

DESCRIPTION OF MODIFICATION

Call sign WJ2XJE

This application requests authority to communicate with two more ground stations within the United States and eight additional ground station locations internationally. This is in addition to the three sites previously authorized (located in Svalbard, Norway, Troll, Antarctica, and Punta Arenas, Chile). All stations would use both S-Band ground-to-space uplink and X-Band space-to-ground downlink signals. This application also requests a modification to the existing high data rate downlink gain and antenna patterns.

Additionally, this application requests a change to the radiation patterns and associated technical characteristics of the X-Band synthetic aperture radar antenna for the second satellite currently authorized under this experimental license. These changes capture a slight design changes and improvement of capabilities between the first to second satellite.

Finally, this application requests the addition of authorization for experimental inter-satellite communications with satellites operated by Inmarsat, pursuant to an agreement with Inmarsat. These capabilities will only exist on the second satellite and not apply to the first.

This application is being submitted during on-going coordination with the NASA Goddard Space Flight Center Spectrum Management Office. Capella has agreed to a Coordination Agreement for the protection of satellite missions operated in the 8025-8400 MHz range.

All other operational characteristics remain identical to those described in the previous underlying application with file no. 0066-EX-CN-2018.

SATELLITE ORBITAL ELEMENTS

The experimental application covers two satellites. Satellite 1 was launched on December 2, 2018. Satellite 1 was decommissioned on January 7, 2020 and is no longer used for uplink or downlink transmissions. Satellite 2 is expected to be launched in March 29, 2020. The orbital parameters of each remain unchanged from the original application, but are reproduced herein for reference.

Satellite 1 (Decommissioned as of January 7, 2020):

NORAD ID	43791
Inclination	97.75°
Orbital Period	5,773 sec
Apogee	585 km
Perigee	570 km
Argument of Perigee	N/A – Near Circular Orbit
LTDN	10:04 AM
RAAN	12.7969°

Satellite 2:

NORAD ID	N/A
Inclination	97.88° ± 1°
Orbital Period	5,800 sec – 100 sec, +25 sec
Apogee (Lifetime)	550 km – 100 km, +75 km
Perigee (Lifetime)	550 km – 100 km, +75 km
Nominal Altitude	620 km – 20 km, + 20 km
Argument of Perigee	N/A – Near Circular Orbit
LTAN	5:57:45 AM ± 10 sec
RAAN	280 ± 10°

NOTE: For satellite 2, the planned injection orbit is a circular orbit with nominal altitude of 610 km. Immediately after commissioning it is planned to lower the orbit using on-board propulsion to 600km. The full range of perigee and apogee of 625km to 450km covers the maximum possible altitude (including launch vehicle injection errors) to the lowest operational altitude is 450 km.

GROUND STATION LOCATIONS

This application requests the addition of 10 additional sites to the experimental license to assist in testing and validating downlink capabilities using a world-wide network of ground stations. Three of the requested additions are located within the United States. The remaining twelve are located internationally. The site locations and antenna performance specifications are provided below.

The Troll station will also only be used for TT&C communications and not X-Band payload downlink communications.

Stations Licensed Under Existing Experimental License:

City	Country	Antenna Type	Notes
Svalbard	Norway	3.7 m Antenna	
Troll	Antarctica	3.7 m Antenna	TT&C Only
Punta Arenas	Chile	3.7 m Antenna	

Requested Additions (In US):

City	Country	Lon [deg]	Lat [deg]	Antenna Type
Boardman, OR	USA	-83.197	40.100	5.0 m Antenna Type 2
Kileville, OH	USA	-119.632	45.855	5.0 m Antenna Type 2

Requested Additions (International):

City	Country	Antenna Type
Hartebeesthoek	South Africa	3.7 m Antenna
Awarua	New Zealand	3.7 m Antenna
Tripoli	Greece	5.0 m Antenna Type 1
Dublin	Ireland	5.0 m Antenna Type 2
Vasteras	Sweden	5.0 m Antenna Type 2
Cape Town	South Africa	5.0 m Antenna Type 2
Manama	Bahrain	5.0 m Antenna Type 2
Sydney	Australia	5.0 m Antenna Type 2

Antenna Specifications:

The following section provides information on the antennas used at each site and their performance characteristics.

3.7m Antenna

Locations Using: Svalbard, Troll, Awarua, Hartebeesthoek, Punta Arenas

Antenna Size: 3.7 meter dish

Antenna Gain: 35.4 dB

Antenna Half-Power Beamwidth: 1.4 degrees (at 2250 MHz)

Maximum Antenna EIRP: 41.0 dBW

5.0m Antenna Type 1

Locations Using: Greece

Antenna Size: 5.0 meter dish

Antenna Gain (isotropic): 38.1 dBi

Antenna Half-Power Beamwidth: 1.06 degrees (at 2250 MHz)

Maximum Antenna EIRP: 41.0 dBW

5.0m Antenna Type 2

Locations Using: Boardman, OR, Kileville, OH, Honolulu HI, Cape Town, Vasteras, Dublin,
Manama, Mumbai, Punta Arenas, Sydney Soeul, Tokyo

Antenna Size: 5.0 meter dish

Antenna Gain: 38.1 dB

Antenna Half-Power Beamwidth: 2.0 degrees (S-band)

Maximum Antenna EIRP: 41.0 dBW

S-BAND UPLINK PARAMETERS

The Capella S-Band TT&C uplink will operate within S-Band (2035.3-2036.7 MHz) at a center frequency of 2036 MHz, maximum bandwidth of 1.4 MHz, and maximum EIRP of 41.0 dBW (ERP of 38.85 dBW) across all ground stations. These characteristics are reproduced here for reference while considering the modification request to add additional ground station locations.

Frequency Range	2035.3-2036.7 MHz
Bandwidth	1.4 MHz
EIRP	41.0 dBW
ERP	38.85 dBW
Polarization	RHCP

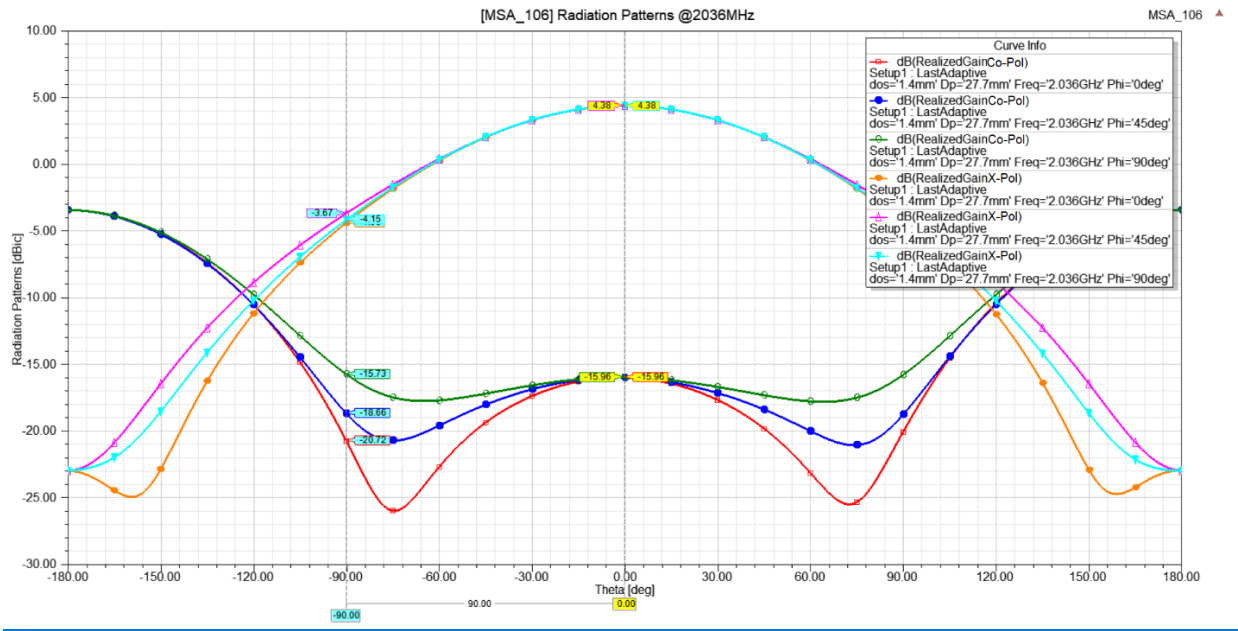


Figure 1. Capella S-Band Receive Gain Pattern

X-BAND DOWNLINK PARAMETERS

The Capella X-Band TT&C downlink will operate within X-Band (8025 MHz to 8029 MHz) at a nominal center frequency of 8027 MHz, a bandwidth 1.4 MHz, and a maximum EIRP of 4.5 dBW (ERP of 2.35 dBW). These characteristics remain identical to the parameters of the original application.

Frequency Range	8025-8029 MHz
Bandwidth	1.4 MHz
EIRP	4.5 dBW
ERP	2.35 dBW
Polarization	RHCP

The Capella X-Band High Data Rate downlink will operate within X-Band (8025 MHz to 8400 MHz) at a nominal center frequency of 8212.5 MHz, a bandwidth 250 MHz, and a maximum EIRP of 26.0 dBW (ERP of 23.85 dBW). These characteristics remain consistent with the parameters of the original application. This modification proposes a general reduction the maximum transmit power from the previous license to ensure that no interference with the NASA Deep Space Network can occur at any of the proposed station additions.

Frequency Range	8025-8400 MHz
Bandwidth	250 MHz
EIRP	26.0 dBW
ERP	23.85 dBW
Polarization	RCHP + LCHP

An analysis demonstrating that X-Band downlink (TT&C or High Data Rate) cannot interfere with the Deep Space Network from either existing or proposed ground station locations is provided in Tables 1 and 2.

Capella has agreed to a Coordination Agreement for the protection of satellite missions operated in the 8025-8400 MHz range. The agreement outlines the process and procedure approved by NASA by which Capella will self-limit though secession X-Band transmissions when a Capella satellite is within 5 degrees of any NASA-listed protected satellites.

The characteristics of both downlink signals are reproduced here for reference while considering the modification request to add additional ground station locations.

Item	Value	Units	Notes
X-Band Downlink EIRP (dBW)	4.5	dBW	
X-Band Downlink Bandwidth (MHz)	1.4	MHz	

X-Band Downlink PSD (dBW/Hz)	-53.86	dBW/Hz	
Spectral Roll-off @ 8.4 GHz (dBc)	-90	dBc	Measured noise floor
X-Band Downlink PSD @ 8.4 GHz	-143.86	dBW/Hz	
Slant Range	450.00	km	Worst-case, lowest orbit
Antenna Offset	0.00	deg	Worst-case DSN station at boresight
Pointing Loss	0.00	dB	
Space Loss @ 8400 MHz	-163.99	dB	
Total Path Loss	-163.99	dB	
DSN Earth Station Antenna Gain	74.00	dB	Per ITU-R SA.1157-1
Received Interference PSD @ 8.4 GHz	-233.85	dBW/Hz	
Protection Criterion	-221.00	dBW/Hz	Per ITU-R SA.1157-1
Margin	14.95	dB	

**Table 1. Capella X-Band TT&C Downlink Deep Space Earth Station Receiver
Worst-Case Interference Analysis**

Item	Value	Units	Notes
X-Band Downlink EIRP	26	dBW	
X-Band Downlink Bandwidth	250	MHz	
X-Band Downlink PSD	-57.98	dBW/Hz	
Spectral Roll-off @ 8.4 GHz	-32	dBc	Measured with RRC alpha=0.35
Output Filter Rejection @ 8.4 GHz	-50	dB	Worst-case filter rejection
X-Band Downlink PSD @ 8.4 GHz	-139.98	dBW/Hz	
Slant Range	450.00	km	Worst-case, lowest orbit
Antenna Offset	0.00	deg	Worst-case, DSN station at boresight
Pointing Loss	0.00	dB	
Space Loss @ 8400 MHz	-163.99	dB	
Total Path Loss	-163.99	dB	
DSN Earth Station Antenna Gain	74.00	dB	Per ITU-R SA.1157-1
Received Interference PSD @ 8.4 GHz	-229.97	dBW/Hz	
Protection Criterion	-221.00	dBW/Hz	Per ITU-R SA.1157-1
Margin	8.97	dB	

Table 1. Capella X-Band High Data Rate Downlink Deep Space Earth Station Receiver

Worst-Case Interference Analysis

Space-to-Space GEO-to-LEO Uplink

The Capella GEO to LEO uplink (i.e., where the Capella satellite will receive transmissions from satellites in geostationary orbit) will operate within the 1518.0 MHz to 1559.0 MHz frequency band, using RHCP polarization. These transmissions fall within Inmarsat's currently licensed spectrum allocation and will only occur with Inmarsat's consent. The exact frequency, channel, and parameters are assigned by the Inmarsat system at the time of connection, pursuant to their existing license. The antenna E- and H-plane gain patterns are shown in Figures 5 and 6 below.

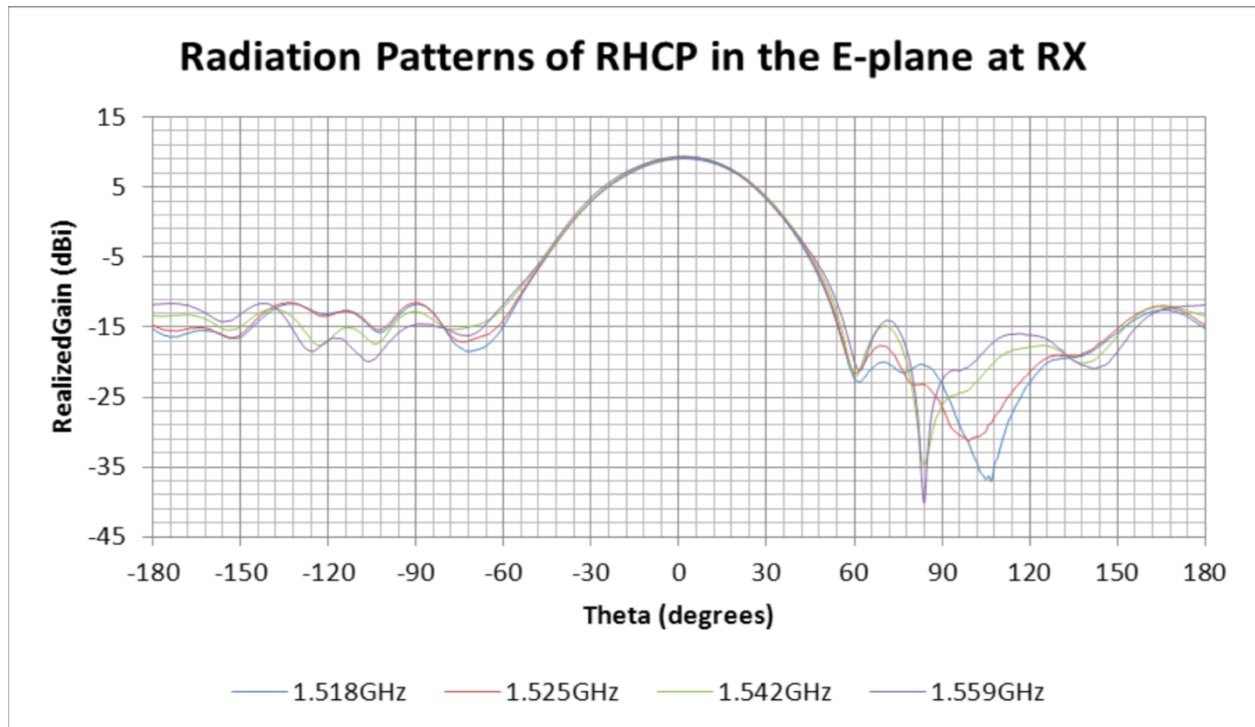


Figure 6. Capella Space-to-Space Uplink E-Plane Gain Pattern

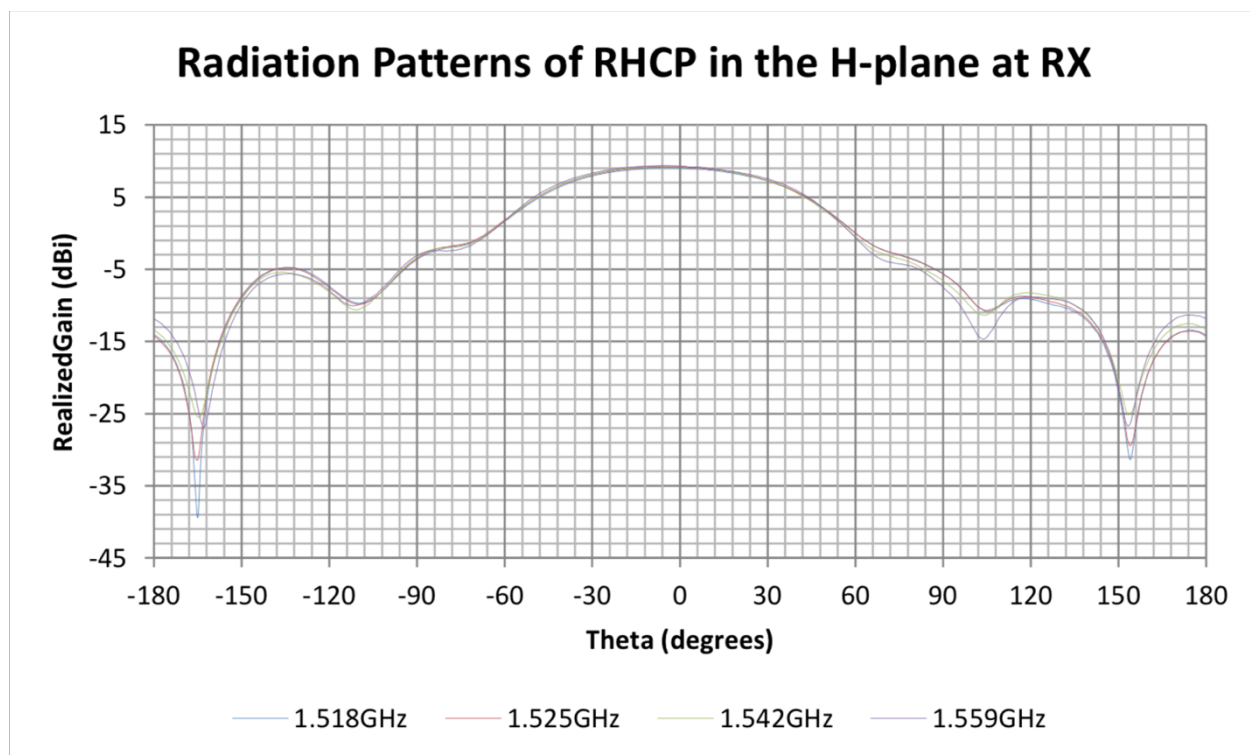


Figure 7. Capella Space-to-Space Uplink H-Plane Gain Pattern

Space-to-Space LEO-to-GEO Downlink

The Capella LEO to GEO downlink (i.e., where the Capella satellite will transmit signals to satellites in geostationary orbit) will operate within the 1626.5 MHz to 1660.5 MHz and 1668.0 to 1675.0 MHz bands with the following technical characteristics:

Frequency Ranges	1626.5 - 1660.5 MHz 1668.0 - 1675.0 MHz
Bandwidth	25-200 kHz
EIRP	8.5 dBW
ERP	6.35 dBW
Polarization	RHCP

These transmissions fall within Inmarsat's currently licensed spectrum allocation and will only occur with Inmarsat's consent. The exact frequency, channel, and parameters are assigned by the Inmarsat system at the time of connection, pursuant to their existing license.

The antenna E- and H-plane gain patterns are shown in Figures 7 and 8 below.

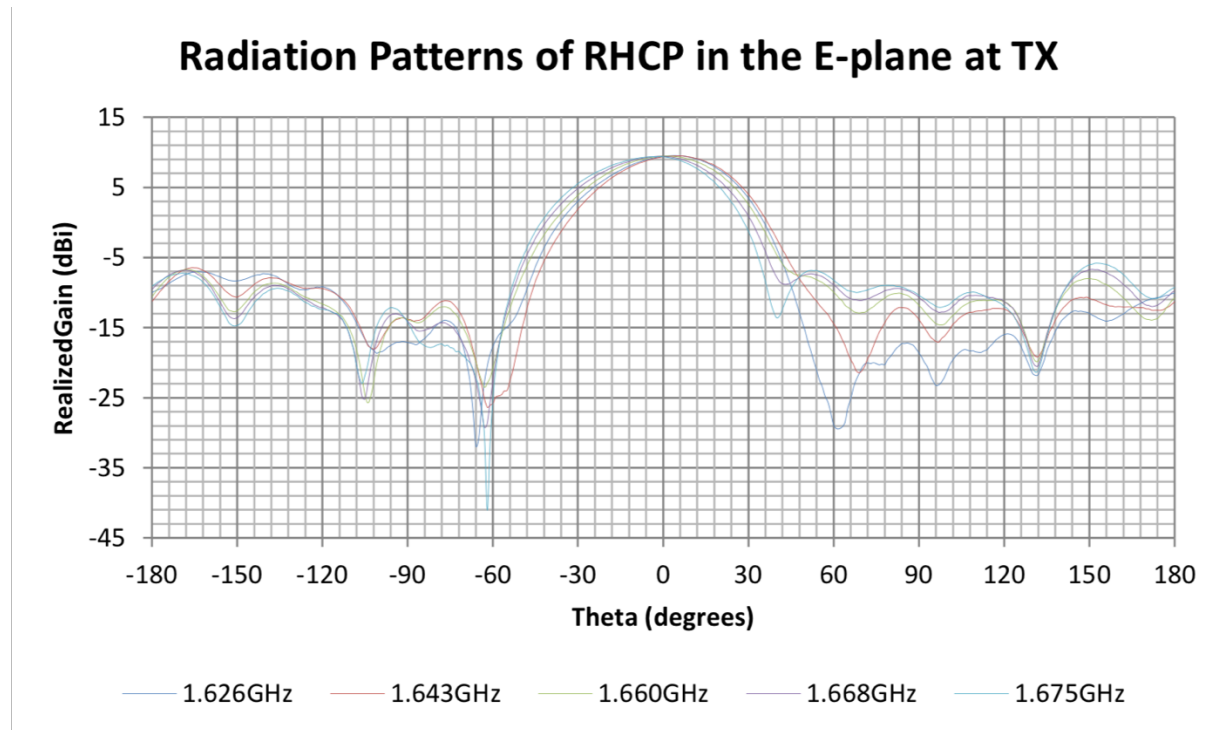


Figure 8. Capella Space-to-Space Downlink E-Plane Gain Pattern

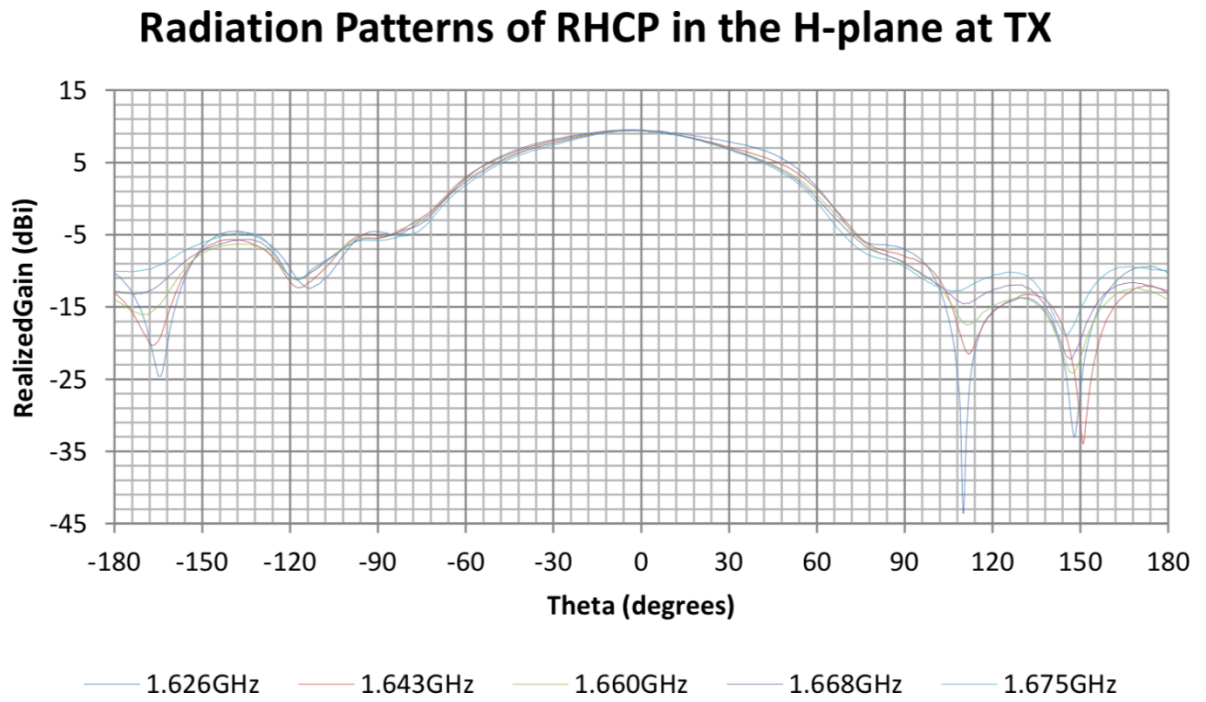


Figure 9. Capella Space-to-Space Downlink H-Plane Gain Pattern

SAR PARAMETERS

For the second experimental satellite this application requests a modification to the transmission parameters of the SAR payload. The SAR payload will condition to operate in X-Band, with a center frequency of 9600 MHz, bandwidth of 600 MHz, and maximum EIRP of 76.0 dBW (ERP of 73.85 dBW). These SAR transmission parameters are tabulated below:

Frequency Range	9300-9900 MHz
Bandwidth	600 MHz
EIRP	76.0 dBW
ERP	73.85 dBW
Polarization	Linear

Capella adheres to the ITU recommendation ITU-R RS.2066-0 for protection of Radio Astronomy Observatories (RAO). Capella will not illuminate radio astronomy observatory sites listed in RS.2066-0 without prior coordination with the observatory owner/operator.

The antenna gain patterns are provided in Figures 1 and 2. Projected ground gain contours for 35 and 60 degree incidence angles are provided in Figures 3 and 4.

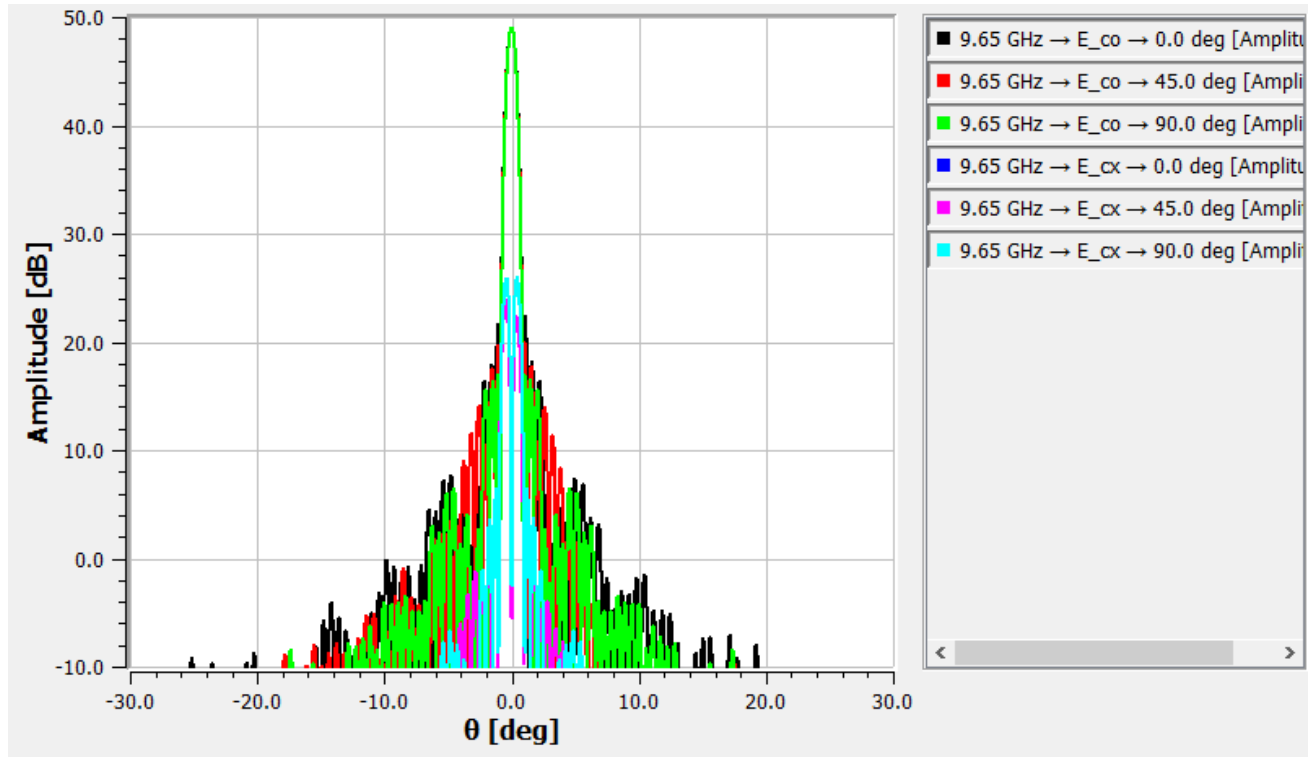


Figure 2. Capella X-Band SAR Antenna Gain Patterns

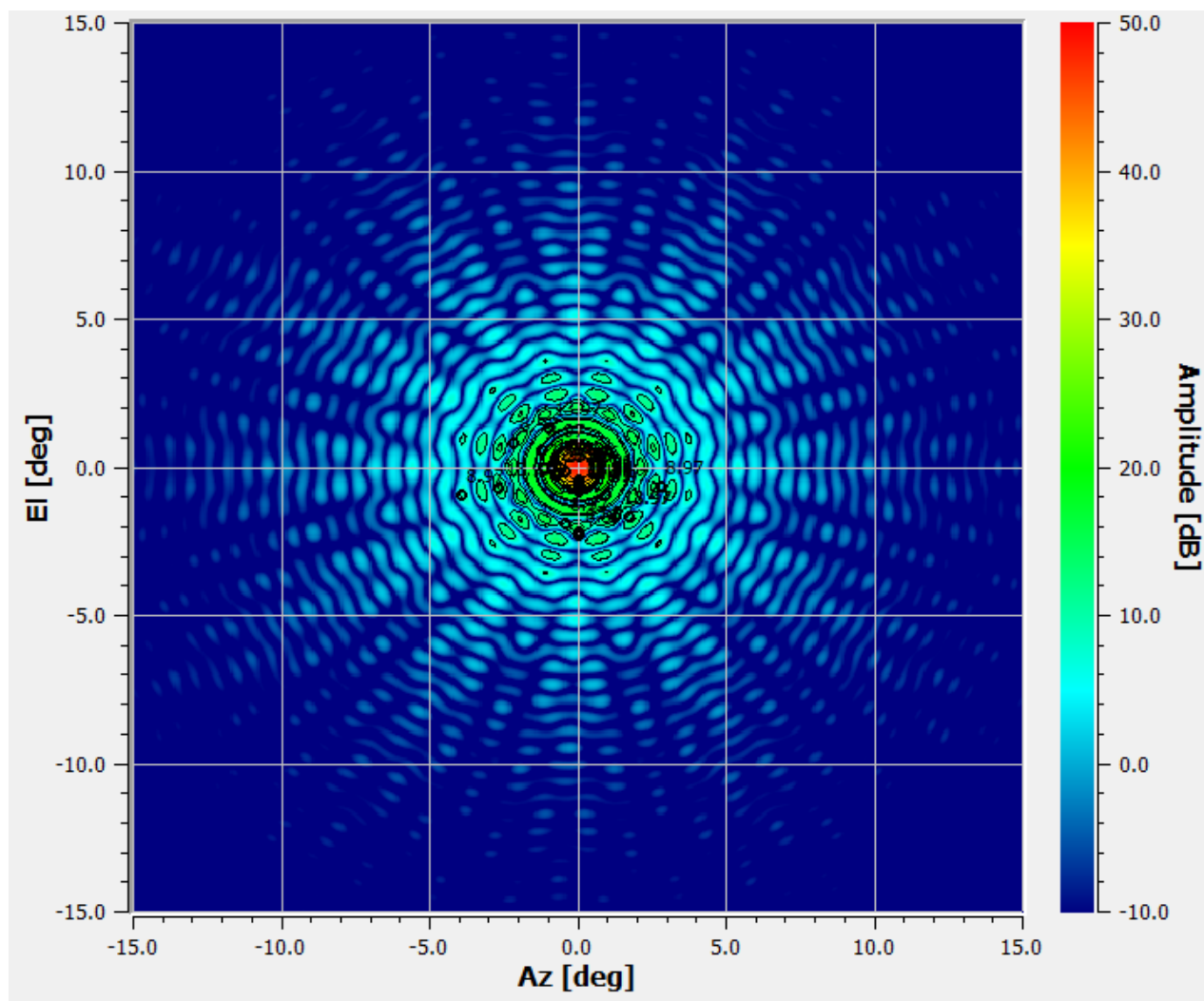


Figure 3. Capella X-Band SAR Antenna Gain Contours

Gain contours projected onto the Earth's surface for nominal X-Band SAR transmission at 450, 575, and 610km altitude and at a 35 degree incidence angle are provided in Figures 3, 4, and 5:

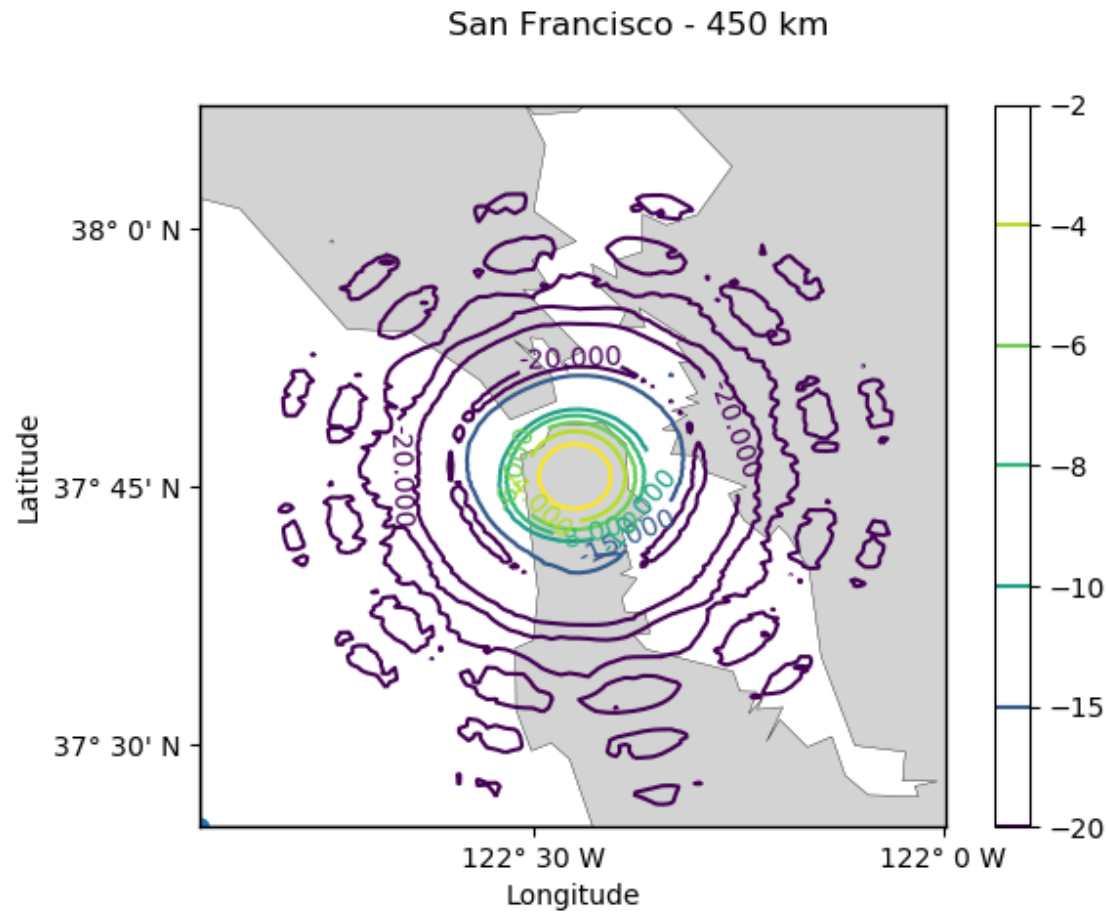


Figure 4. Capella X-Band SAR Ground-Projected Gain Contours For 35 Degree Incidence Angle at 450 km Altitude

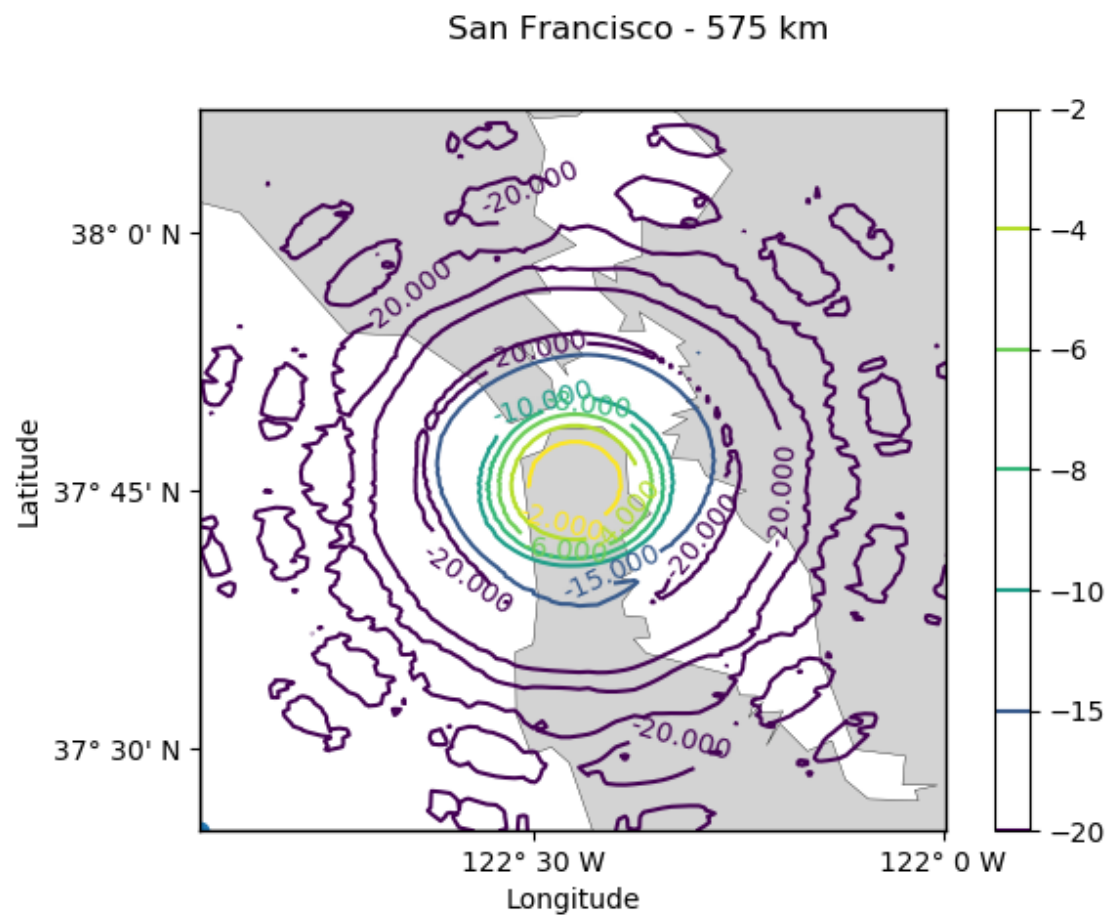


Figure 4. Capella X-Band SAR Ground-Projected Gain Contours For 35 Degree Incidence Angle at 450 km Altitude

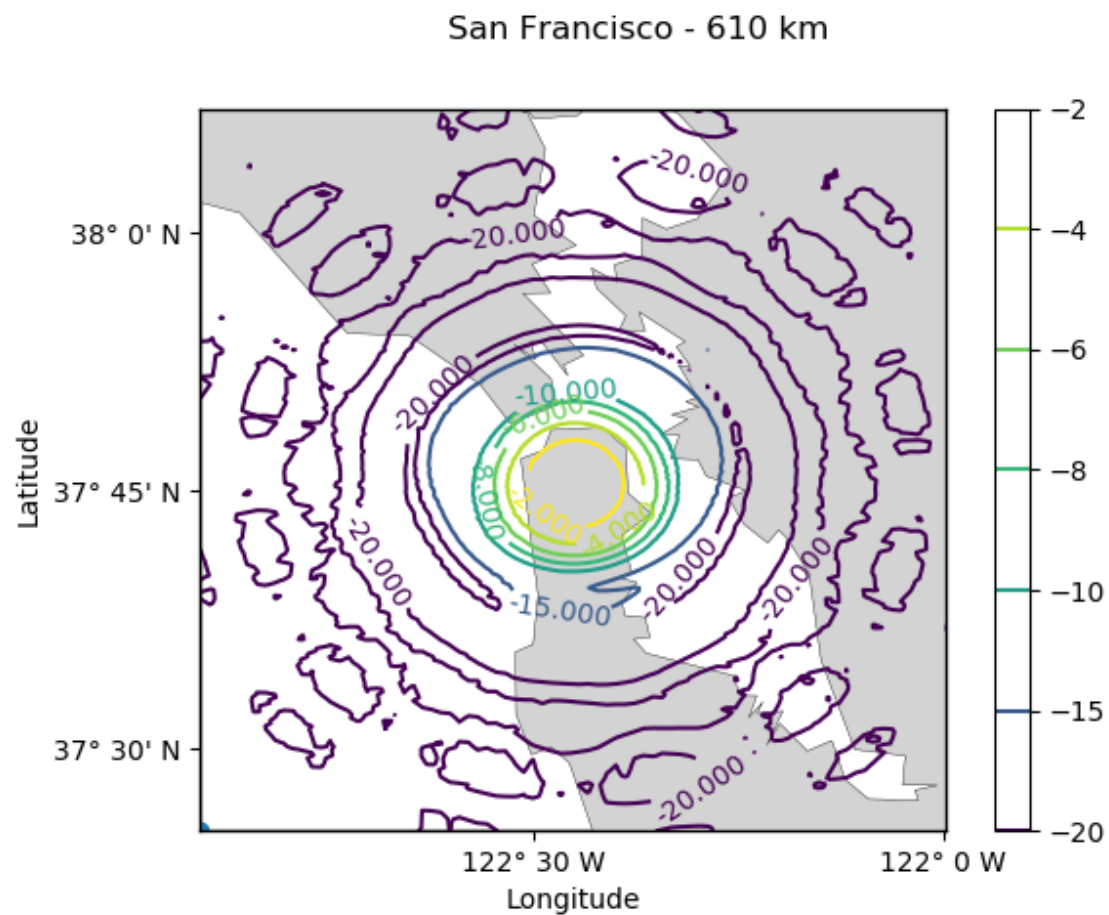


Figure 5. Capella X-Band SAR Ground-Projected Gain Contours For 35 Degree Incidence Angle at 610 km Altitude