Preliminary Design of the NISAR L-Band Feed Antenna Tiles

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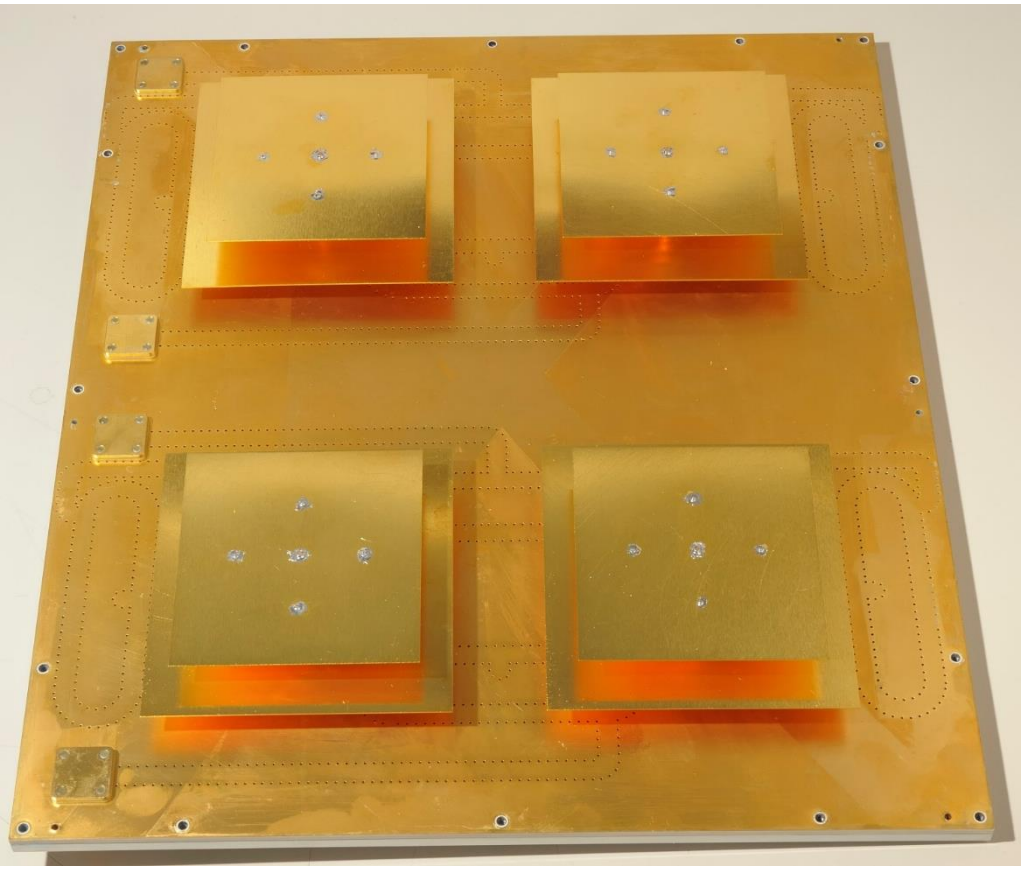
EuCAP '17,
Paris, France

Agenda

- Mission Overview
- Observatory Configuration
- L-SAR Instrument
- L-SAR Measurement Technique
- Radar Antenna Subsystem
- L-Band Feed Array
- L-FRAP/LFTA RF Models
- Preliminary Results
- Conclusions



Prototype L-Band Feed Tile without Radome

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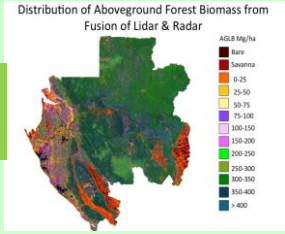
Mission Overview

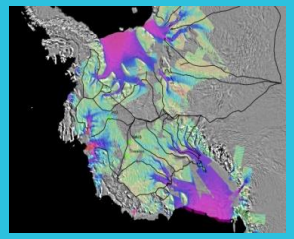
Mission Science

Ecosystem Structure



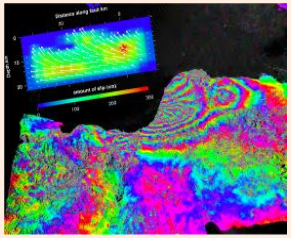
Biomass disturbance; effects of changing climate on habitats and CO_2

Cryosphere



Ice velocity, thickness; response of ice sheets to climate change and sea level rise

Solid Earth



Surface deformation; geo-hazards; water resource management

- Directed mission within the Earth Systematic Missions Program under NASA Earth Science Division
- Major international partner: Indian Space Research Organization (ISRO) who is supplying the launch vehicle, S/C, and S-band radar
- Baseline launch date: Not earlier than December 2020
- Dual frequency L- and S-band Synthetic Aperture Radar (SAR)
  - L-band SAR from NASA and S-band SAR from ISRO
- Sweep SAR technique (large swath) for global data collection
- Baseline orbit: 747 km altitude circular, 98 degrees inclination, sun-synchronous, dawn-dusk (6 PM–6 AM), 12-day repeat
- Repeat orbit within ± 250 m
- Spacecraft: ISRO I3K (flown at least 9 times)
- Launch vehicle: ISRO Geosynchronous Satellite Launch Vehicle (GSLV) Mark-II (4-m fairing)
- 3 years science operations (5 years consumables)
- All science data (L- and S-band) will be made available free and open, consistent with the long-standing NASA Earth Science open data policy

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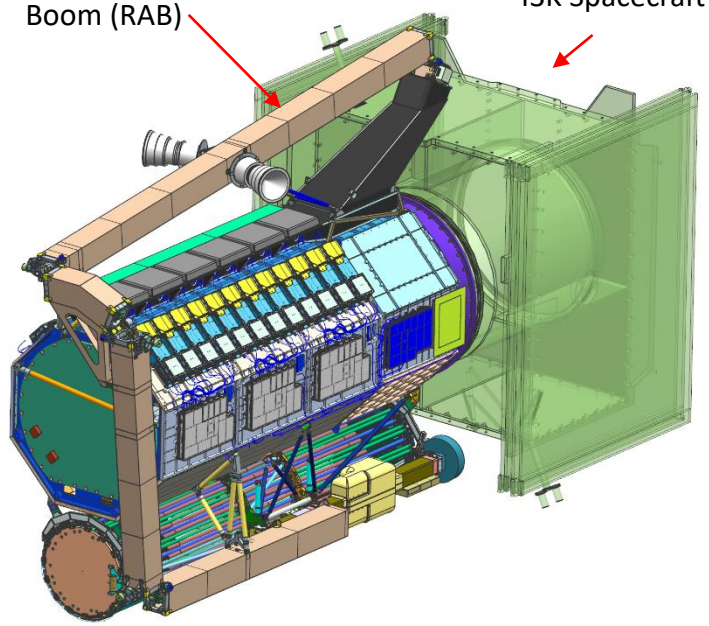
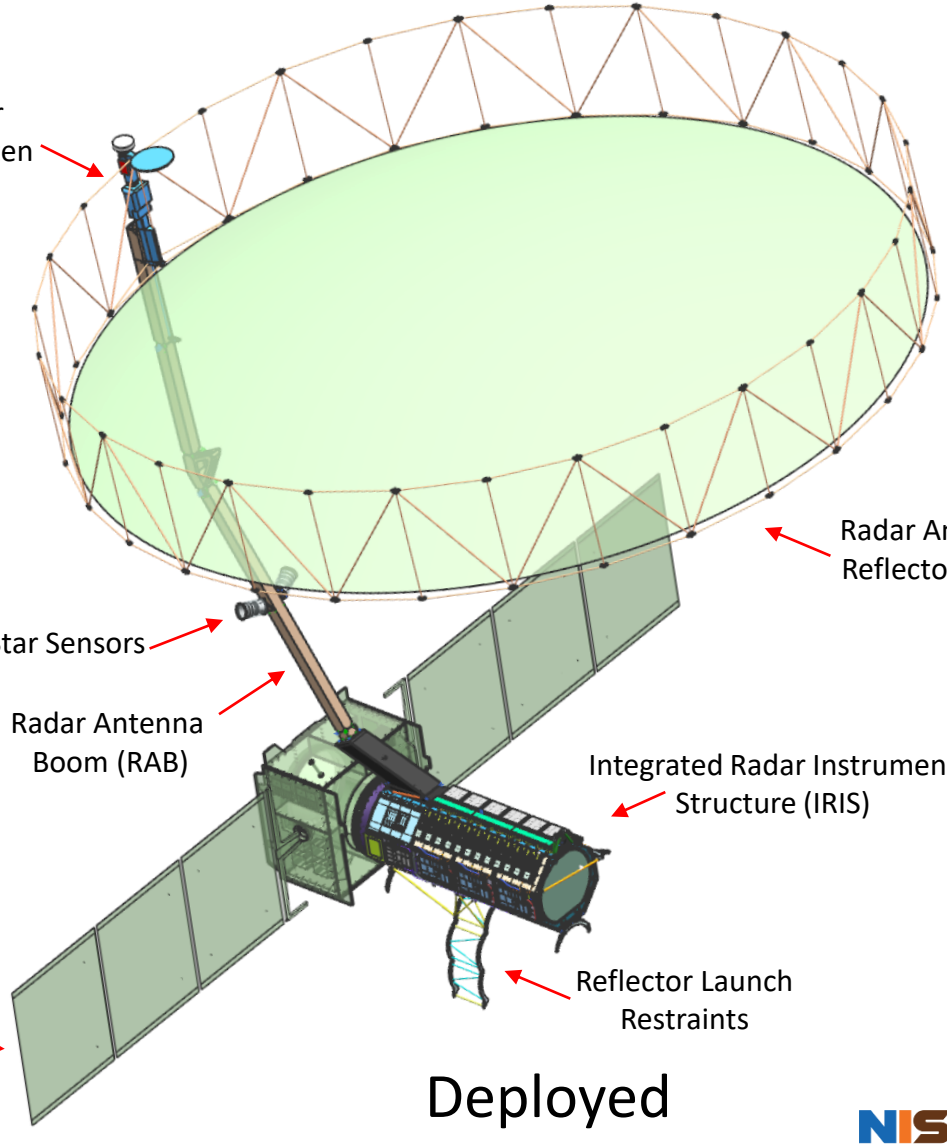
Observatory Configuration

Stowed





Deployed

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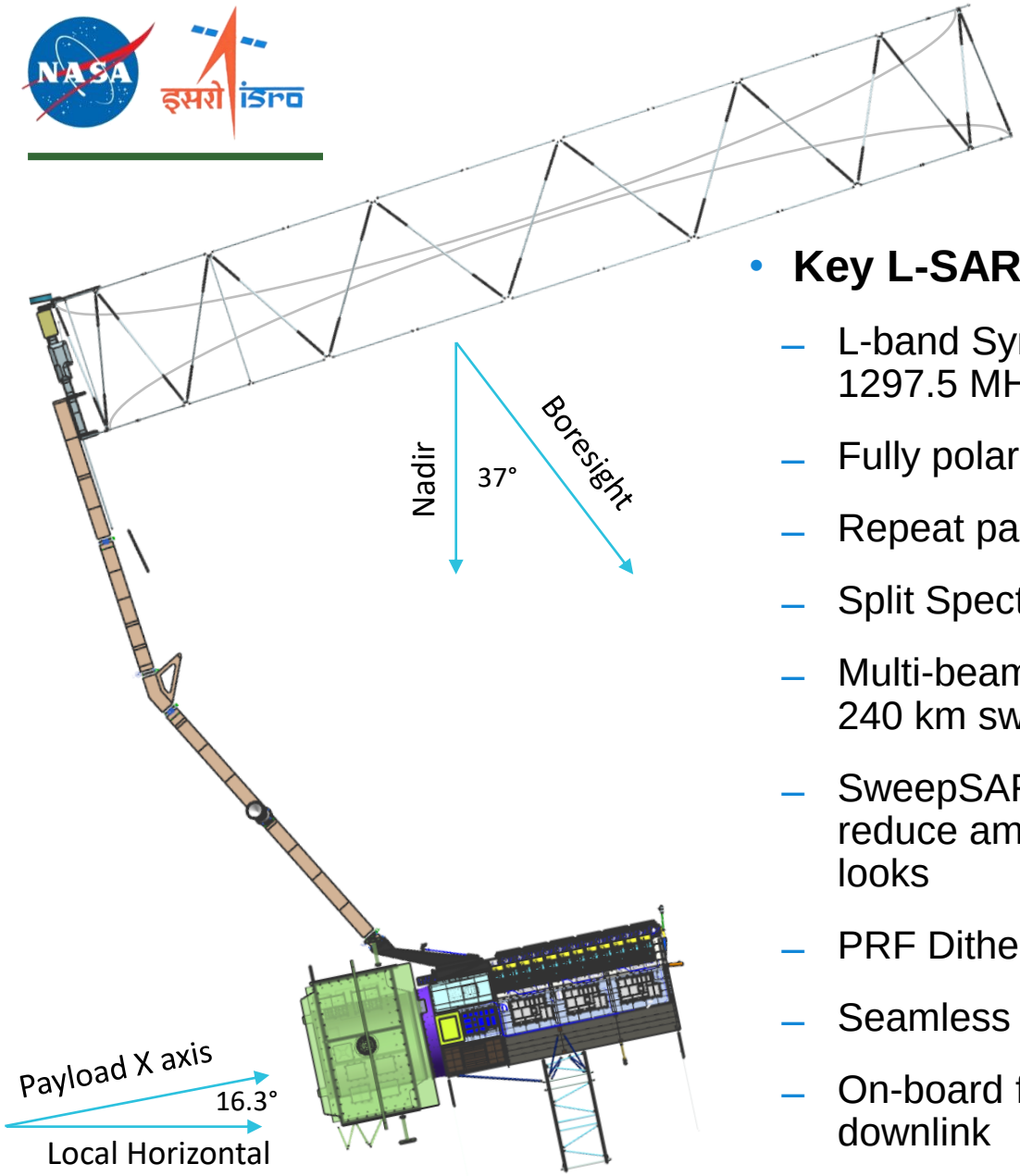
L-SAR Instrument



- **Key L-SAR Instrument Features:**
  - L-band Synthetic Aperture Radar (1215.5 – 1297.5 MHz)
  - Fully polarimetric for classification and Biomass
  - Repeat pass interferometry for deformation
  - Split Spectrum for Ionosphere mitigation
  - Multi-beam Array fed Reflector to achieve a 240 km swath
  - SweepSAR timing and Digital Beam Forming to reduce ambiguities and preserve resolution / looks
  - PRF Dithering to fill transmit interference gaps
  - Seamless mode transitions to minimize data loss
  - On-board filtering and compression to reduce downlink

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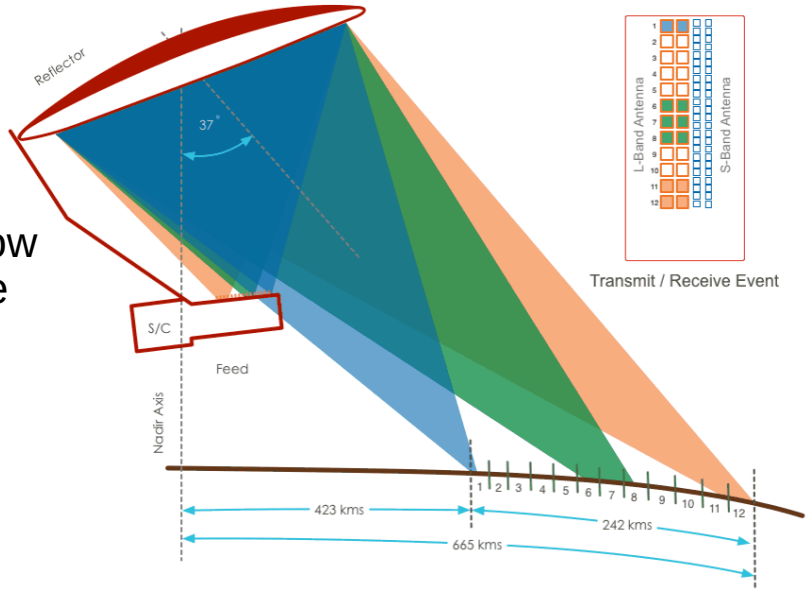
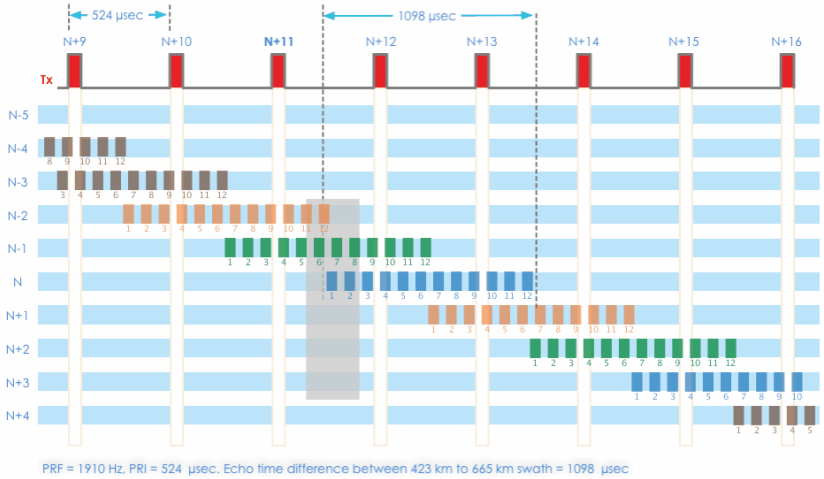
L-SAR Measurement Technique

- **SweepSAR Basics**
  - On Transmit, illuminate the entire swath of interest (red beam)
  - On Receive, steer the beam in fast time to follow the angle of the echo coming back to maximize the SNR of the signal and reject range ambiguities
  - Allows echo to span more than 1 Inter Pulse Period (IPP)
- **Consequences**
  - 4 echoes can be simultaneously returning to the radar from 4 different angles in 4 different groups of antenna beams
  - Each echo needs to be sampled, filtered, Beam-formed, further filtered, and compressed
  - On-Board processing is not reversible – Requires on-board calibration before data is combined to achieve optimum performance





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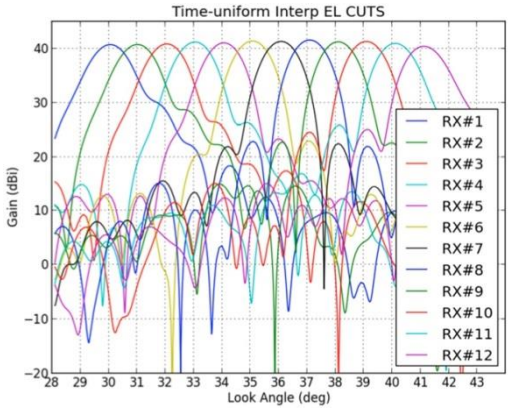
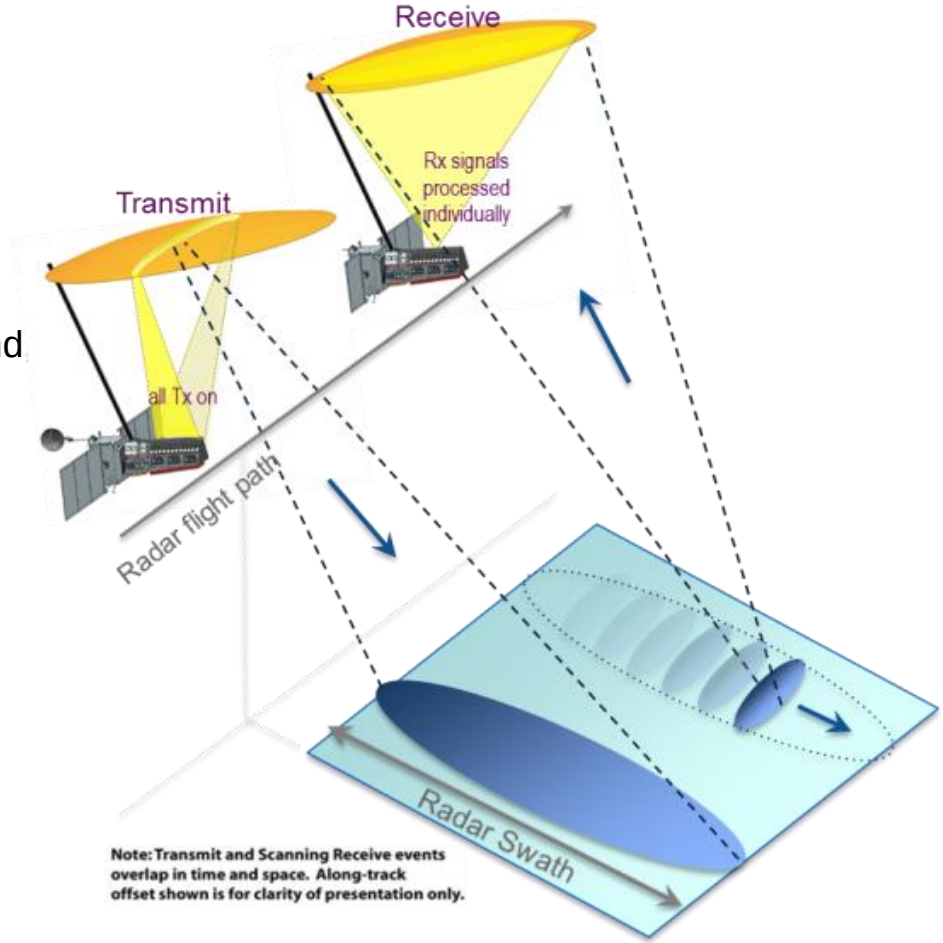
Radar Antenna Subsystem

- Reflector: 12m deployable mesh reflector by Northop-Grumman Astro
- Boom: JPL In-house co-development with SWOT
- L-Band Feed (aka L-FRAP): 2x12 element dual linearly-polarized patch array; JPL in-house design
- S-Band Feed (aka S-FRAP): 2x24 element dual linearly-polarized patch array; ISRO in-house design
- High power: Nominal peak power is ~3kW for L-Band and ~8kW for S-Band
- Transmit mode: All feed elements are used to generate a large swath
- Receive mode: Individual patch pairs are used to create small beams, with digital beamforming performed in post-processing





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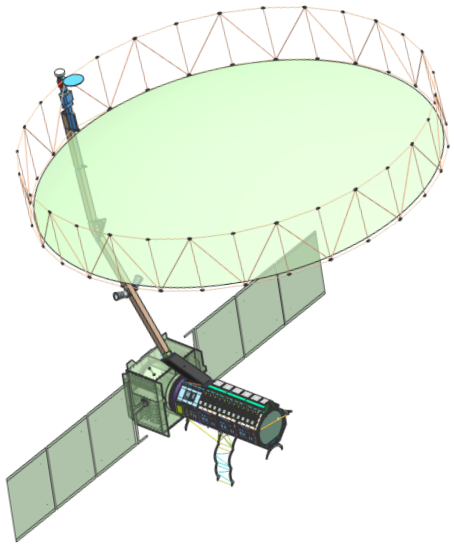
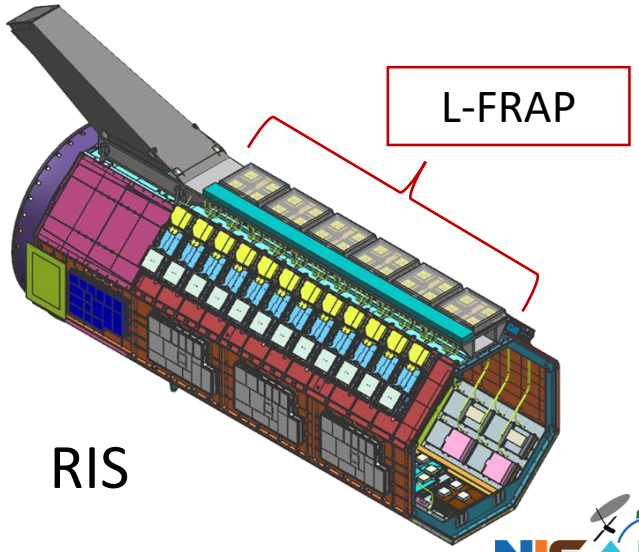
L-Band Feed Array

- The L-Band 2x12 element array is made by six 2x2 patch tiles
- Each pair of patches in the short dimension of the array function as a single element with dual linear polarization
- This results in 12 H-pol and 12 V-pol beams
- During transmit operations, each patch pair is fed with a linear phase ramp to scan the beam 5°. This affects the return loss
- The Radar Instrument Structure (RIS), lies in the projected aperture of the 12m reflector. This also affects the return loss seen at the tile





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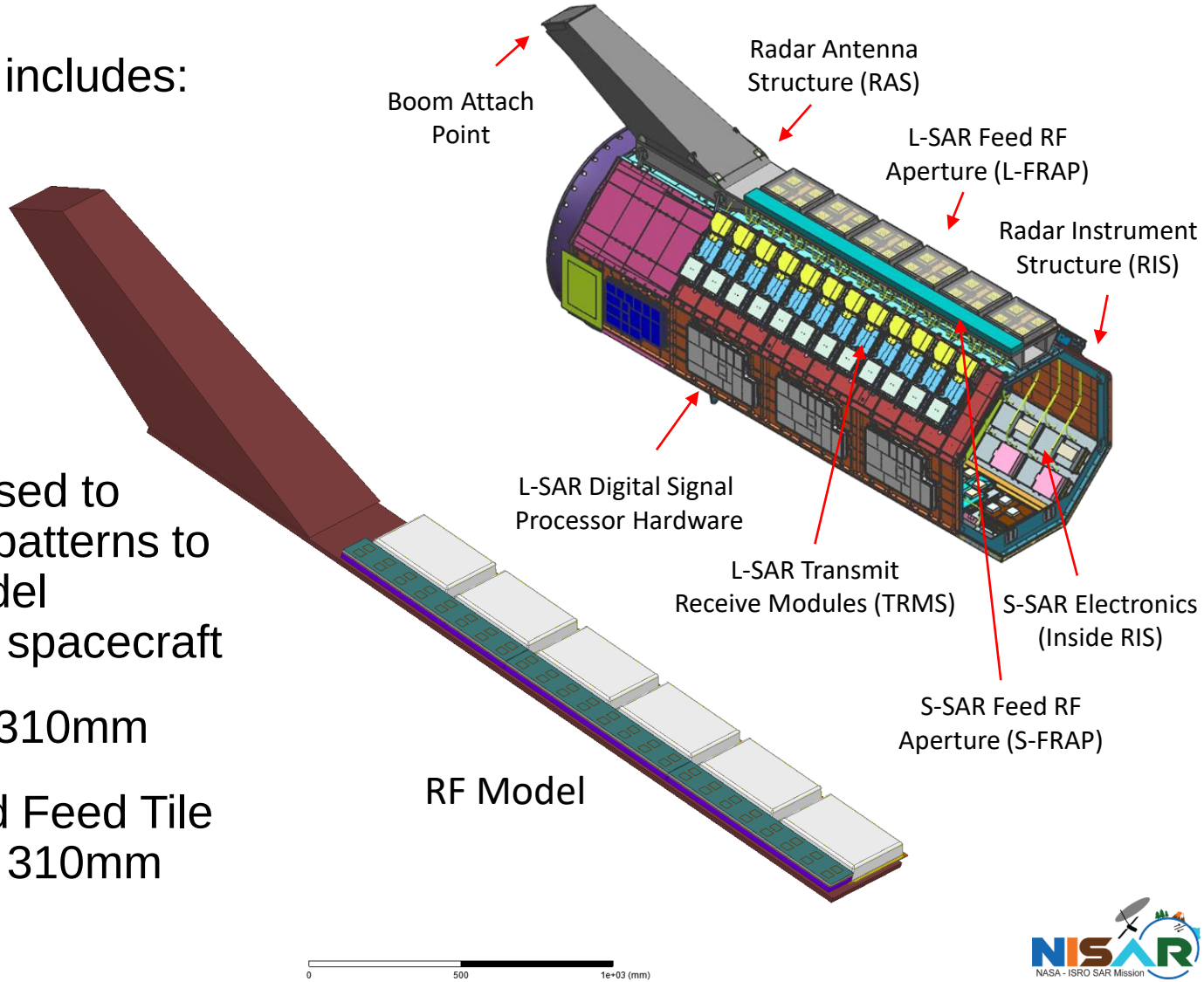
L-FRAP RF Model

- RF model in HFSS includes:
  - L-FRAP
  - S-FRAP
  - Top RAS plate
  - Boom base

- L-FRAP model is used to generate radiation patterns to feed a GRASP Model including the entire spacecraft
- L-FRAP is 2,158 x 310mm
- Each LFTA (L-Band Feed Tile Assembly) is 358 x 310mm



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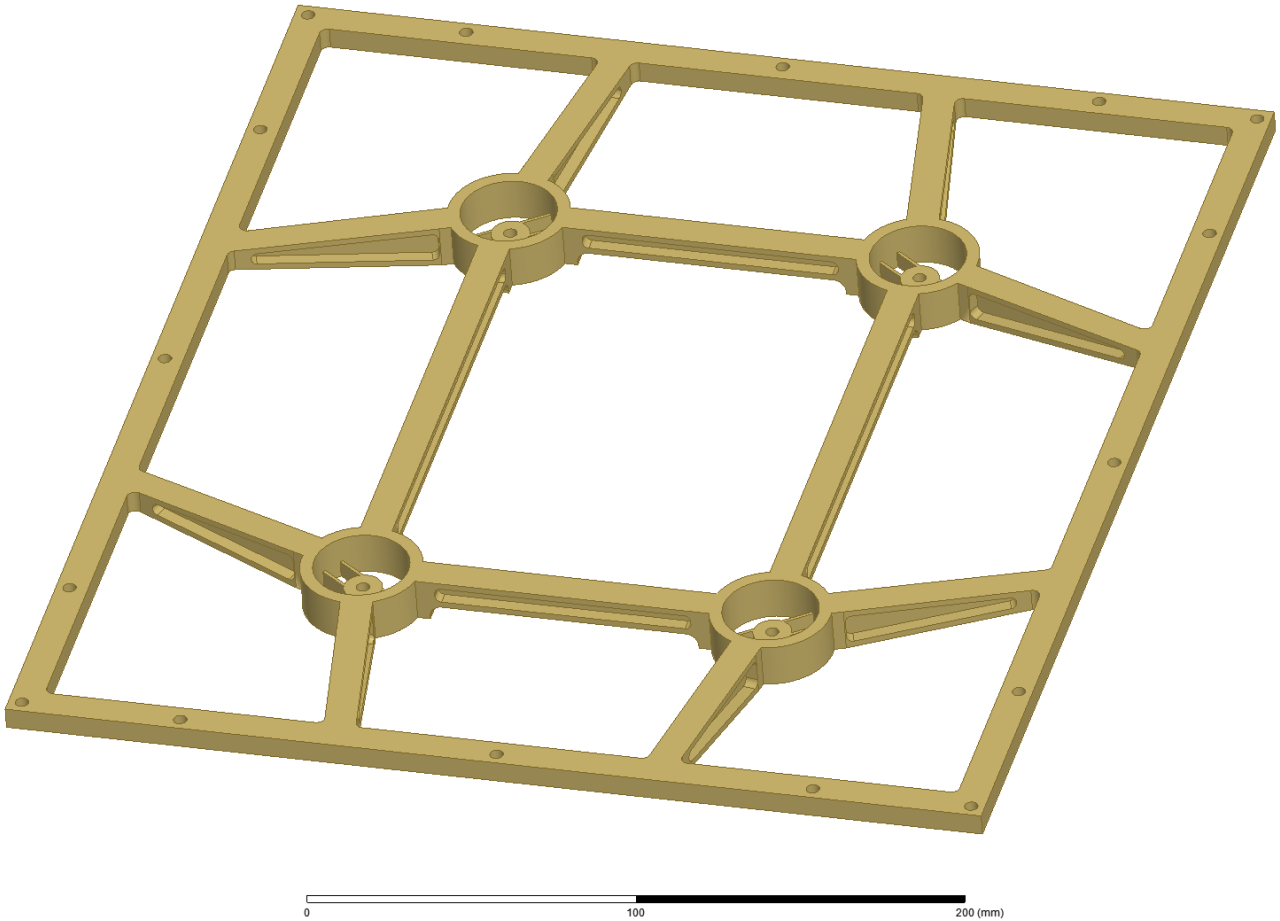
LFTA RF Model

Aluminum frame



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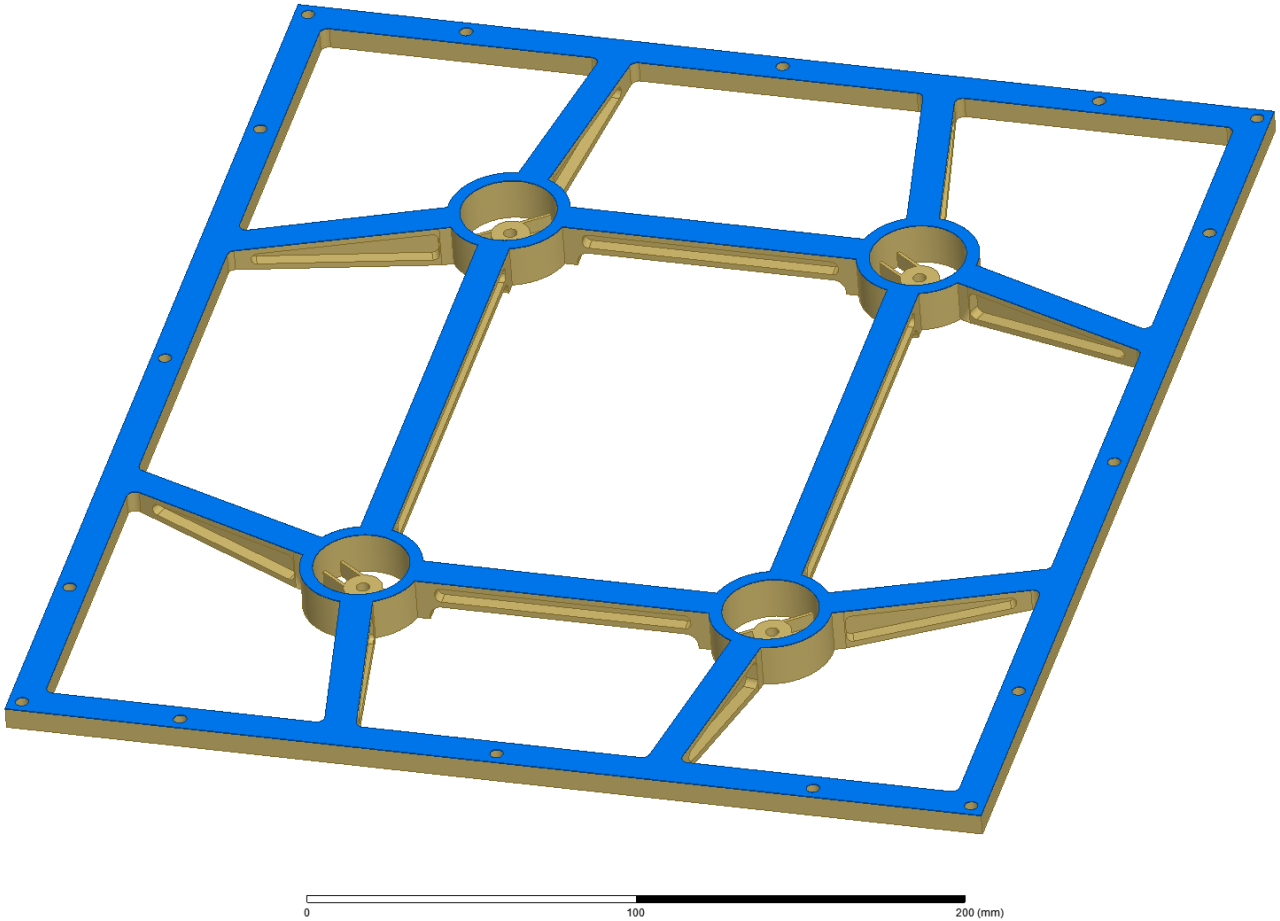
LFTA RF Model

Adhesive



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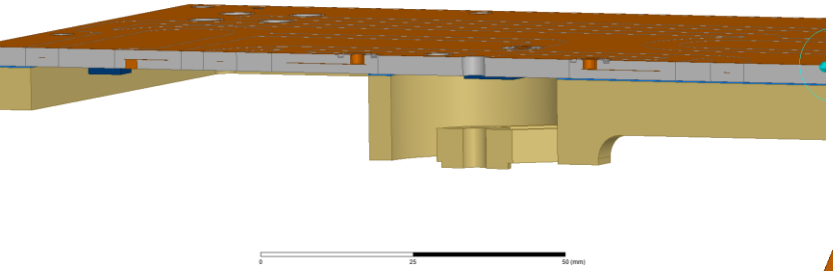
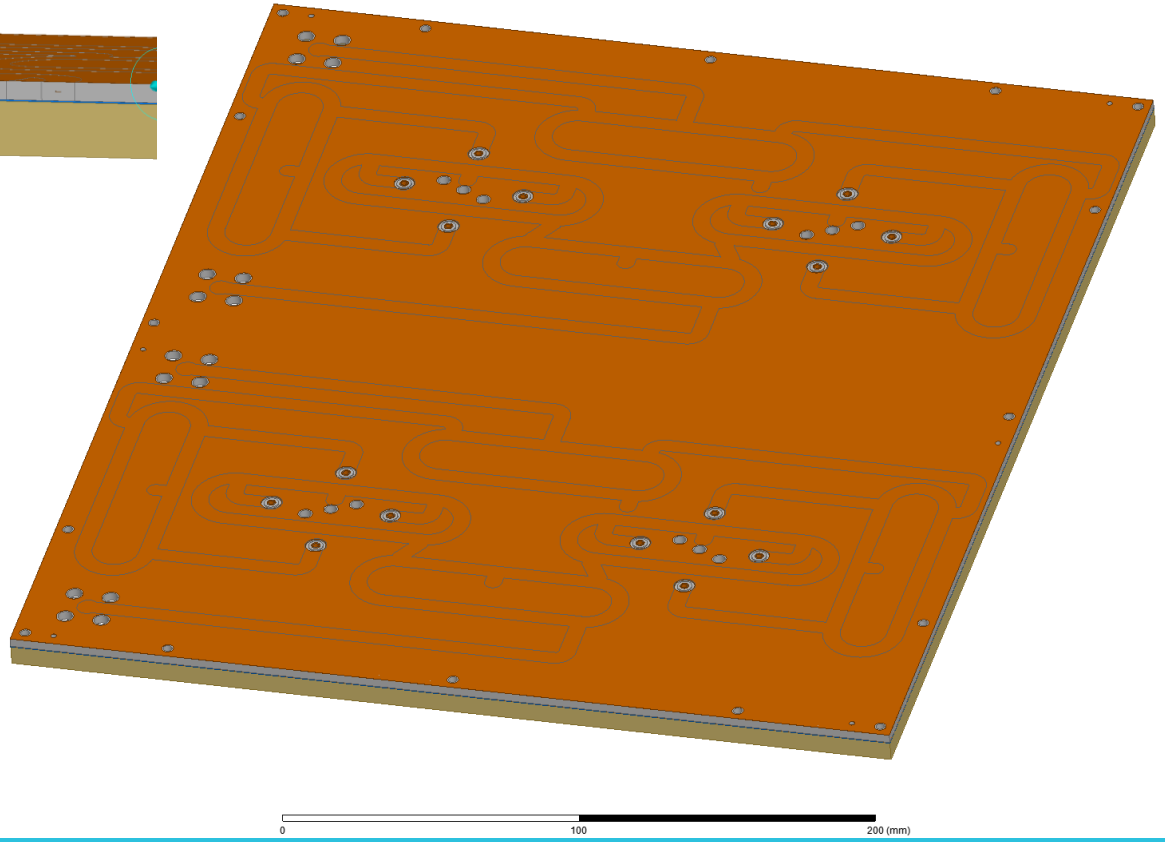
LFTA RF Model

Feeding Network board made of Rogers 6002





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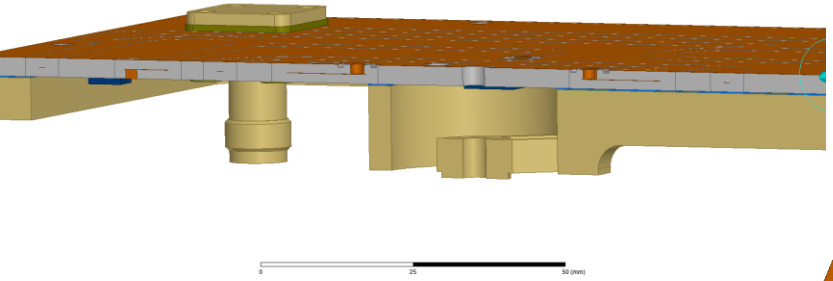
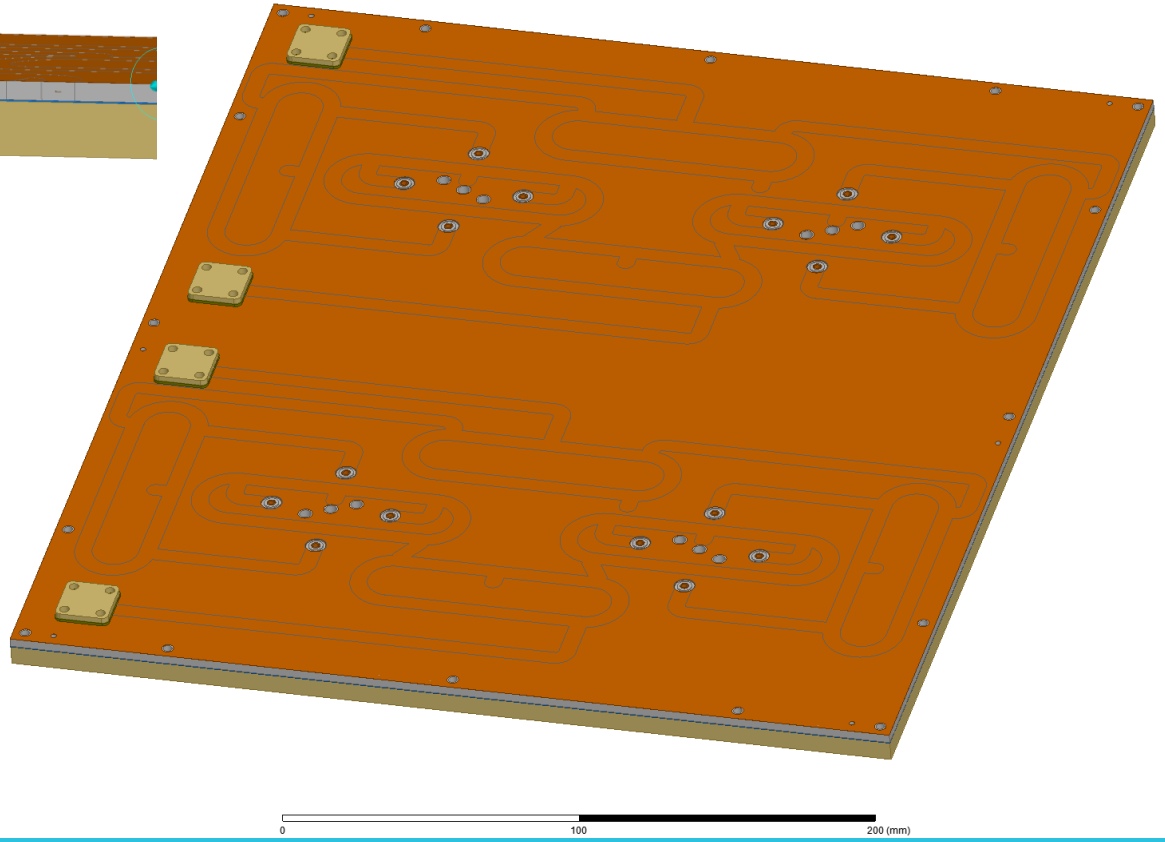
LFTA RF Model

TNC Connectors





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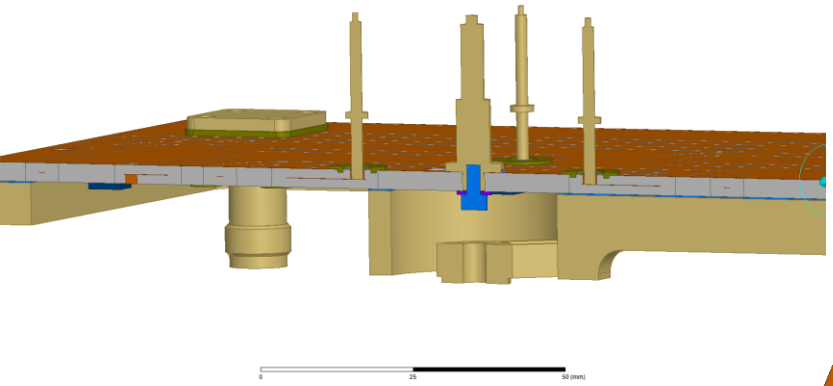
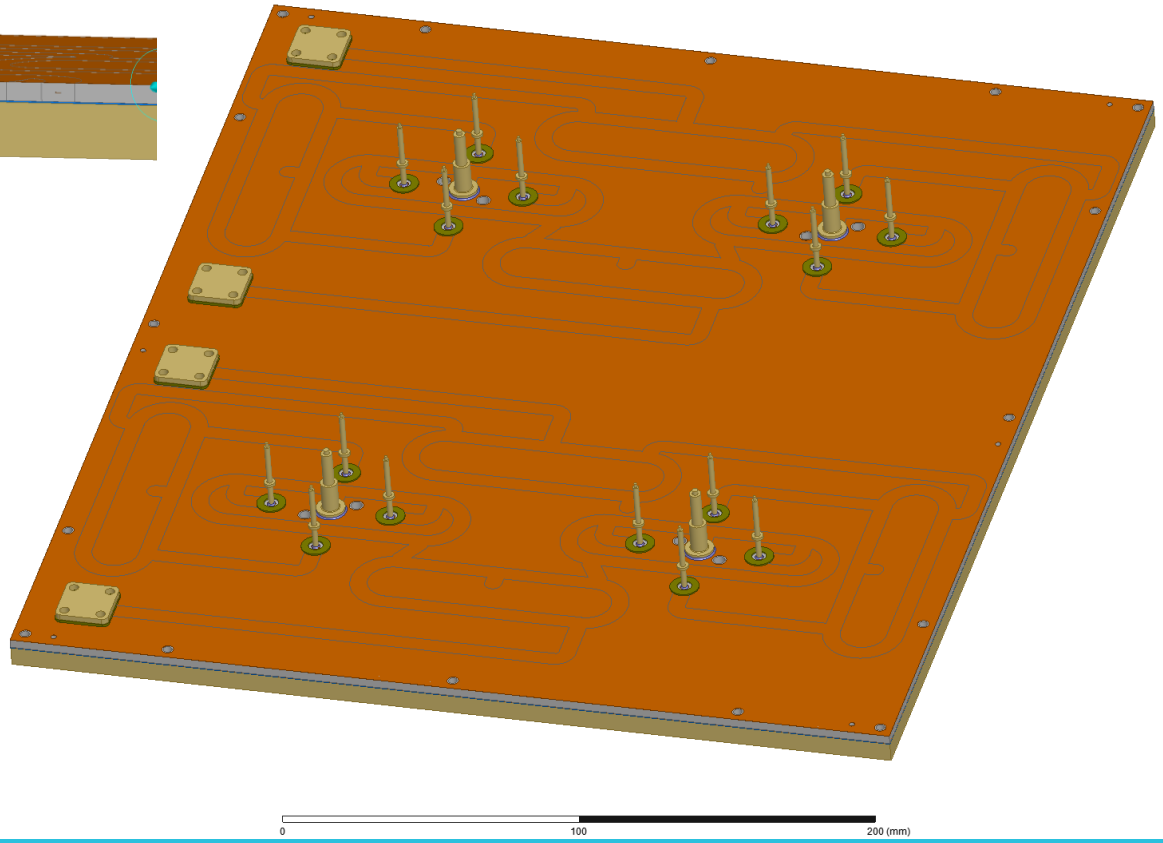
LFTA RF Model

Patch probes, center posts and dielectric washers





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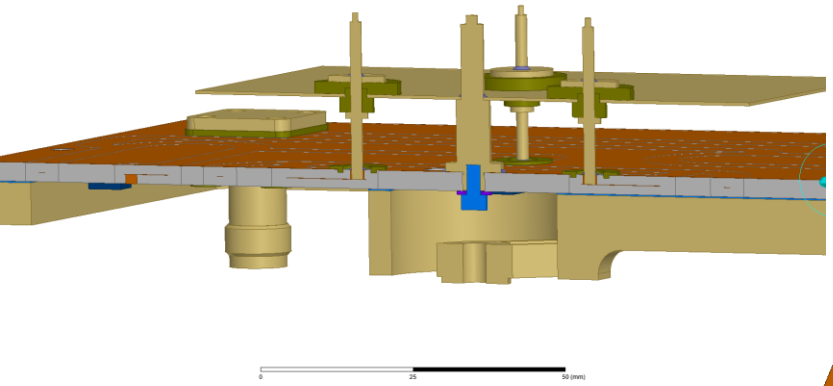
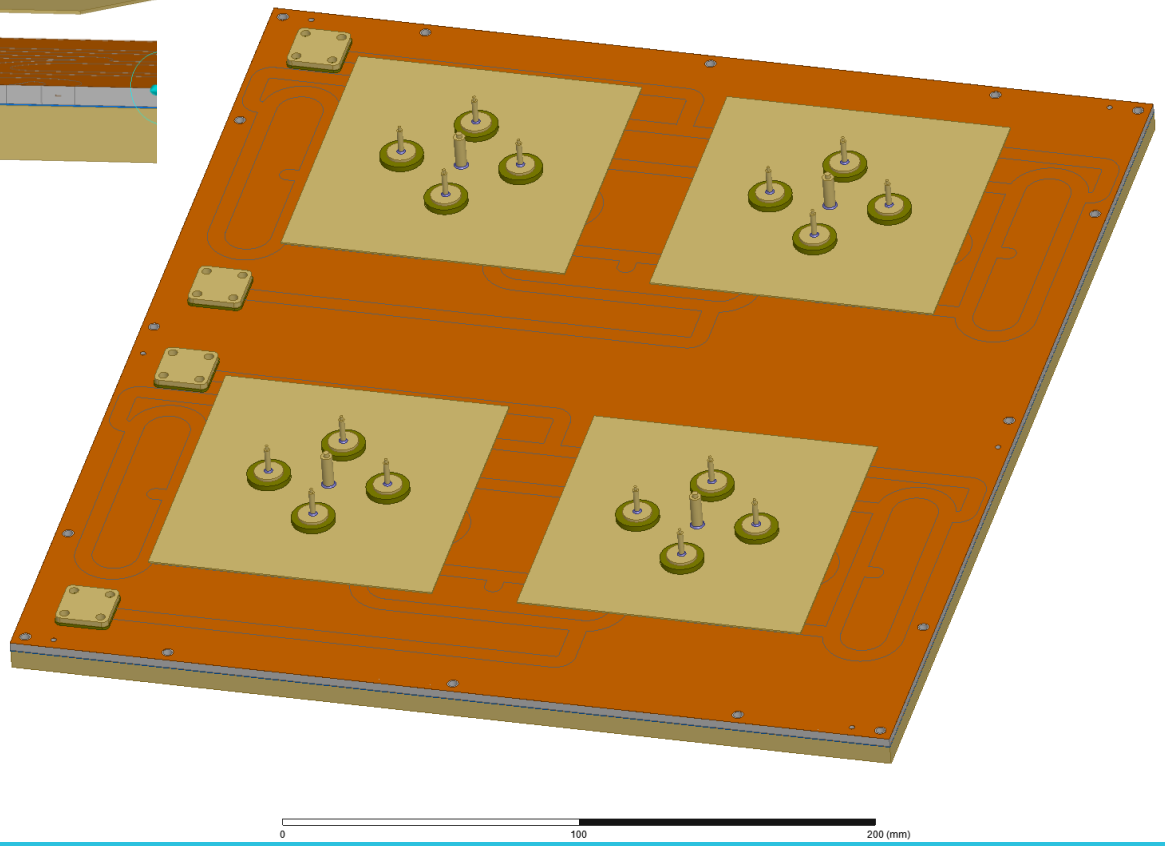
LFTA RF Model

Lower patches





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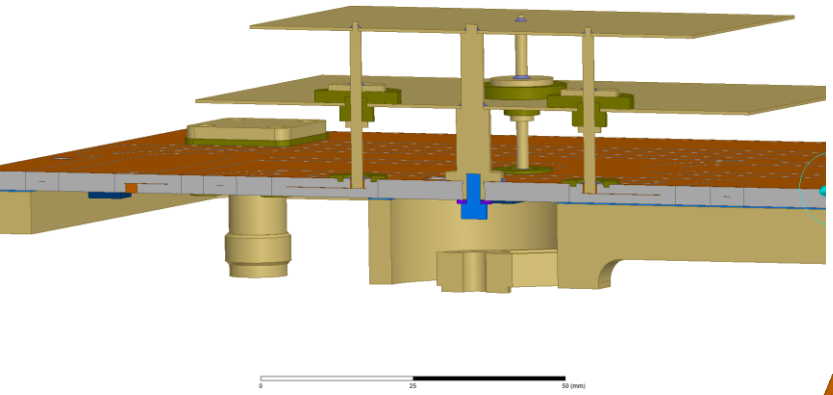
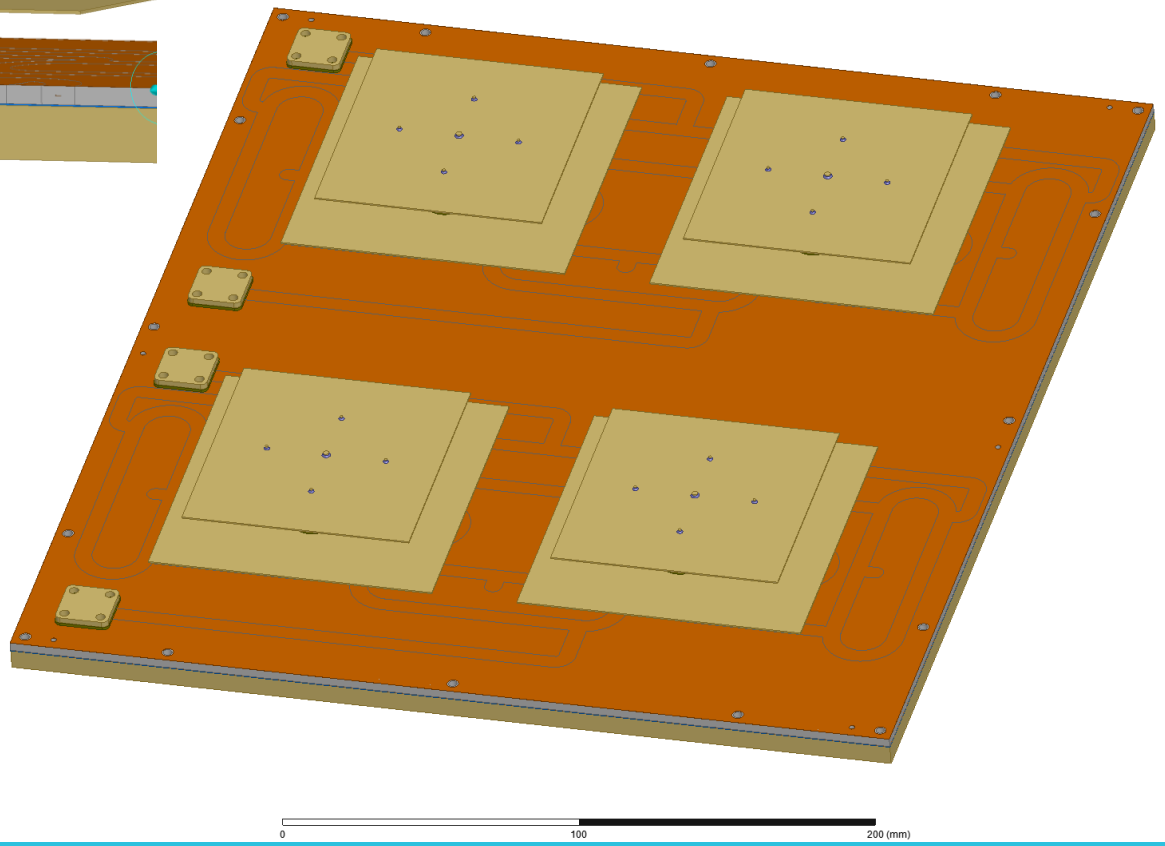
LFTA RF Model

Upper patches





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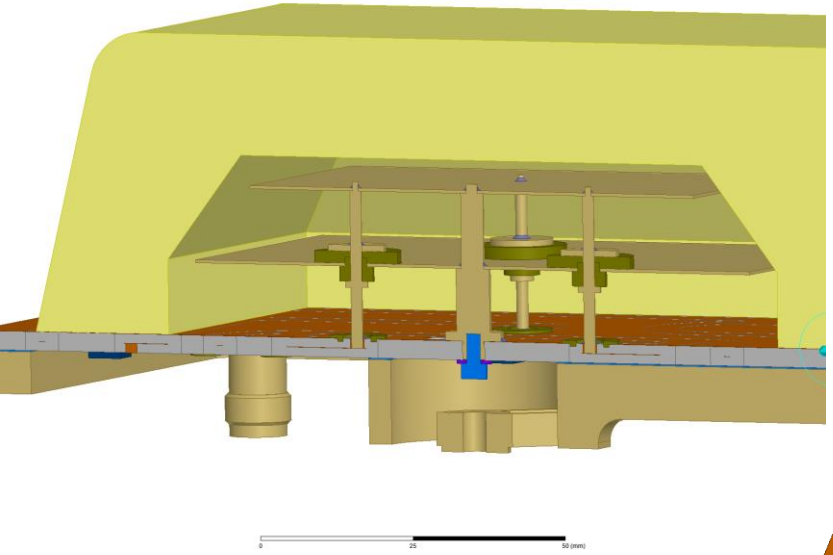
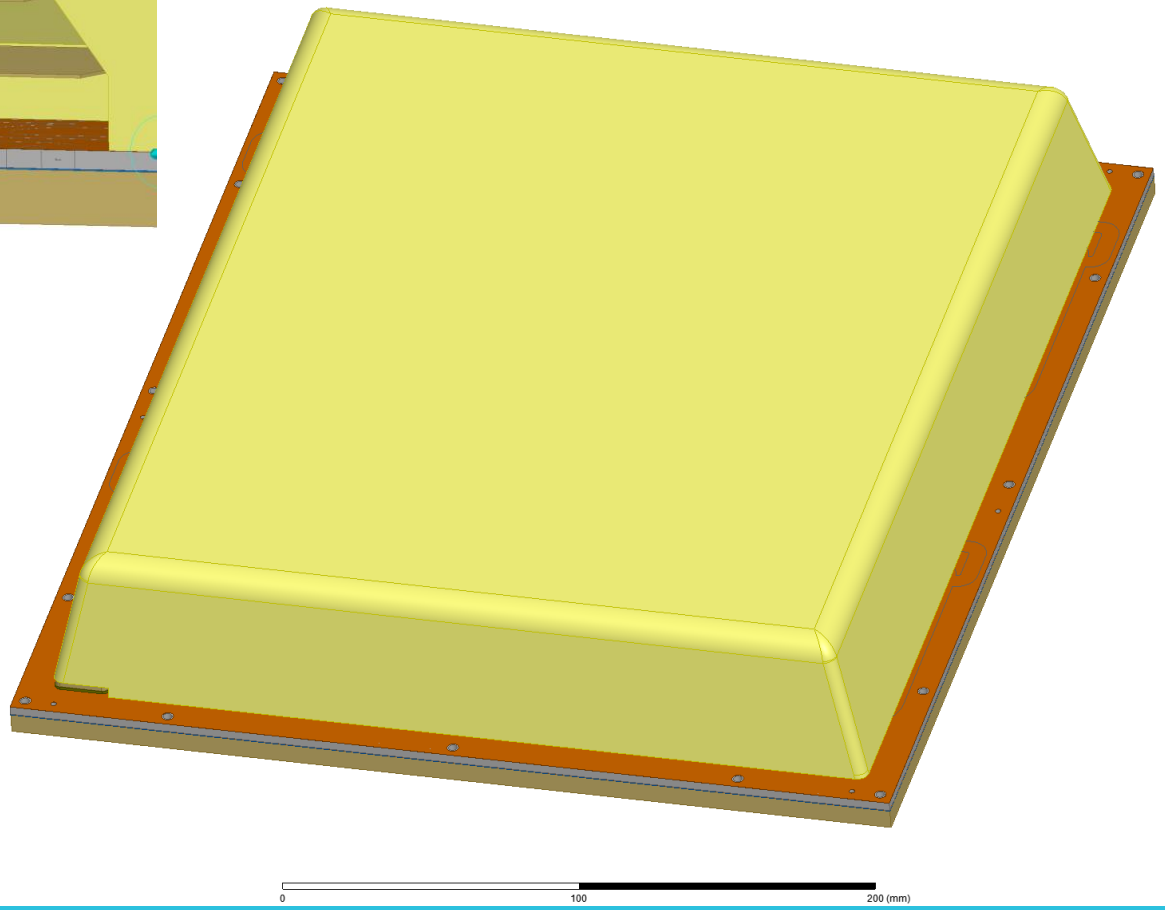
LFTA RF Model



Radome foam



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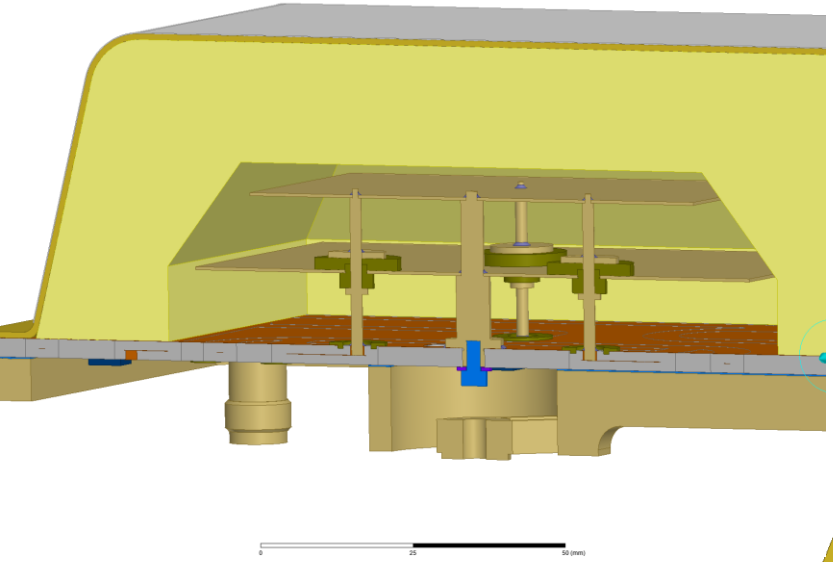
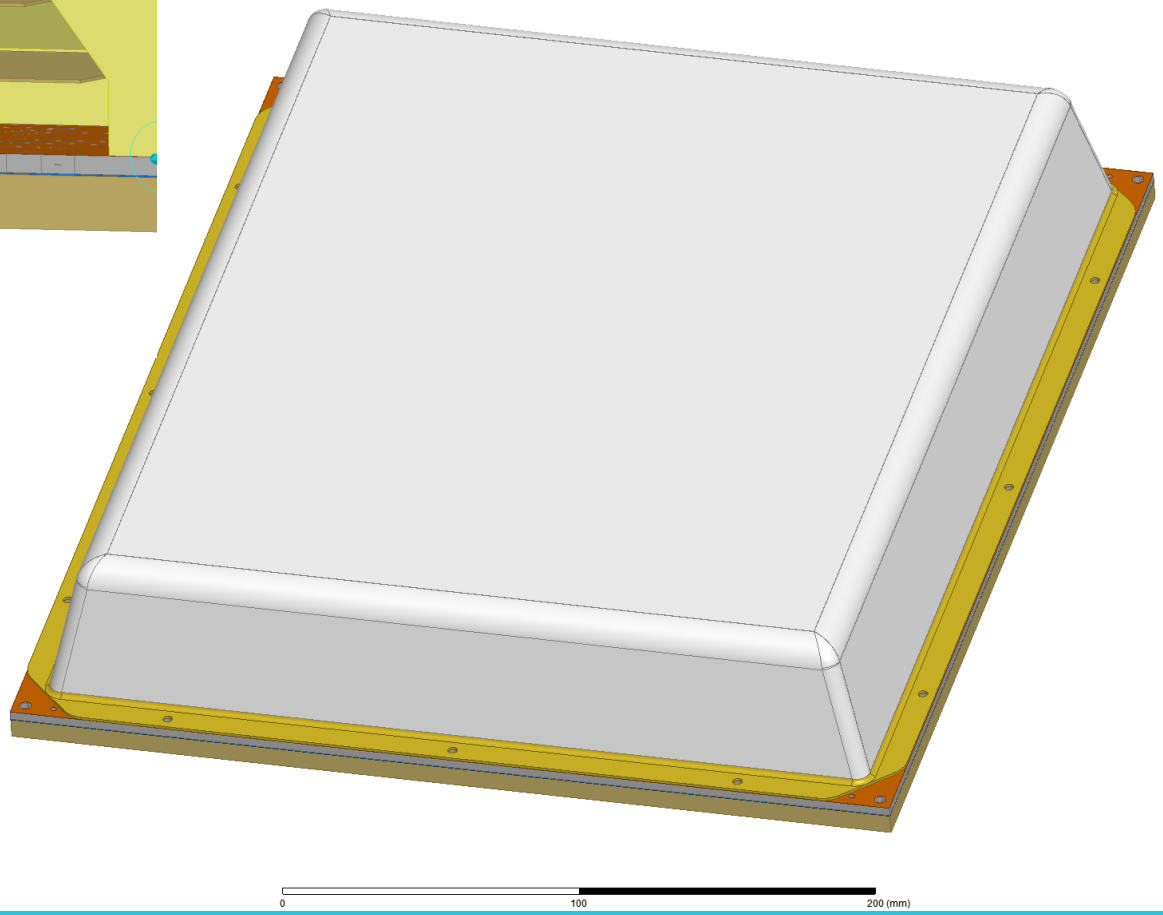
LFTA RF Model



Painted radome shell



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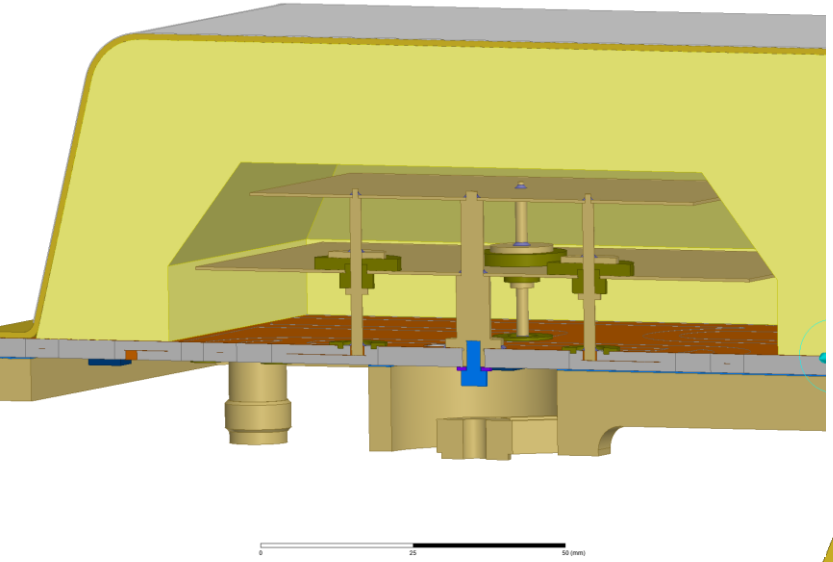
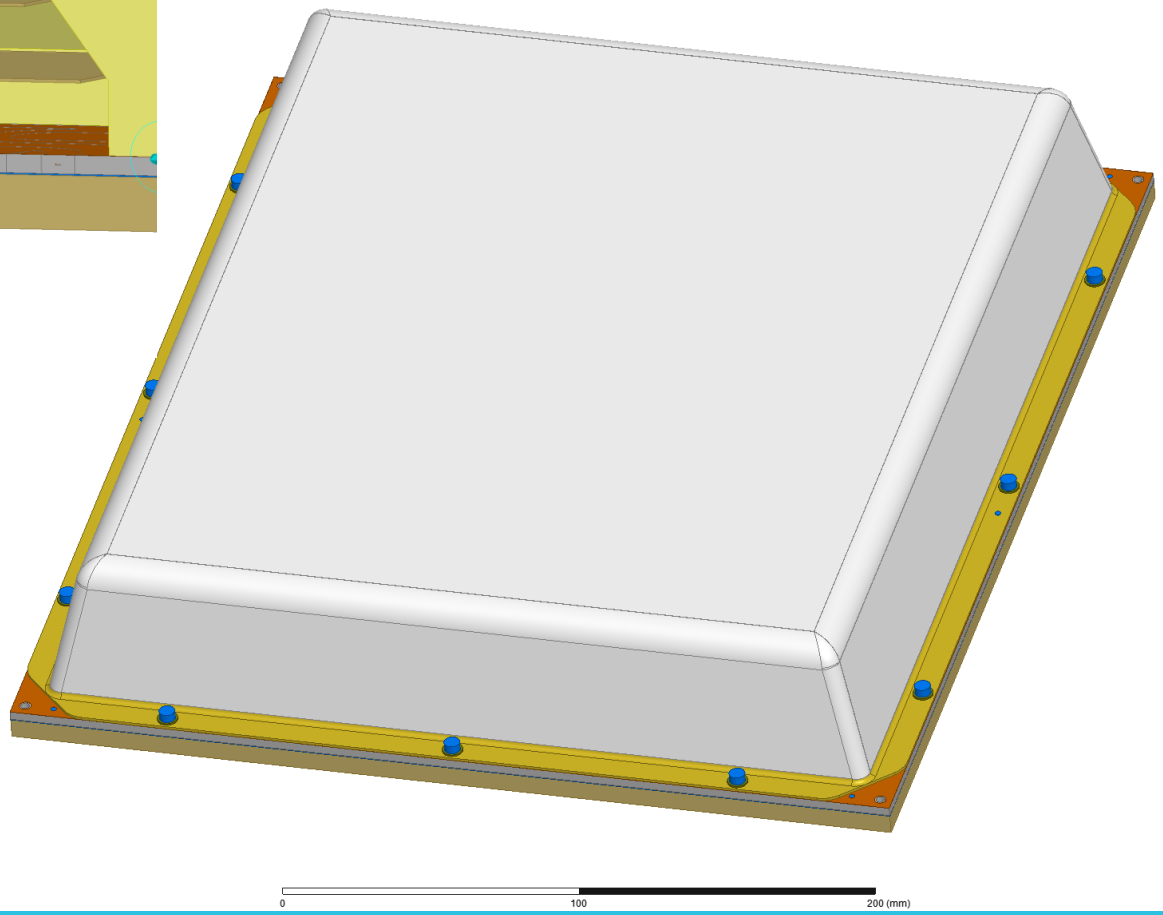
LFTA RF Model



Fasteners



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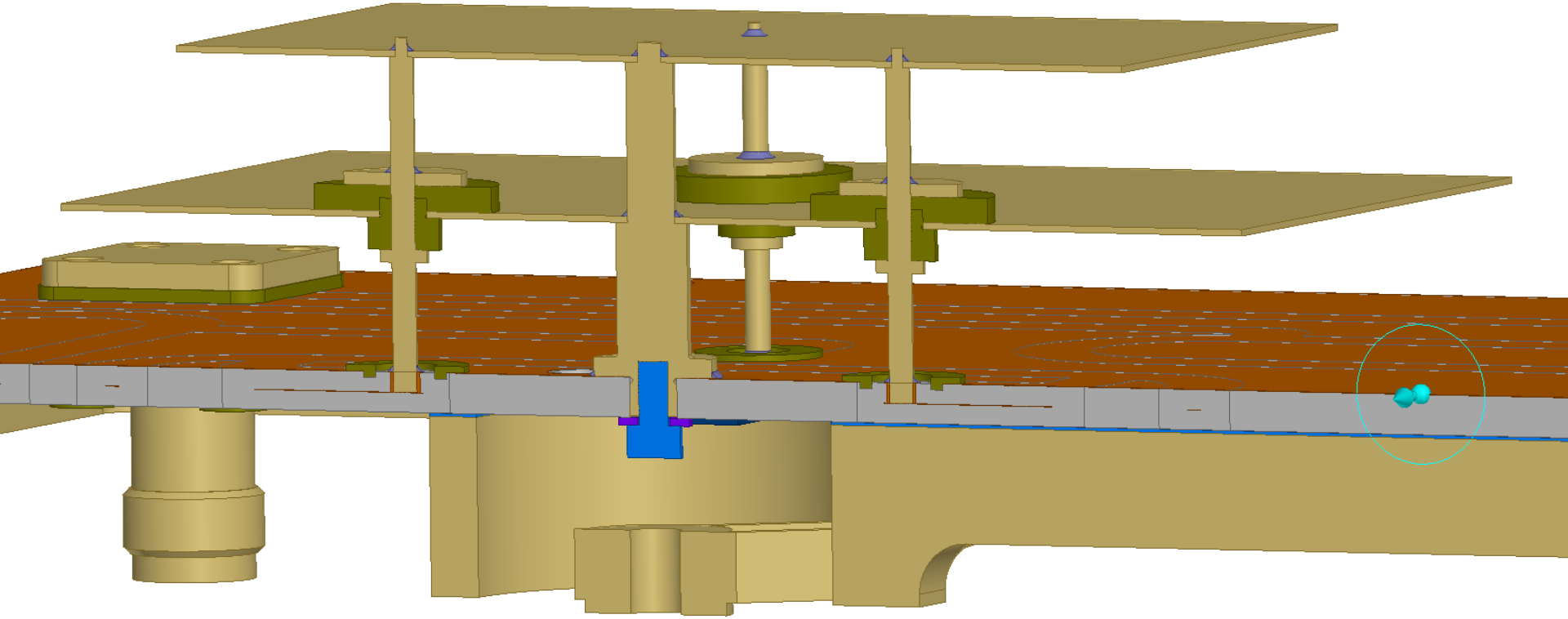
LFTA RF Model

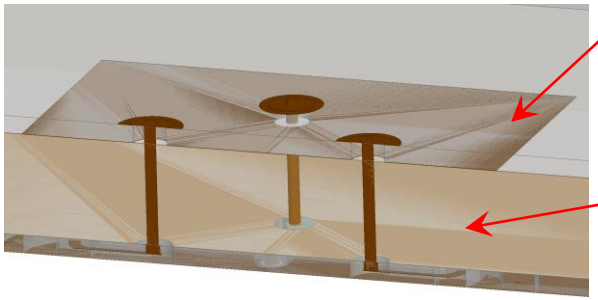
- Each patch pair is fed by its own feeding network capable of radiating H-Pol and V-Pol independently
- Each patch assembly is made of a stacked patch configuration with a center post and 4 probes
- Each probe is tuned with a dielectric bushing and a metal washer soldered above the lower patch



Feed Tile Design Evolution

Old Design

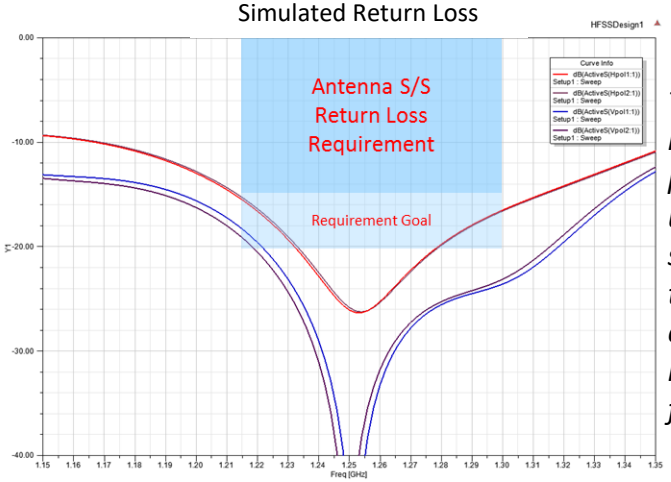
No radome, which resulted in large temperature gradient predictions through the honeycomb layer



Single patch layer

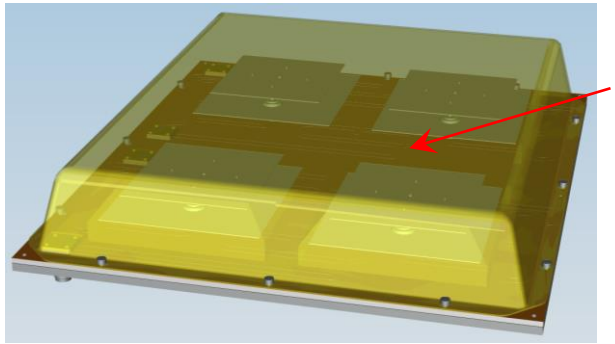
Honeycomb layer between patch and ground plane (not shown)

Simulated Return Loss



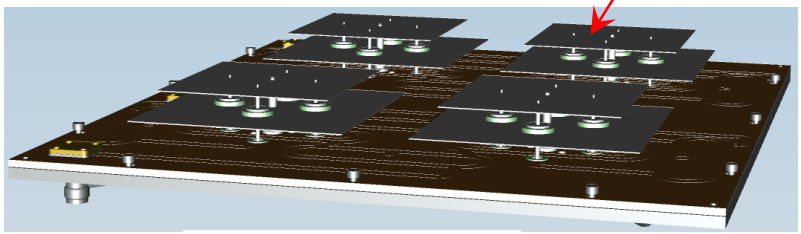
The measured return loss on the single prototype tile varied up to 3 dB from the simulated results, so the design was not expected to meet the requirement over the full band

New Design



Radome with rigid outer shell and foam interior

Stacked patches, air dielectric



Simulated Return Loss

The new design shows enough margin that the requirement is expected to be met with margin

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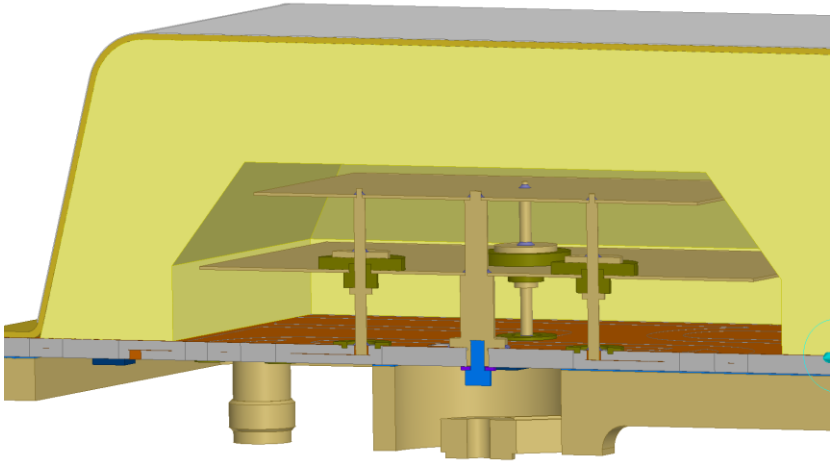
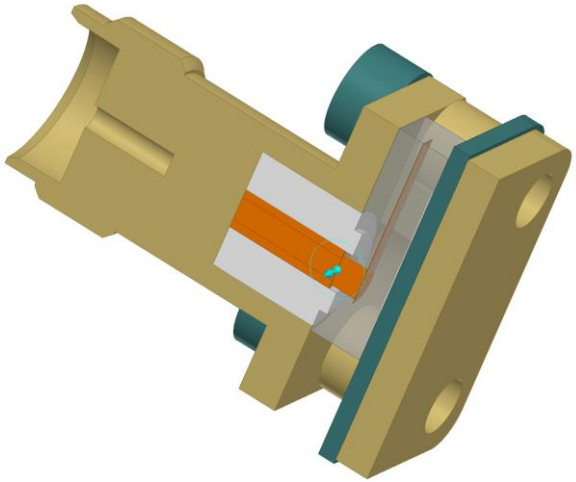
RF Design Highlights

- The mission thermal environment drove us toward a metal patch design without dielectric support
- The RF Bandwidth requirement made us add a second patch in stacked configuration
- A center post was added for mechanical support and has the added advantage of minimizing the second harmonic
- Radome and heaters were added to minimize thermal gradients
- A number of features were added to increase the power handling capabilities of the feed assembly



Feed Tile Assembly Section



Modified TNC Connector

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Prototype Tile Summary

- Two complete prototype LFTA and one extra feeding network board were fabricated and tested
- Performed tests included:
  - Radiation pattern measurements
  - S-parameter/Insertion loss measurements
  - Thermal cycling
  - Coupons for mechanical/electrical/thermal/structural testing
- S-Parameter measurements showed some discrepancy with the model which prompted us to test the electrical properties of the dielectric materials
- Once the accurate values for dielectric constant and loss tangent were added to the RF model, calculations agreed well with measurements

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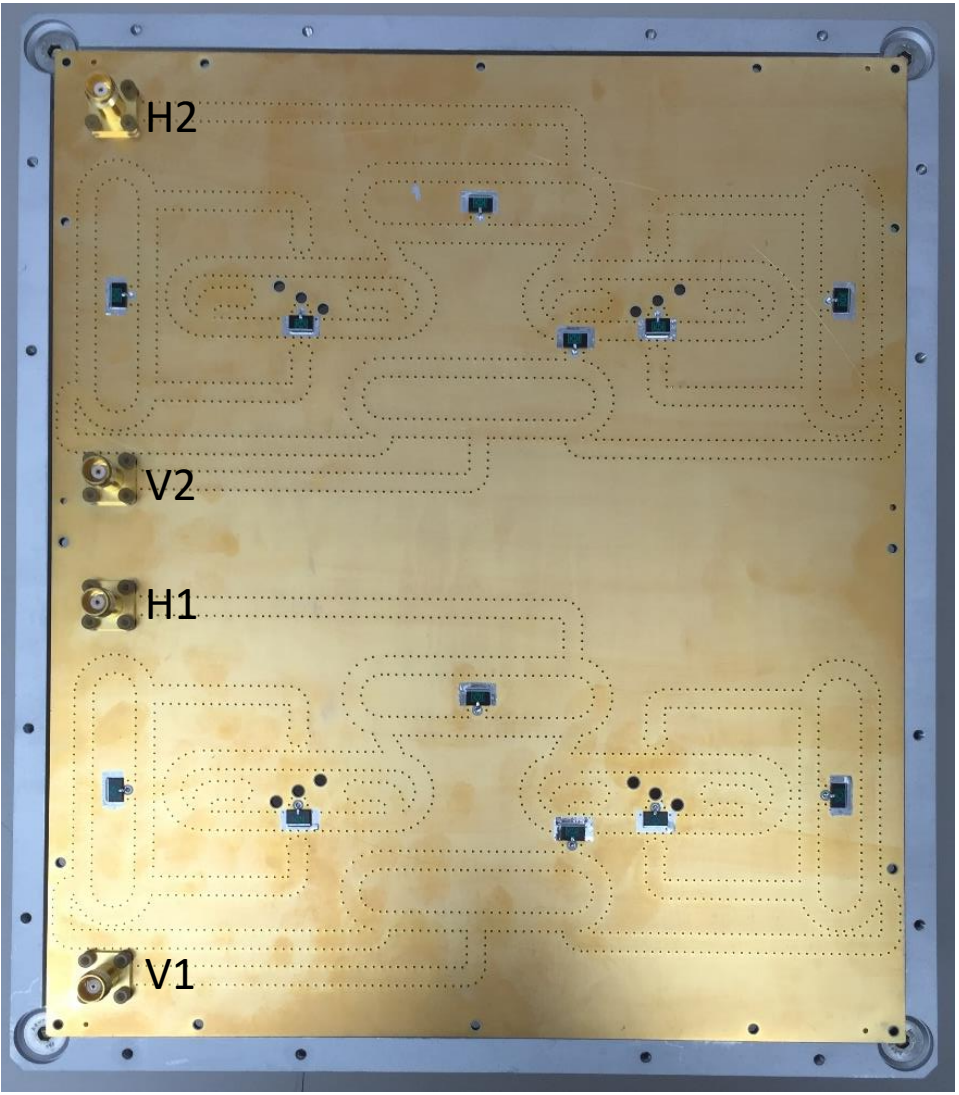
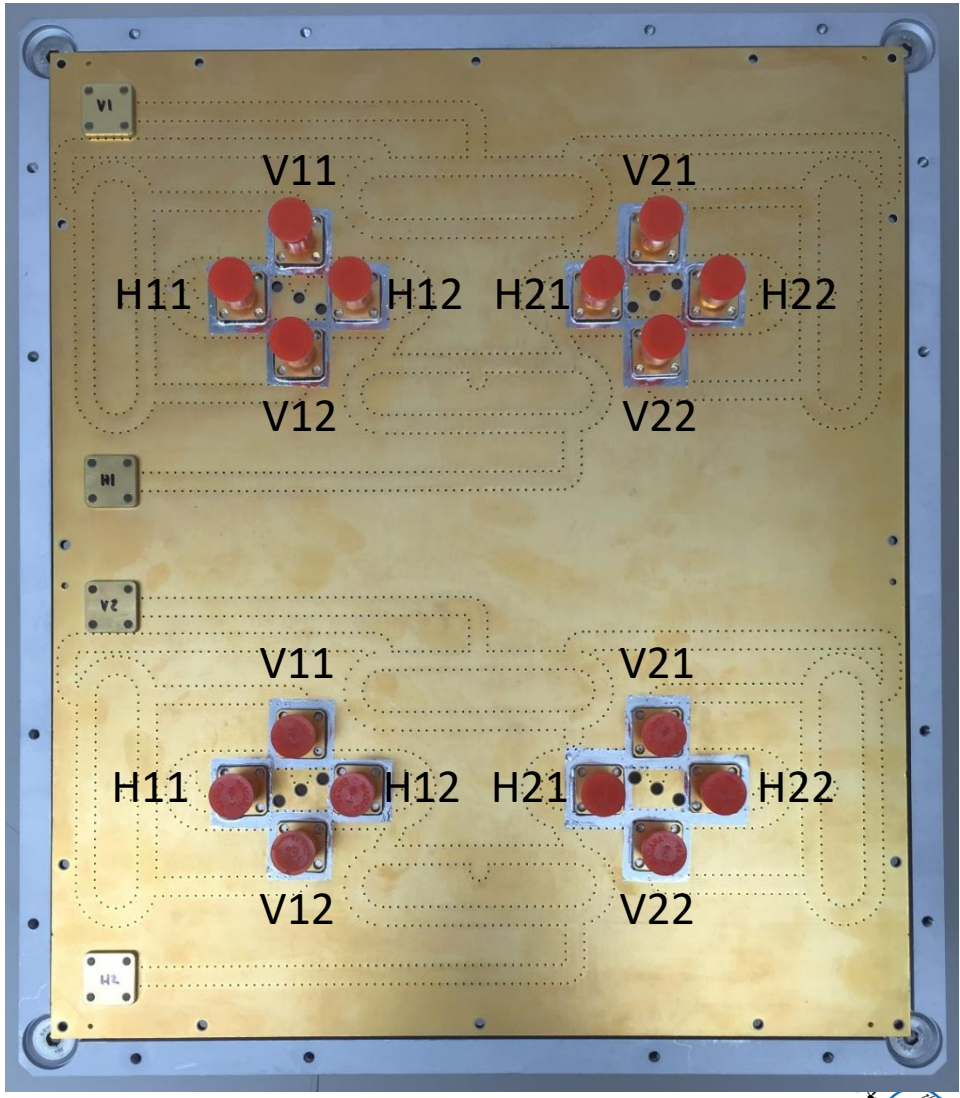
Feeding Network Test Board



Bottom View



Top View

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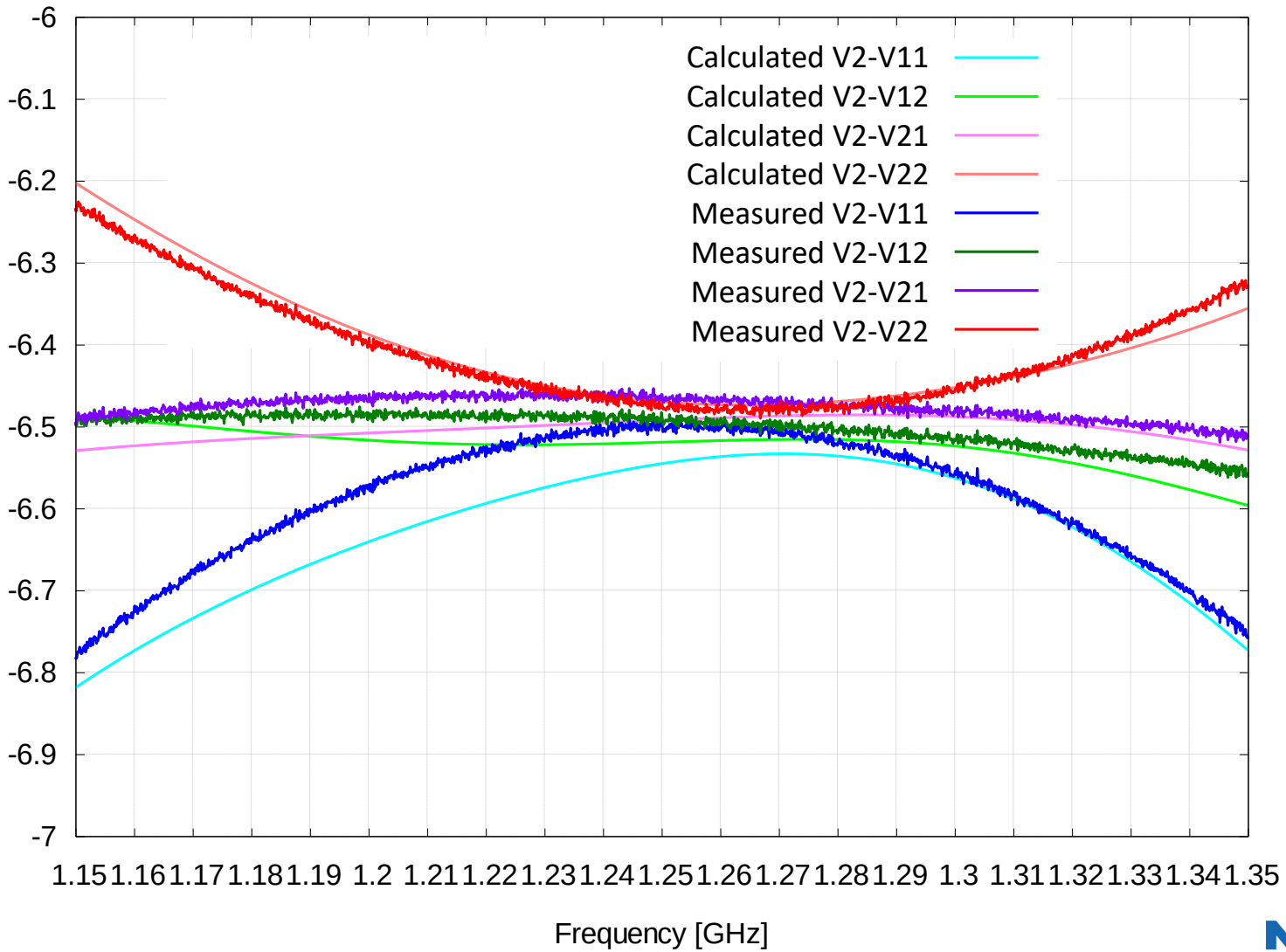
Power Distribution – V-Pol



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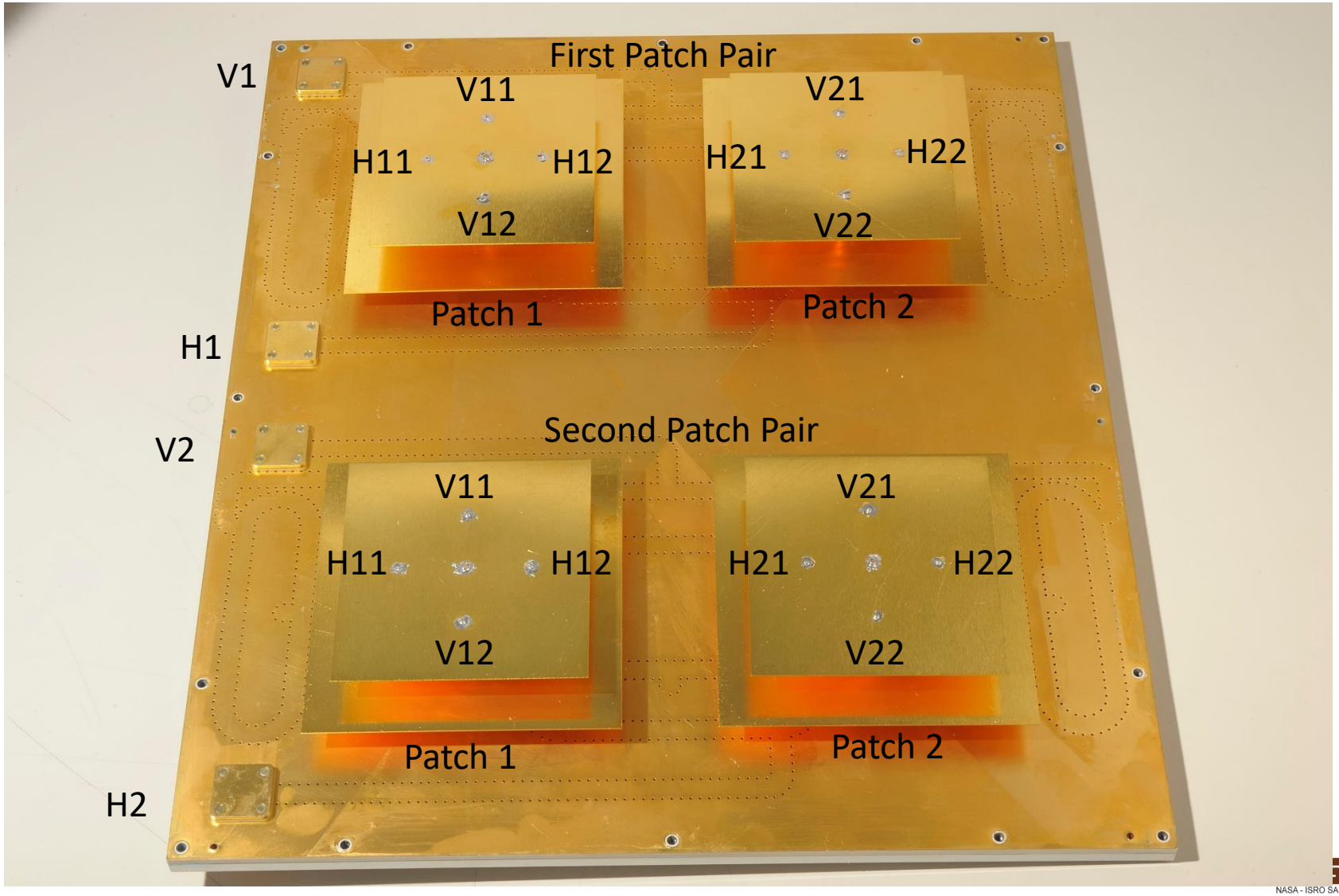
Prototype Tile – Under the "Hood" View



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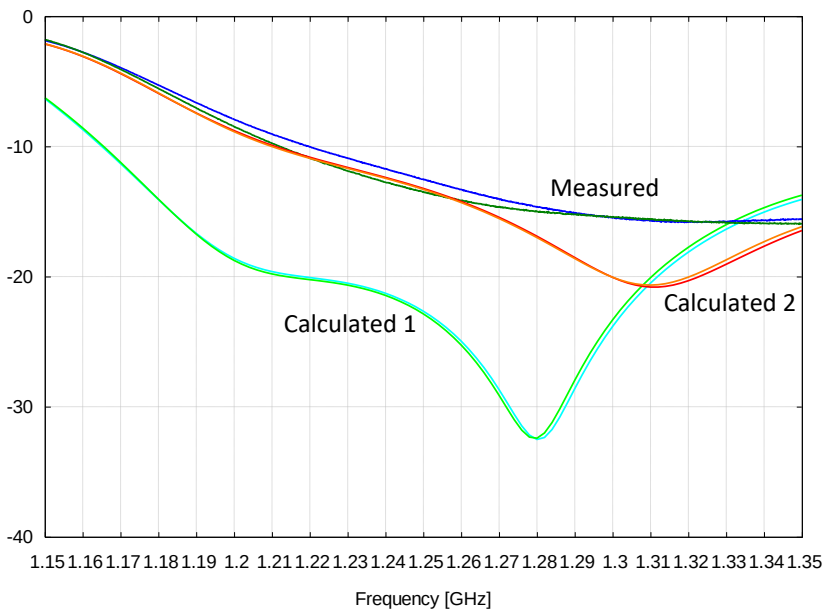
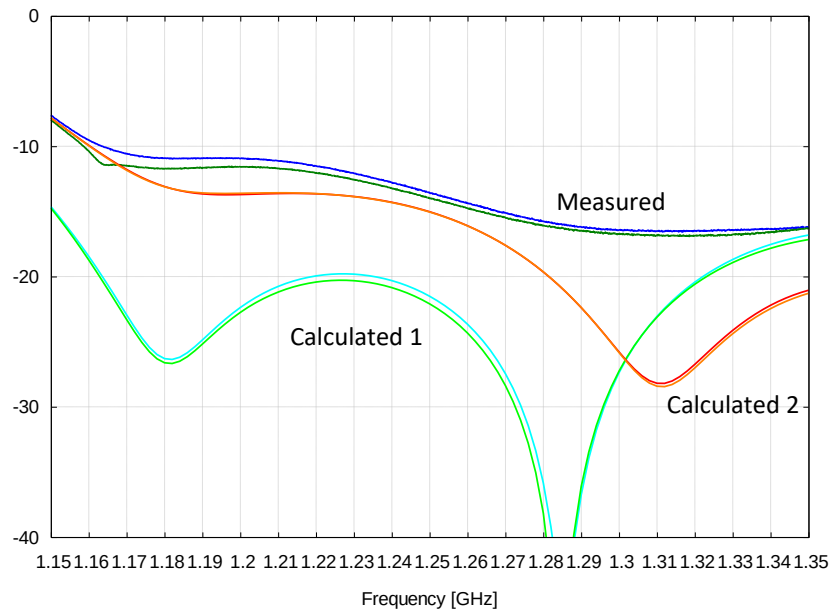
Return Loss, Measured Vs. Calculated

Measured results are from SN2 after thermal cycling

H-Pol



V-Pol



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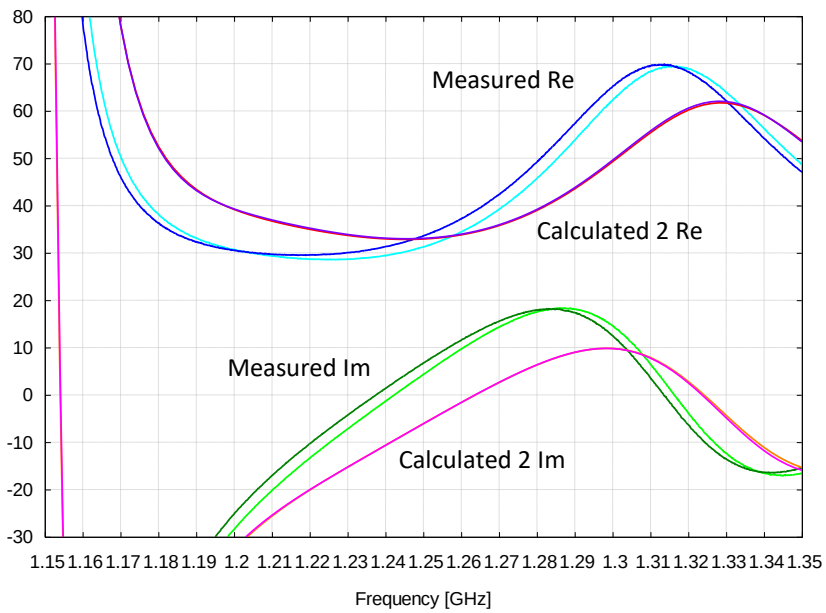
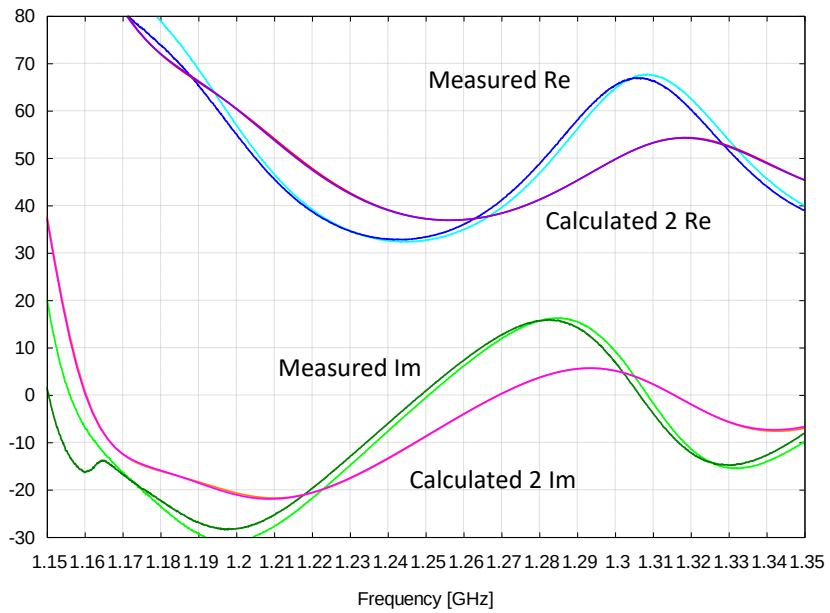
Input Impedance, Measured Vs. Calculated

Measured results are from SN2 after thermal cycling

H-Pol



V-Pol



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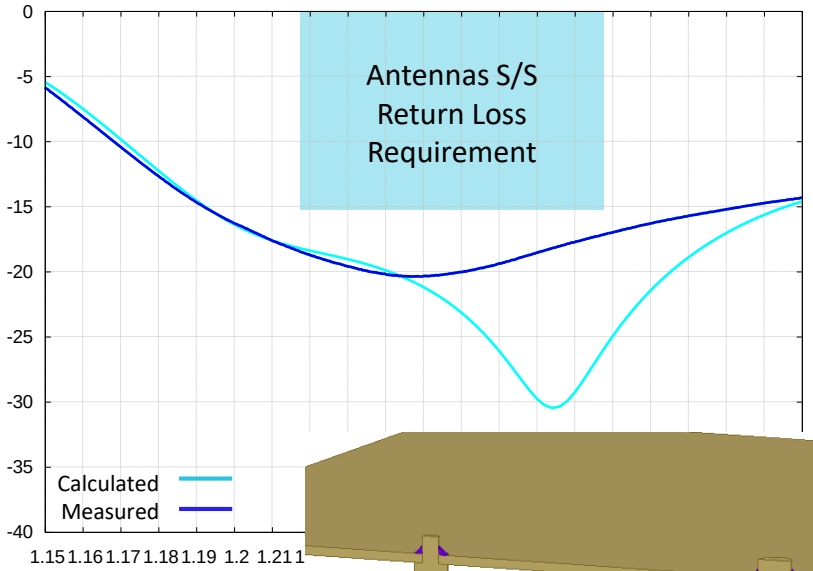
Re-Tuned Tiles

H-Pol



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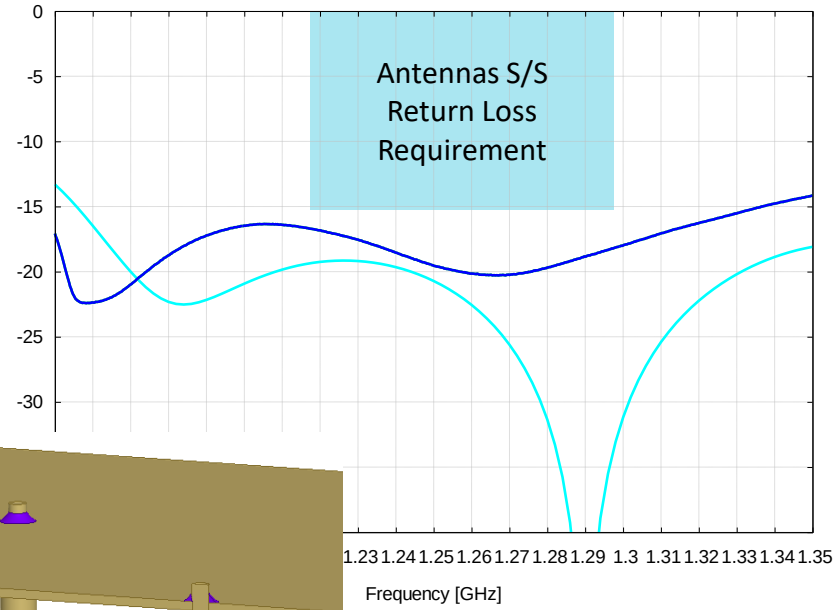
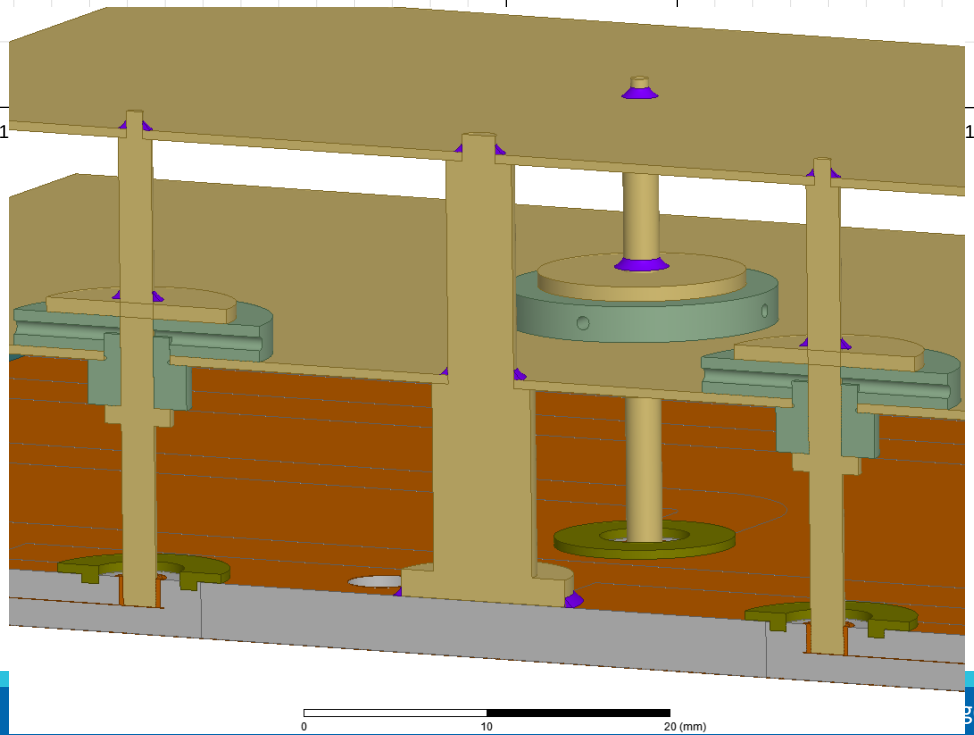
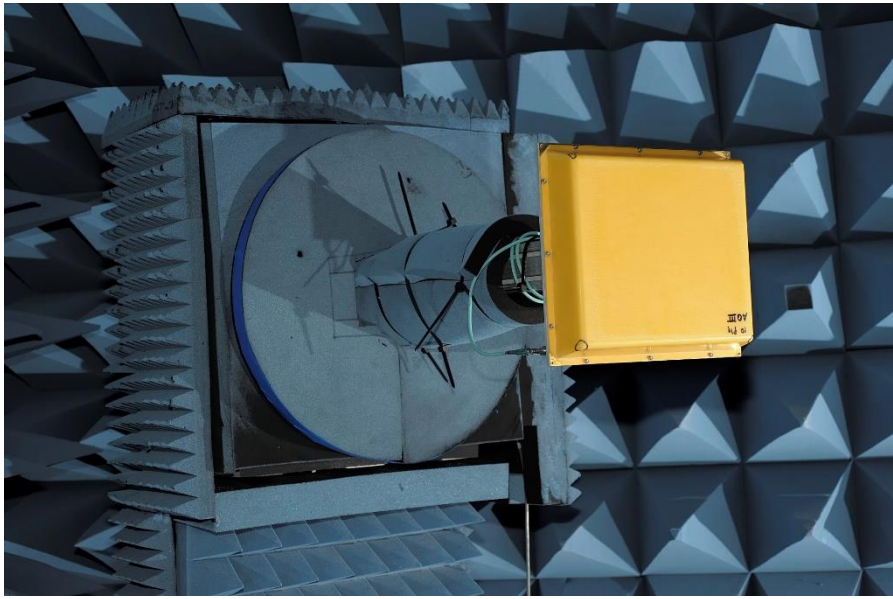




Prototype Tile Radiation Patterns

- Both prototype tiles were measured at NSI in a spherical near field range
- Standard Gain Horn was also measured in the same chamber
- Alignment was performed using a laser tracker



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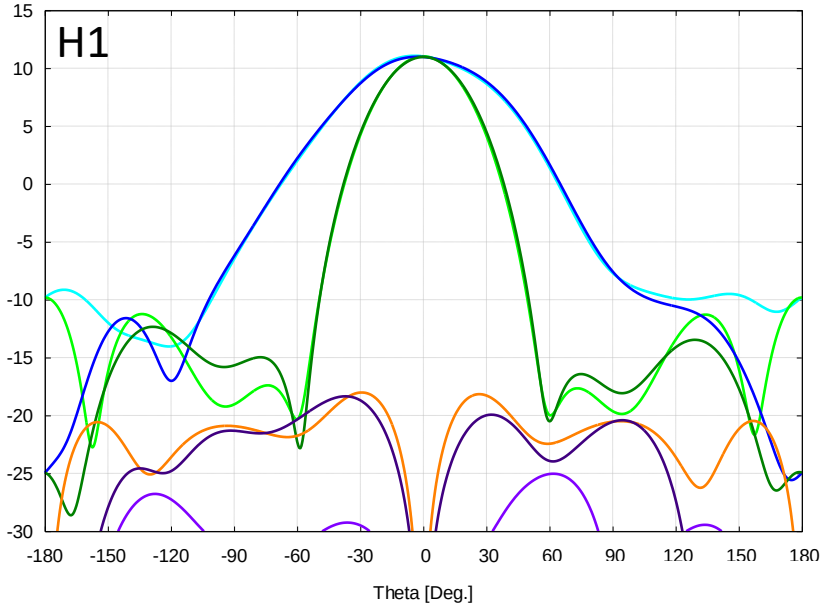
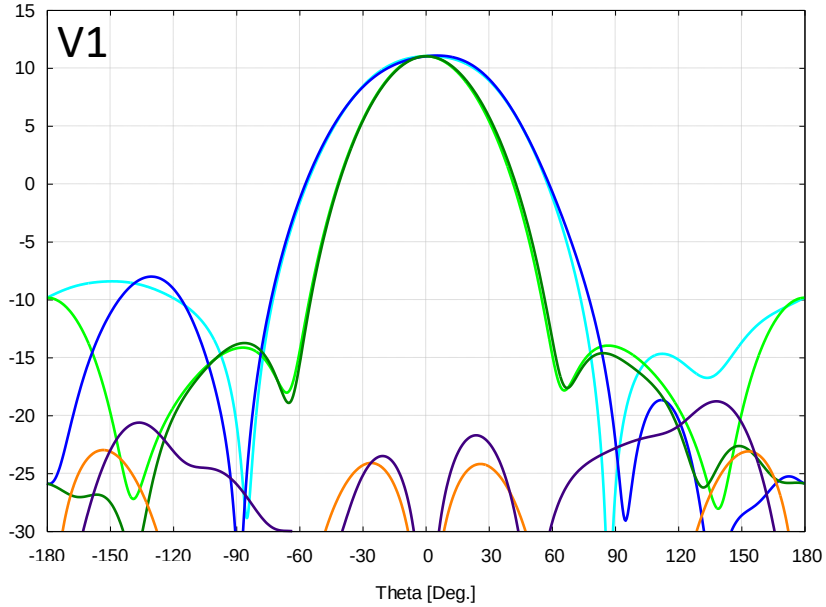
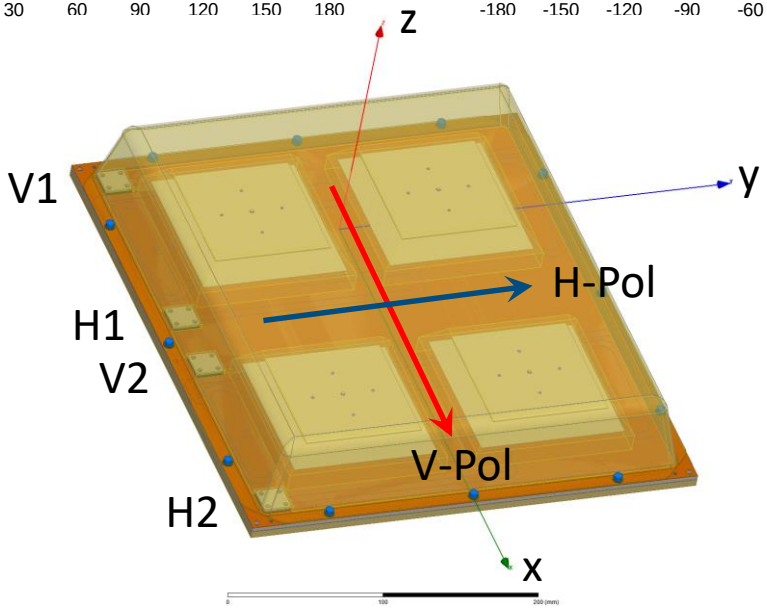
Calculated Vs. Measured Patterns







Calculated Co-pol 00°
Calculated Co-pol 90°
Measured Co-pol 00°
Measured Co-pol 90°
Calculated Cx-pol 00°
Calculated Cx-pol 90°
Measured Cx-pol 00°
Measured Cx-pol 90°

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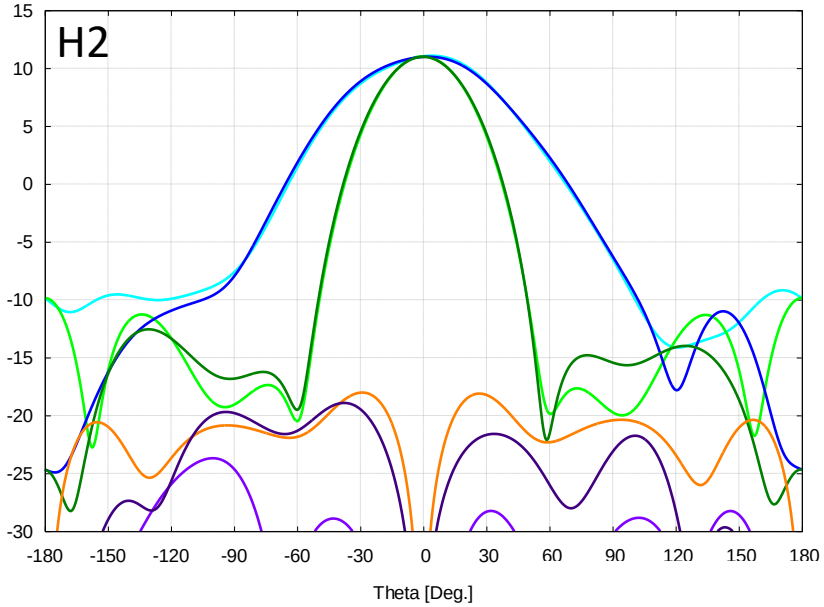
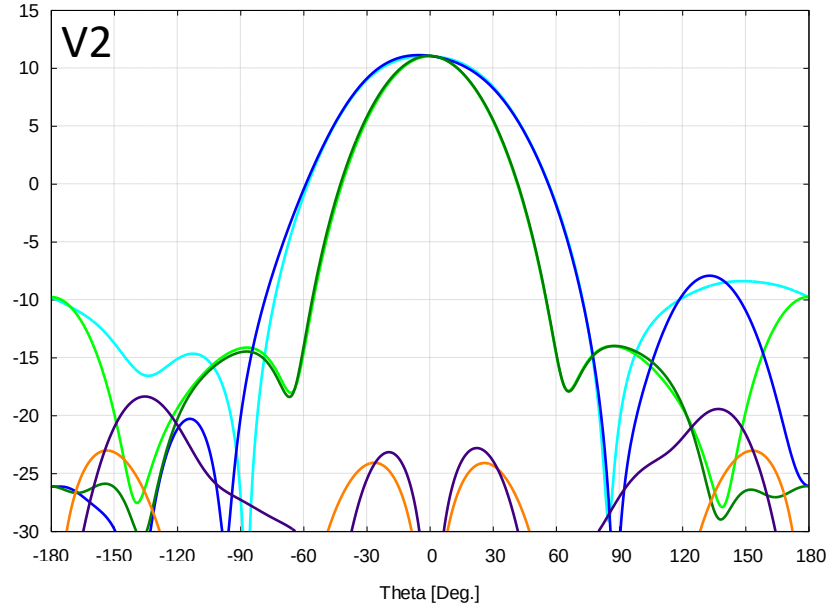
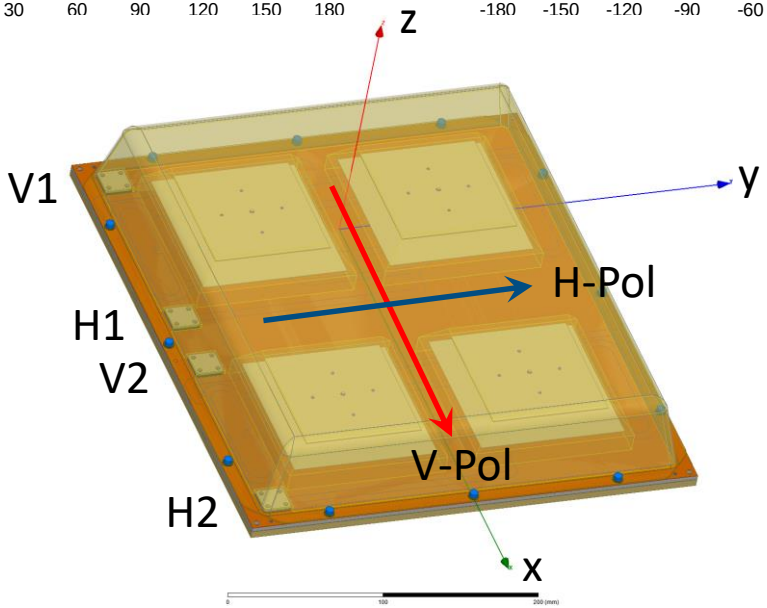
Calculated Vs. Measured Patterns







Calculated Co-pol 00°
Calculated Co-pol 90°
Measured Co-pol 00°
Measured Co-pol 90°
Calculated Cx-pol 00°
Calculated Cx-pol 90°
Measured Cx-pol 00°
Measured Cx-pol 90°

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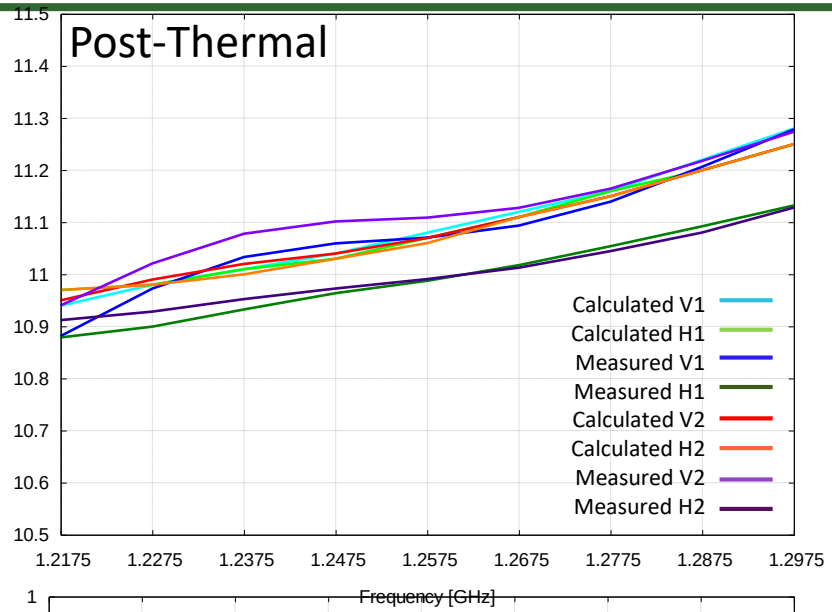
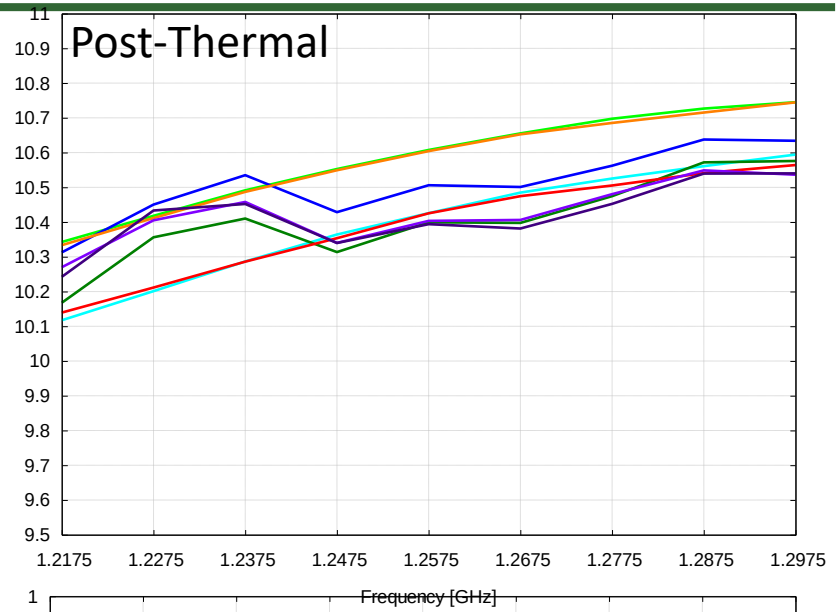
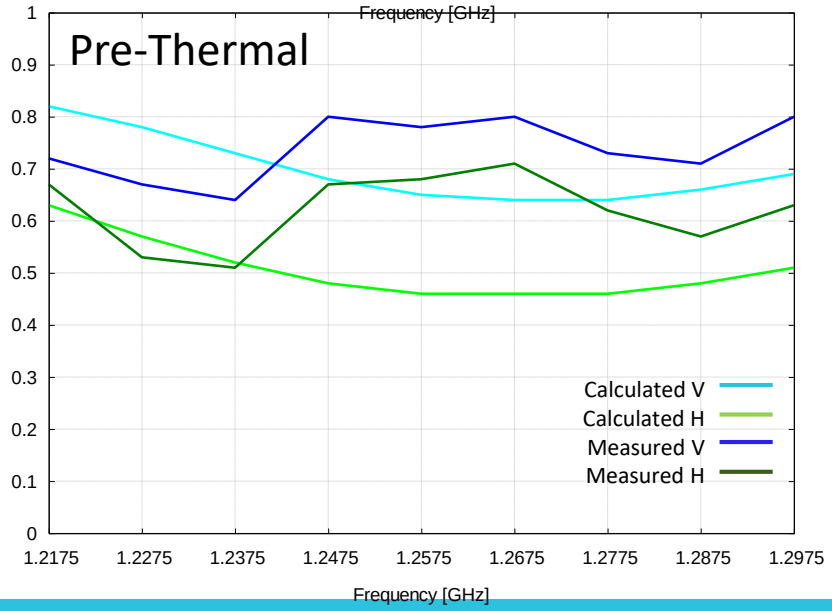
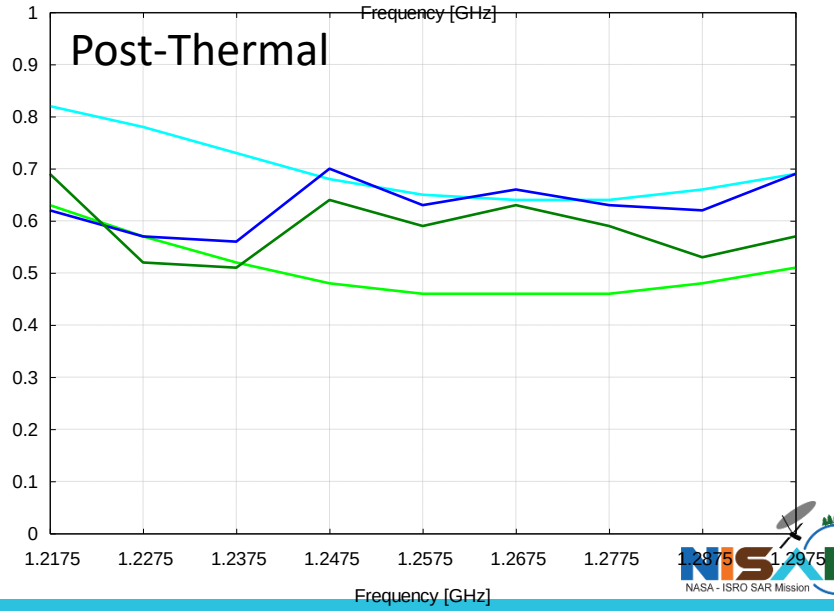
Directivity, Gain & Insertion Loss









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Conclusions

- Based on the above results we are confident we have a good design that will meet all our requirements
- We recently tested a full set of EM tiles in the array configuration
- They are currently being shipped to India for a test along with the S-FRAP at ISRO SAC facility in Ahmedabad

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