and Troll S-Band measured earth station transmit antenna gain pattern

The UHF receive earth station antenna located in Santa Clara has a peak gain of 21.0 dBi and the relative gain pattern is shown in Figure C-UHF-TX-GS-1. For the UHF receive earth station antenna located in Tromsø, the peak antenna gain is 20.5 dBi and the relative gain pattern is shown in Figure C-UHF-TX-GS-2.

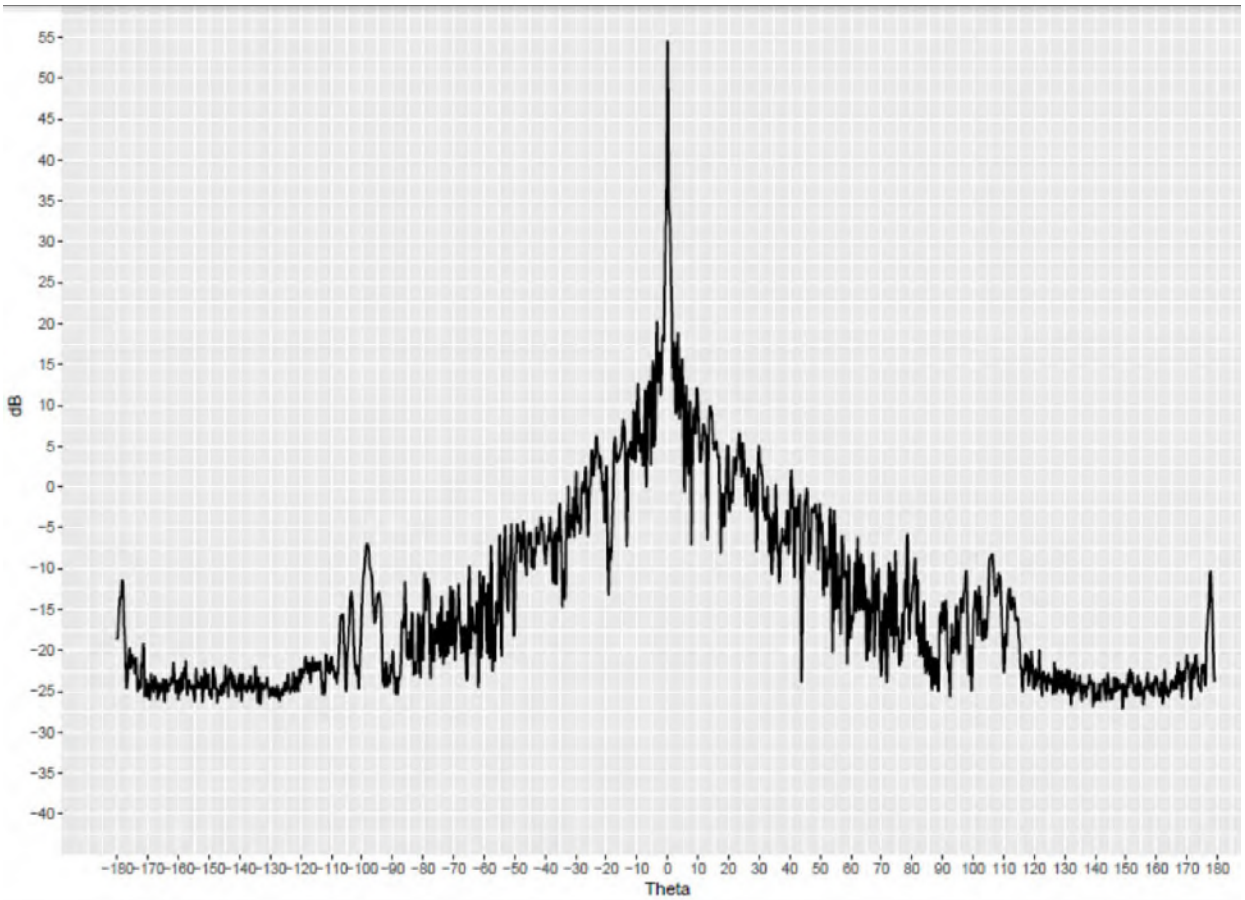


<u>Figure C-UHF-TX-GS-1</u> Santa Clara earth station receive antenna gain pattern (Relative to peak)



<u>Figure C-UHF-TX-GS-2</u> Tromsø earth station receive antenna gain pattern (Relative to peak)

The Ka-band receive earth stations located in Svalbard and Troll will be identical with a maximum receive gain of about 54.4 dBi depending on the specific transmit center frequency. The measured off-axis antenna gain pattern for these antennas is shown in Figure C-Ka-RX-GS-5/6.



<u>Figure C-Ka-RX-GS-5/6</u> Ka-Band earth station receive antenna gain pattern

<u>ASTRO DIGITAL SATELLITE ANTENNA BEAM CONTOURS</u>

Astro Digital used a map system provided on-line by Google Earth® to generate the diagrams for the gain contours of each beam on the Astro Digital satellites at an orbital altitude of 525 km. This map application provides tools for calculating ground surface distances directly on the graphic. Off-boresight angles for each antenna roll-off value were converted to ground surface distances for the four target locations (the Earth stations at Santa Clara, CA; Svalbard, Norway; Tromsø, Norway; and Troll, Antarctica) and the contours were generated using the surface distance measuring feature of Google Earth for each map. Roll-off contour rings were then constructed at suitable angles from boresight for each antenna case using surface distance graphics. Roll-off. Astro Digital has also attached the beam contours as GIMS-readable files to its Schedule S technicalexhibit, filed concurrently with this application.

The Ka-band transmit antenna gain contours for the Ka beam when an Astro Digital satellite is directly above the Svalbard earth station is shown in Figure C-Ka-TX-GH-M1.

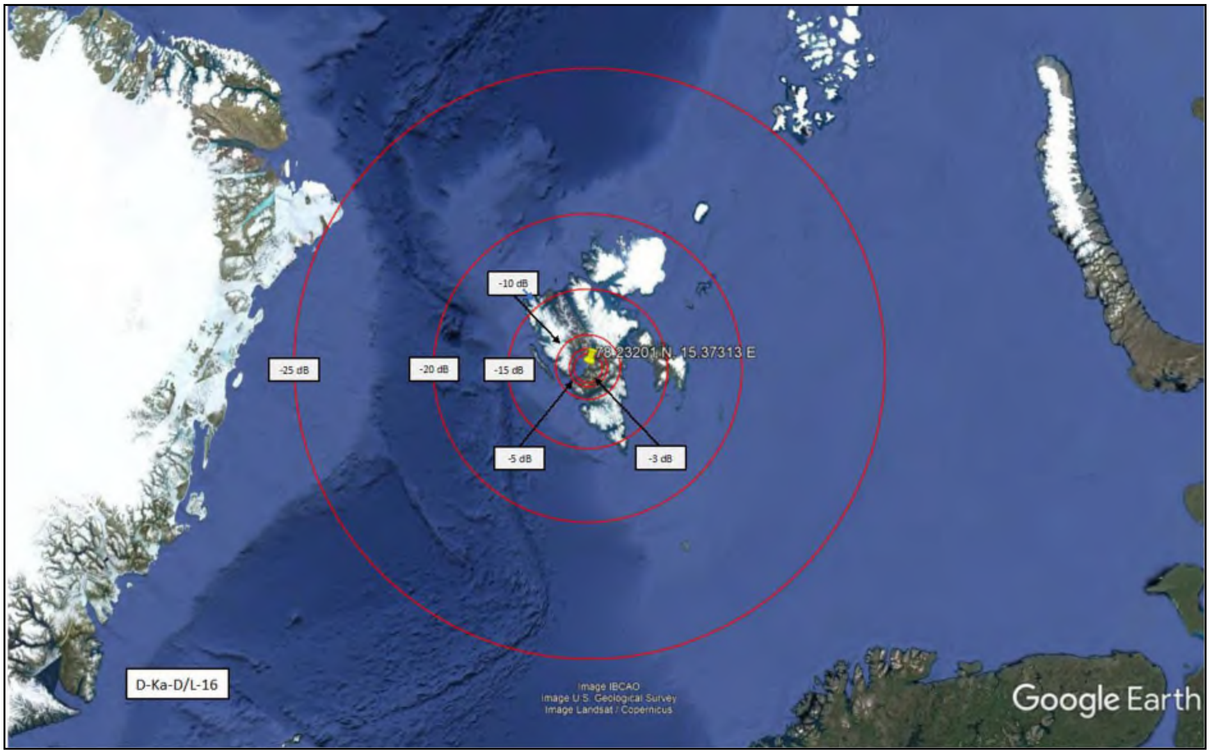


Figure C-Ka-TX-GH-M1-A: Ka transmit antenna gain contours - Svalbard

The Ka-band transmit antenna gain contours for the Ka beams when an Astro Digital satellite is directly above the Troll earth station is shown in Figure C-Ka-TX-GH-M1-B.

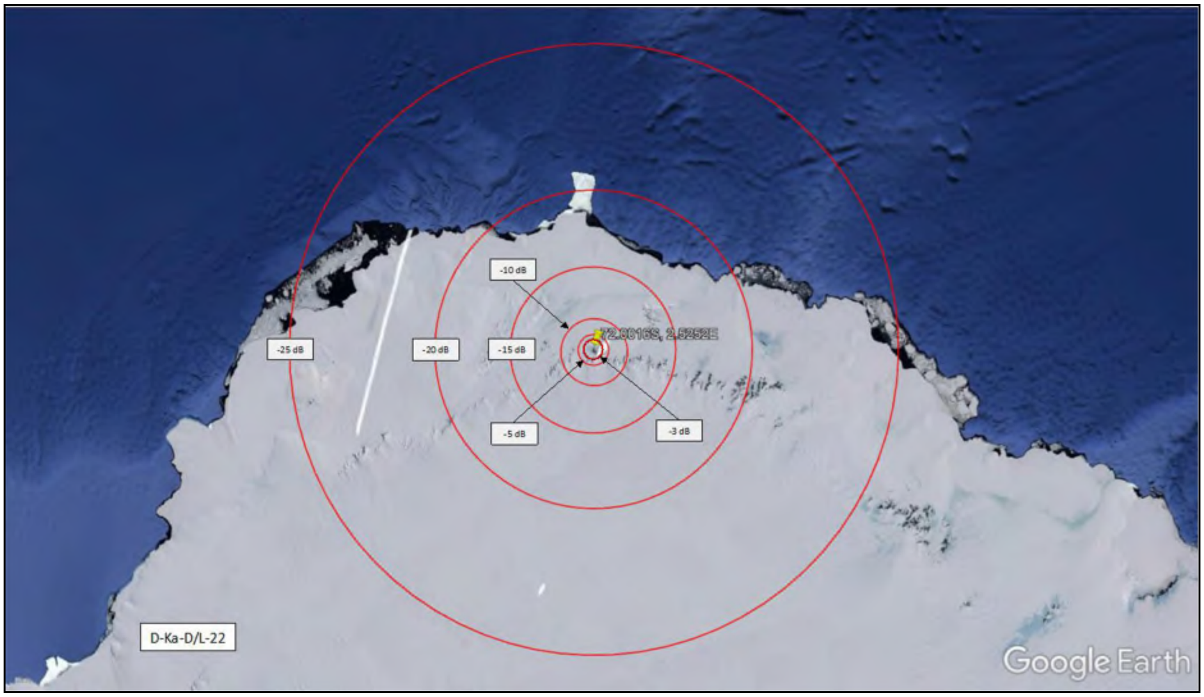


Figure C-Ka-TX-GH-M1-B Ka transmit antenna gain contours - Troll

The S-band receive antenna gain contours for the SCMD beams when an Astro Digital satellite is directly above Tromsø and Svalbard are shown in Figure C-S-RX-GH-1-A and Figure C-S-RX-GH-1-B, respectively.

Figure C-S-RX-GH-1-A SCMD receive antenna gain contours – Tromsø

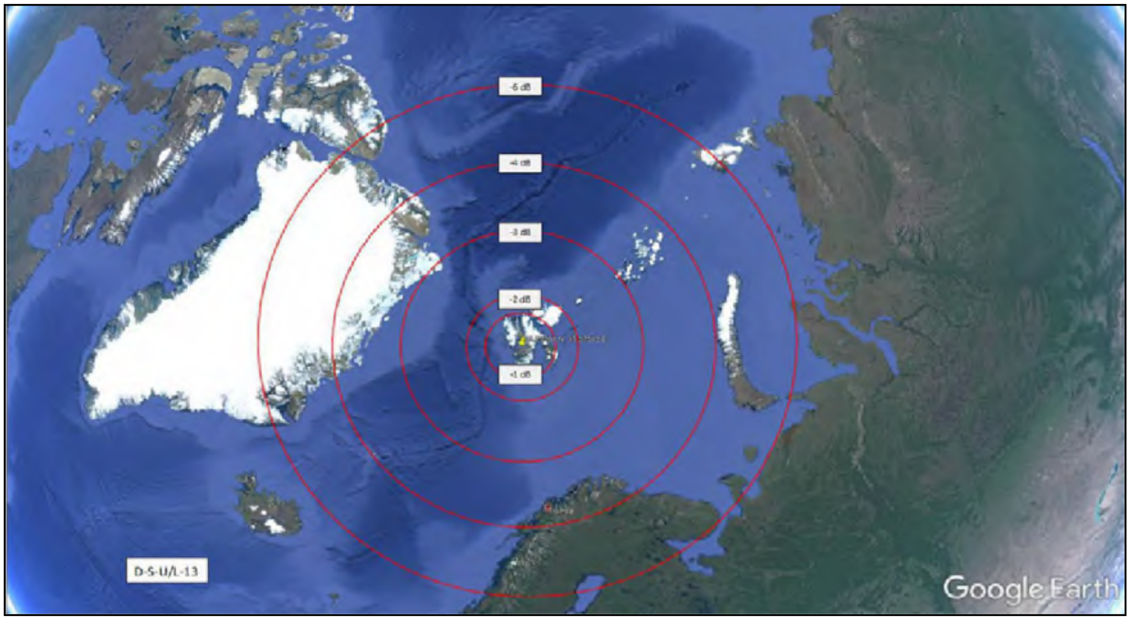


Figure C-S-RX-GH-1-B SCMD receive antenna gain contours – Svalbard

The S-band receive antenna gain contours for the SCNT beams when an Astro Digital satellite is directly above the Svalbard and Troll earth stations are shown in Figure C-S-RX-GH-M1-A and C-S-RX-GH-M1-B, respectively.

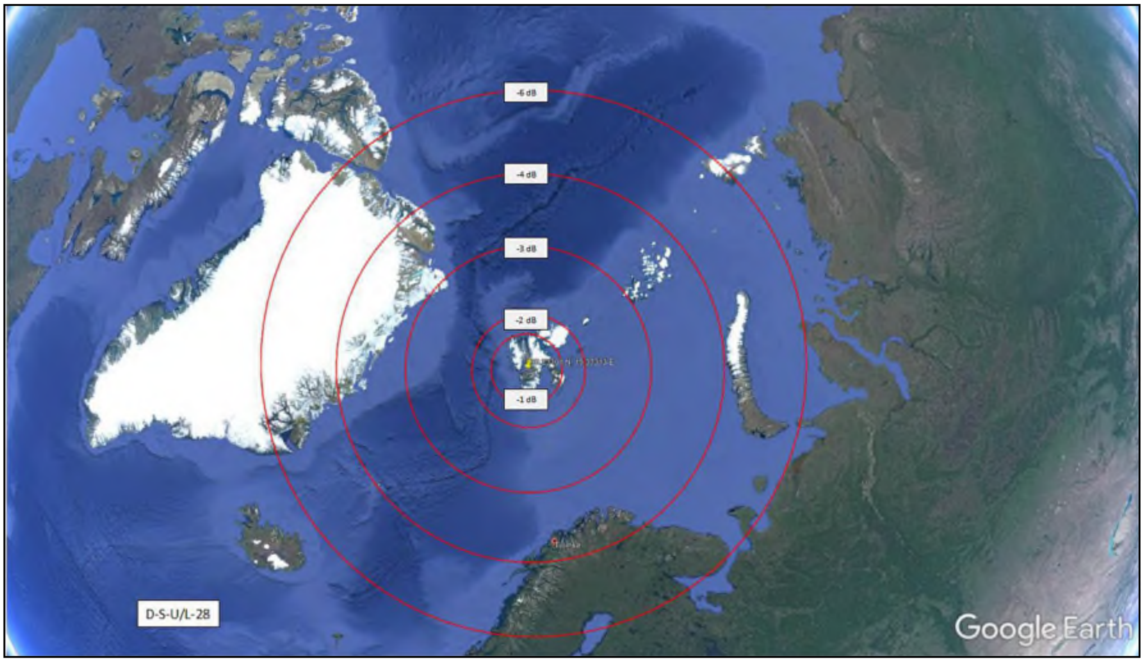


Figure C-S-RX-GH-M1-A SCNT receive antenna gain contours – Svalbard

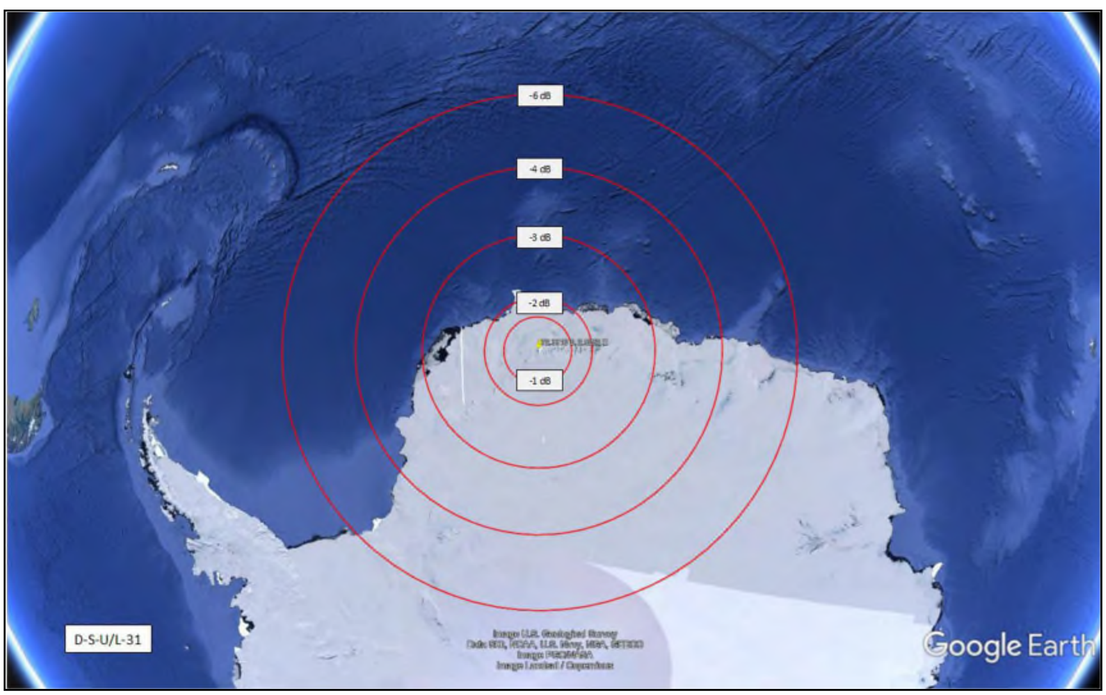


Figure C-S-RX-GH-M1-B SCNT receive antenna gain contours – Troll

The UHF receive antenna gain contours for the UTLM beams when an Astro Digital satellite is directly above the Santa Clara and Tromsø earth stations are shown in Figure C-UHF-TX-GH-1/2-A and C-UHF-TX-GH-1/2-B, respectively.

Figure C-UHF-TX-GH-1/2-A UTLM receive antenna gain contours – Santa Clara

Figure C-UHF-TX-GH-1/2-B UTLM receive antenna gain contours – Tromsø