Jet Propulsion Laboratory
California Institute of Technology

Europa Lander

All-metal Dual Frequency RHCP High Gain Antenna for the Extreme Environments of a Potential Europa Lander

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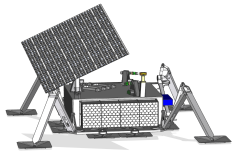
Nacer Chahat
NASA Jet Propulsion Laboratory / California Institute of Technology

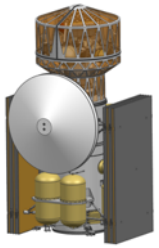
April 4, 2019

13th European Conference on Antennas and Propagation – Krakow, Poland
Pre-Decisional Information – For Planning and Discussion Purposes Only

Europa Lander Mission Concept

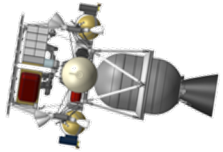


Launch
- SLS Block 1B
- Nov 2026

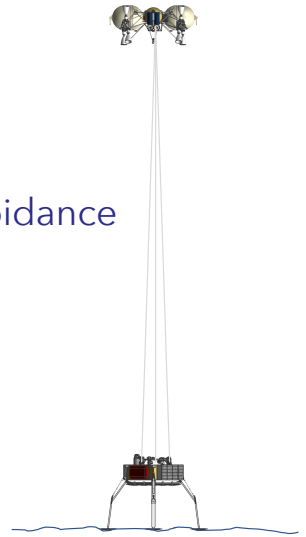


Cruise/Jovian Tour
- Jupiter Orbit Insertion: June 2031
- Europa Landing: 2033

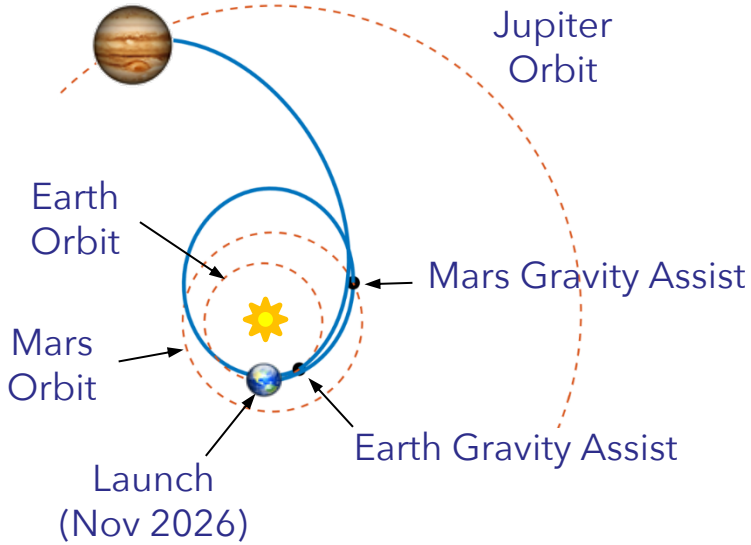
Carrier Stage
- **1.5 Mrad TID radiation exposure**
- **No longer an independent spacecraft**
- **Elliptical disposal orbit**



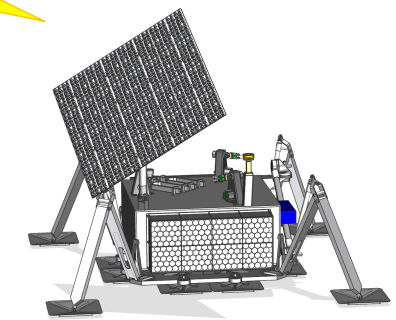
Deorbit, Descent, Landing
- Hazard detection and avoidance
- Sky Crane landing system
- 100-m accuracy
- Adaptive stabilizers
- **DTE tones only**



Jupiter Arrival

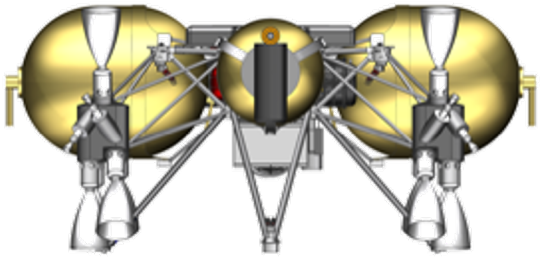


Surface Mission
- **Biosignature Science**
- 20+ days
- **3 samples from 1 trench**
- **Direct to Earth Comm or Clipper (contingency)**
- **1.5 Gbit data return**
- 50 kWh battery
- 2.0 Mrad TID radiation exposure

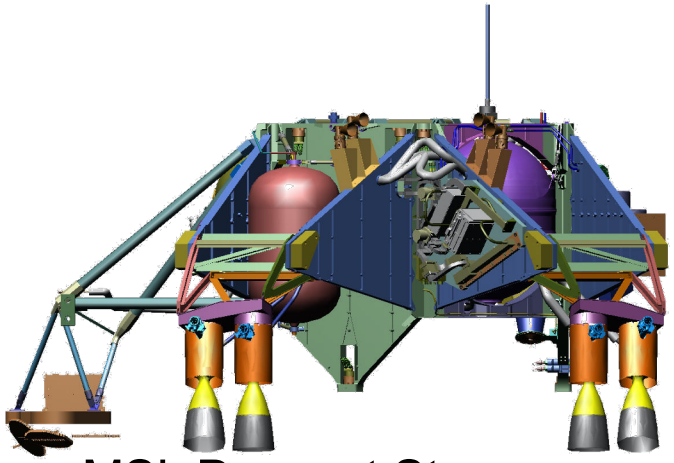


Scale Comparisons

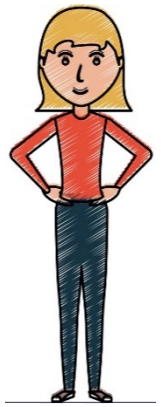
Europa Lander Engineer



Europa Lander Descent Stage

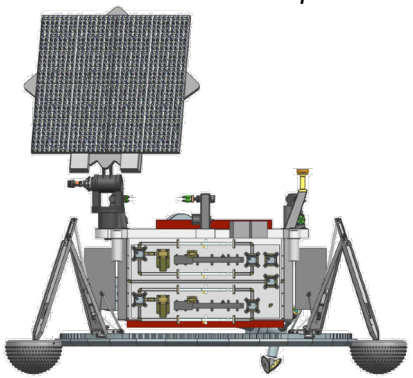


MSL Descent Stage

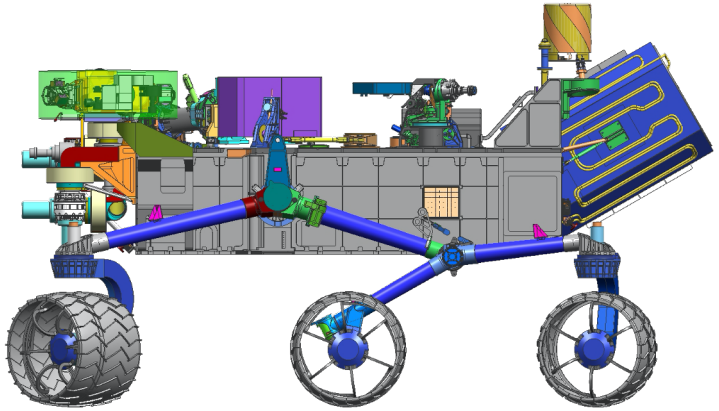


Europa Lander Engineer

Artist's Concept

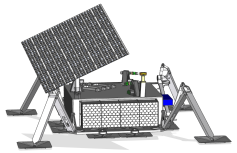


Europa Lander



MSL Rover

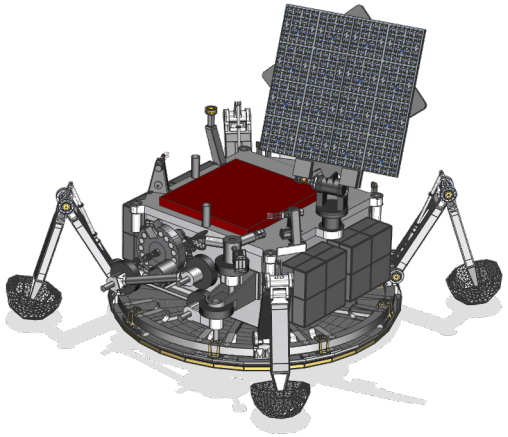
HGA DTE Enabling Technology



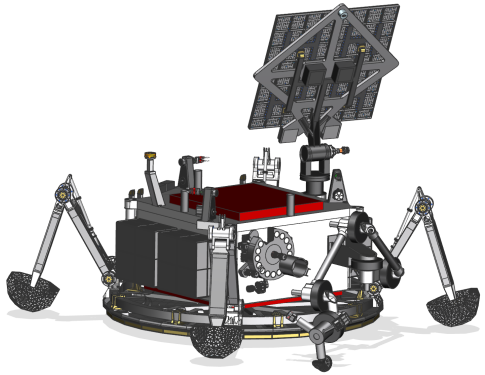
Enable Direct to Earth Link communication between the Lander and the DSN

Challenges:

- Drastic stowage volume constraints requiring the antenna to be low profile
- Survivability in the harsh environment (high radiation levels, iESD, cryogenic temperature) requiring the antenna to be mostly made of metal
- High aperture efficiency* requirement (>80%) with RHCP at uplink and downlink frequency range

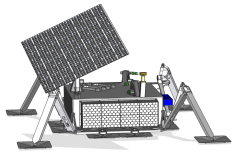


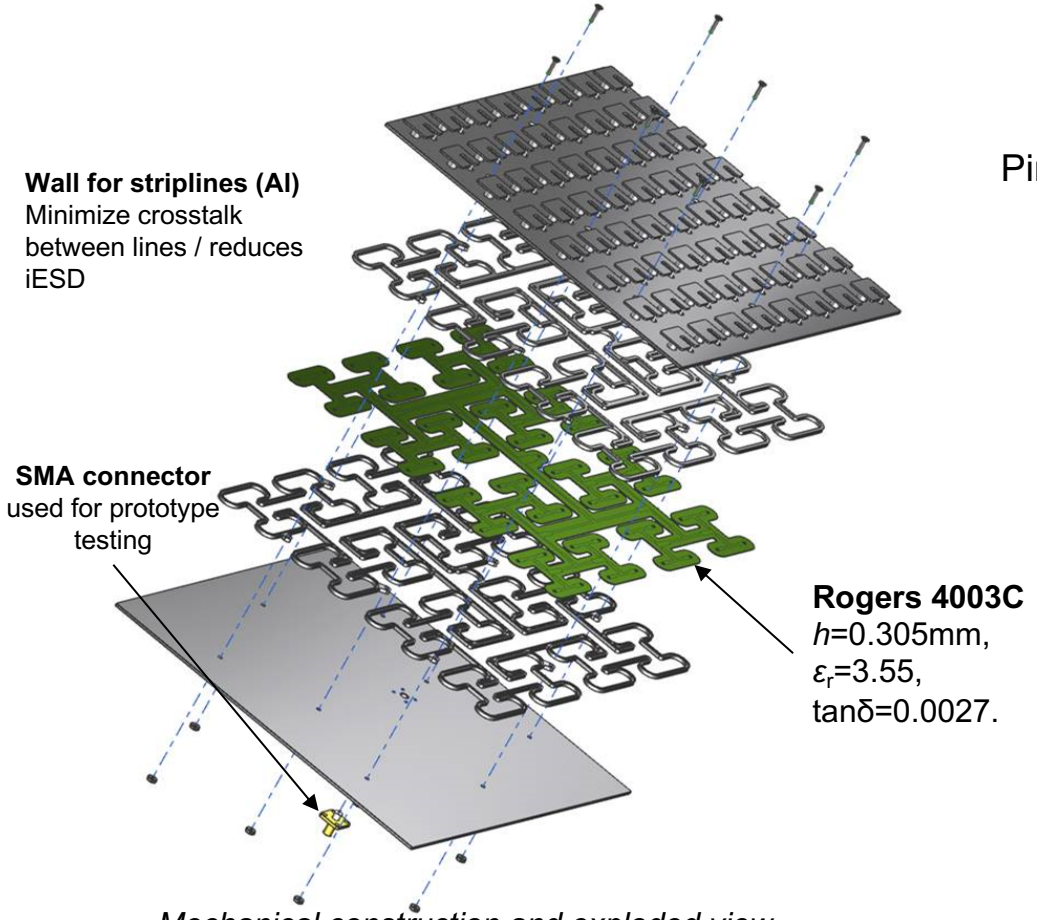
Artist's Concept



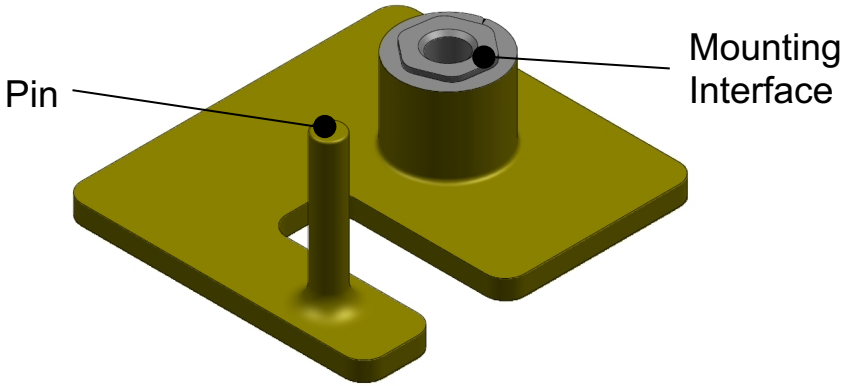
Aperture efficiency is defined here as ***the ratio of the realized gain of the antenna to its standard directivity.*** *The standard directivity is* $4\pi A/\lambda_0^2$*, where A the area of the antenna aperture and* λ_0 *is the free space wavelength. This defines how efficiently the area of an antenna is used.*

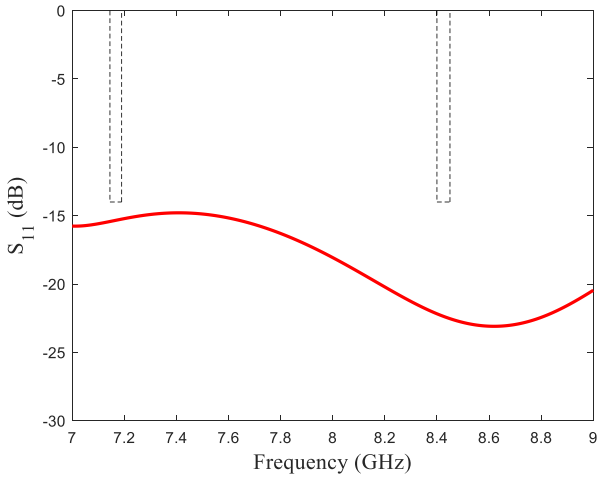
Subarray (8×8 patch array)



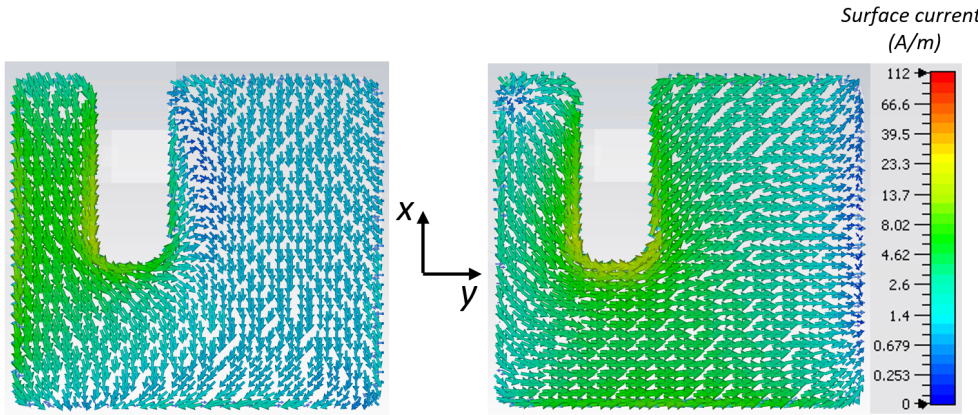


Mechanical construction and exploded view



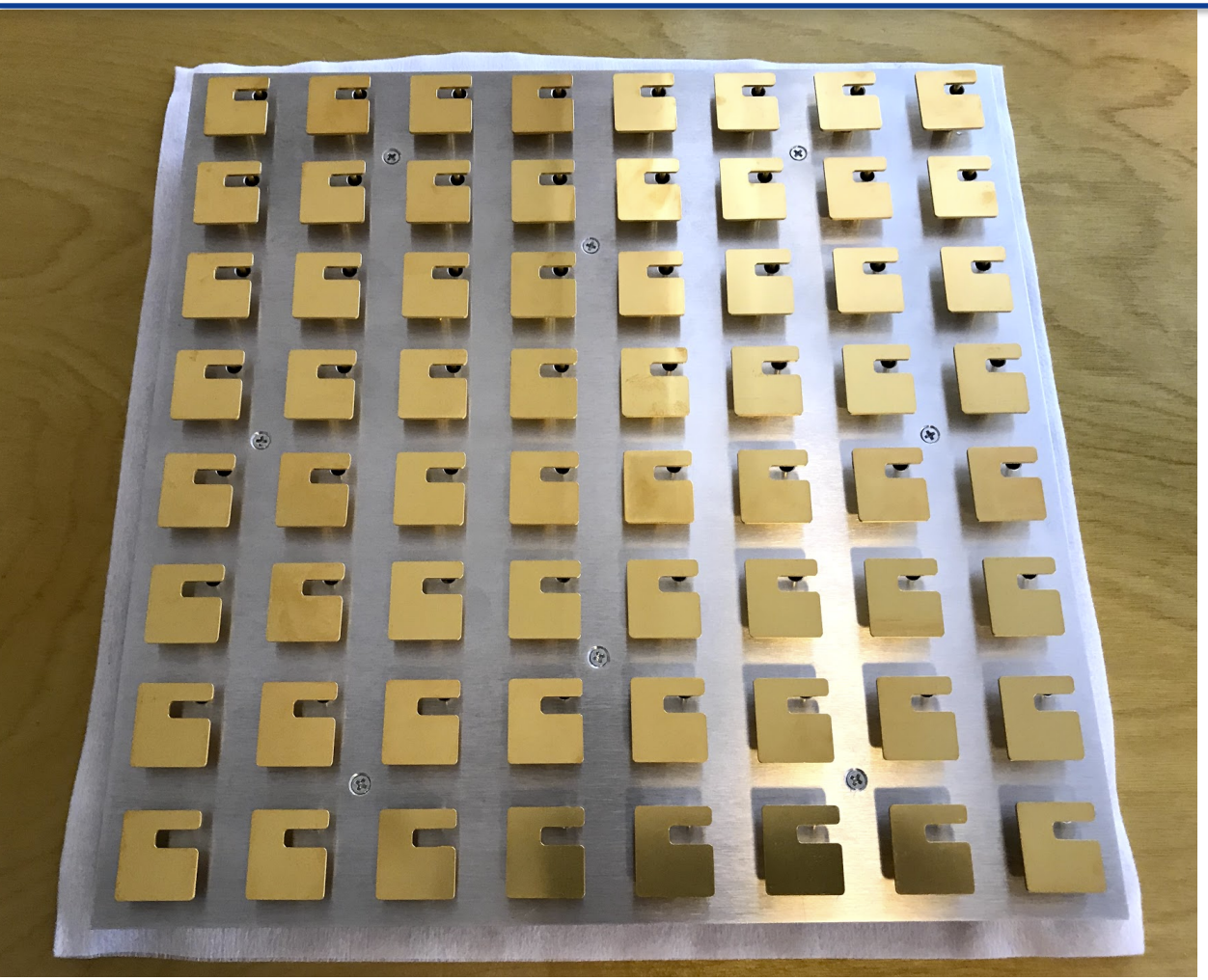


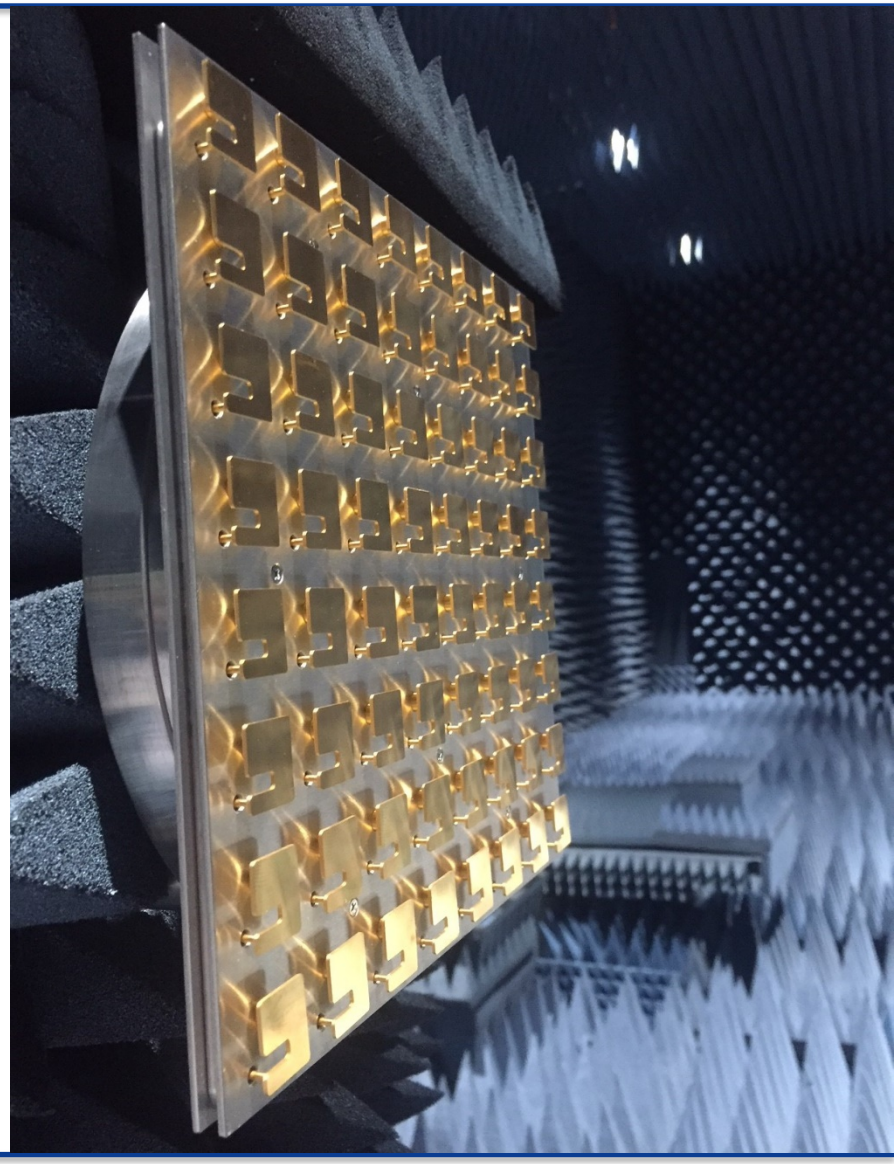
Reflection coefficient of unit cell



$\omega t = \Omega_0$ $\omega t = \Omega_0 + \pi/2$

Subarray (8×8 patch array)

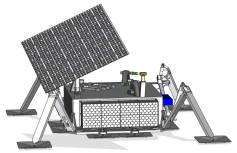




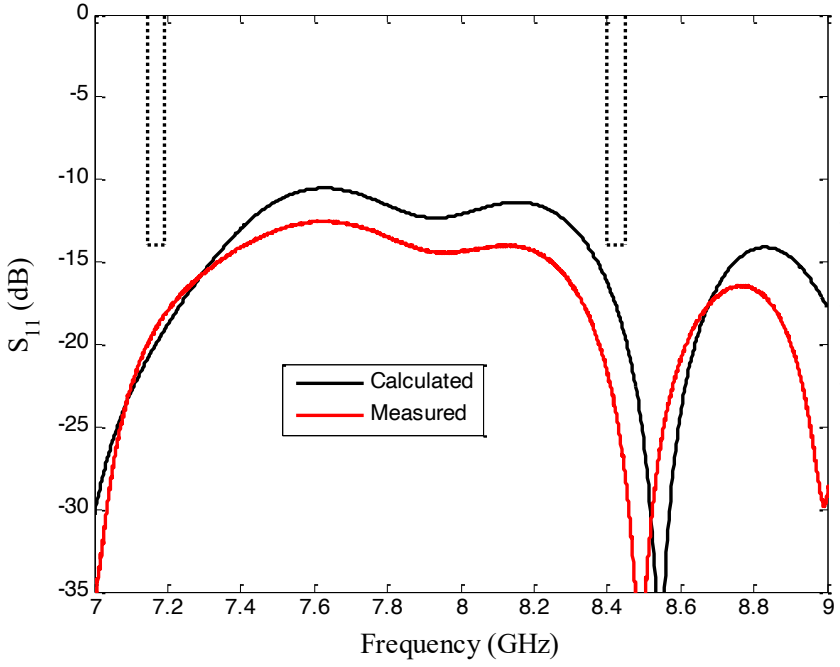
Patent pending: Chahat *et al.* “High-efficiency dual-band circularly-polarized antenna for harsh environment for Telecommunication”, filed on 12/18/17.

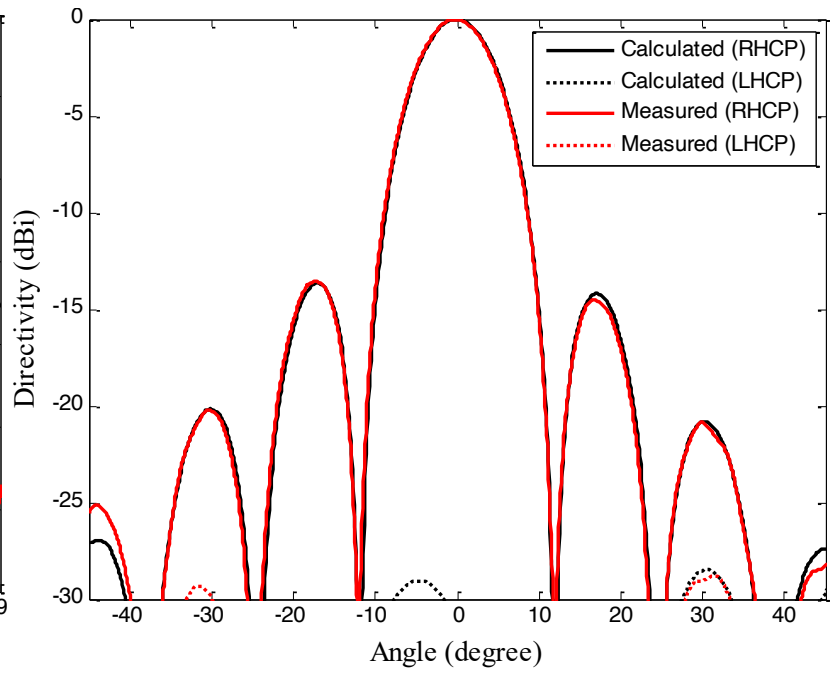
Publication: Chahat *et al.*, "All-Metal Dual-Frequency RHCP High-Gain Antenna for a Potential Europa Lander," *IEEE Transactions on Antennas and Propagation*, vol. 66, no. 12, pp. 6791-6798, Dec. 2018.

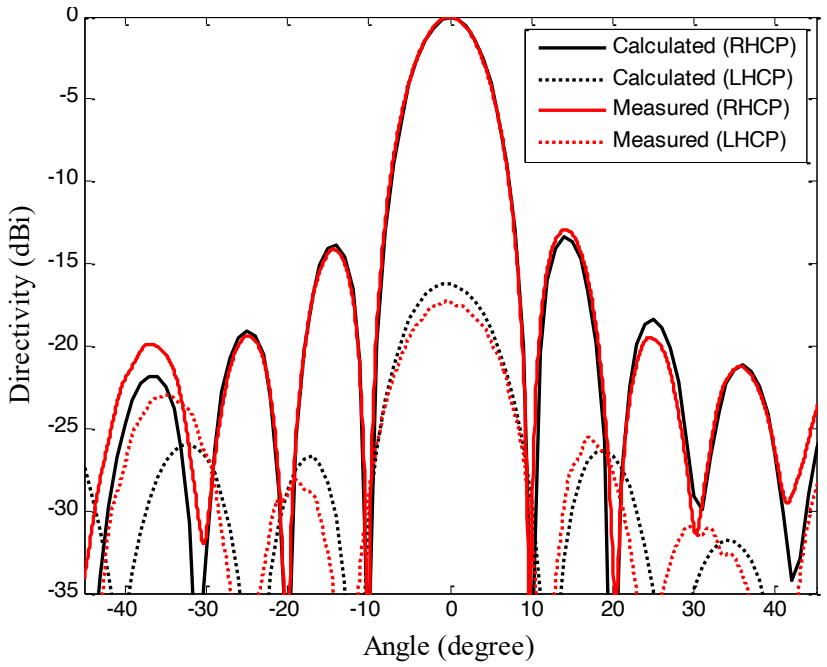
Subarray (8×8 patch array)



Subarray prototype and S_{11} measurement:







➔ Wide thermal guard.
➔ Wide bandwidth performance

➔ Outstanding agreement between calculation and measurement.

Gain at 7.1675Hz = 24.1 dBi ➔ Aperture efficiency ~ 84%
Gain at 8.425GHz = 25.3 dBi ➔ Aperture efficiency ~ 80%

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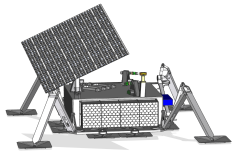
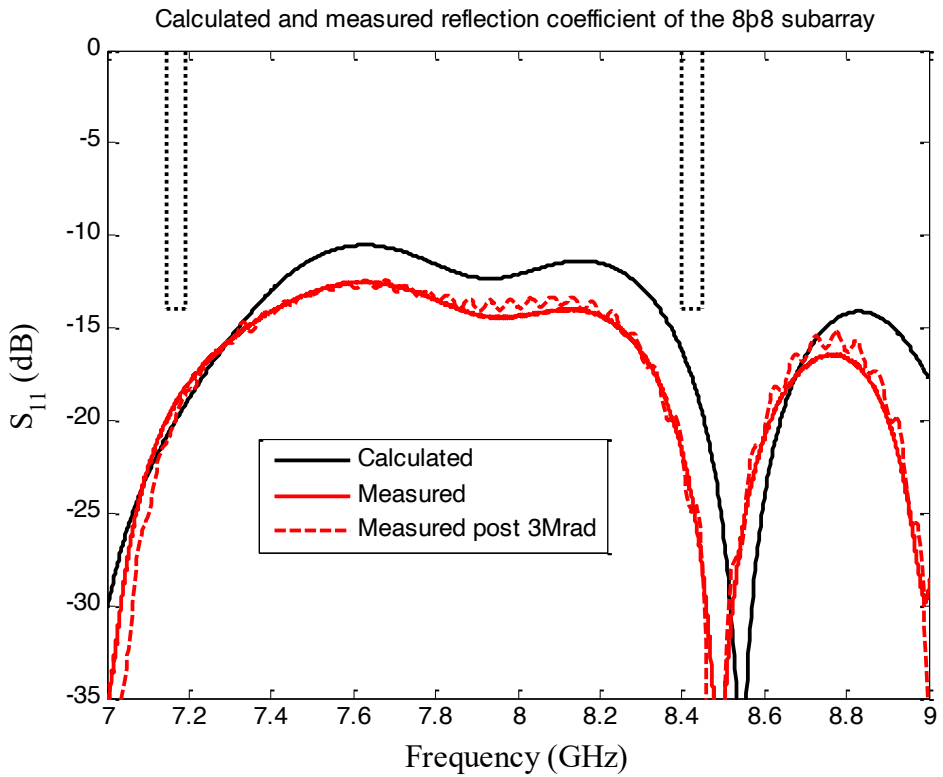
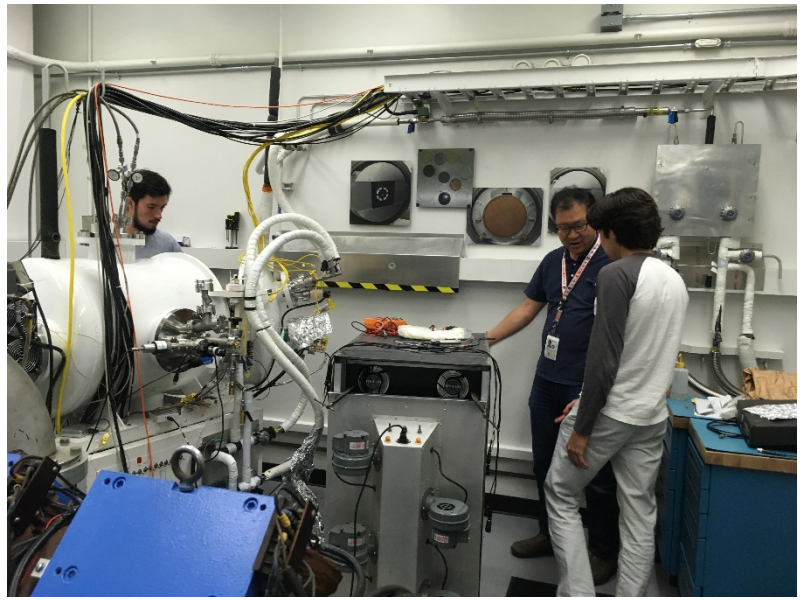
Subarray (8×8 patch array)

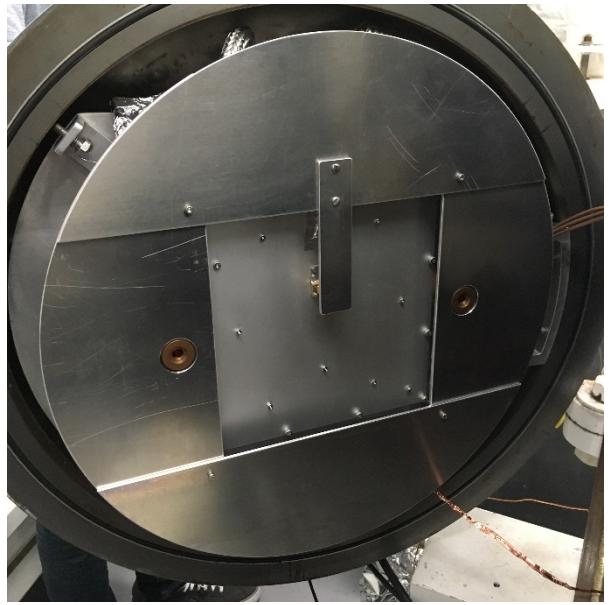


Subarray and Radiation test (TID and iESD):

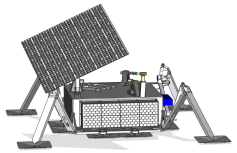
- Accelerated test (i.e. 90 days in 8hours) was performed in the Dynamitron at JPL at -170C on the 8x8 patch array for TID (3Mrad with RDF = 2) and iESD.
- The iESD environment was defined for the last 90days. The average charging rate for the total 90.5 days is **3.82 pA/cm³ (**with RDF = 2**)**.
- No harmful discharges were measured or defects observed.
- S_{11} was measured before after radiation to assess whether there are any damage caused by potential discharges.



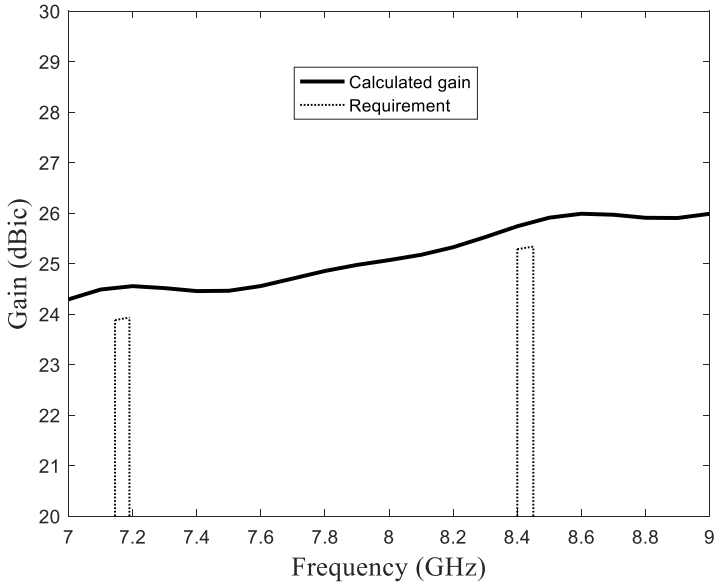




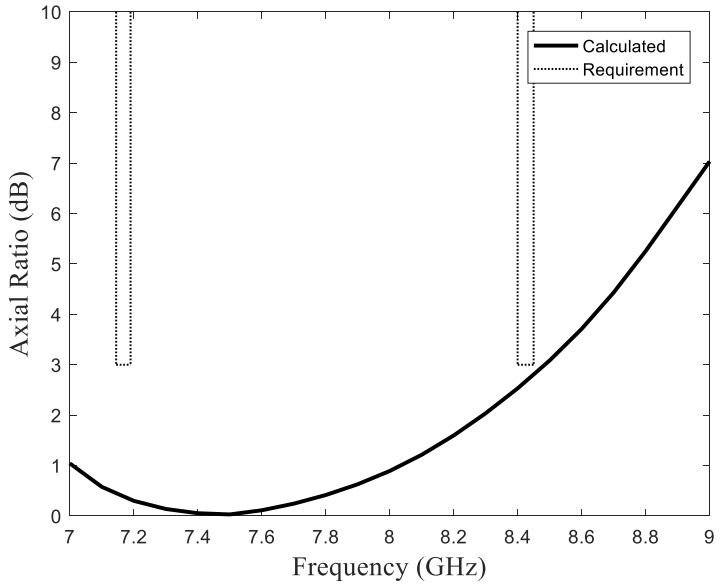
Subarray (8×8 patch array)



Subarray prototype and performance over frequency band:



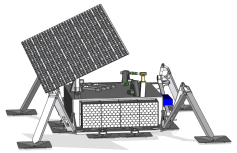
Gain over frequency



Axial ratio over frequency

Frequency (GHz)	Directivity (dBi)		Gain (dBic)		Axial Ratio (dB)	
	Calc.	Meas.	Calc.	Meas.	Calc.	Meas.
7.1675	24.9	24.9	24.5	24.1±0.4	0.3	0.3
8.425	26.0	26.0	25.6	25.3±0.4	2.7	2.2

Subarray (8×8 patch array)



Comparison with state-of-the-art:

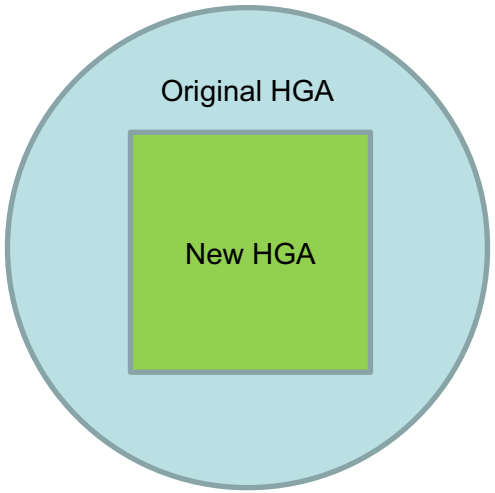
	Aperture Efficiency (%)	Gain (dBic)	Area (cm^2)	HPBW (degree)	Mass (kg)
APL [1]	37 / 18	25.3 / 23.5	1256.6 40cm diameter	6.0 / 5.1	1.24
MSL [2]	49 / 44	22.9 / 23.8	551.2	10.0 / 8.4	1.4
MER [3]	25 / 49	20.5 / 24.8	615.8	10.0 / 8.4	1.1
This work	84/ 80	24.1 / 25.3	428.5 20.7cm×20.7cm	10.4 / 8.7	0.5

In summary:

- Smaller,
- more efficient,
- relaxes pointing accuracy,
- can handle more power.

Important: Performance extrapolates to larger antenna since we use waveguides to interconnect the subarrays.

Size comparison

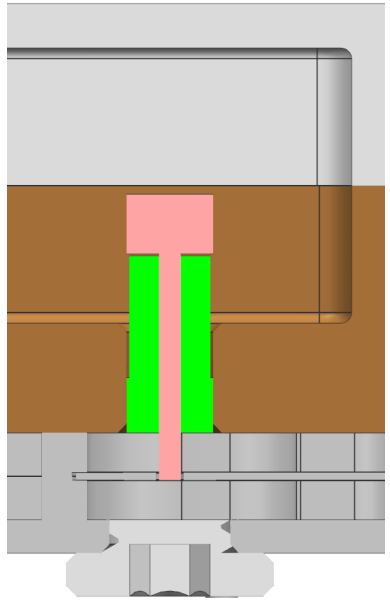


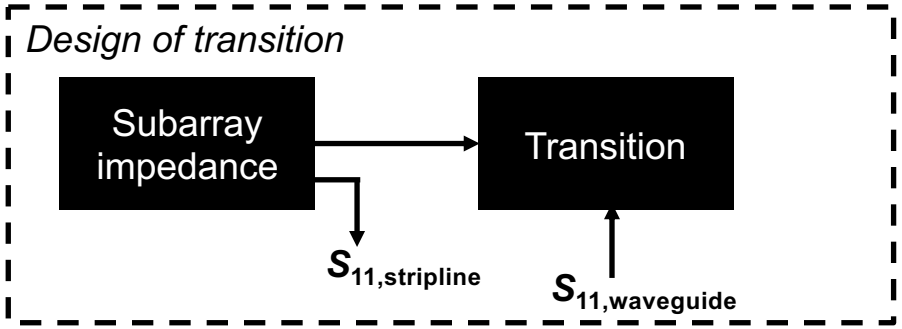
16×16 patch array

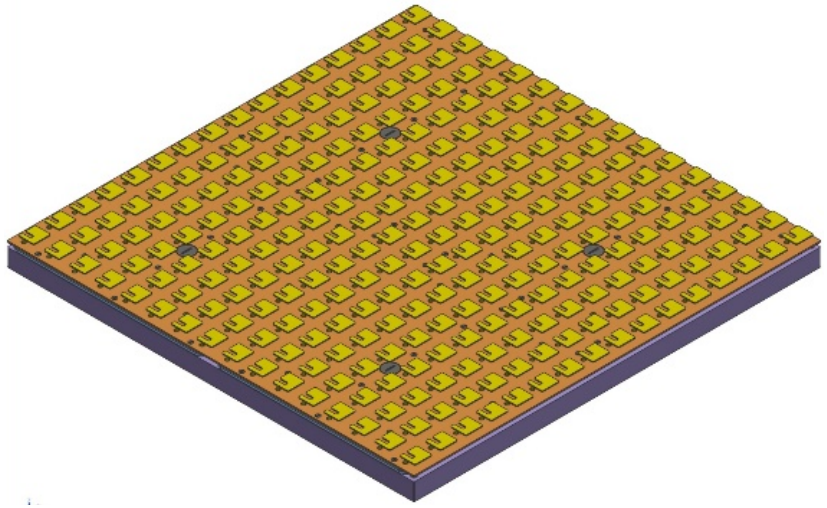
16x16 patch array description:

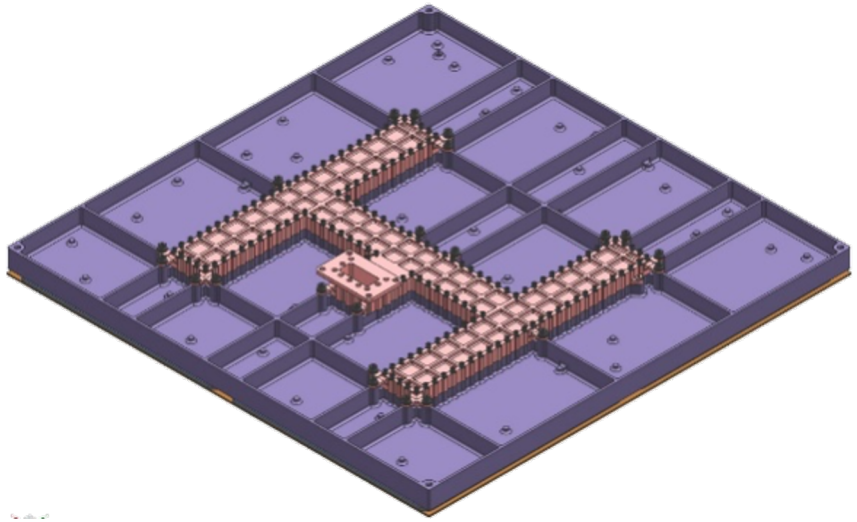
- The 16×16 patch array antenna prototype is made up of four 8×8 subarrays
- Each subarray are fed by waveguides using a waveguide to stripline transition

Transition Interface

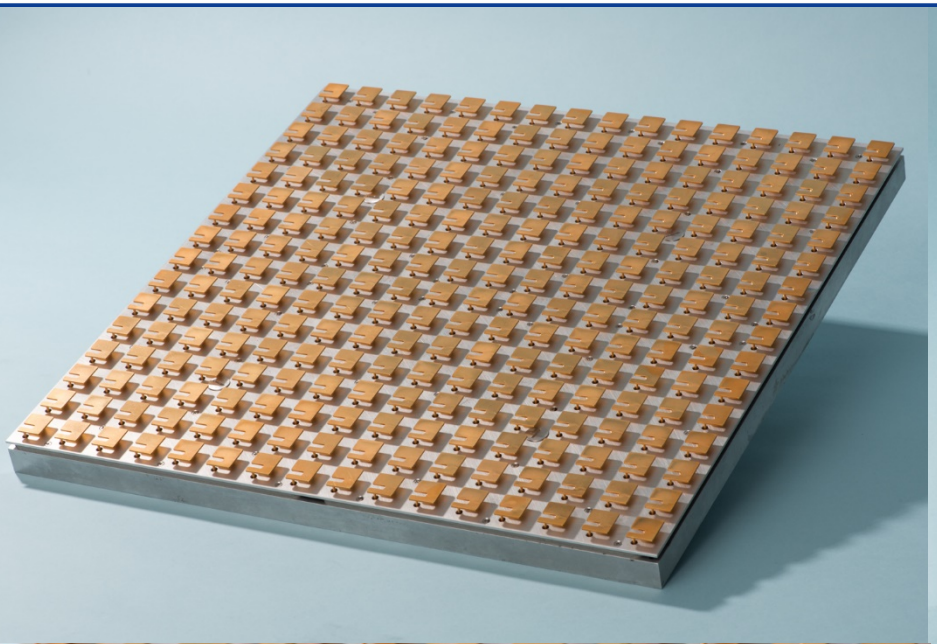


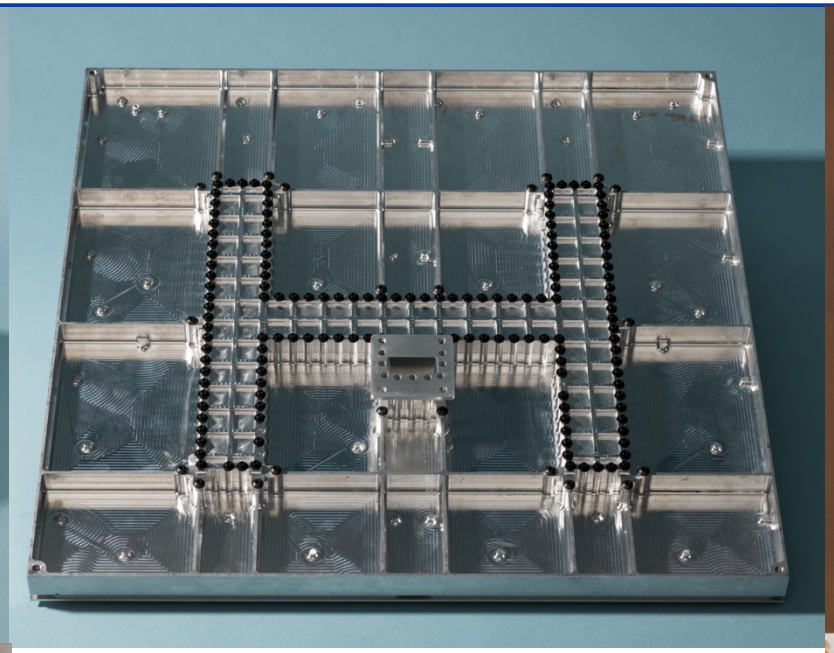


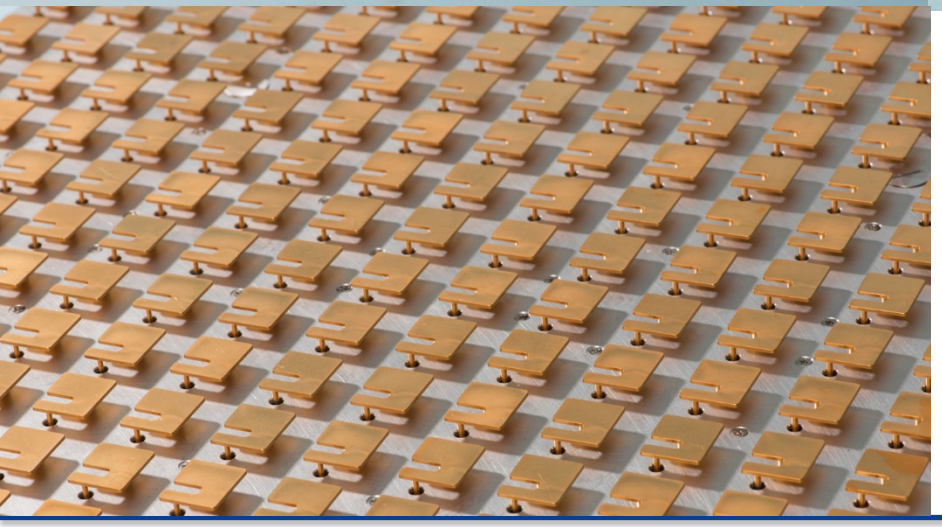




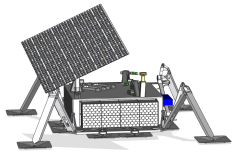
16×16 patch array



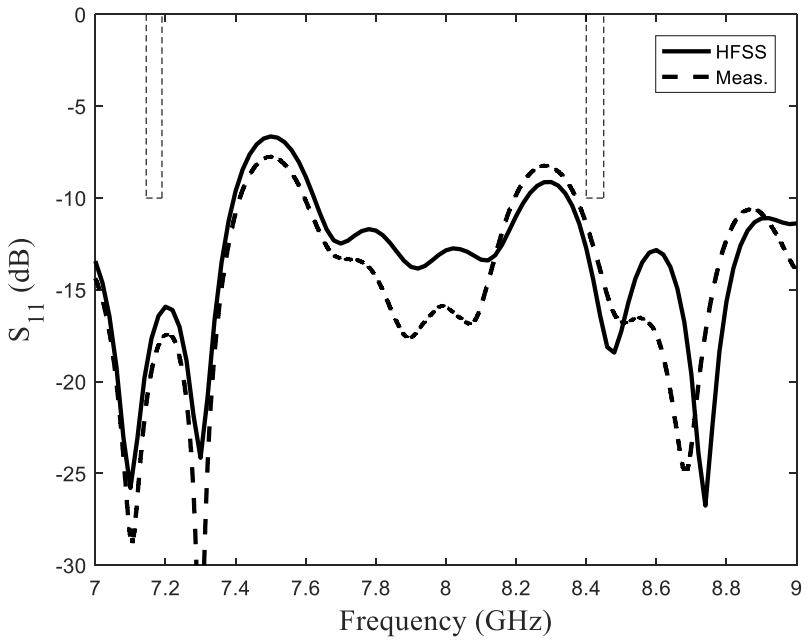




16×16 patch array

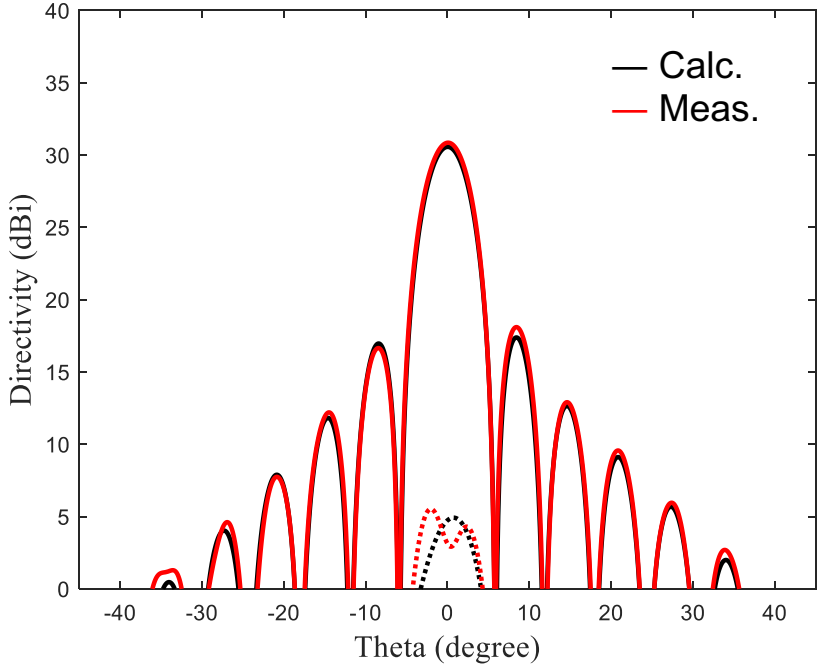


- **Measured performance:**



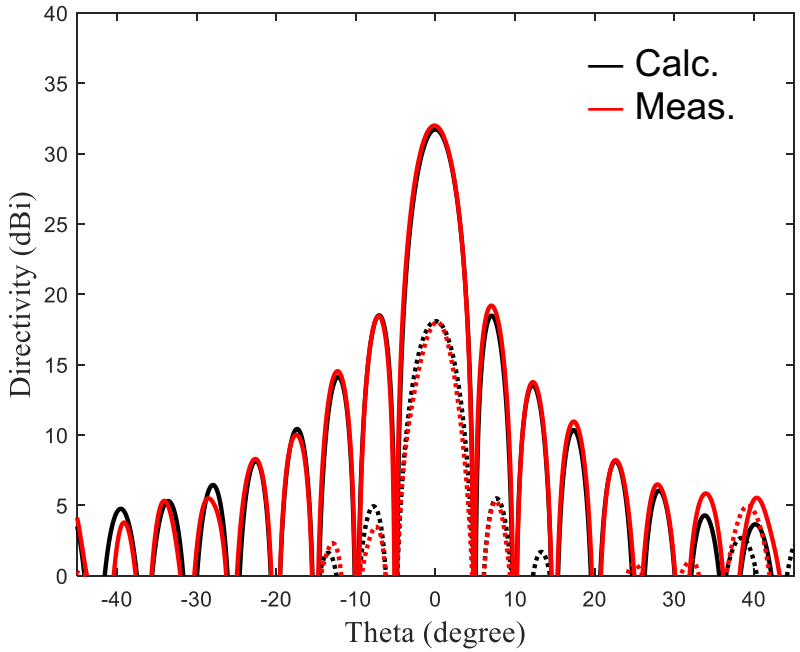
Antenna successfully tested from -170C to +110C

f = 7.19GHz



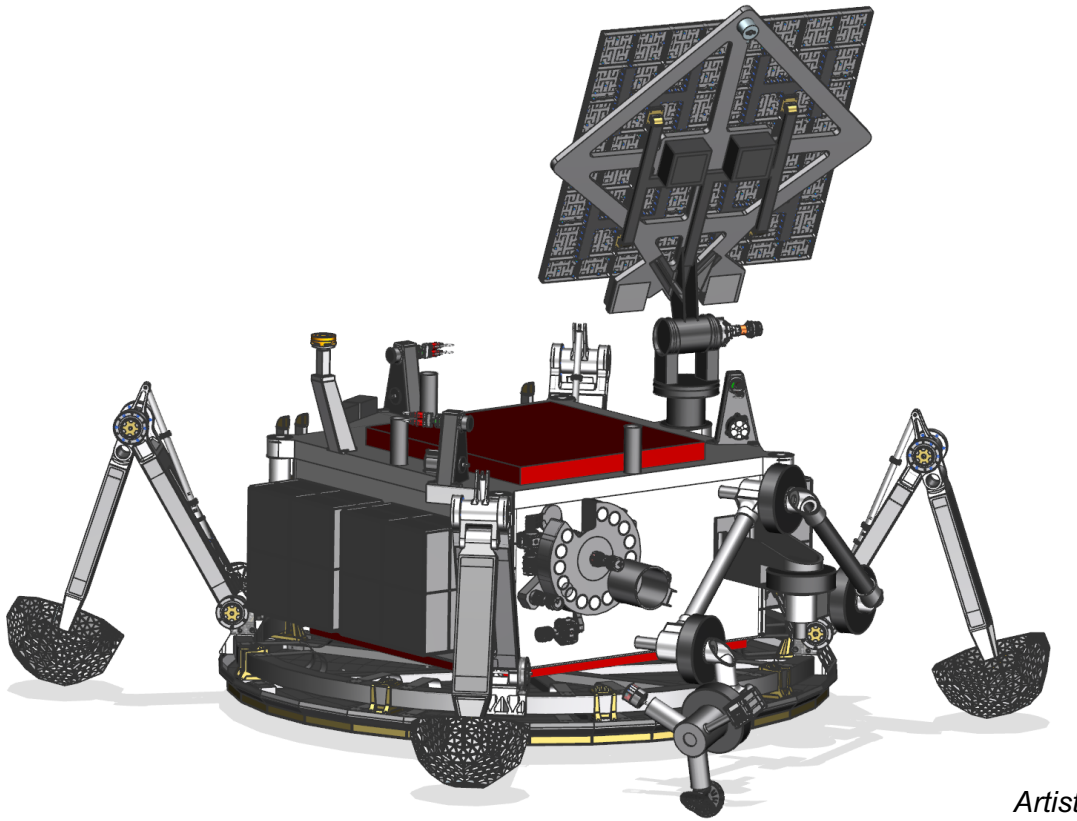
Gain = 29.6dBic
η = 75%

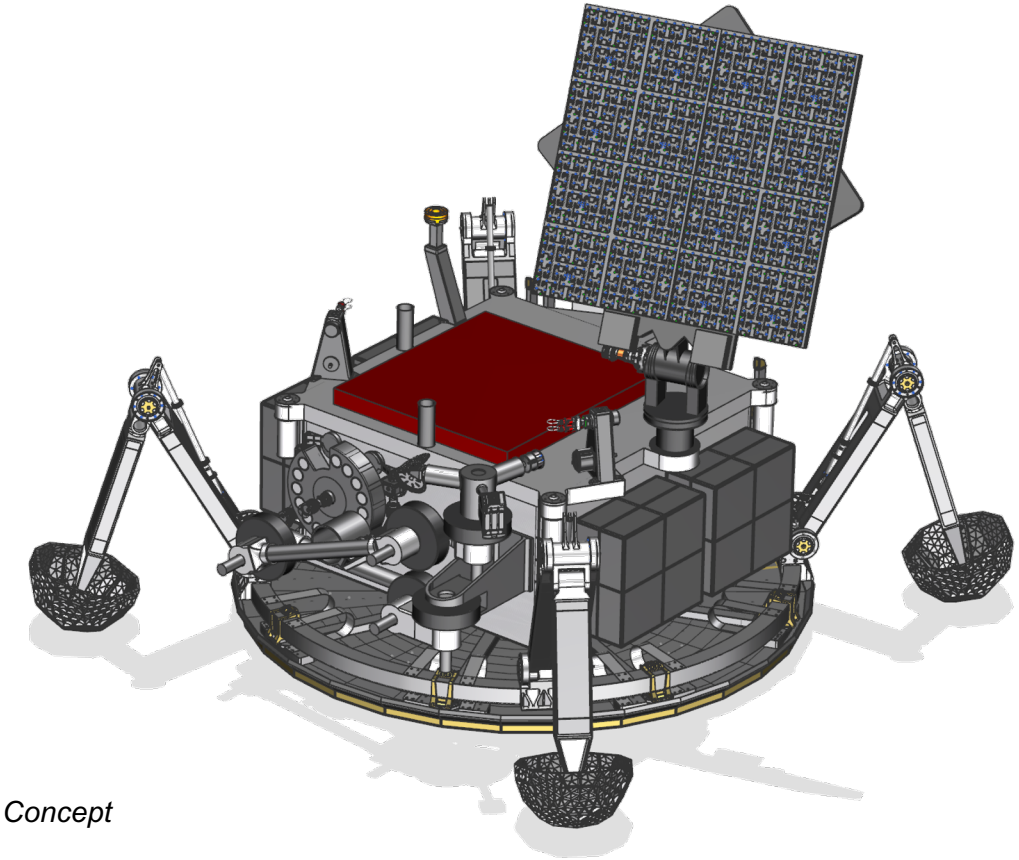
f = 8.425GHz



Gain = 31.3dBic
η = 81%

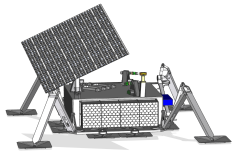
32×32 patch array





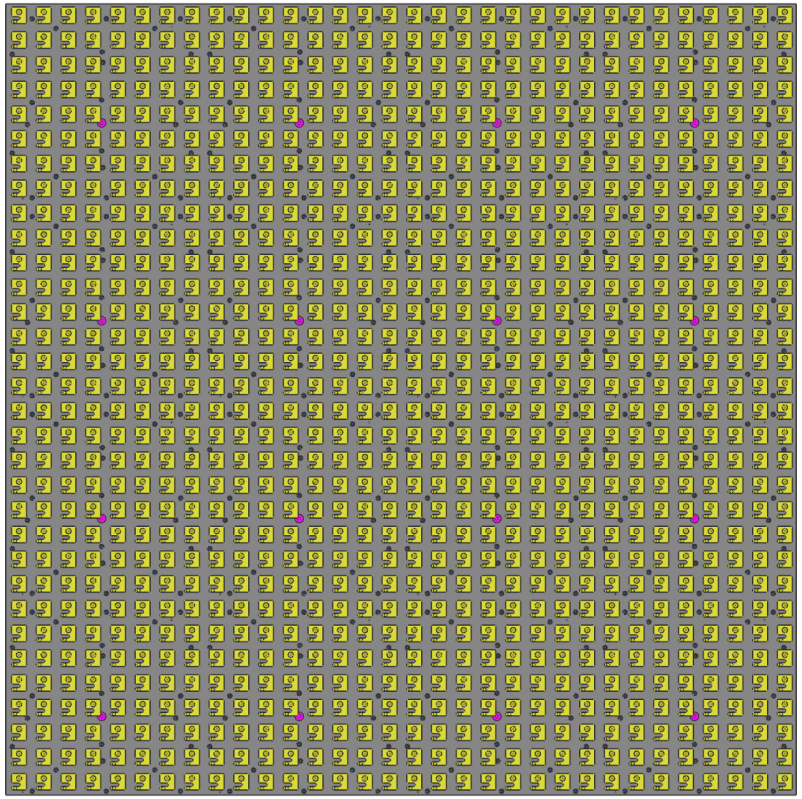
Artist's Concept

32×32 patch array



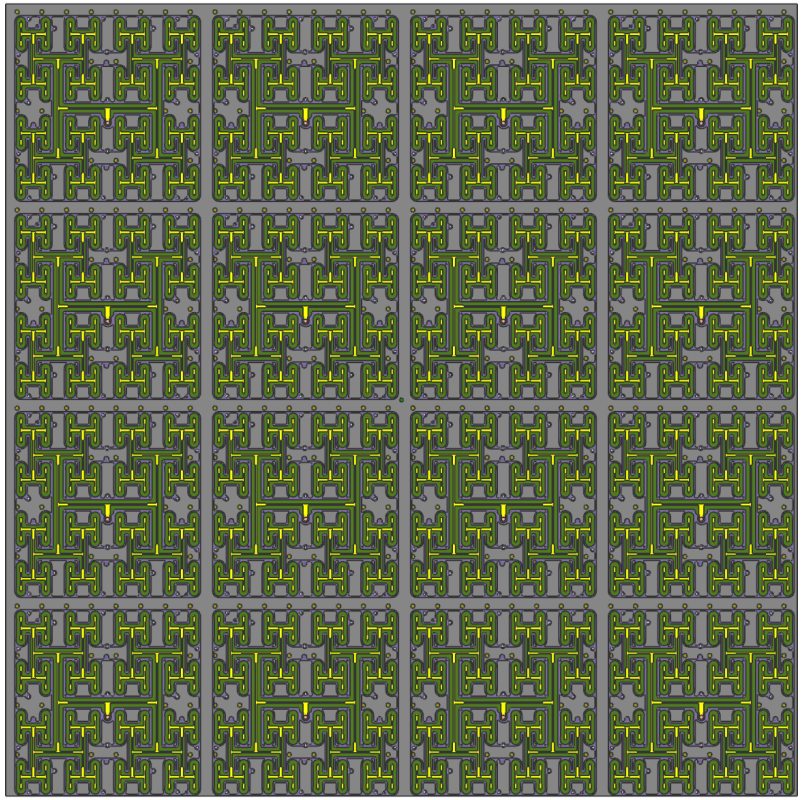
Front View

32x32 Patch Elements on Front Plate. Linear array 25.4mm spacing, both directions.



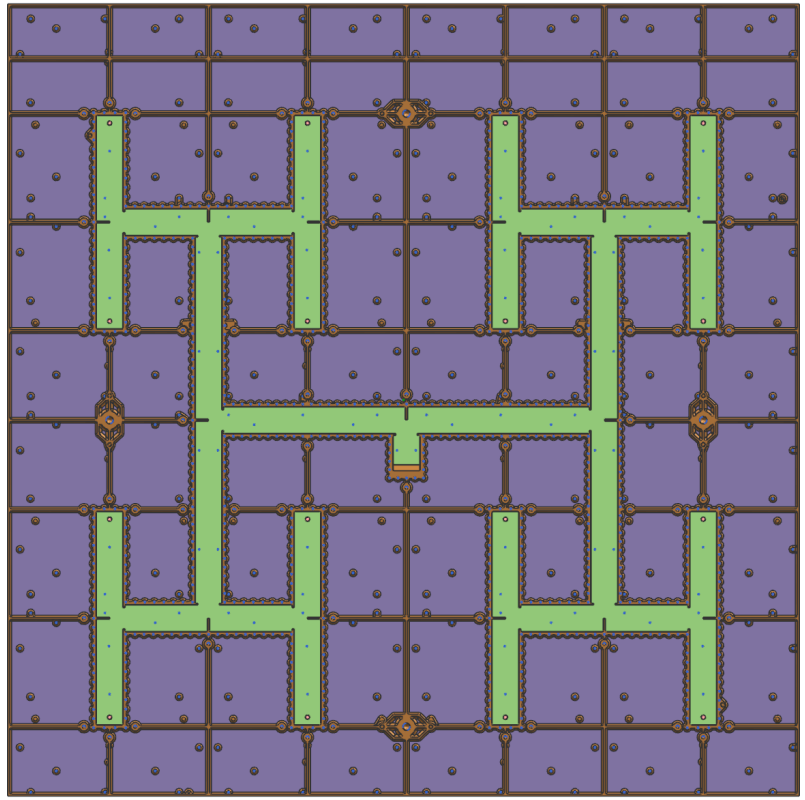
Back View

4x4 Guides/PWB. Linear array 206.24mm spacing, both directions.



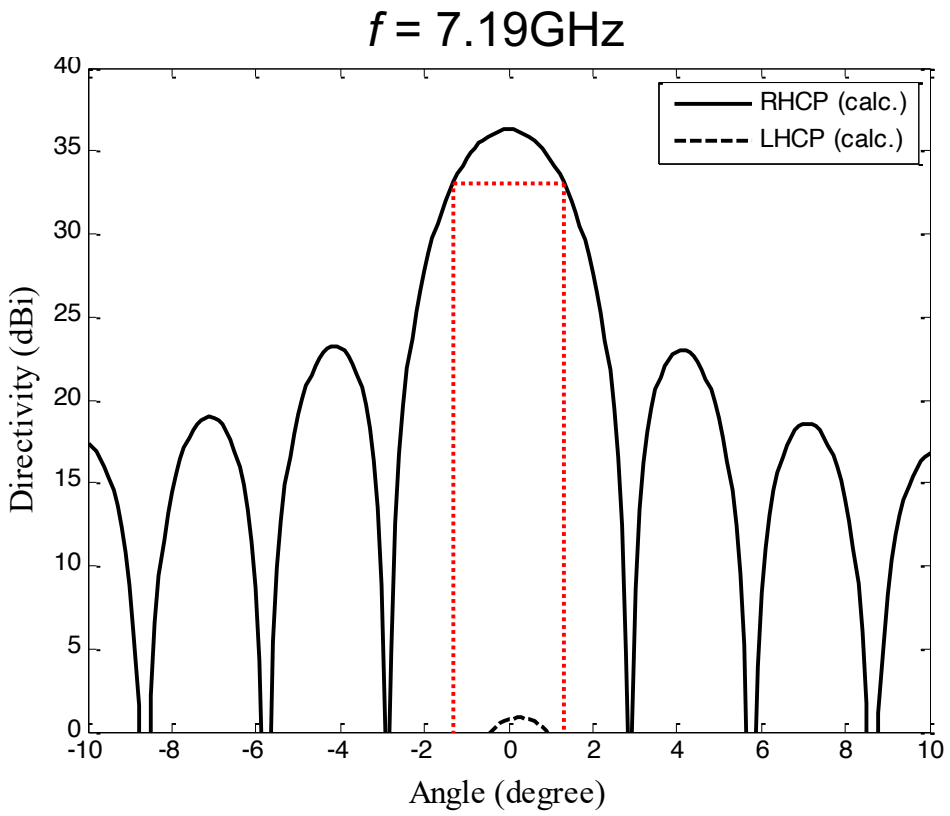
Back View

Transitions and waveguide connect all sets of Guides/PWB

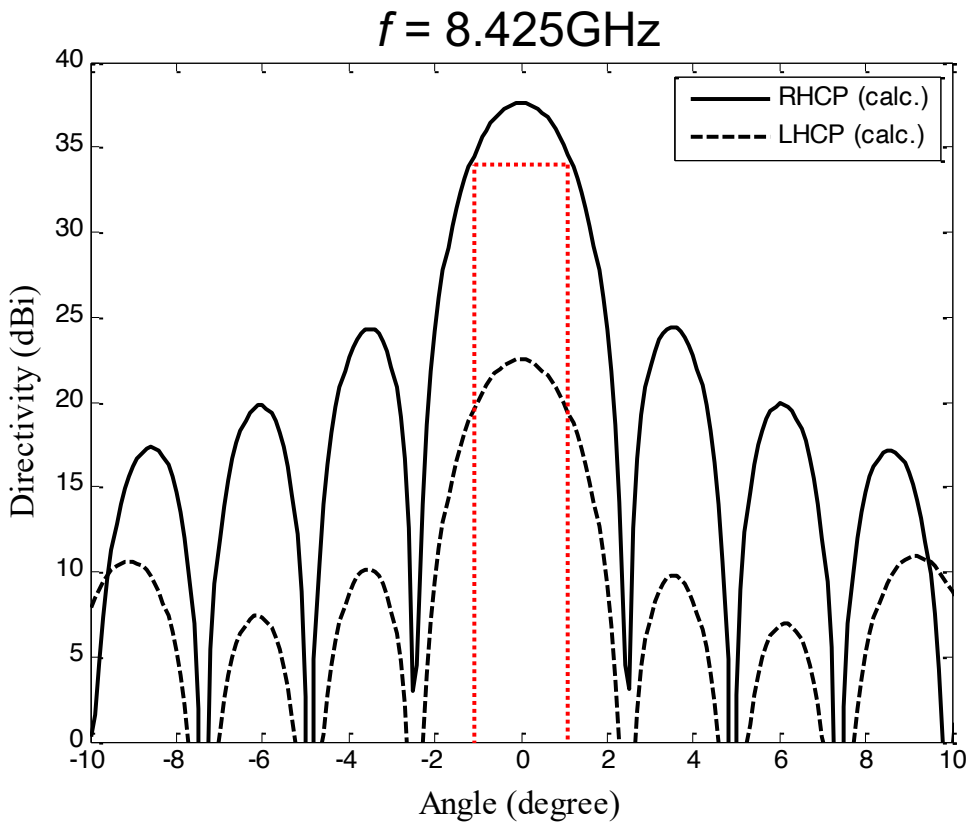


32×32 patch array

- **Antenna radiation pattern:**



Predicted gain = 36.0dBic



Predicted gain = 37.5dBic

Jet Propulsion Laboratory
California Institute of Technology

Europa Lander

All-metal Dual Frequency RHCP High Gain Antenna for the Extreme Environments of a Potential Europa Lander

Nacer Chahat

April 4, 2019