

EXPERIMENTAL LICENSE APPLICATION TECHNICAL ATTACHMENT

DESCRIPTION OF APPLICATION

This application requests authority to launch and operate a SAR satellite at a mid-latitude inclination as well as communicate with a network of 11 ground stations, two of which are located within the United States.

All stations would use both S-Band for ground-to-space uplink and X-Band for space-to-ground downlink. This application also seeks authorization for use of experimental LEO-to-GEO, and GEO-to-LEO inter-satellite communications link between the satellite licensed herein and Geostationary communications satellites operated by Inmarsat.

This application is being submitted during ongoing 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.

SATELLITE ORBITAL ELEMENTS

This is an experimental application to cover one (1) satellite. The launch is not a Sun-Synchronous orbit therefore the LTAN will not be constant, instead it will be determined by the exact launch date and evolve due to natural orbit perturbations. Current plan is to launch this satellite no earlier than May 21, 2020.

Satellite 1:

NORAD ID	N/A
Inclination	$45.00^{\circ} \pm 1^{\circ}$
Orbital Period	5,800 sec – 100 sec, +25 sec
Apogee (Lifetime)	525 km – 75 km, + 25 km
Perigee (Lifetime)	525 km – 75 km, + 25 km
Nominal Altitude	525 km – 75 km, + 25 km
Argument of Perigee	N/A – Near Circular Orbit

GROUND STATION LOCATIONS

This application requests usage of 13 ground station locations to support spacecraft launch, commissioning, and operations. Two of the requested stations are located within the United States. The remaining 11 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.

Requested Stations (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

Table 1: Ground stations located in the United States

Requested Stations (International):

City	Country	Antenna Type
Svalbard	Norway	3.7 m Antenna
Troll	Antarctica (Norway)	3.7 m Antenna
Punta Arenas	Chile	3.7 m Antenna
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

Table 2: Ground stations located internationally

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, Kilevile, OH, Cape Town, Vasteras, Dublin, Manama, Punta Arenas, Sydney

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.

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

Table 3: S-Band TT&C ground-to-space characteristics

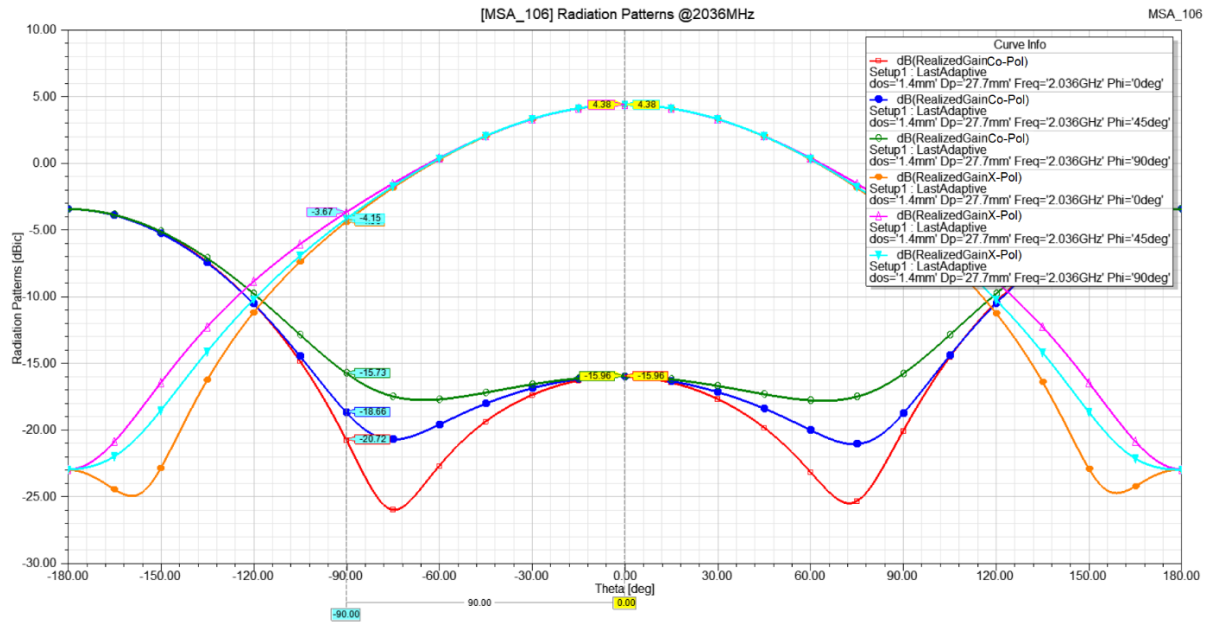


Figure 1: Capella S-Band receive antenna gain pattern

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). See Figure 4 for the TT&C downlink antenna gain pattern and [Figure 3](#) for the ground-projected gain contour.

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

Table 4: X-Band TT&C space-to-ground characteristics

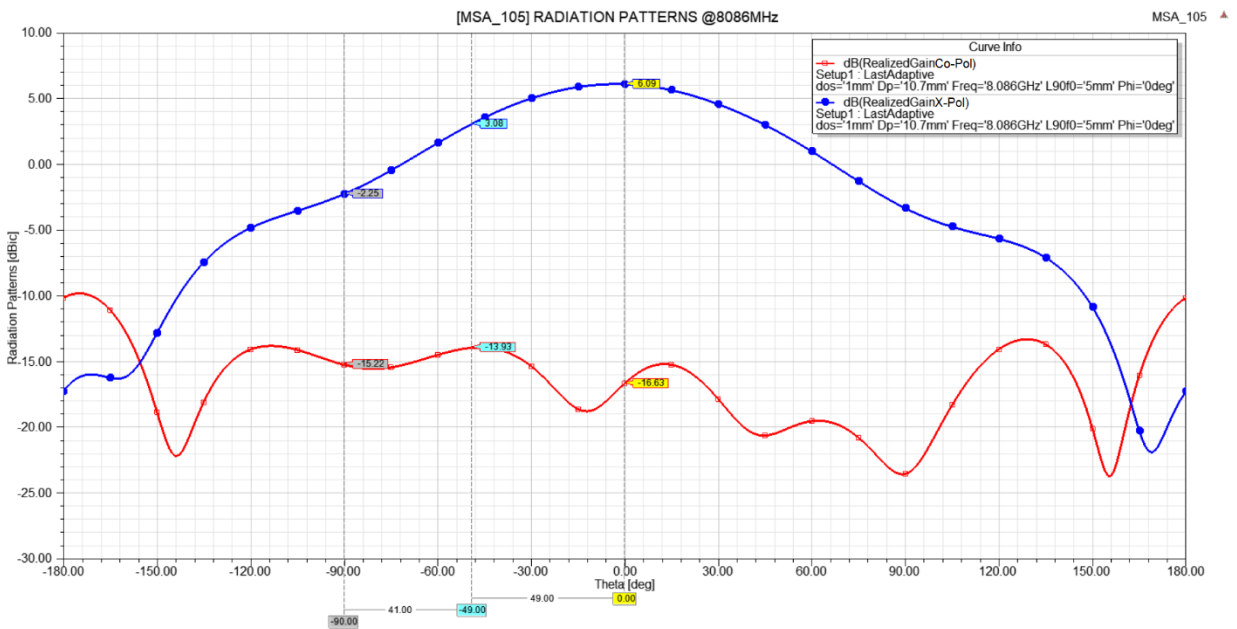


Figure 2: Capella X-Band TT&C space-to-ground transmit antenna gain pattern

San Francisco 525 km

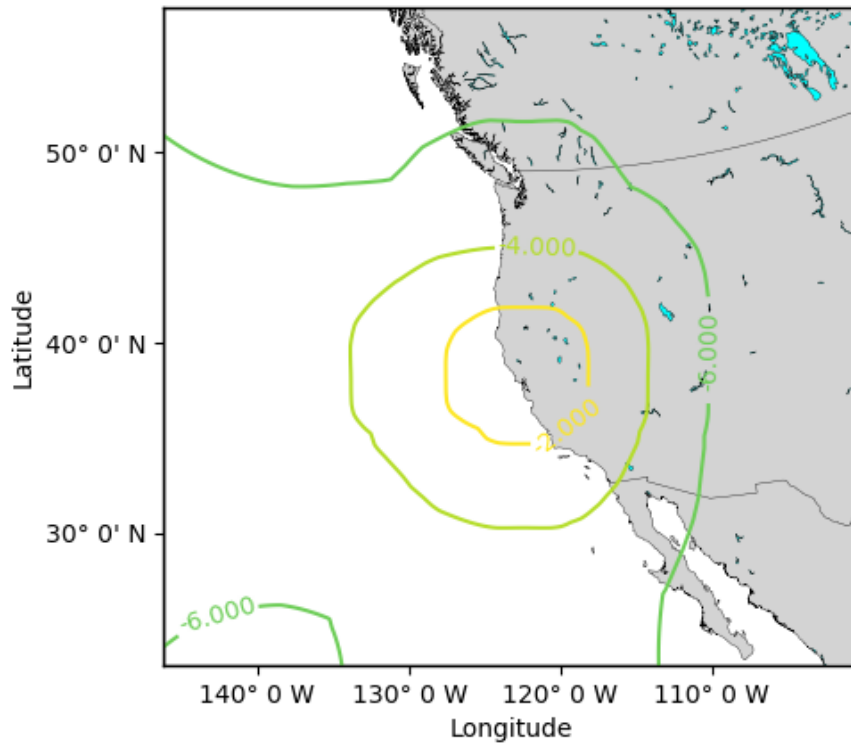


Figure 3: Capella X-Band TT&C downlink ground-projected gain contour at 525 km altitude

The Capella X-Band High Data Rate (HDR) 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). The transmitted power is set at a level that ensures no interference with the NASA Deep Space Network can occur when communicated with any of the proposed ground station locations. See [Figure 4](#) for the HDR downlink antenna gain pattern and [Figure 5](#) for the ground-projected gain contour.

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

Table 5: X-Band High Data Rate (HDR) space-to-ground link characteristics

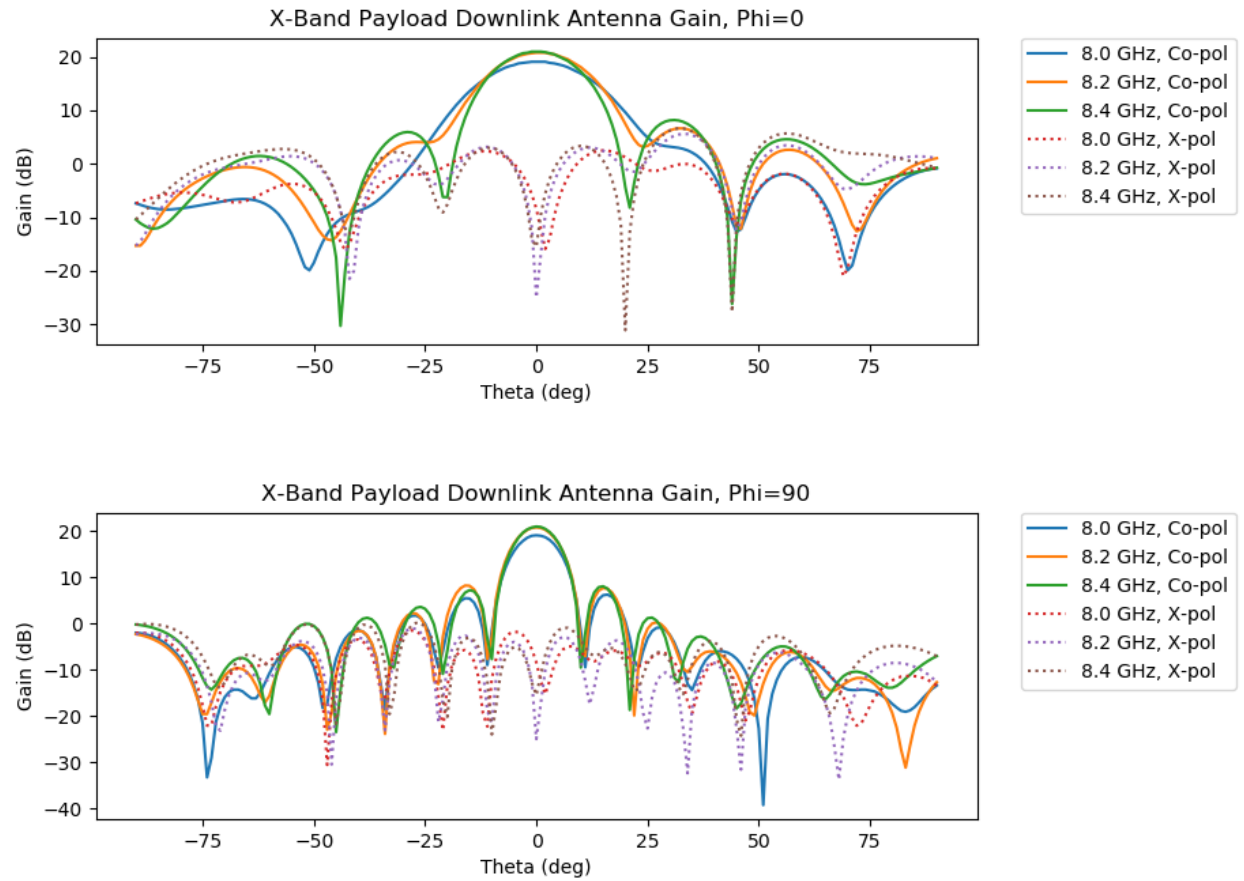


Figure 4: Capella X-Band HDR space-to-ground transmit antenna gain pattern

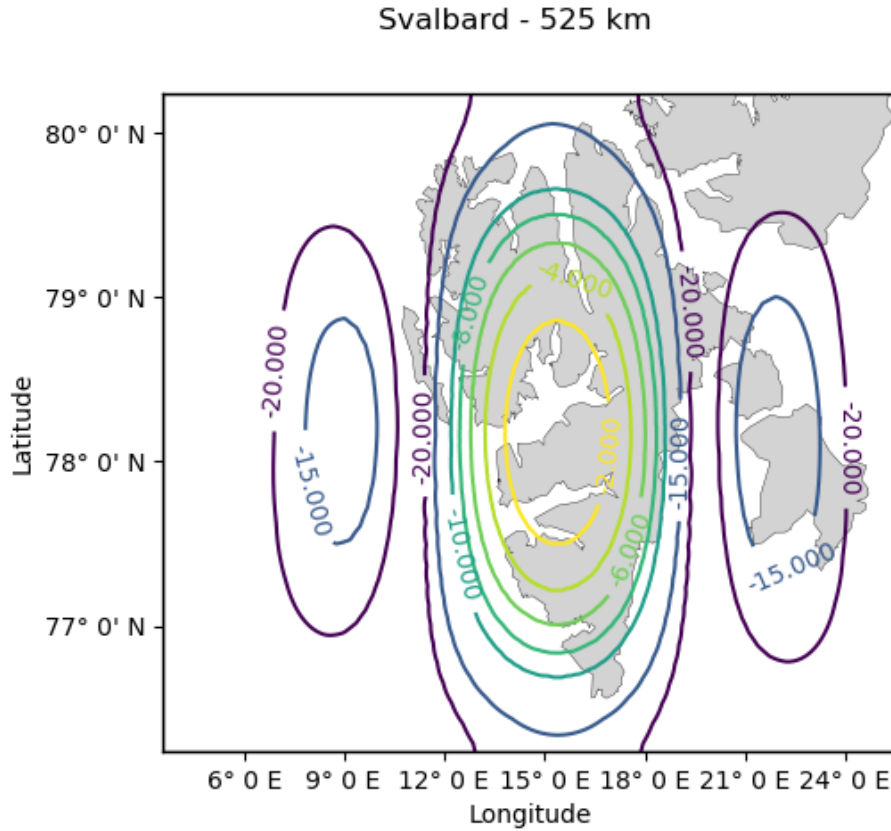


Figure 5: Capella X-Band HDR downlink ground-projected gain contour at 525km altitude

A detailed analysis demonstrating that neither the X-Band TT&C or HDR downlinks will interfere with the Deep Space Network while in communication with the proposed ground station locations is provided in [Table 6](#) and [Table 7](#) below.

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.

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 6: Capella X-Band TT&C downlink Deep Space Network protection margin 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 7: Capella X-Band HDR downlink Deep Space Network protection margin 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 [Figure 6](#) and [Figure 7](#) below.

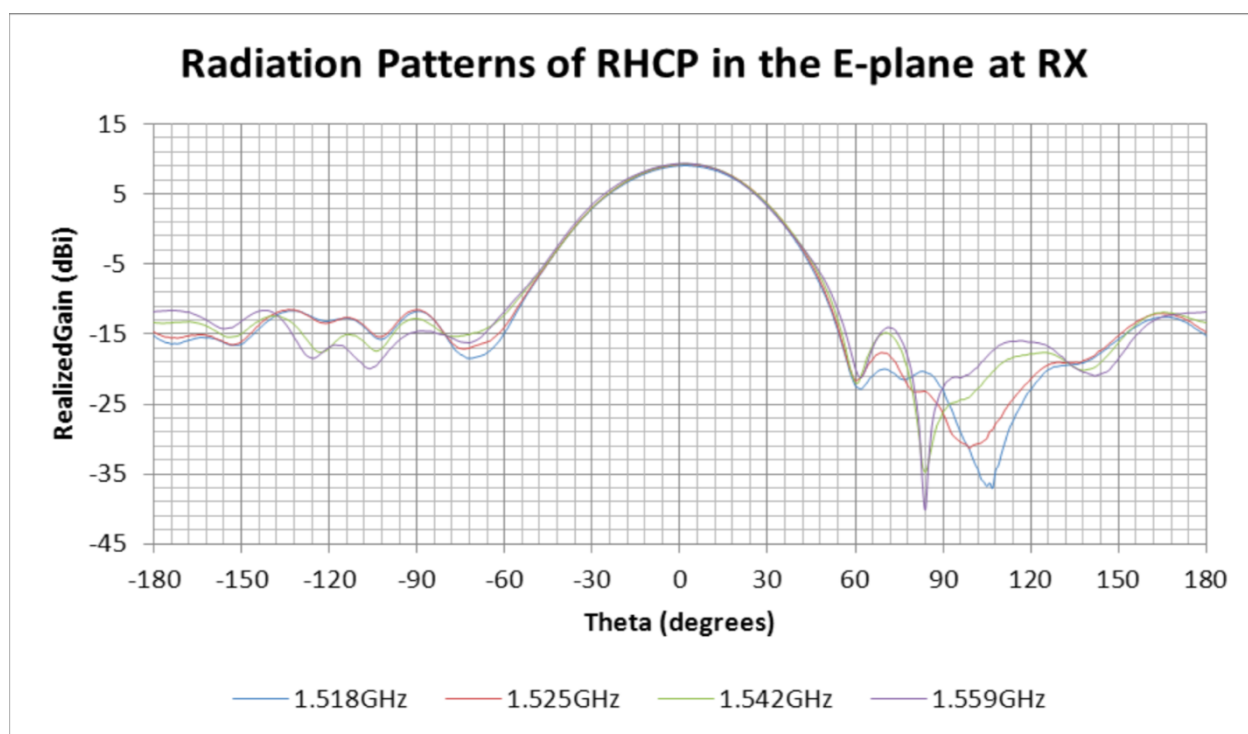


Figure 6: Capella space-to-space uplink E-Plane transmit antenna gain pattern

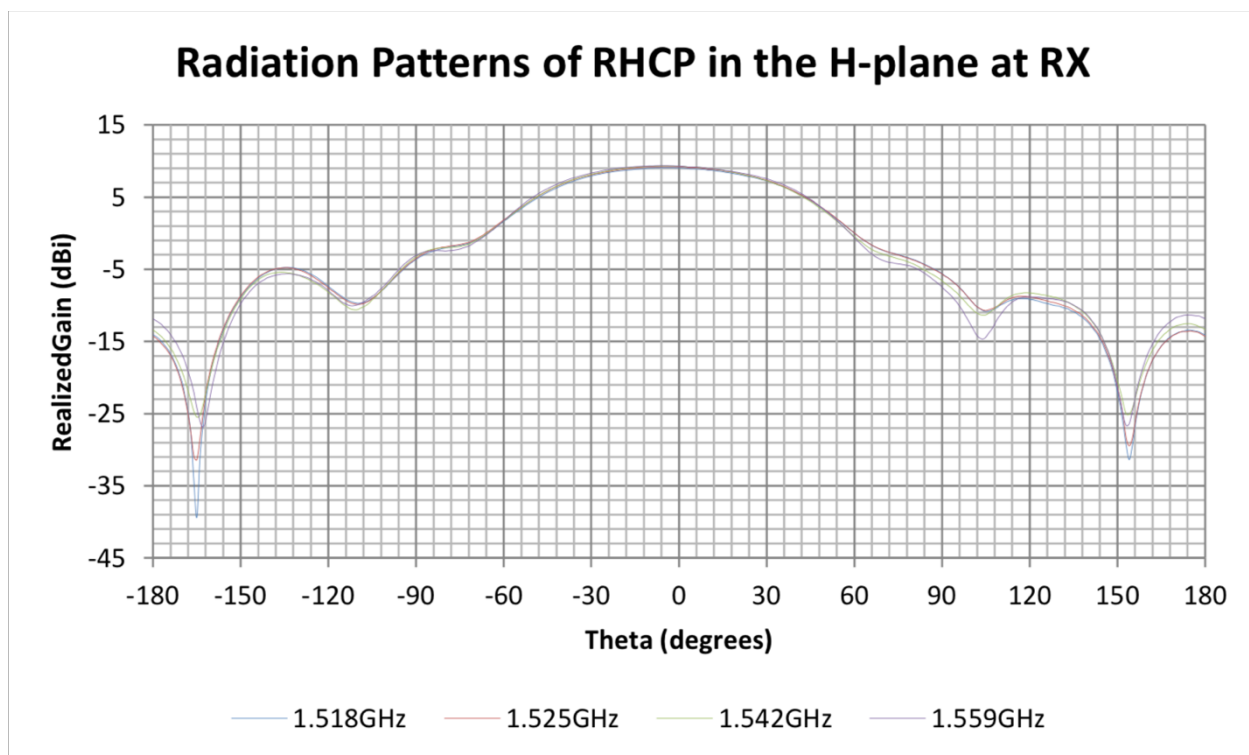


Figure 7: Capella space-to-space uplink H-Plane transmit antenna gain pattern

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

Table 8: L-Band Inmarsat space-to-space uplink characteristics

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 [Figure 8](#) and [Figure 9](#) below.

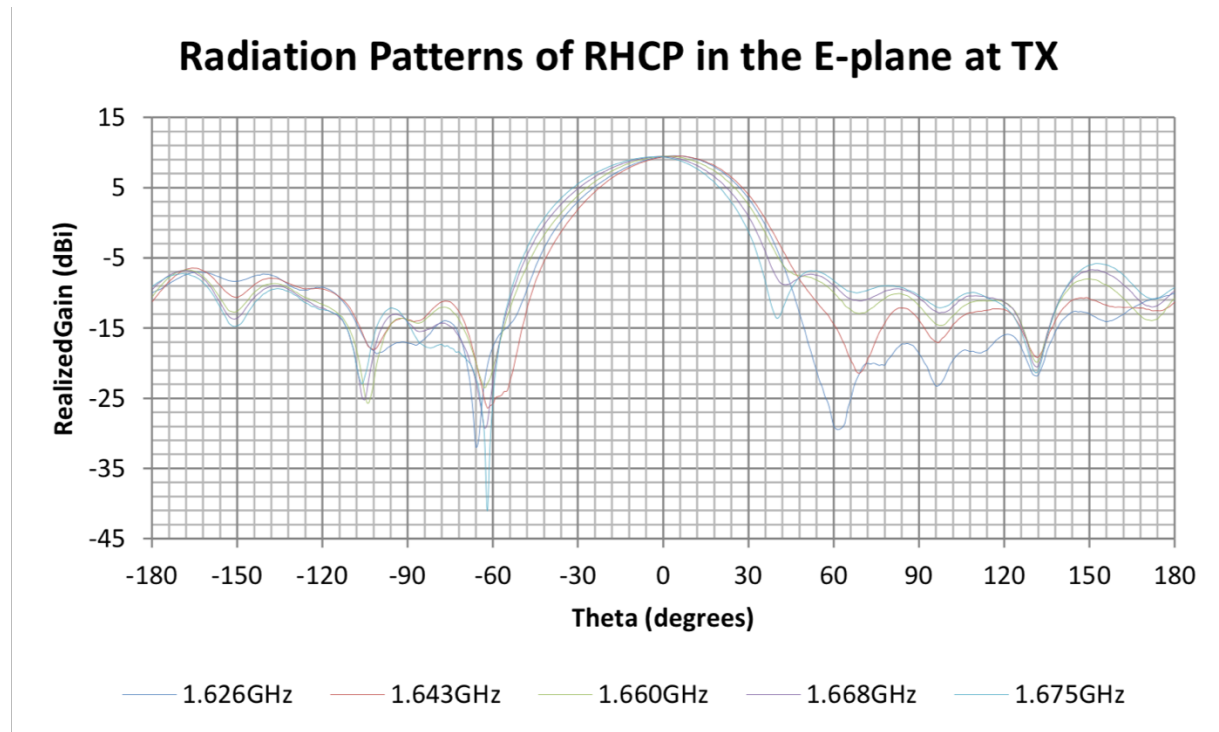


Figure 8: Capella space-to-space downlink E-Plane transmit antenna gain pattern

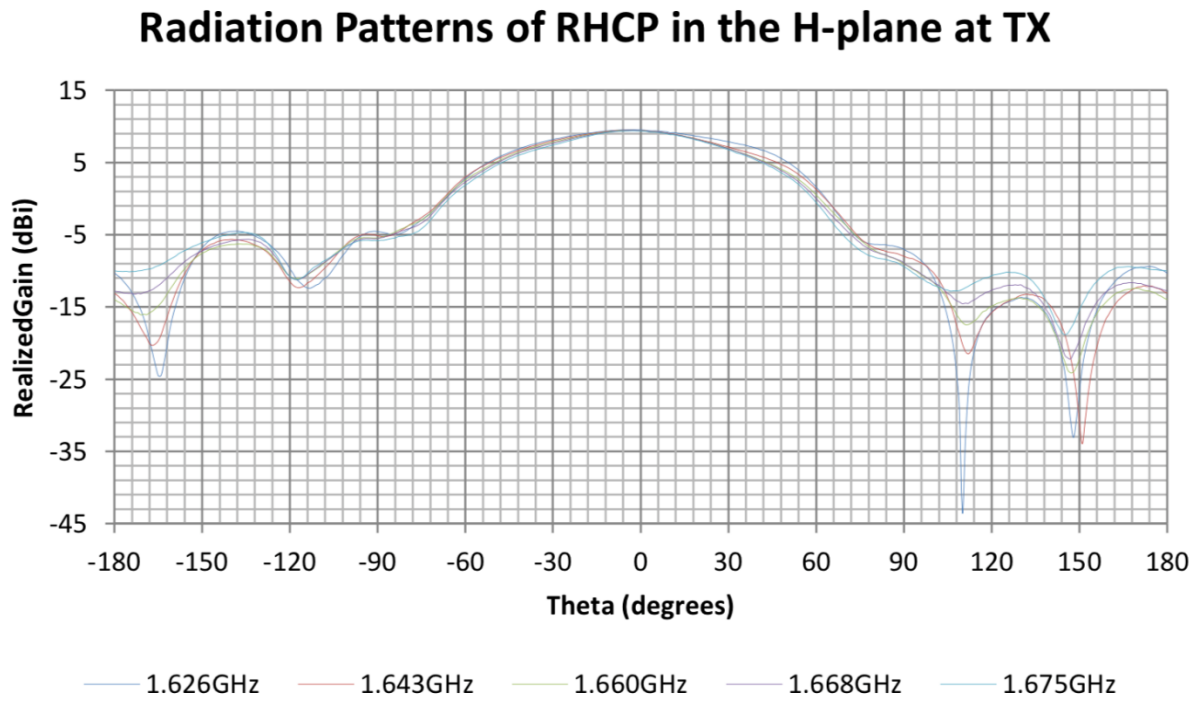


Figure 9: Capella space-to-space downlink E-Plane transmit antenna gain pattern

SAR PARAMETERS

The primary payload for the spacecraft is a SAR instrument, which will operate in the X-Band, has 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

Table 9: Radar payload RF characteristics.

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 [Figure 10](#) and [Figure 11](#). Projected ground gain contours for 30 incidence angles over a range of altitudes are provided in [Figure 12](#), [Figure 13](#), and [Figure 14](#) below.

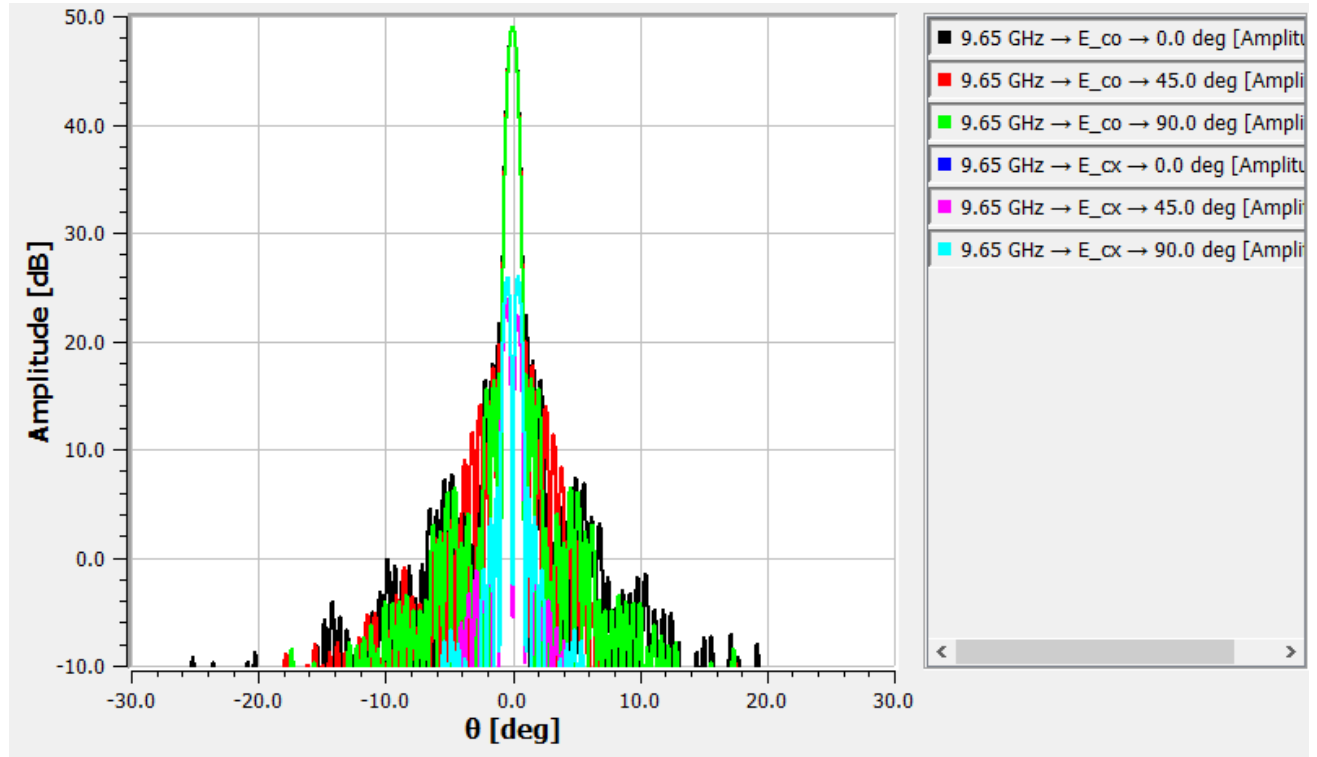


Figure 10: Capella X-Band radar antenna gain pattern

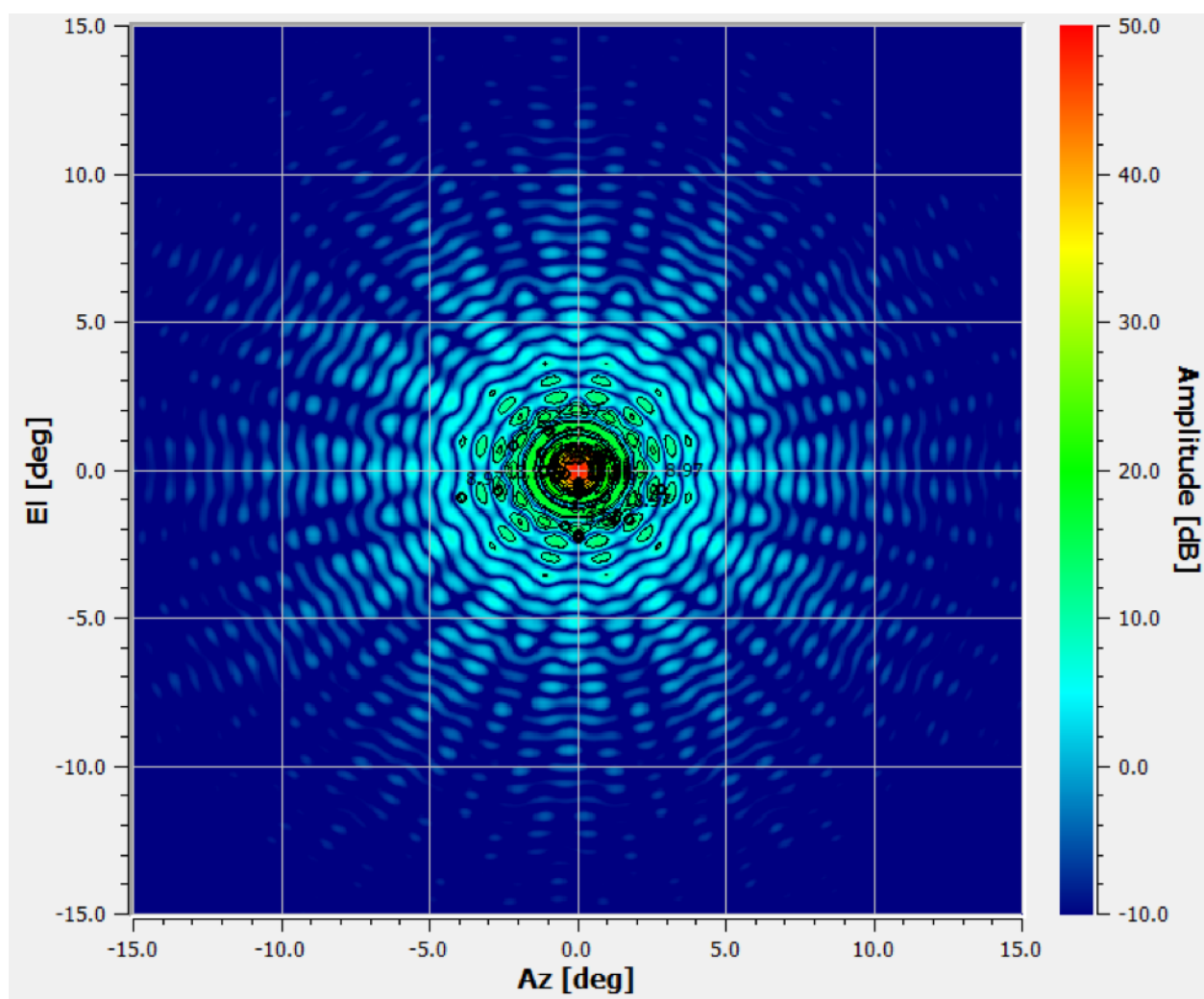


Figure 11: Capella X-band radar antenna gain contour

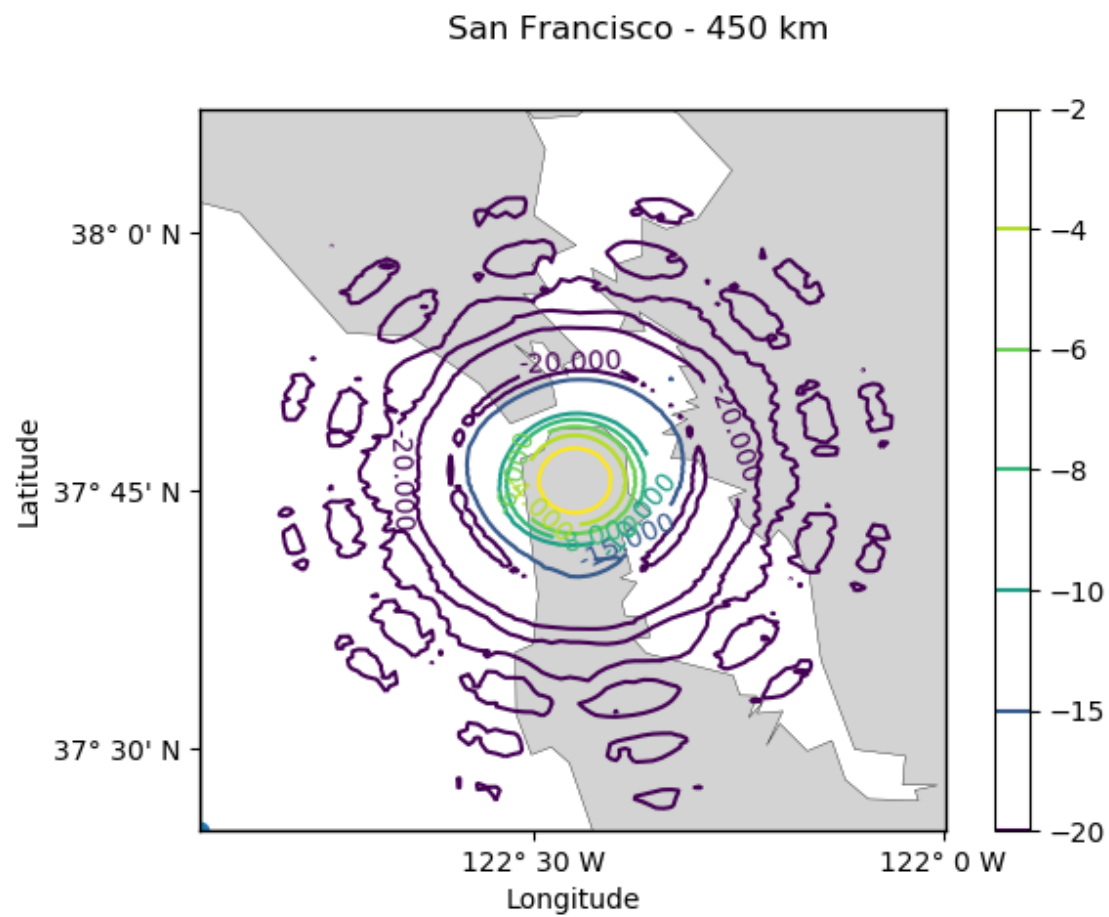


Figure 12: Capella X-Band SAR ground-projected gain contours for 30 degree incidence angle at 450 km altitude

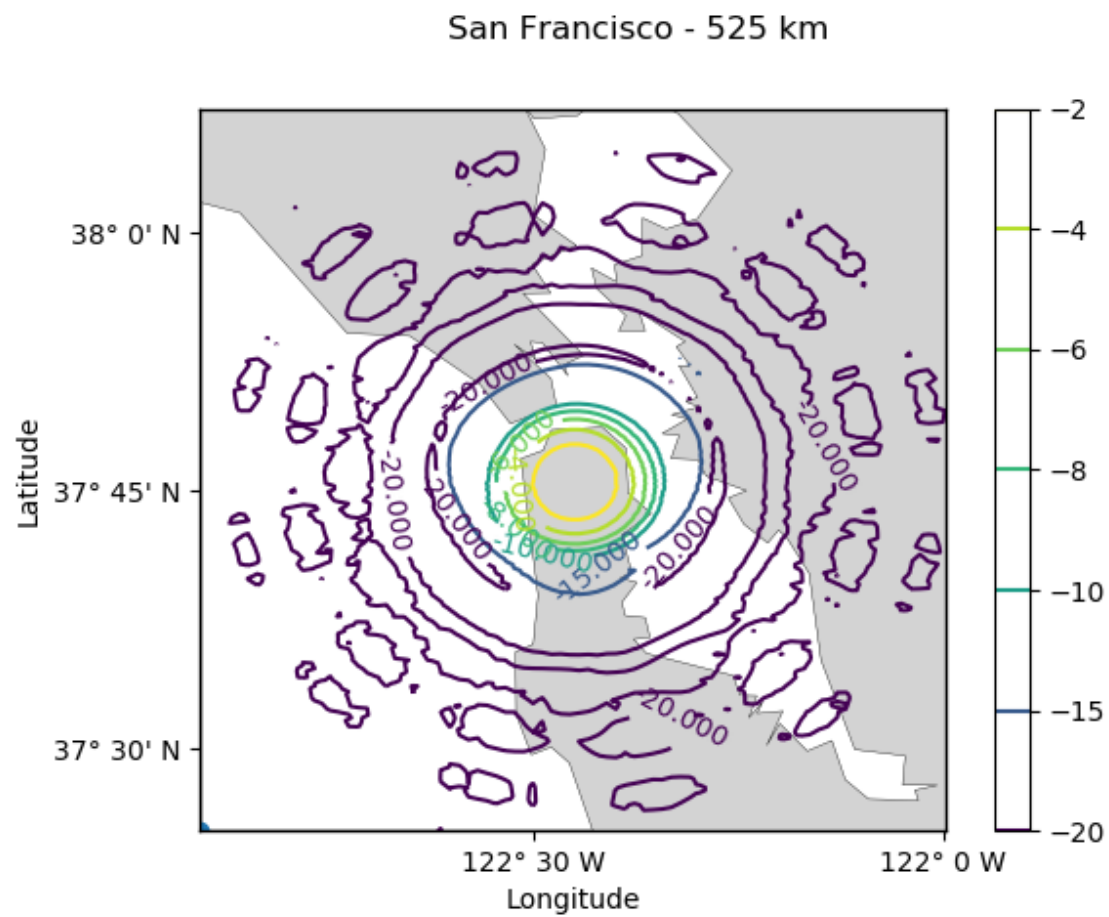


Figure 13: Capella X-Band SAR ground-projected gain contours for 30 degree incidence angle at 525 km altitude

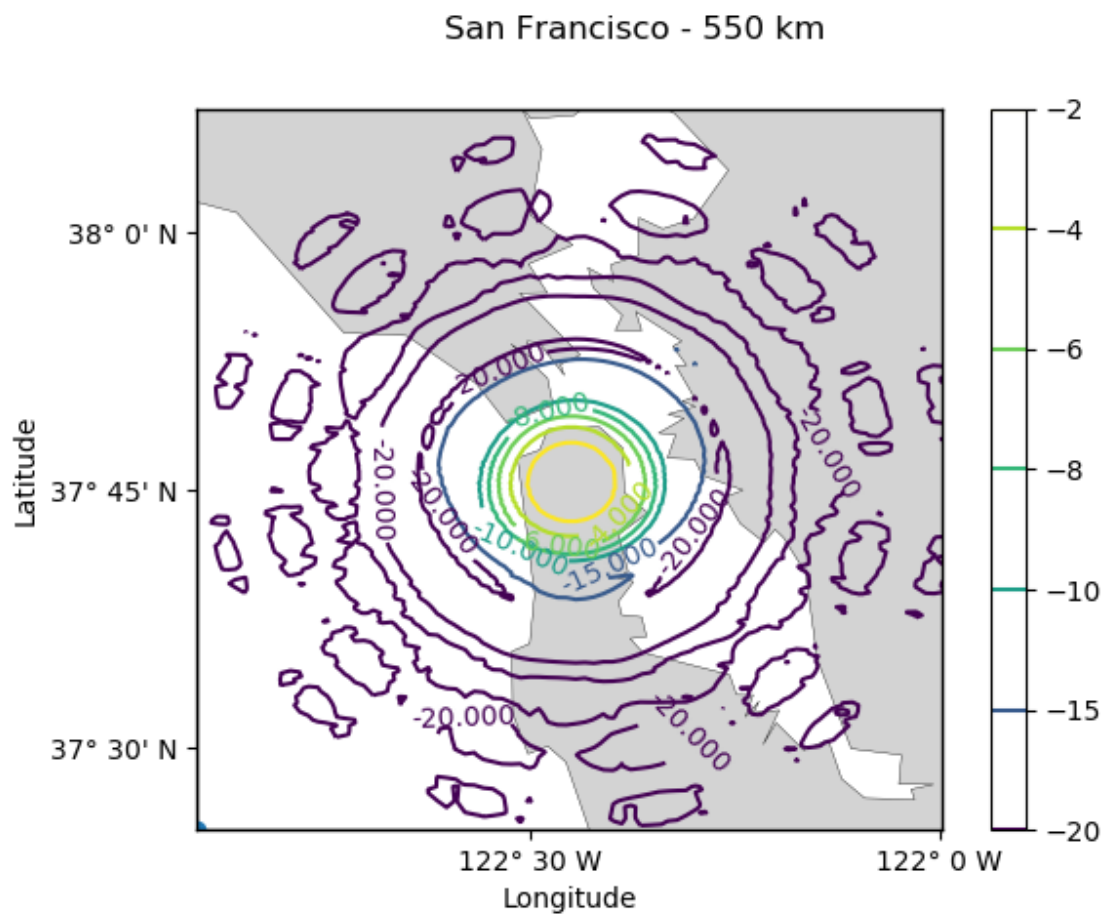


Figure 14: Capella X-Band SAR ground-projected gain contours for 30 degree incidence angle at 550 km altitude