



**EuCAP 2018**  
**London, UK**



# **NISAR L-Band and S-Band Instrument Antennas: Compatibility Test and Results**

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Jet Propulsion Laboratory  
California Institute of Technology



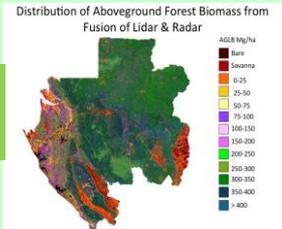
- NISAR Project Overview
- Observatory Configuration
- Deployment Phases
- L-SAR Instrument
- Sweep-SAR Measurement Technique
- Radar Antenna Sub-System
- L-FRAP/LFTA RF Models
- Test Results
  - S-Parameters
  - Radiation Patterns
- Conclusions



NISAR L-Band and S-Band EM Antenna,  
Space Applications Centre (SAC),  
Ahmedabad, India

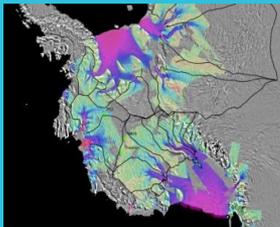
## Mission Science

### Ecosystem Structure



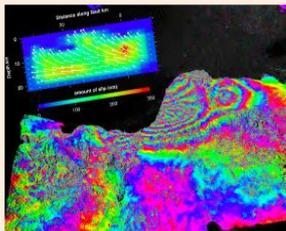
Biomass disturbance; effects of changing climate on habitats and CO<sub>2</sub>

### Cryosphere



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

### Solid Earth

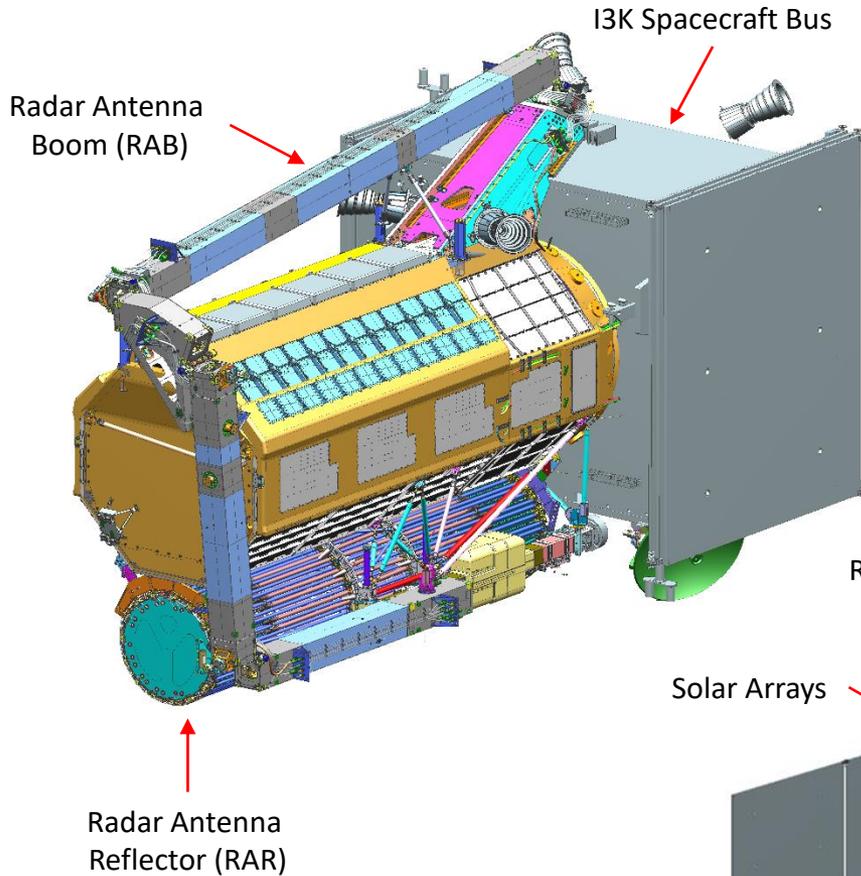


Surface deformation; geo-hazards; water resource management

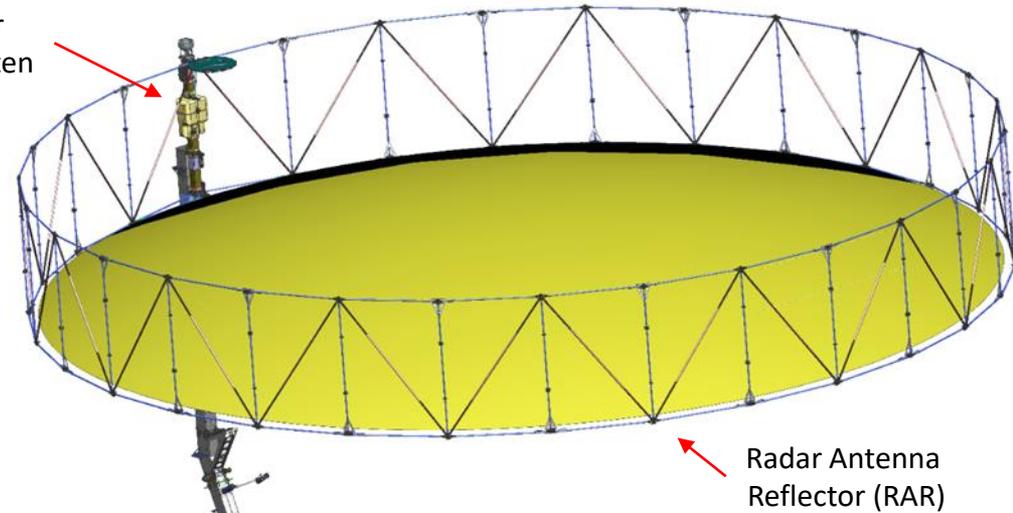
- Directed mission within the Earth Systematic Missions Program under NASA Earth Science Division
- Major international partner: Indian Space Research Organization (ISRO) who is supplying the launch vehicle, S/C, and S-band radar
- Baseline launch date: Not earlier than December 2020
- Dual frequency 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  $\pm 250$  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

# Observatory Configuration

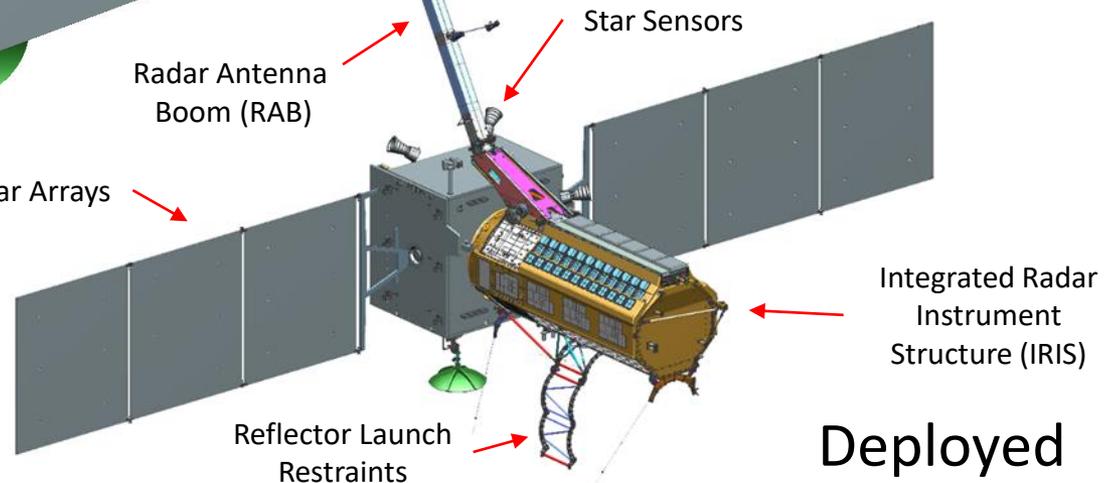
Stowed



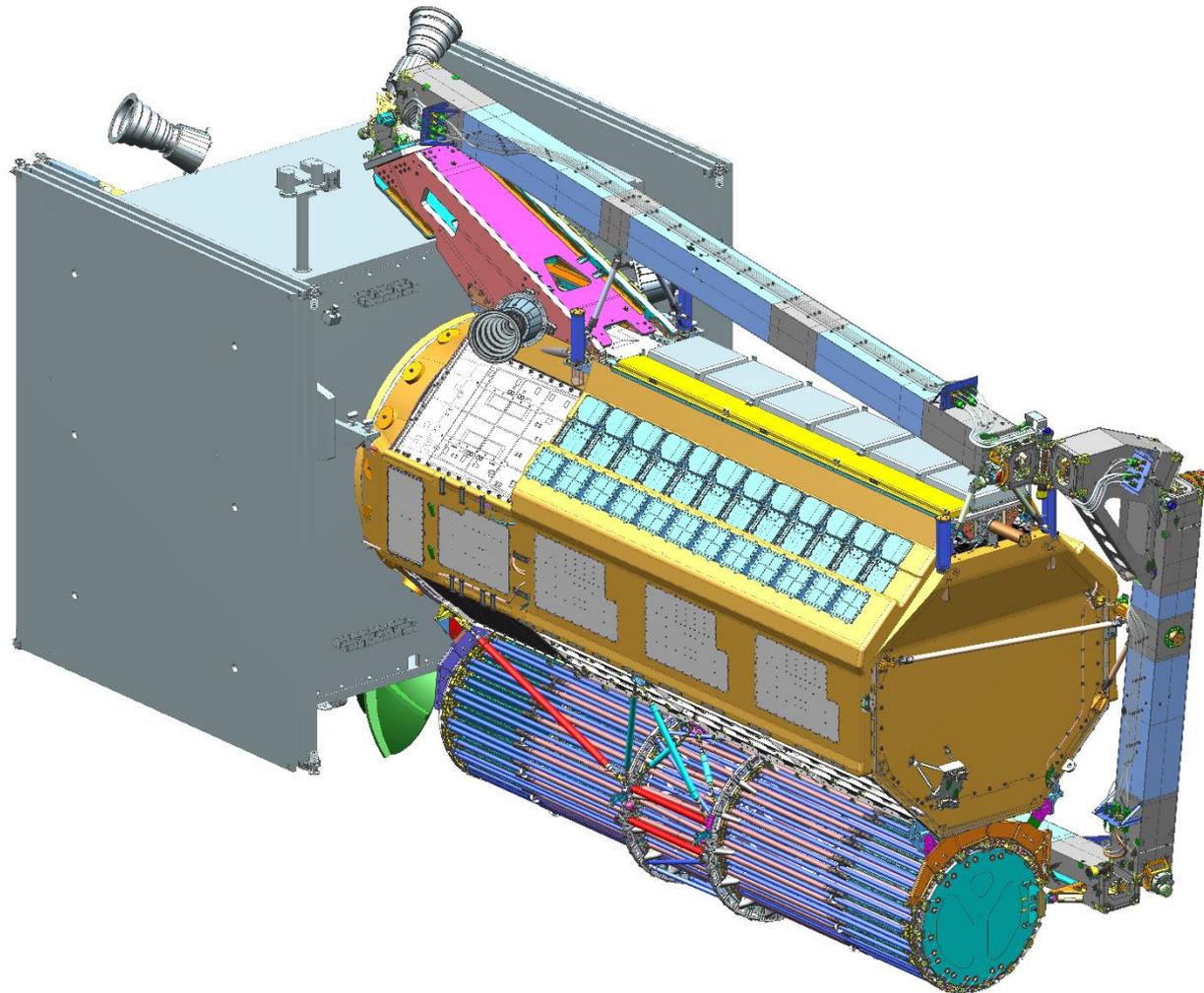
Reflector Prime Batten

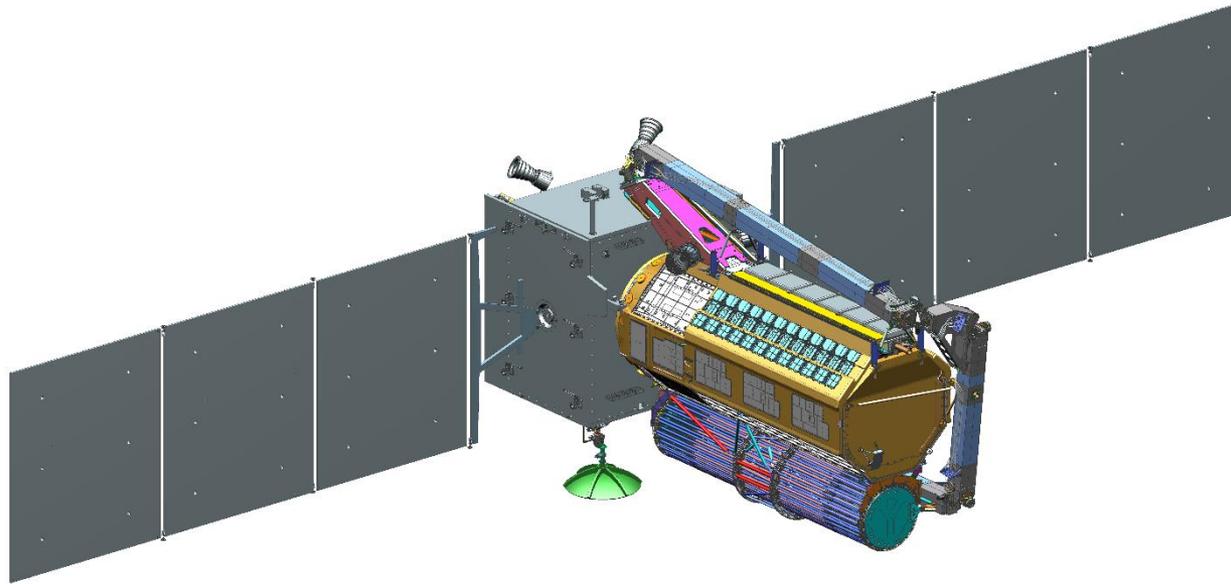


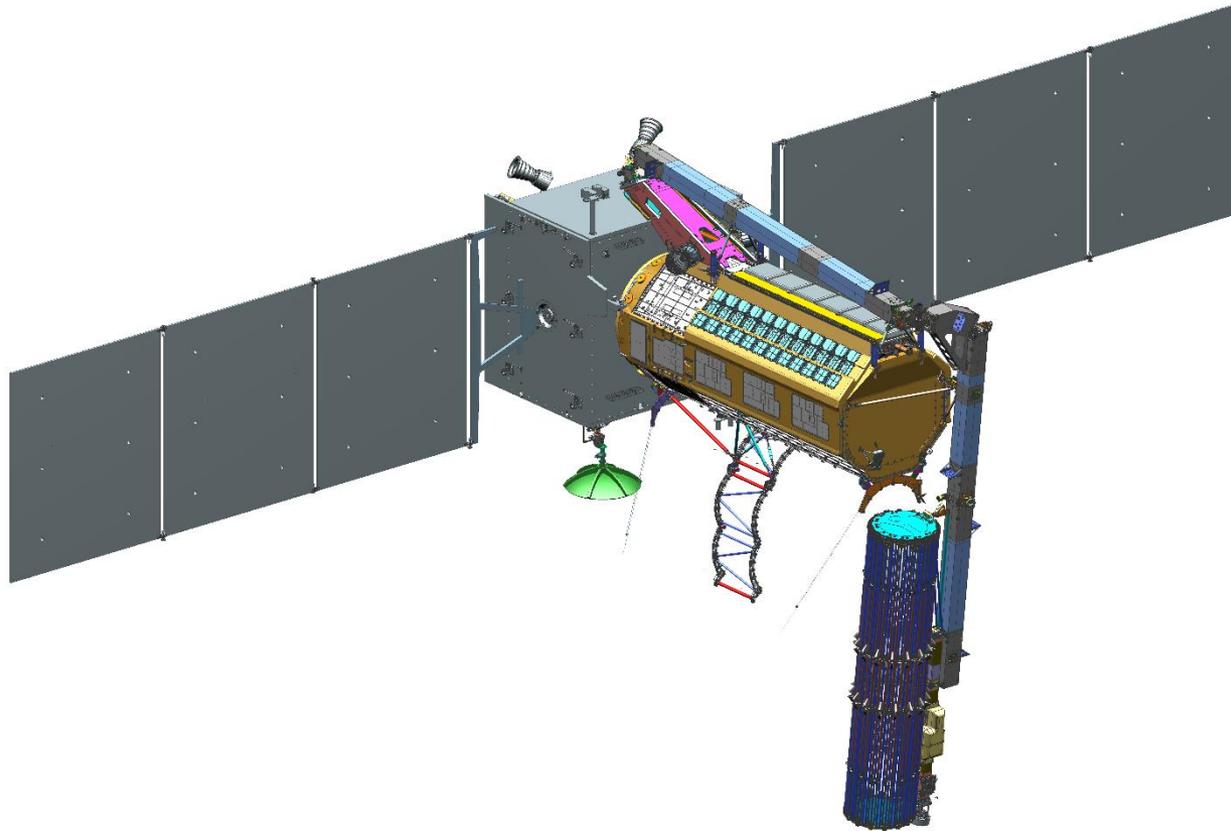
Solar Arrays

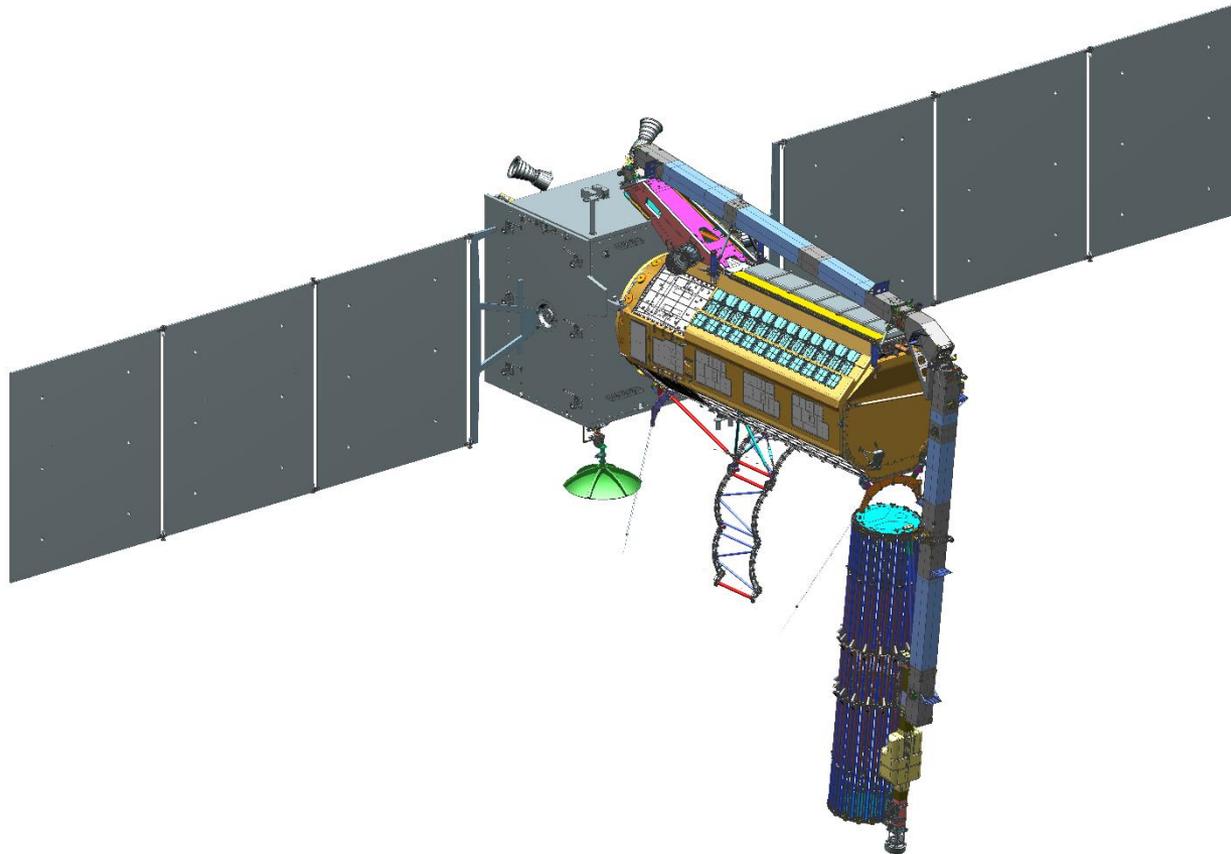


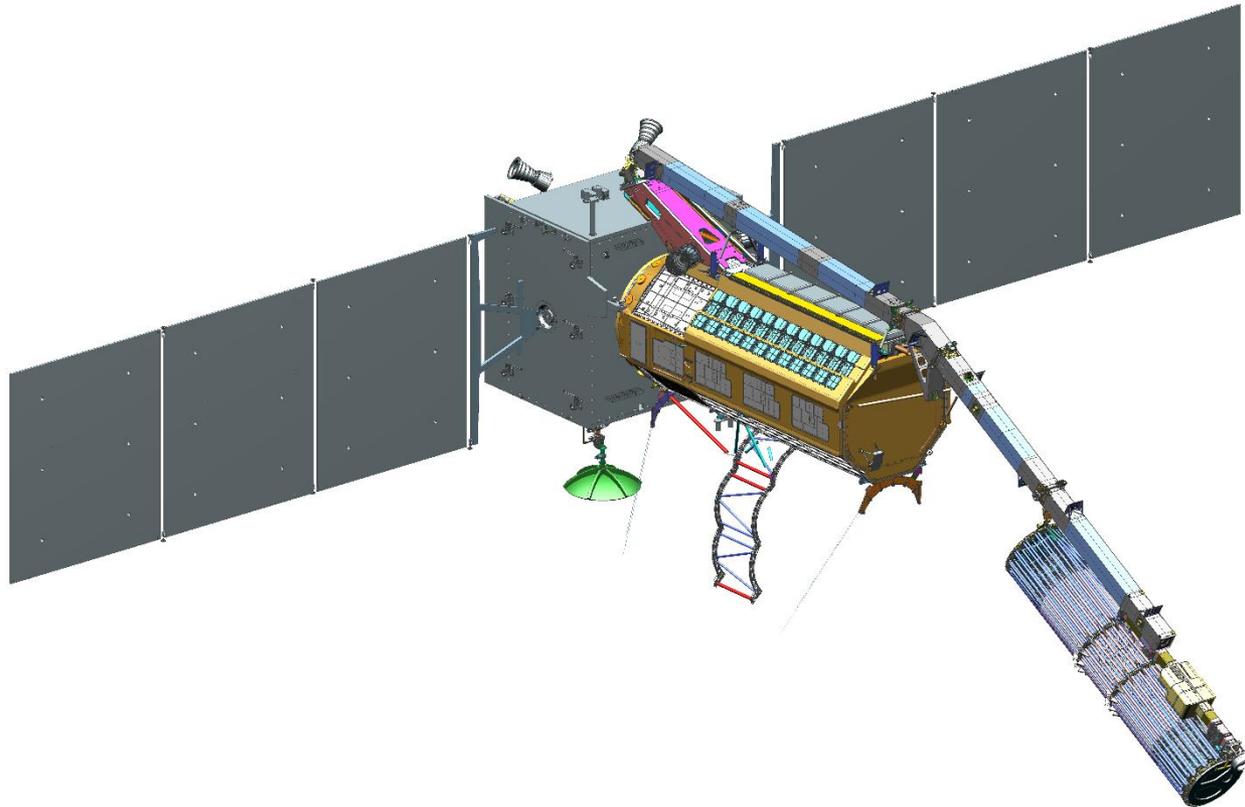
# Deployment Phases, 1/7

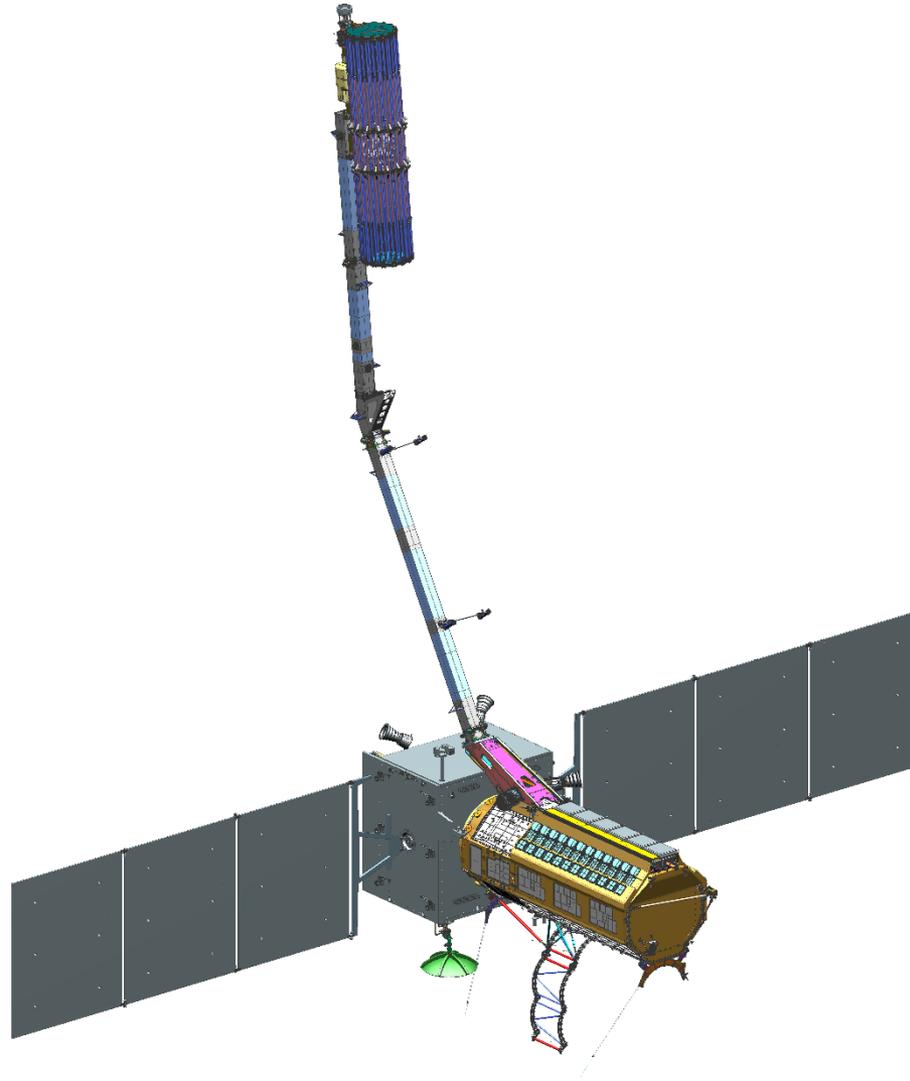


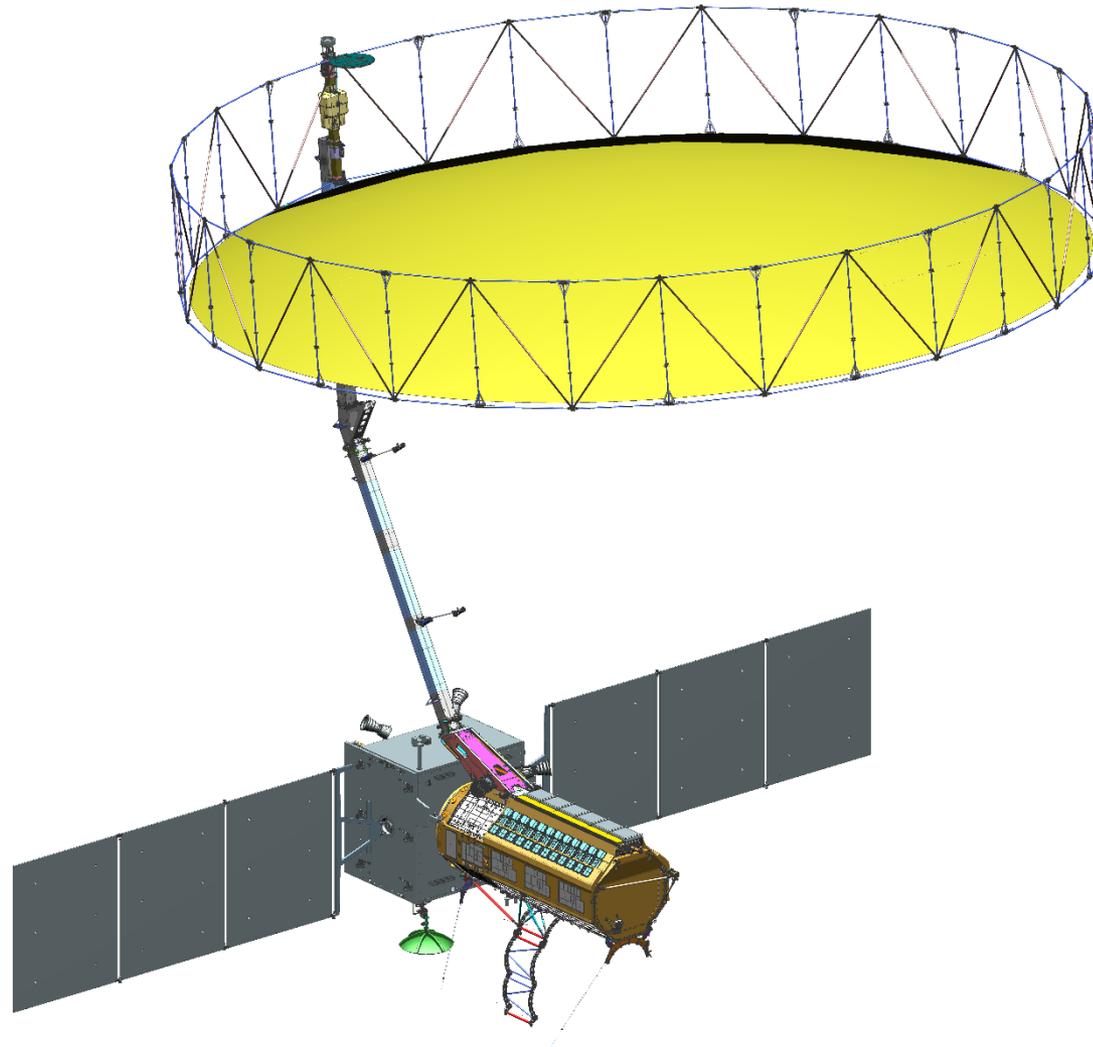


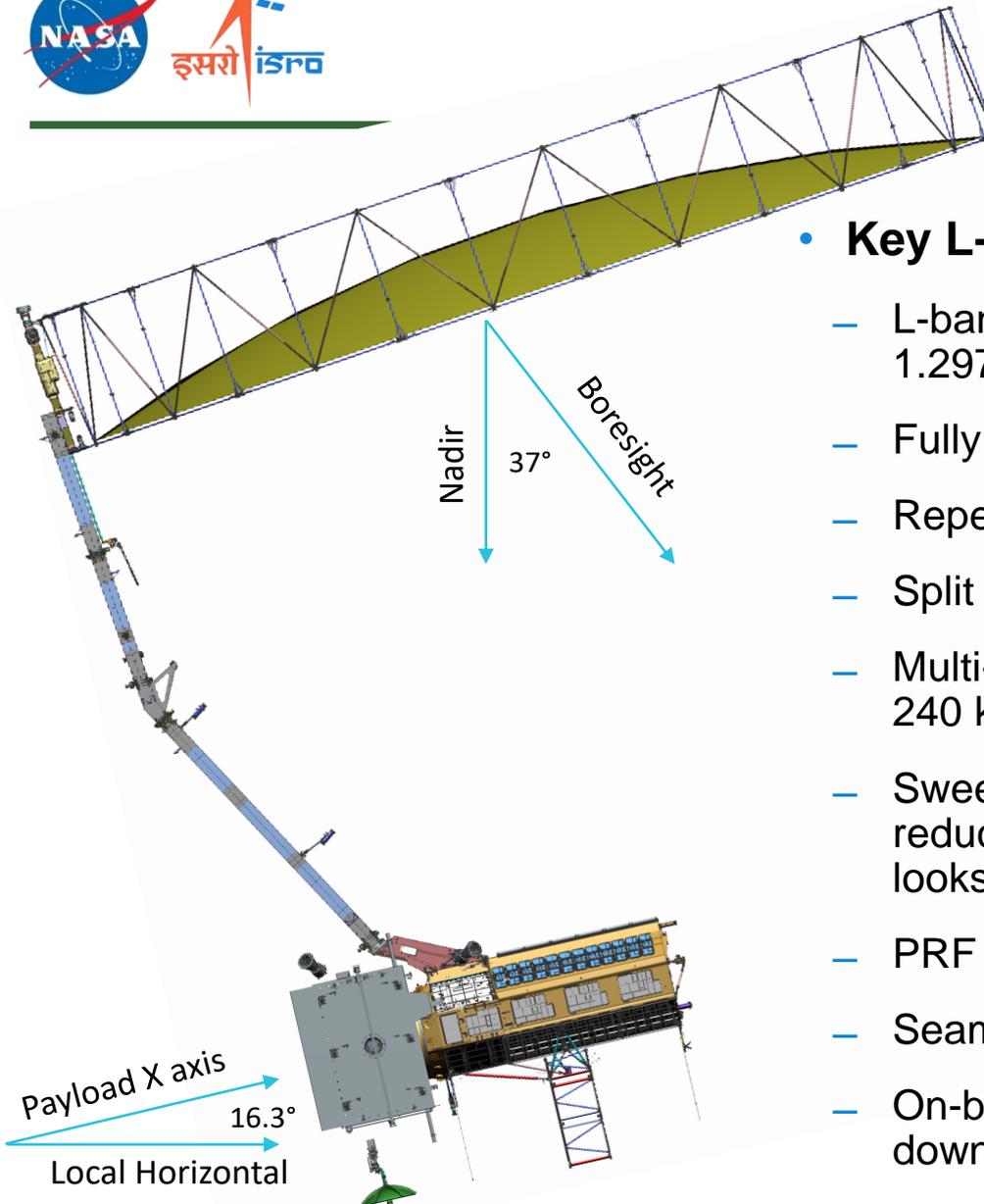












- **Key L-SAR Instrument Features:**

- L-band Synthetic Aperture Radar (1.2175 – 1.2975 GHz)
- 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

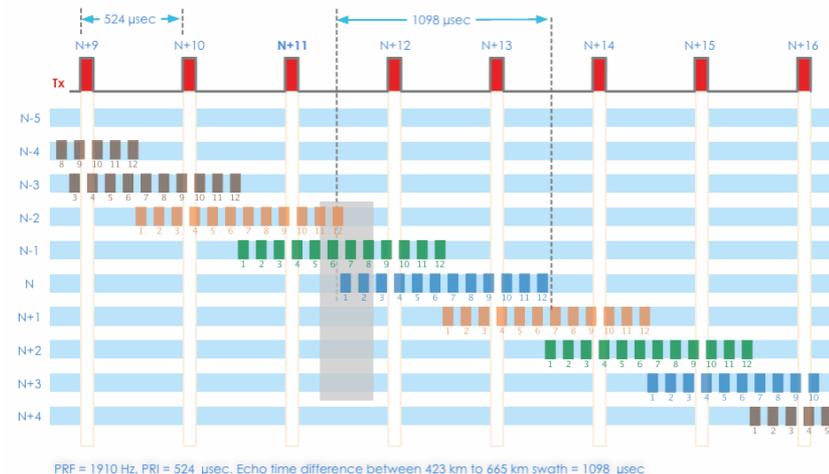
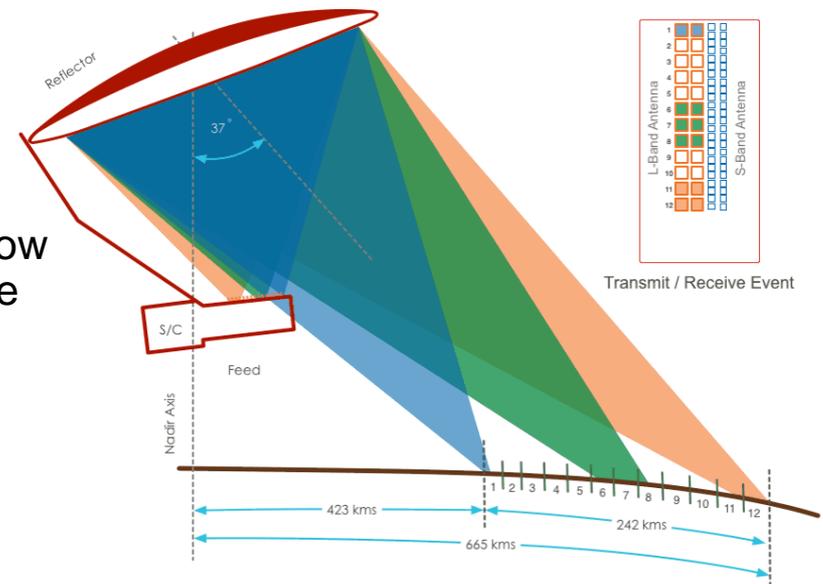
# Sweep-SAR Measurement Technique

## • Sweep-SAR 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)

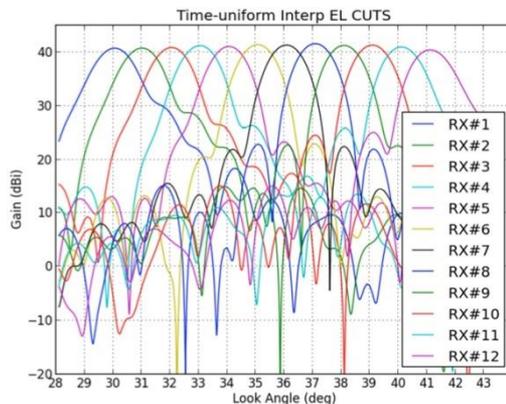
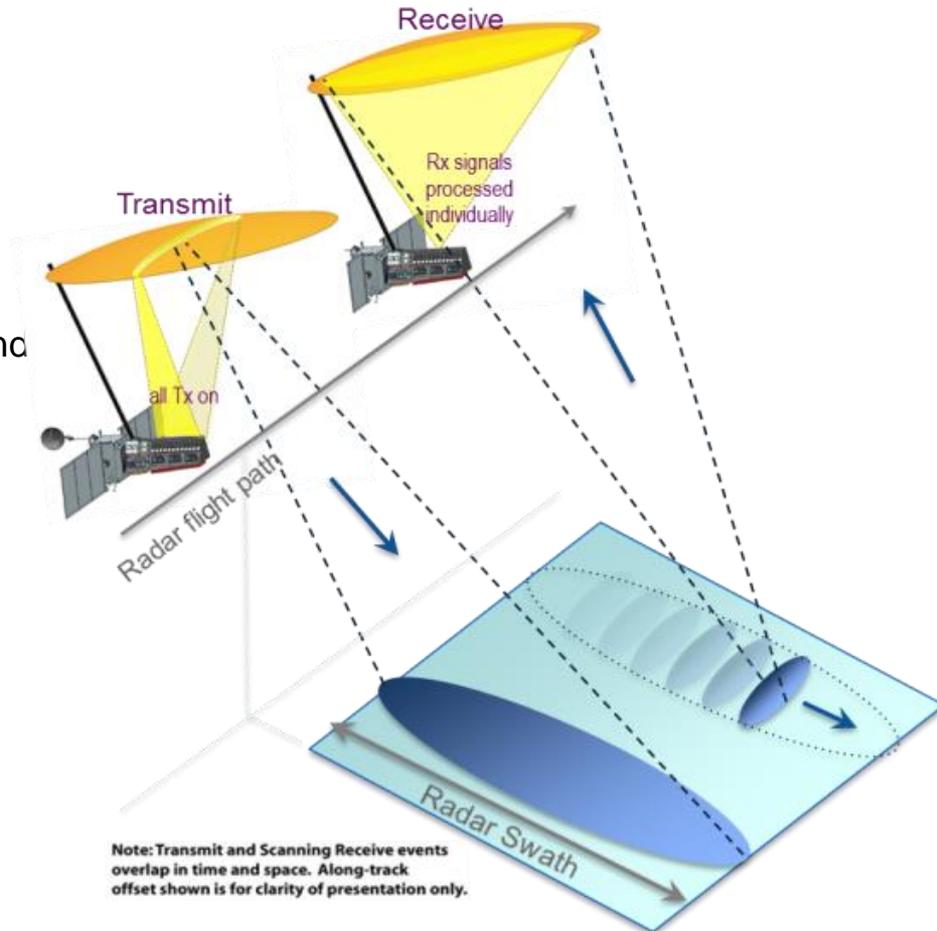
## • Consequences

- 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



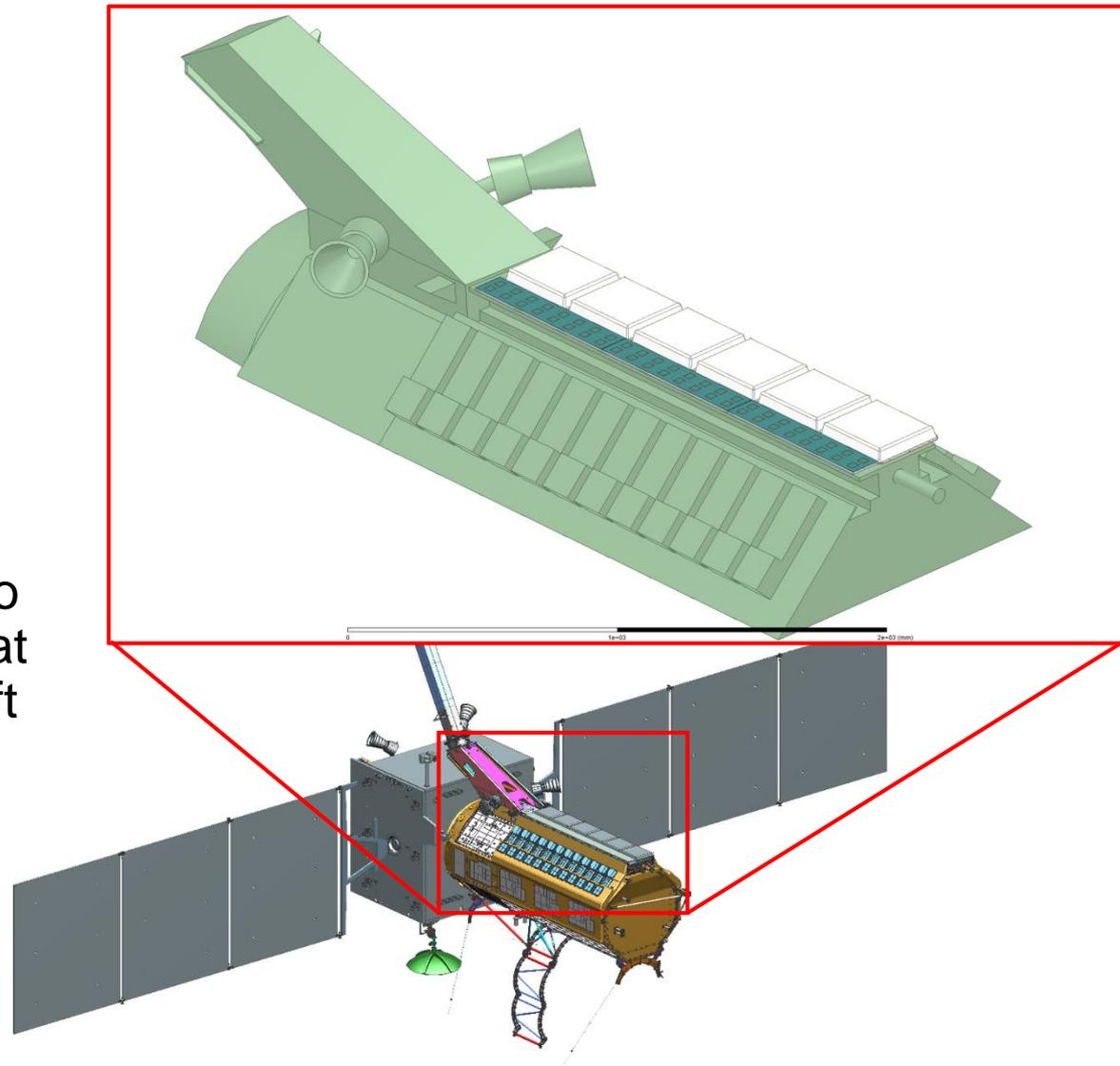
# Radar Antenna Sub-System

- **Reflector:** 12m deployable mesh reflector by Northrop-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
- **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



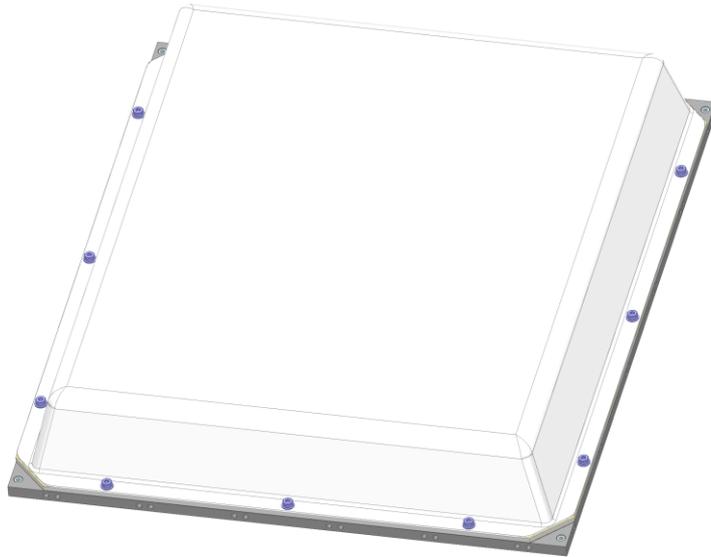
# L-Band Feed RF Aperture (L-FRAP) RF Model

- Latest RF model includes:
  - Complete L-FRAP
  - Simplified version of:
    - S-FRAP
    - RAS
    - Top 3 panels of RIS
    - Boom base
    - Star Sensors
- This RF model is used to generate radiation patterns to feed the GRASP analysis that includes the entire spacecraft
- Each LFTA is 358 x 310mm
- L-FRAP is 2,158 x 310mm

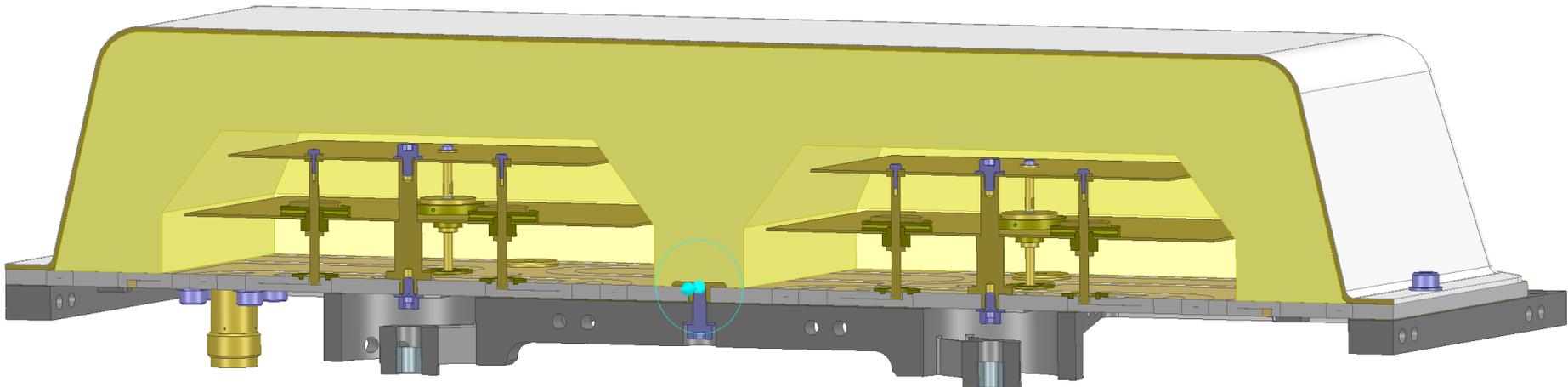
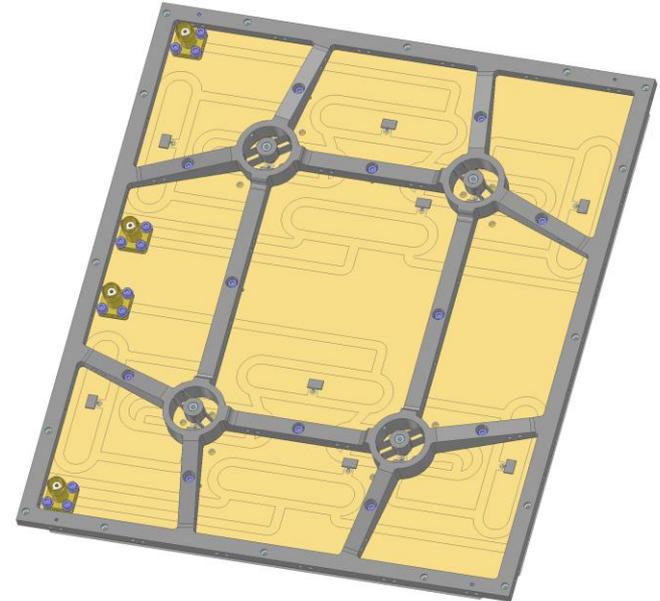


# L-Band Feed Tile Assembly (LFTA) RF Model

Top

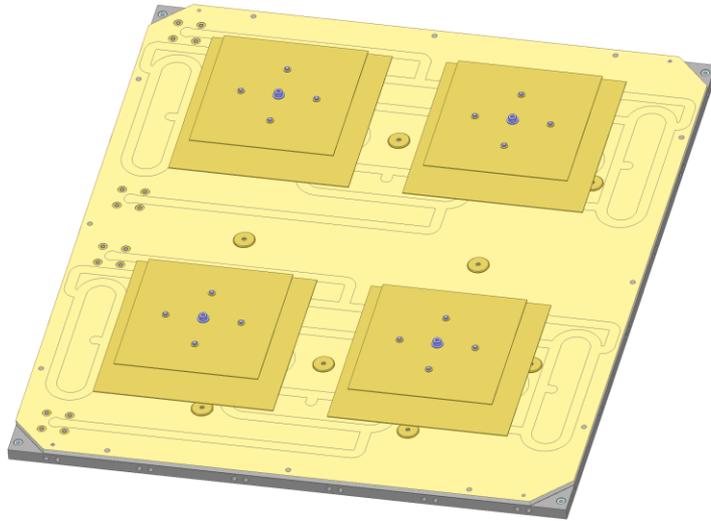


Bottom

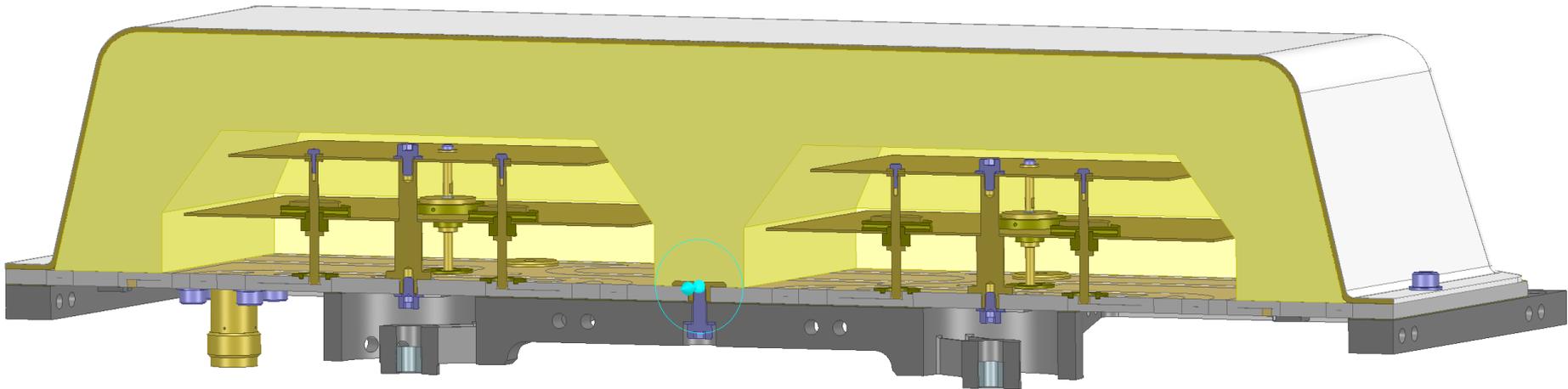
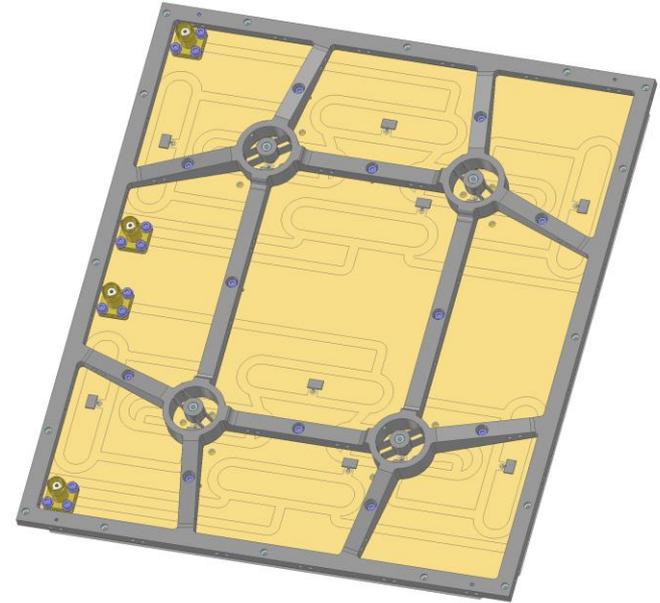


# L-Band Feed Tile Assembly (LFTA) RF Model

Top



Bottom



SN08

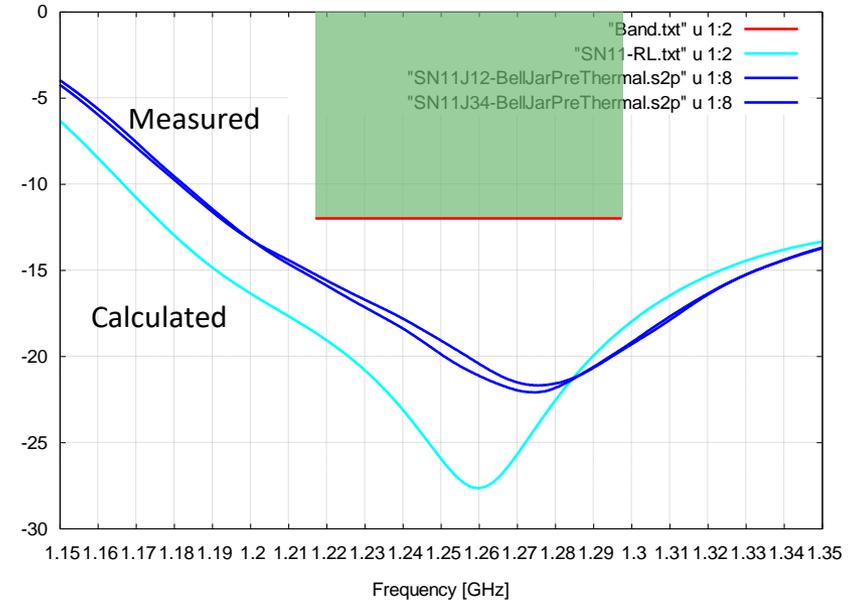
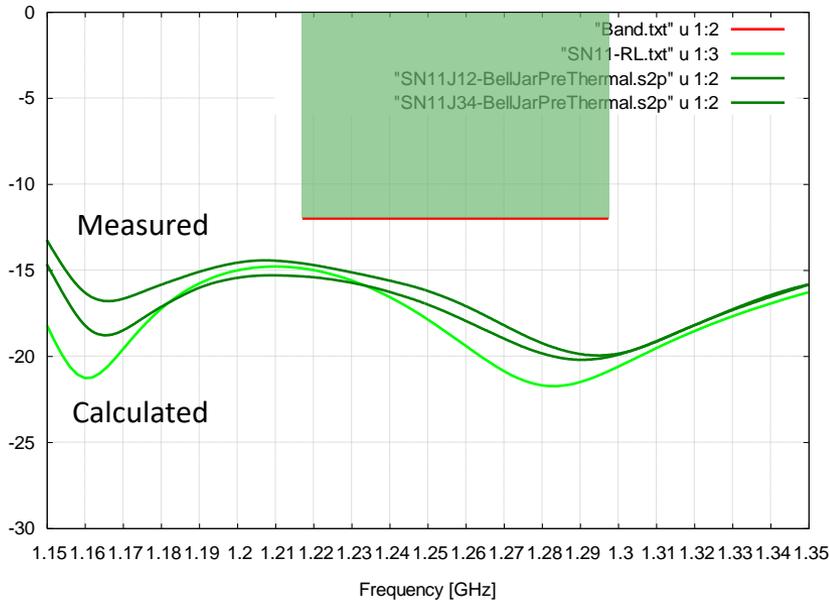
SN11



V-Pol



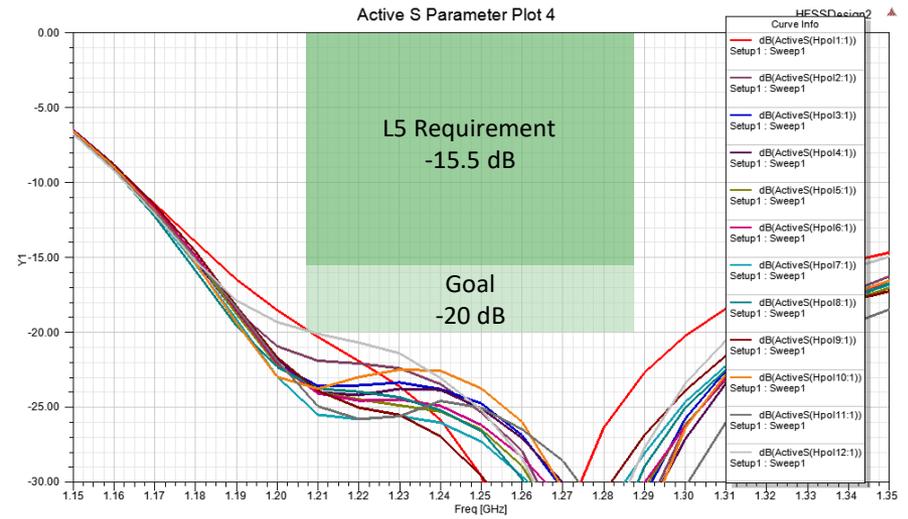
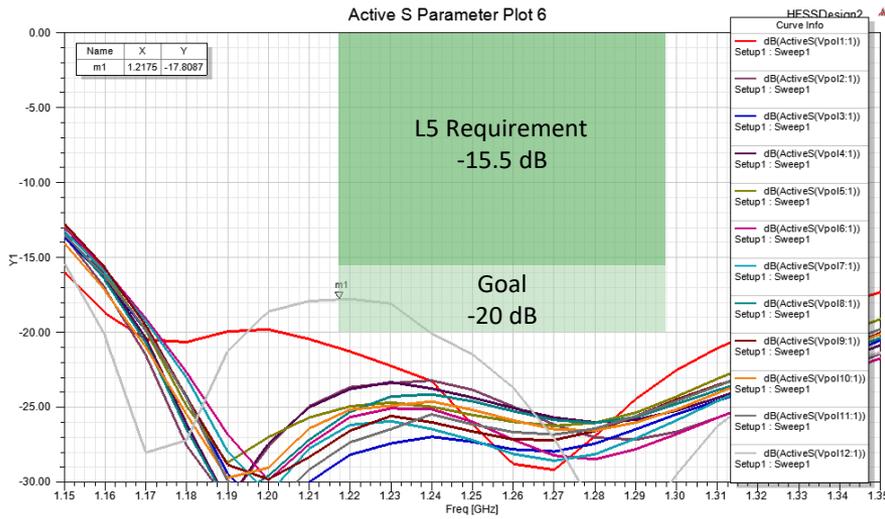
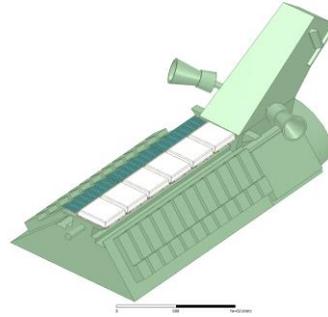
H-Pol



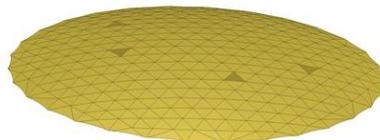
# Full Array Active Return Loss During TX

V-Pol

H-Pol

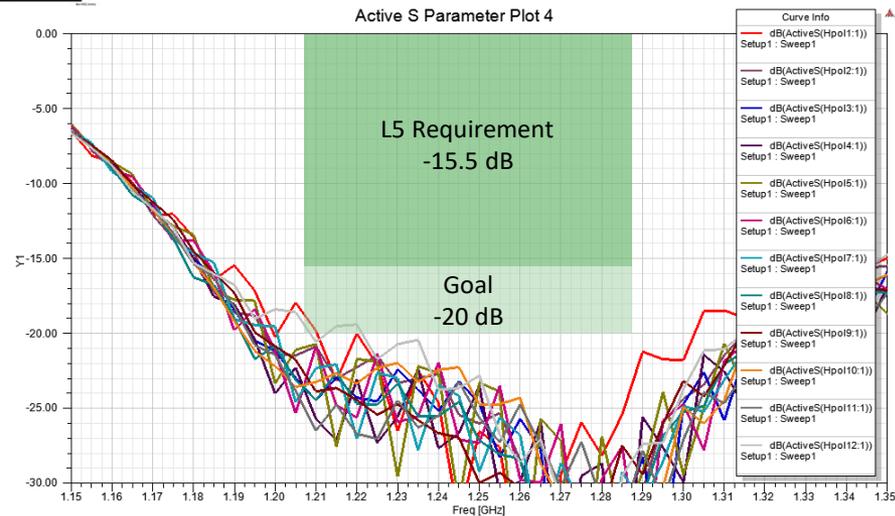
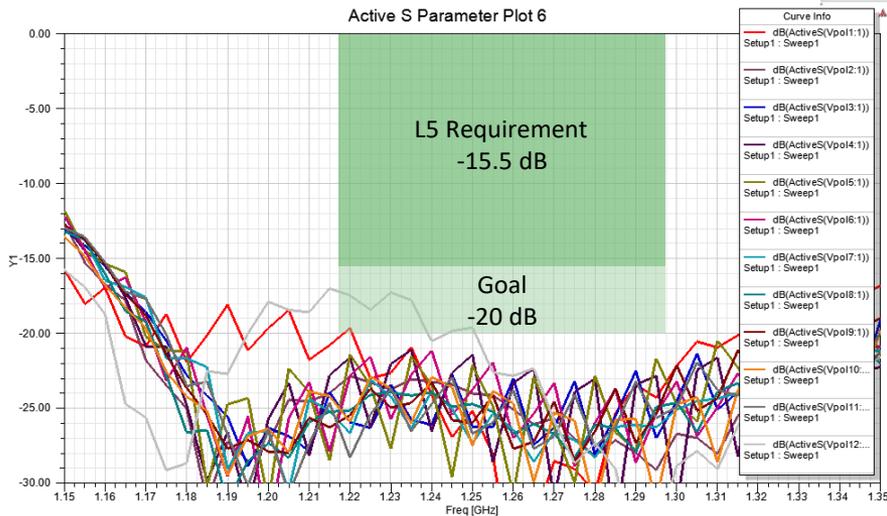


# Full Array Active Return Loss During TX, Including The Reflector



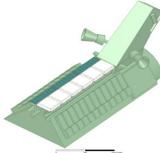
V-Pol

H-Pol



The presence of the reflector adds a strong ripple to all return loss curves, but it doesn't change the general behavior. V12 remains the worst case port

# Active Vs. Passive Return Loss



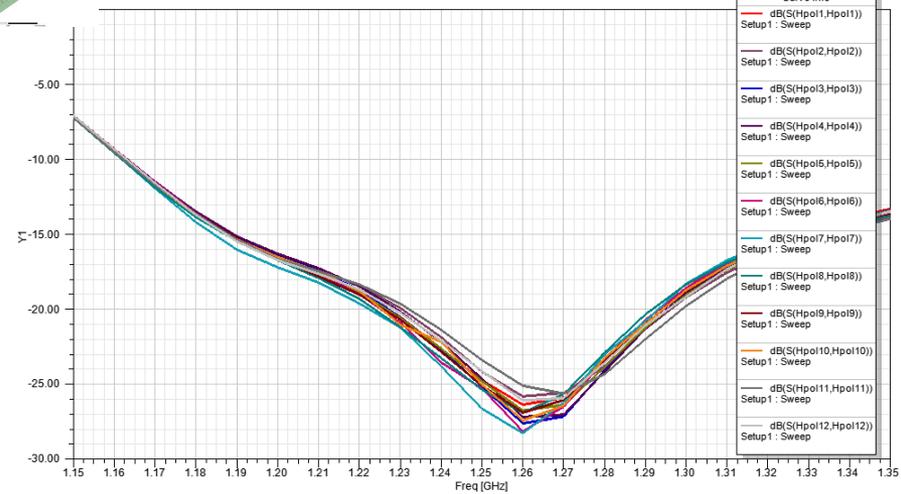
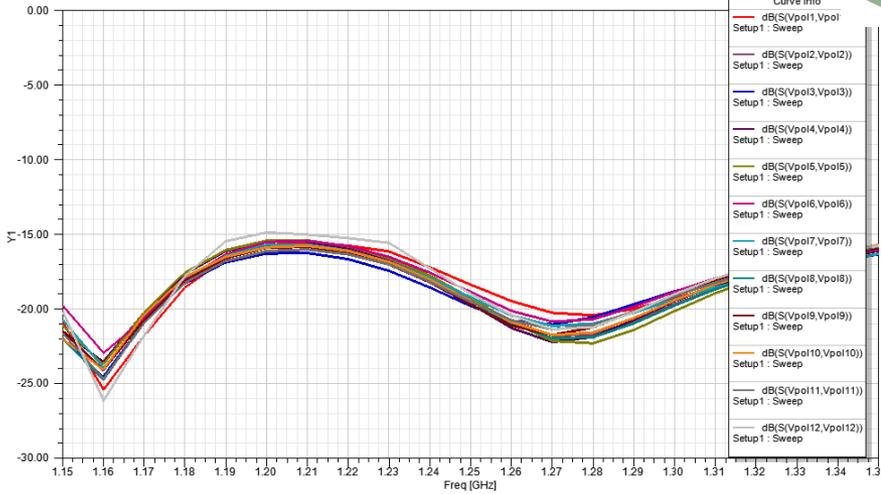
V-Pol

H-Pol

S Parameter Plot 2

S Parameter Plot 1

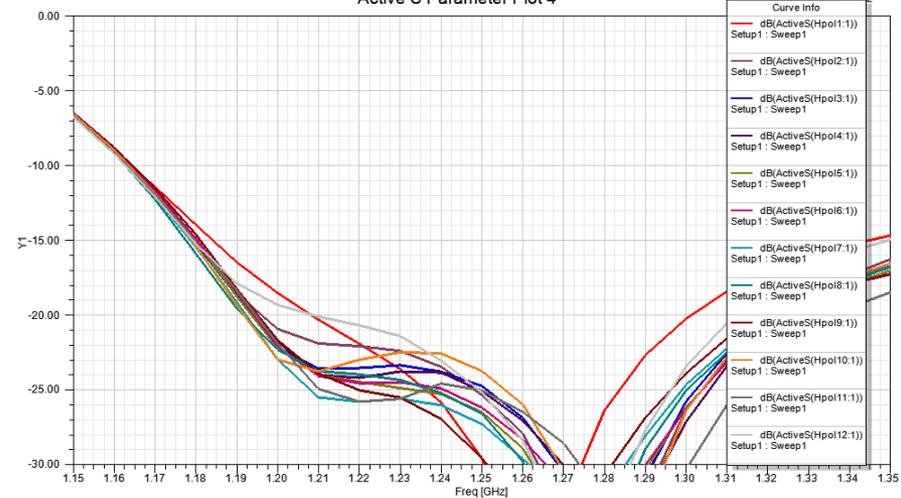
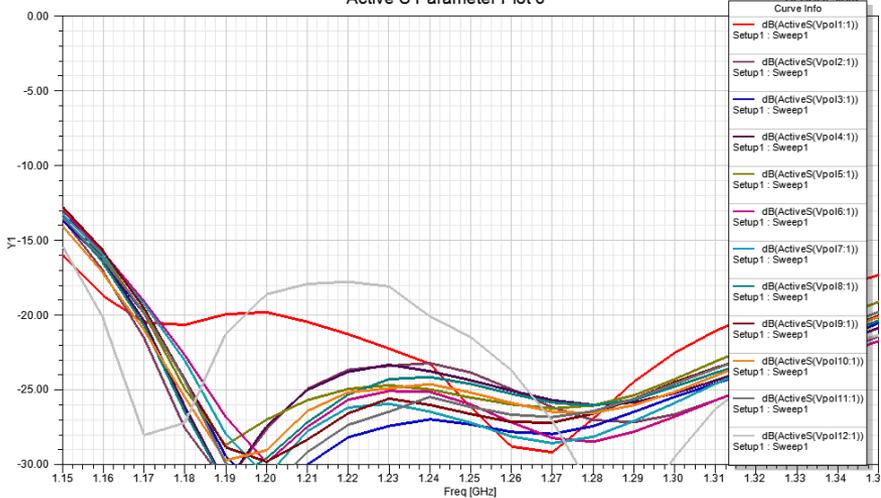
Passive



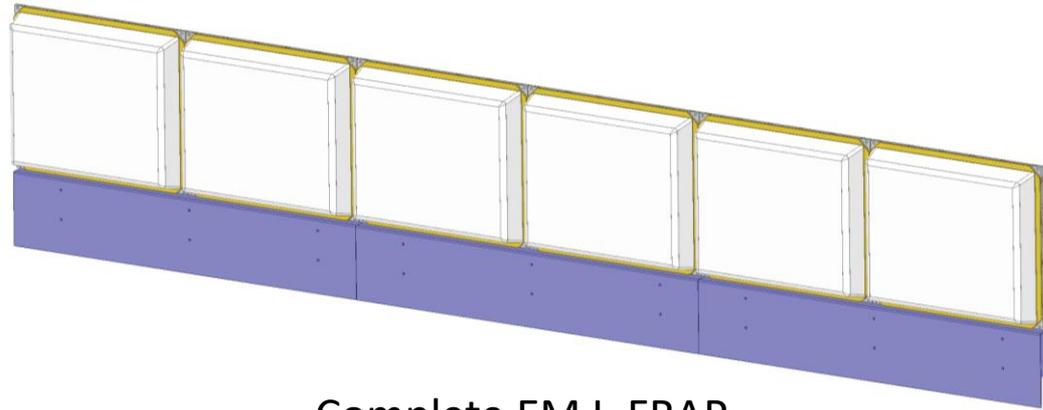
Active

Active S Parameter Plot 6

Active S Parameter Plot 4



# EM L-FRAP Performance Verification



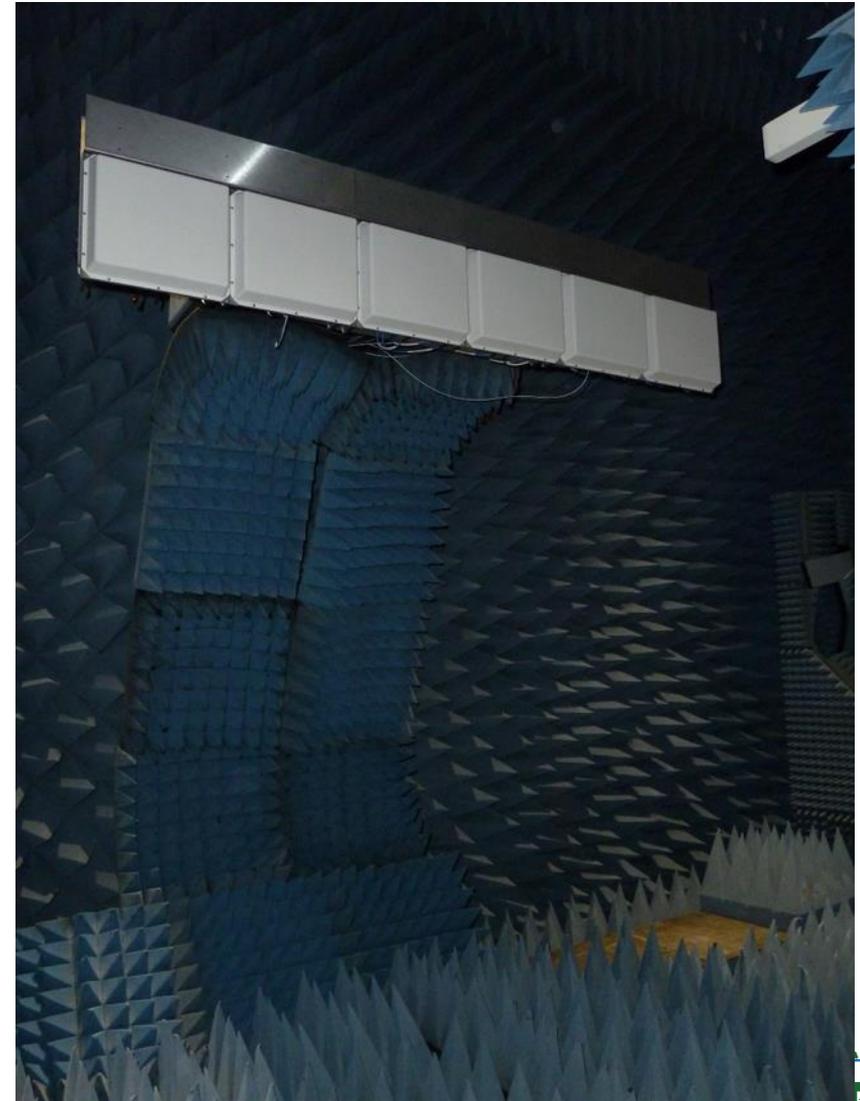
Complete EM L-FRAP



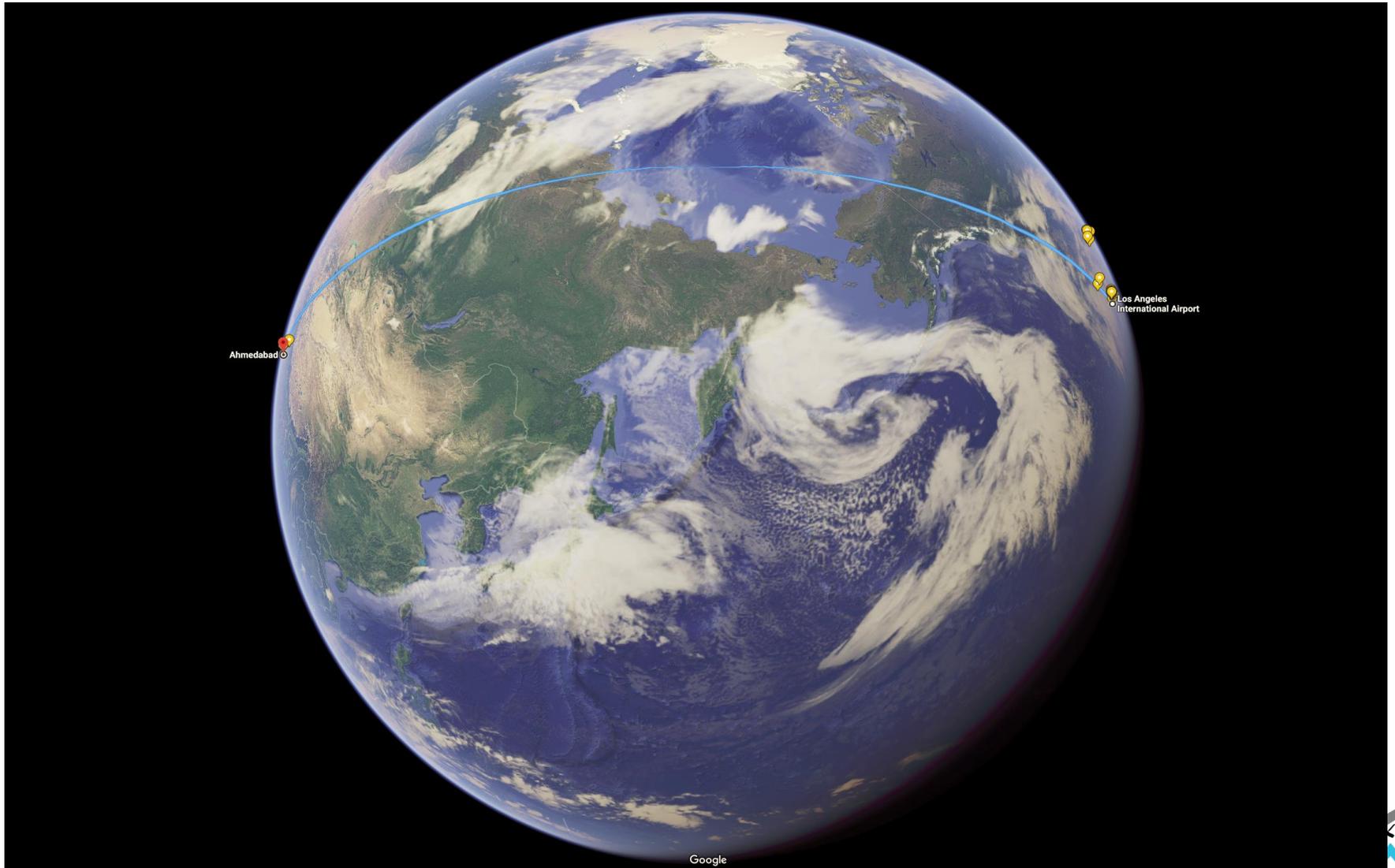
## EM L-FRAP Being Tested at JPL

JPL RF tests included:

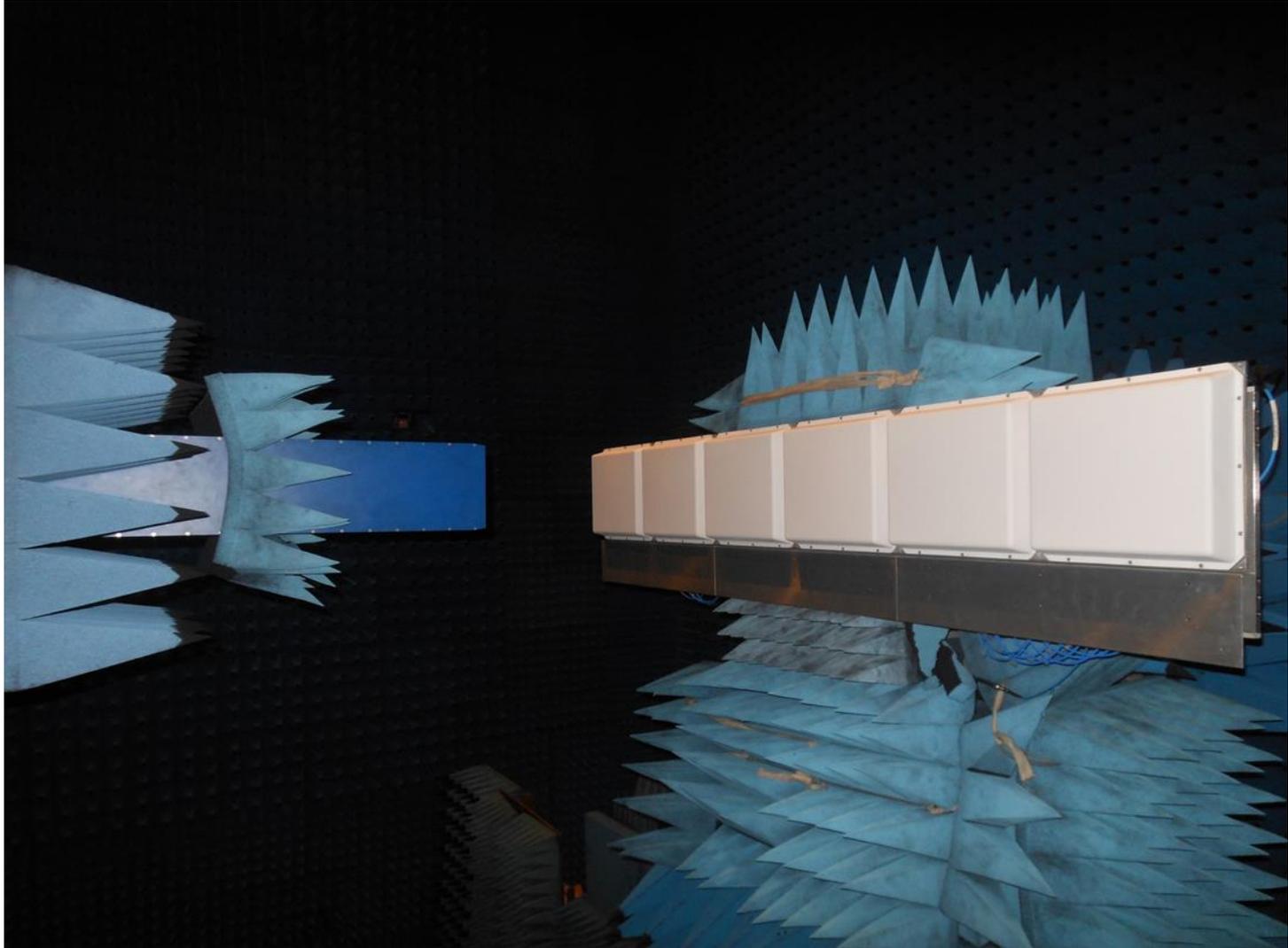
- Single LFTAs (8 Units)
  - S-parameters
  - Radiation Patterns
- Complete L-FRAP (6 Units)
  - S-parameters
  - Radiation Patterns
  - Gain



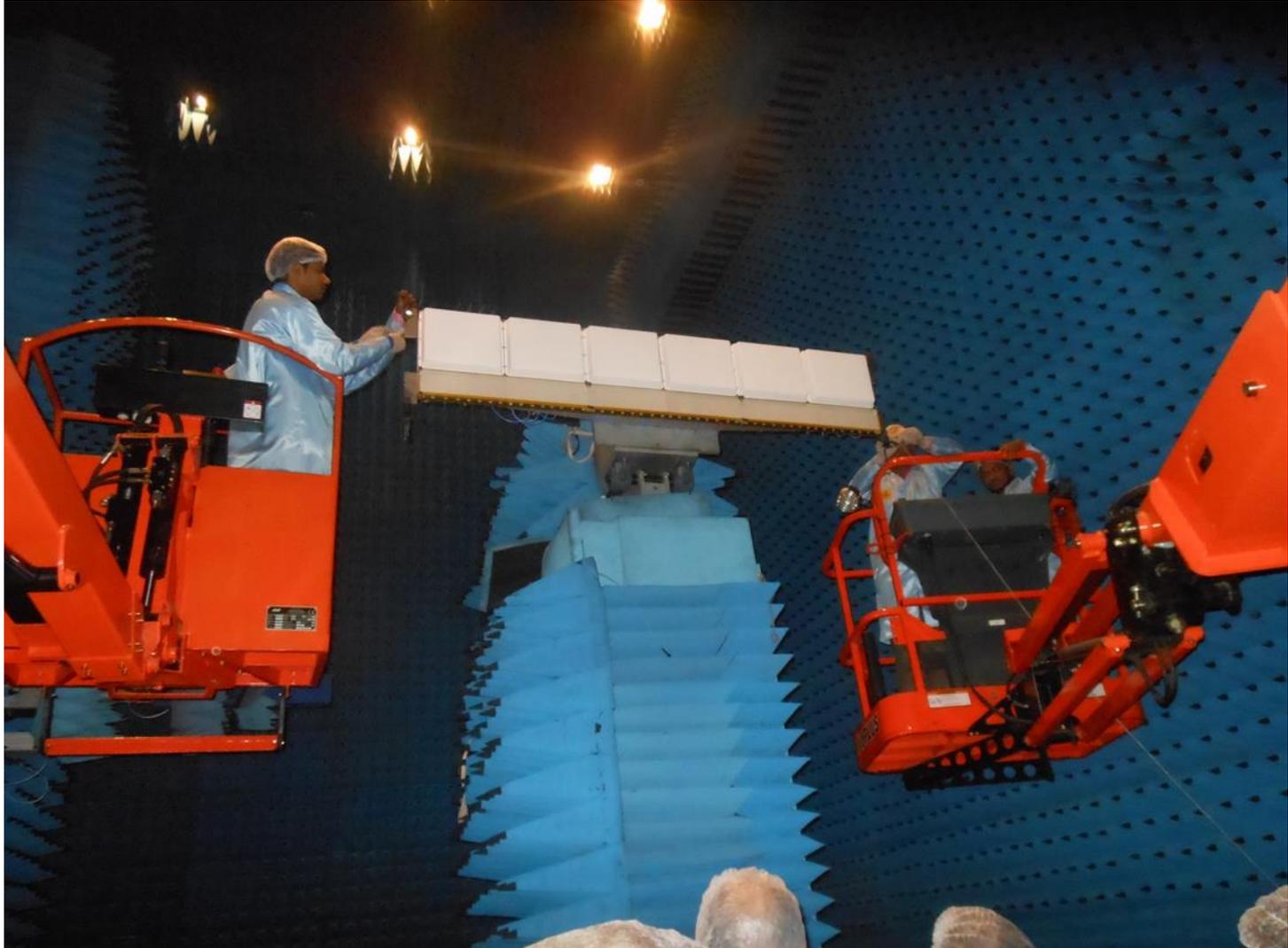
# We Shipped the EM L-FRAP to Ahmedabad



# EM L-FRAP Being Tested at SAC in L-Band Only Configuration

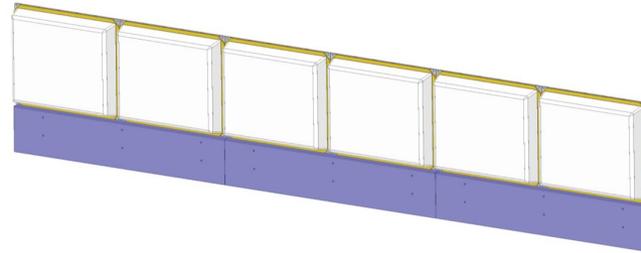


# EM L-FRAP Being Tested at SAC with S-FRAP

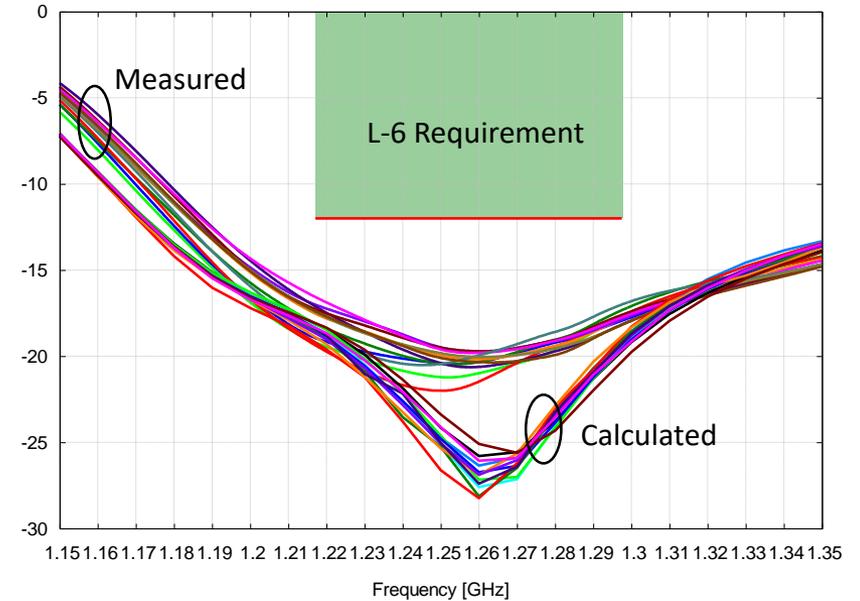
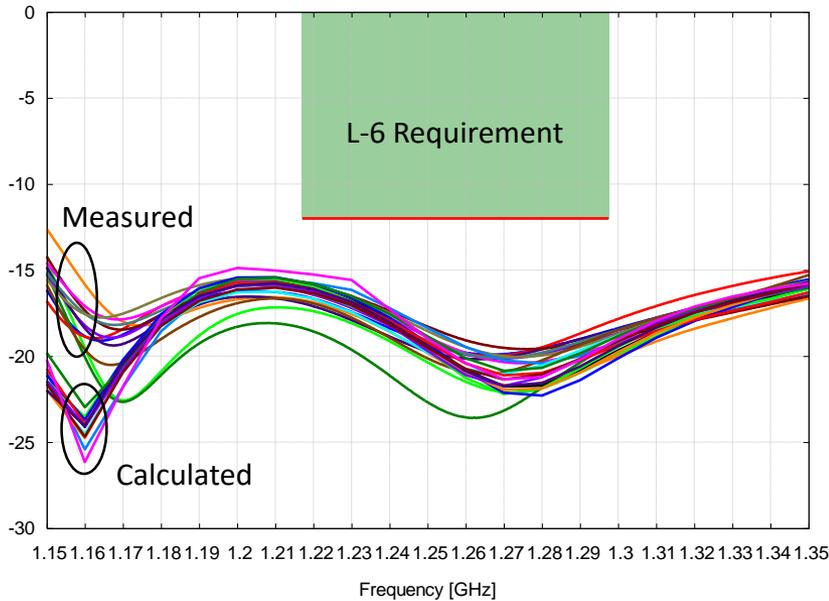


# L-FRAP Passive Return Loss Measured at SAC

V-Pol



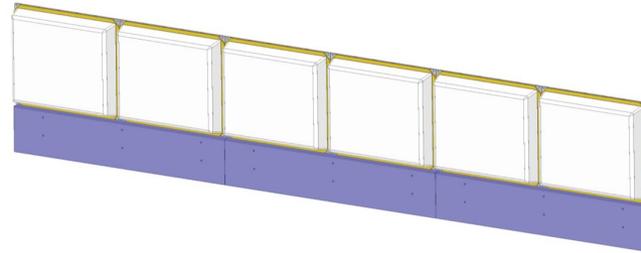
H-Pol



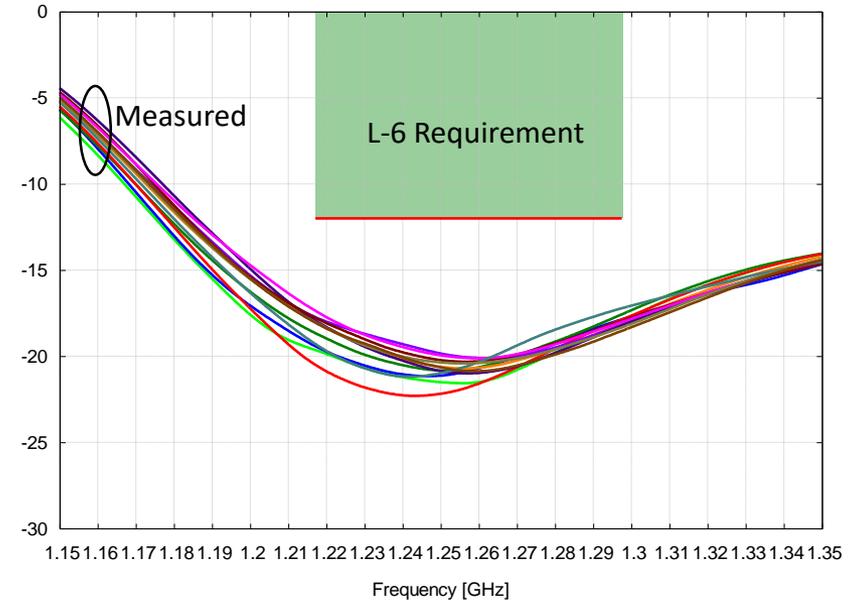
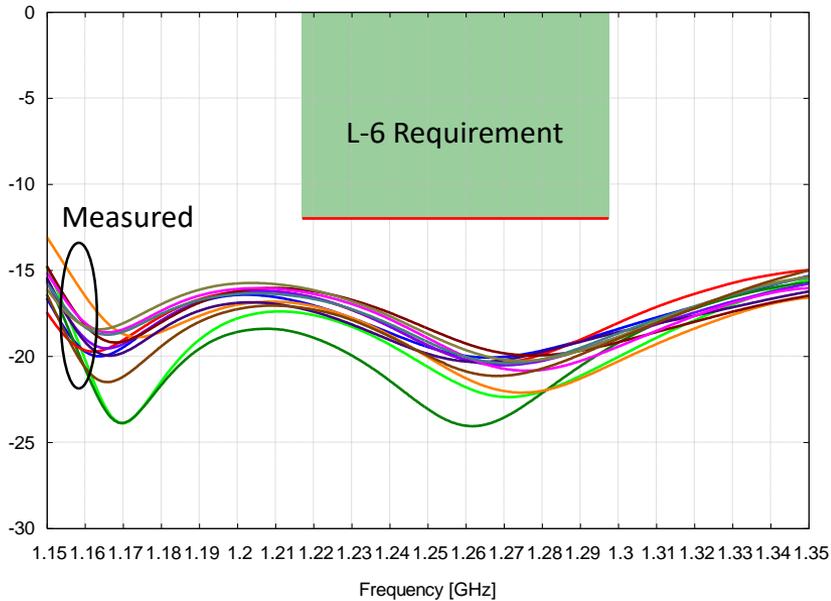
With S-FRAP Mock-up

# L-FRAP Passive Return Loss Measured at SAC

V-Pol

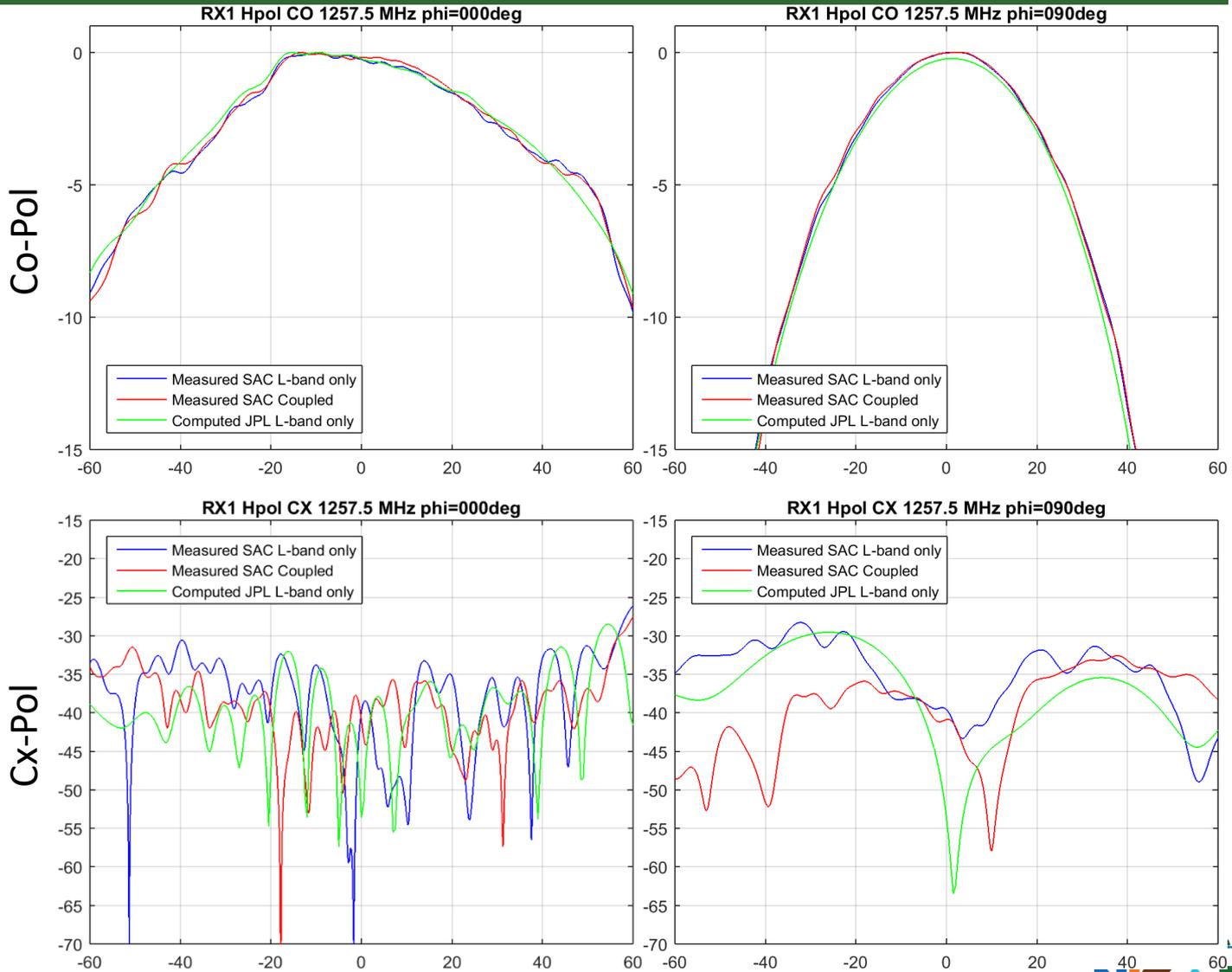
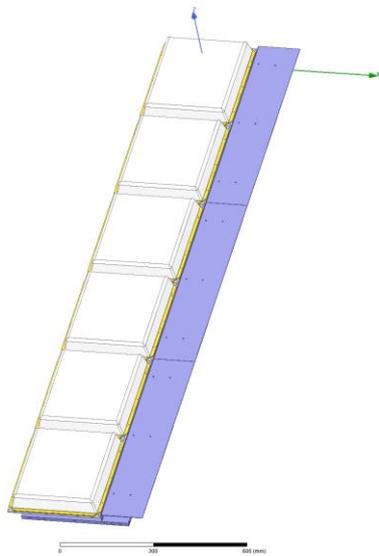


H-Pol

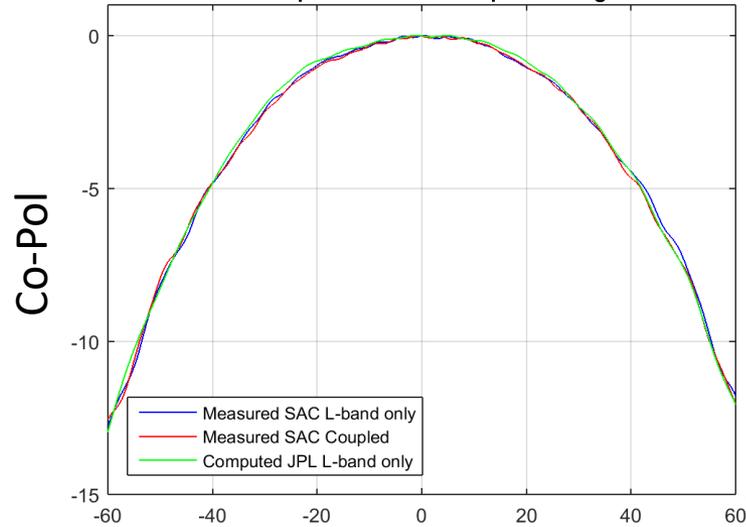


With Actual S-FRAP

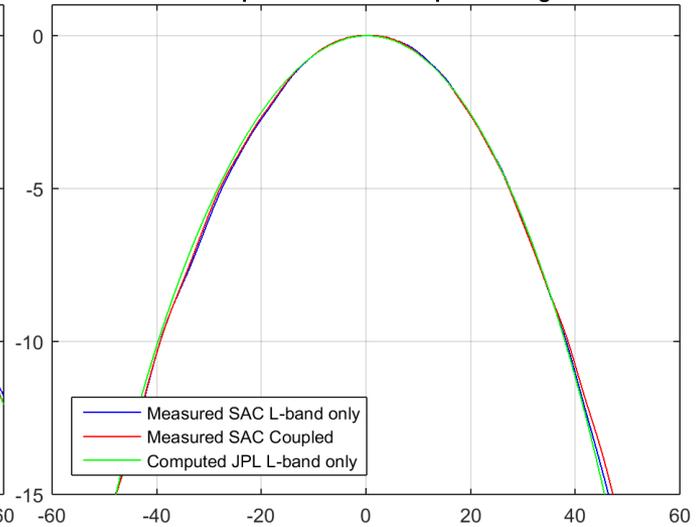
# RX1 Hpol @ 1.2575 GHz



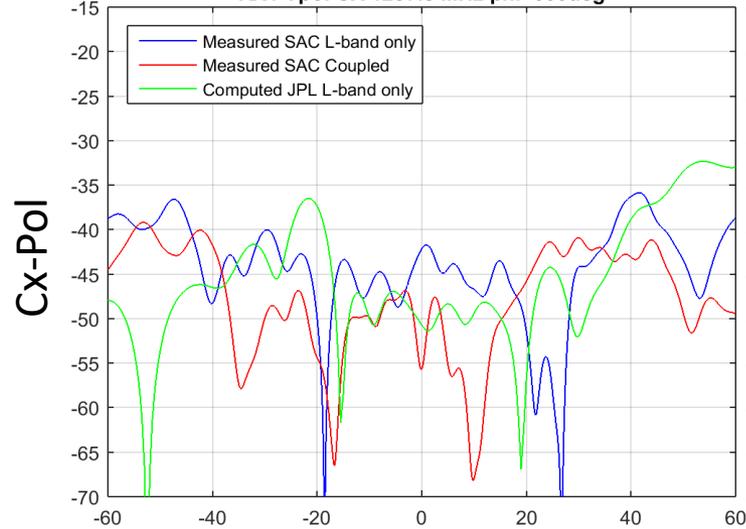
RX1 Vpol CO 1257.5 MHz phi=000deg



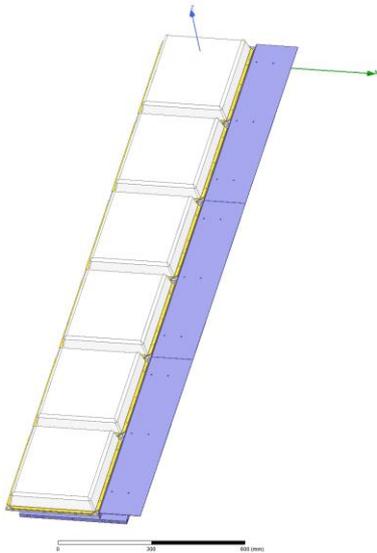
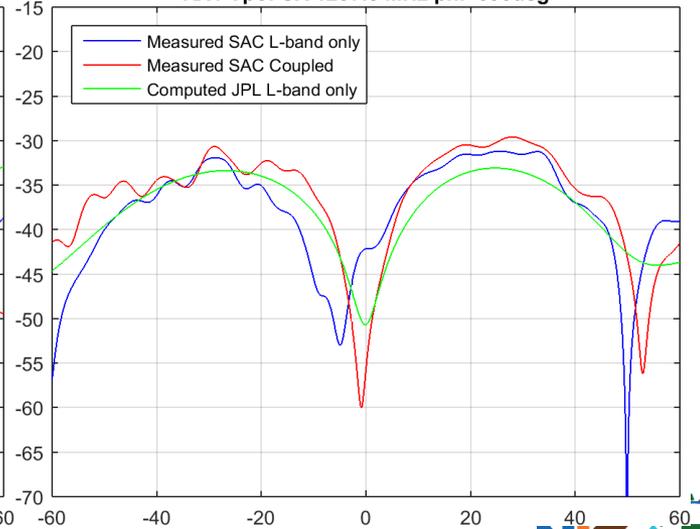
RX1 Vpol CO 1257.5 MHz phi=090deg



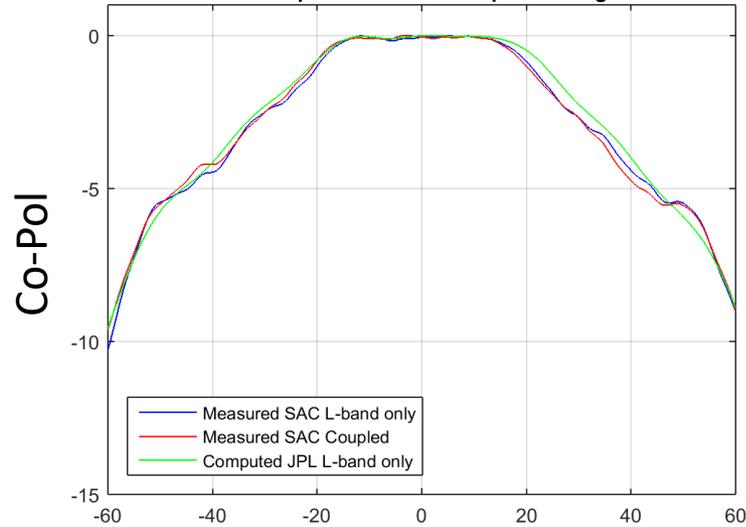
RX1 Vpol CX 1257.5 MHz phi=000deg



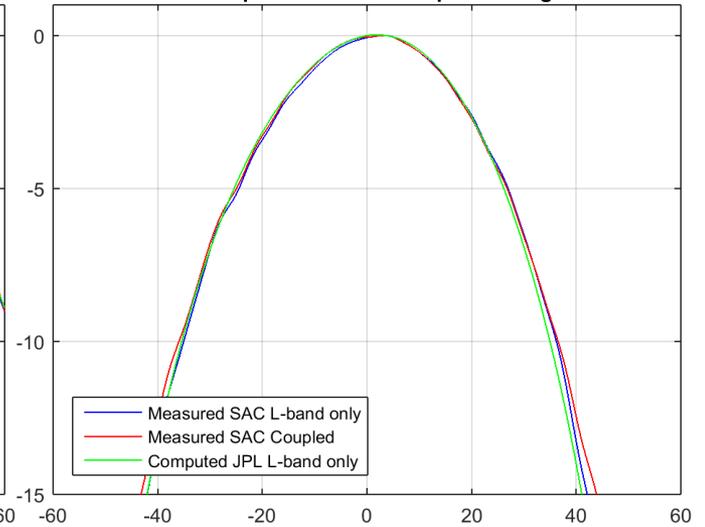
RX1 Vpol CX 1257.5 MHz phi=090deg



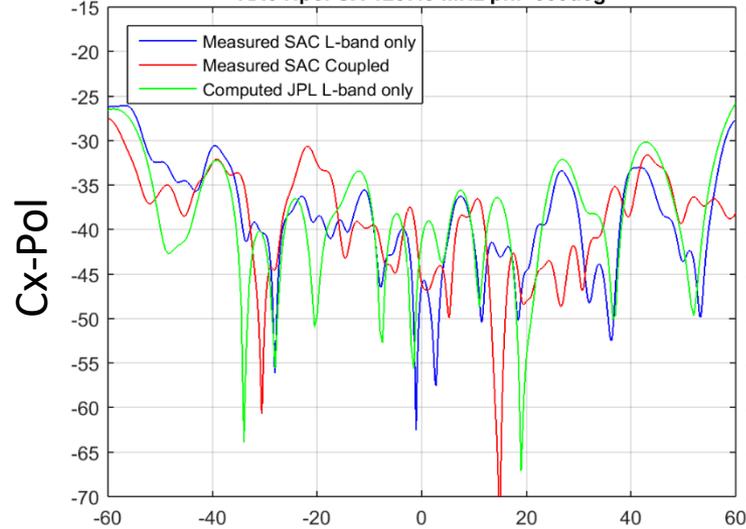
RX6 Hpol CO 1257.5 MHz phi=000deg



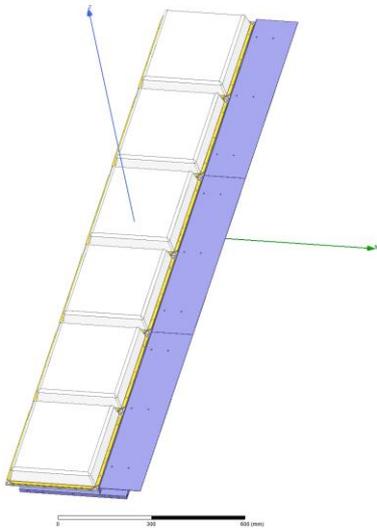
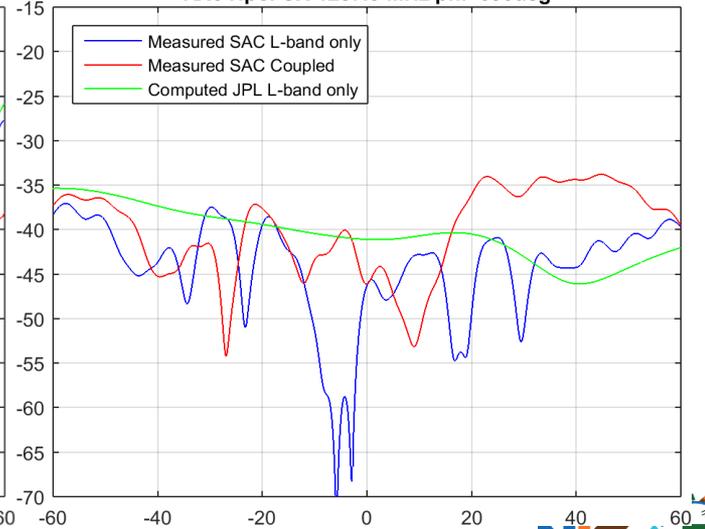
RX6 Hpol CO 1257.5 MHz phi=090deg



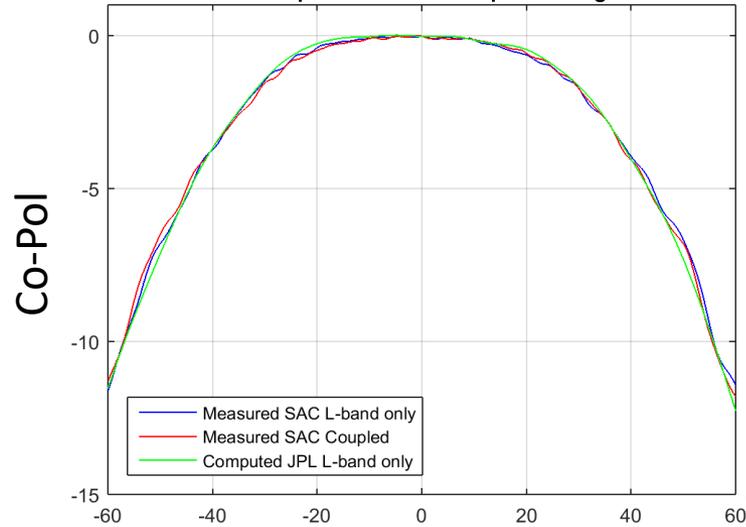
RX6 Hpol CX 1257.5 MHz phi=000deg



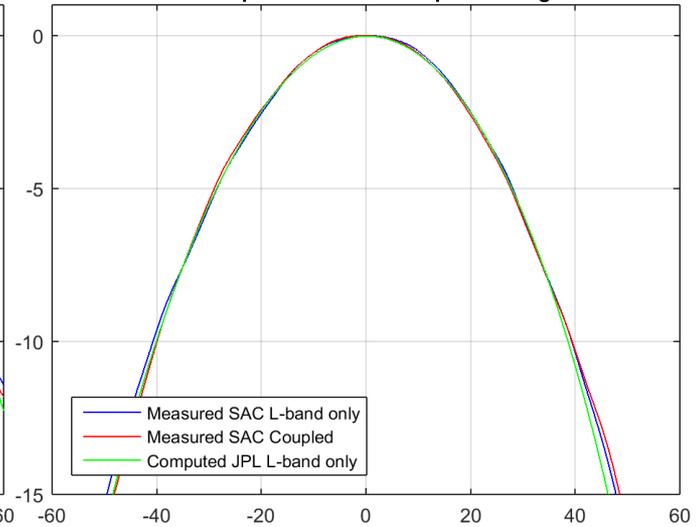
RX6 Hpol CX 1257.5 MHz phi=090deg



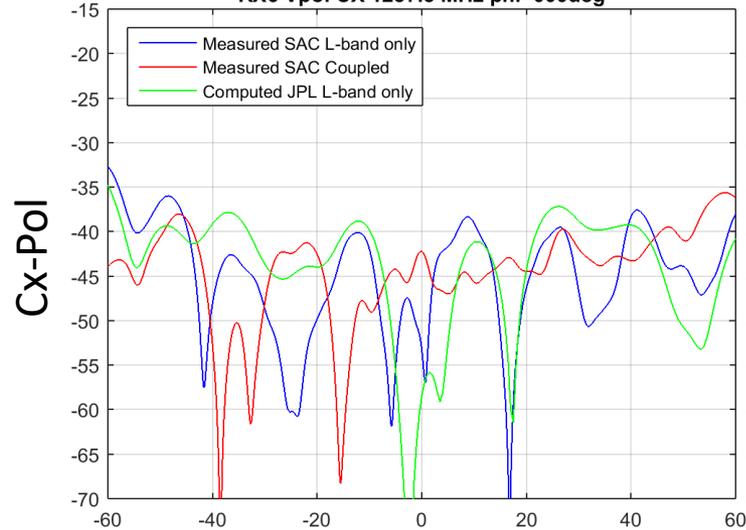
RX6 Vpol CO 1257.5 MHz phi=000deg



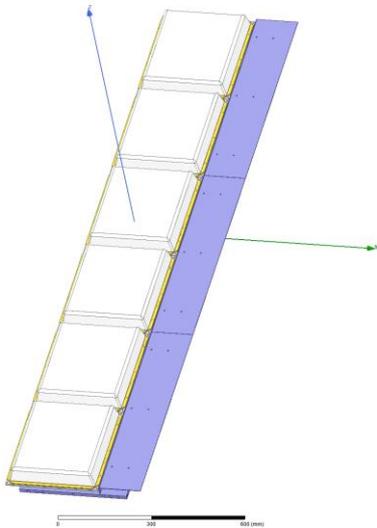
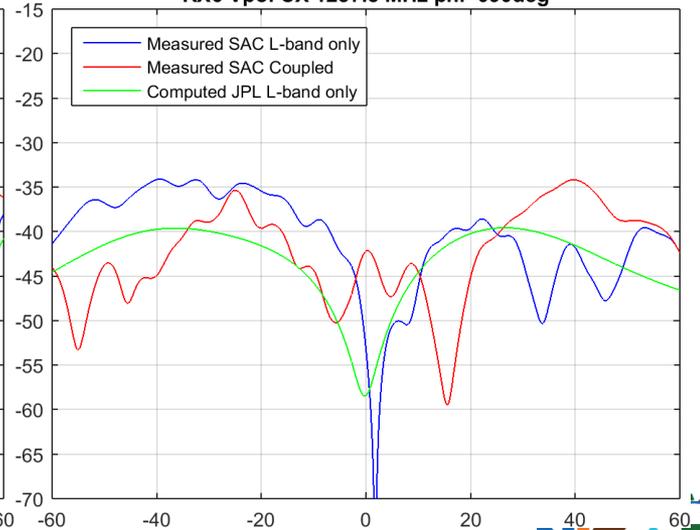
RX6 Vpol CO 1257.5 MHz phi=090deg

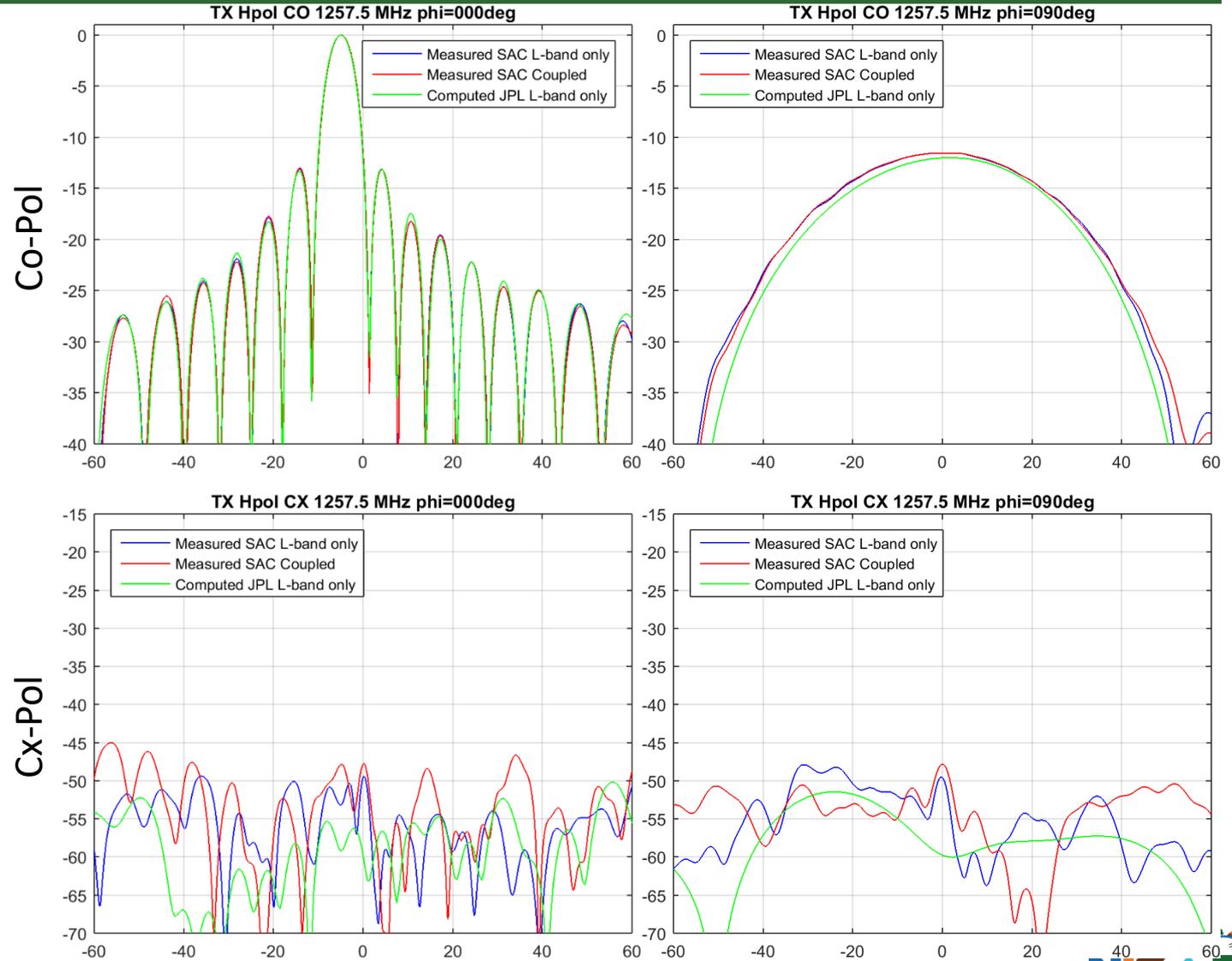
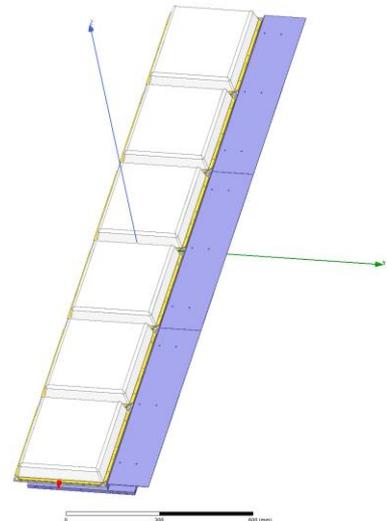


RX6 Vpol CX 1257.5 MHz phi=000deg

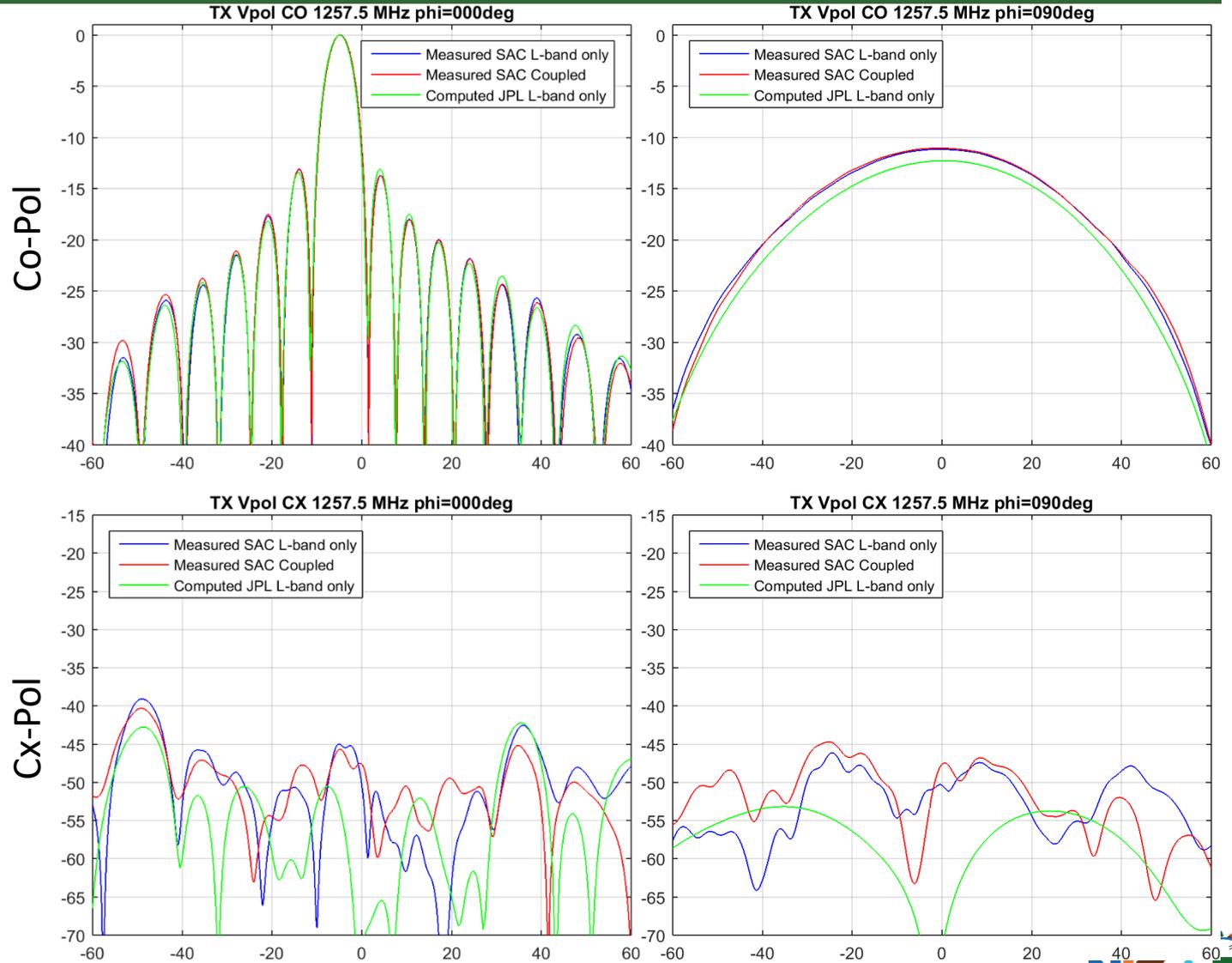
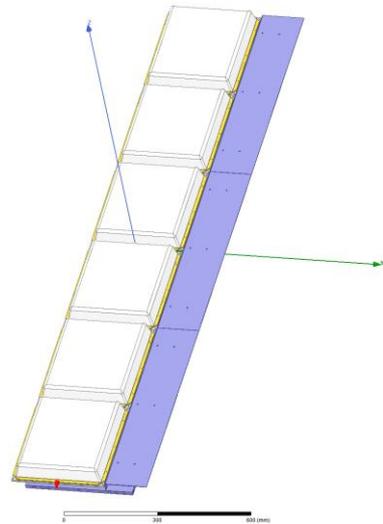


RX6 Vpol CX 1257.5 MHz phi=090deg



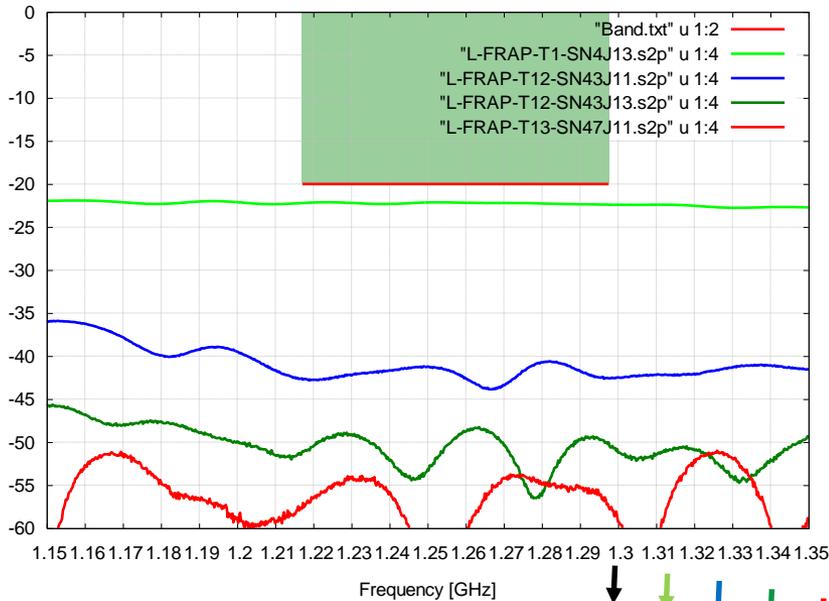


# TX Vpol @ 1.2575 GHz

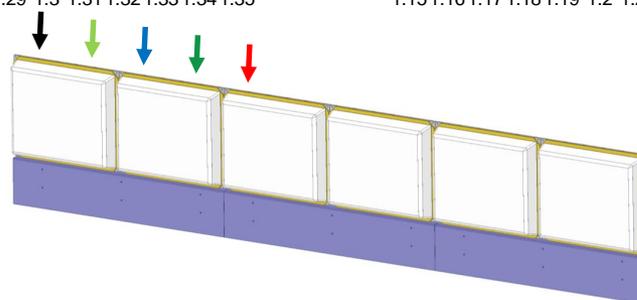
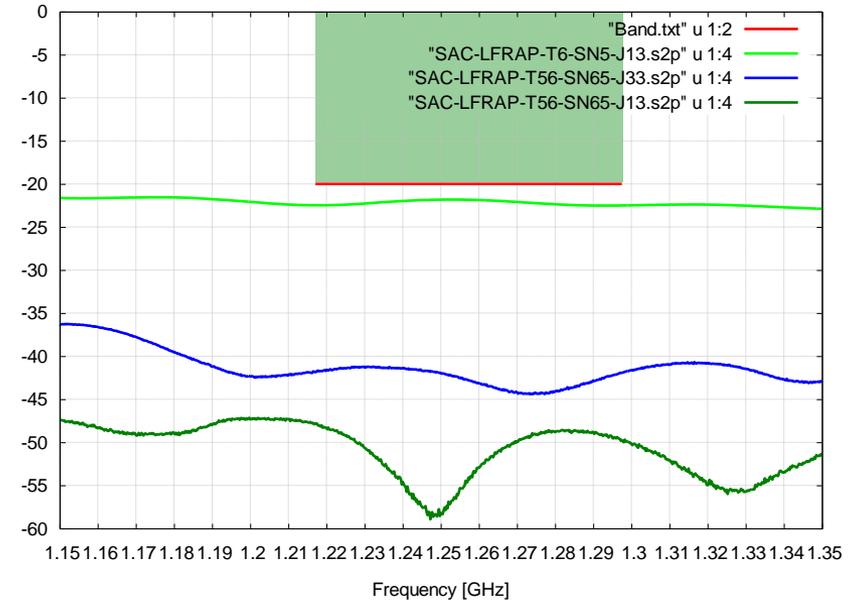


Coupling between beams measured with L-Band antennas and S-Band mock-up

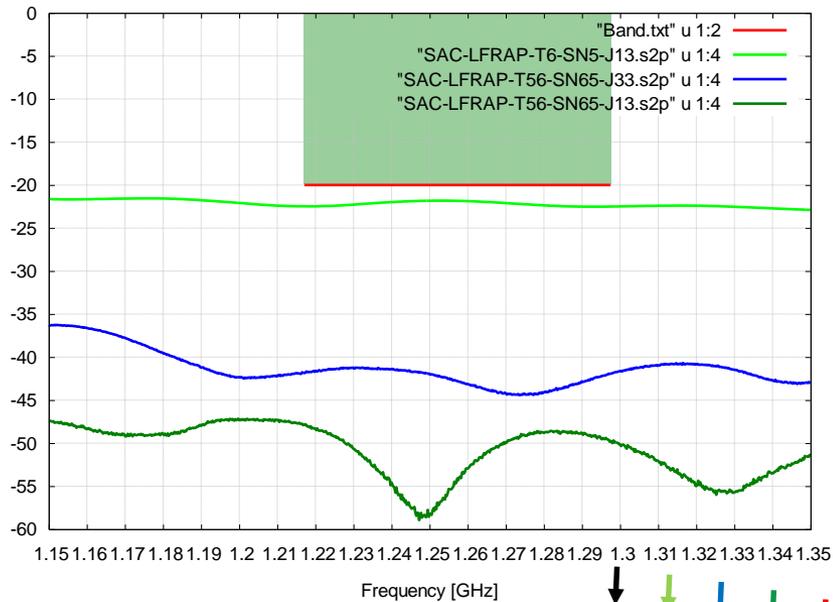
JPL



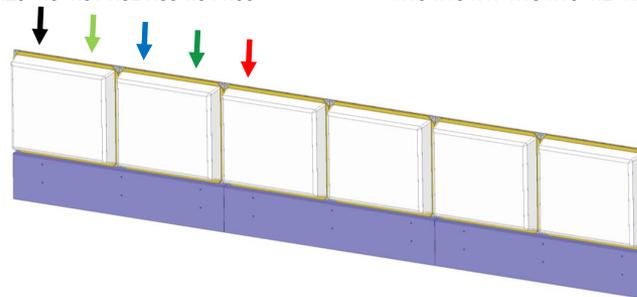
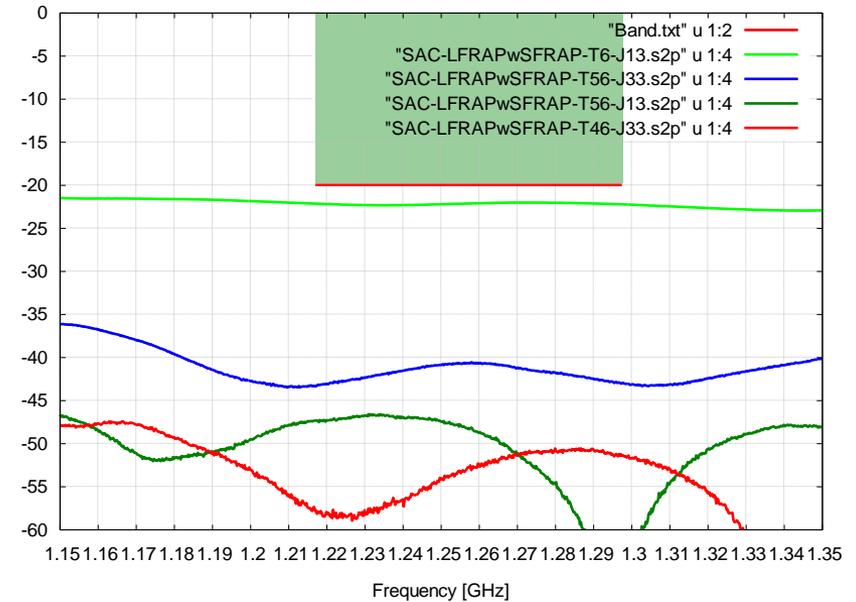
SAC



## Without S-FRAP

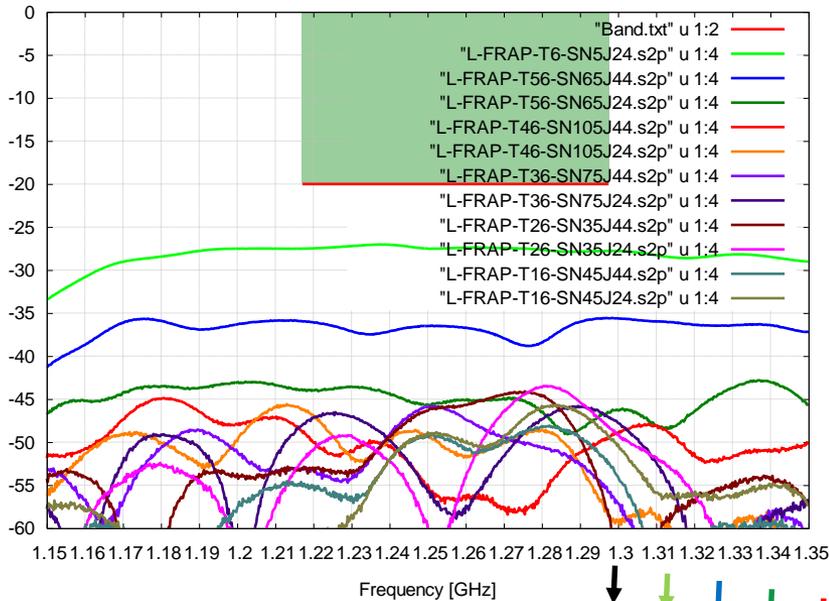


## With S-FRAP

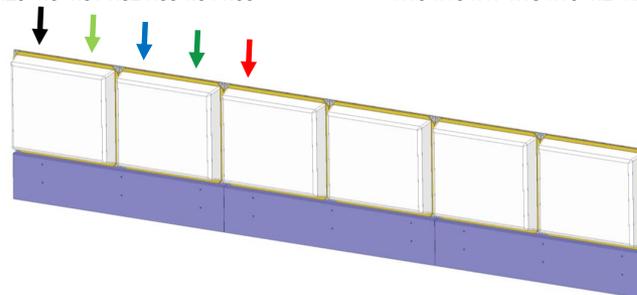
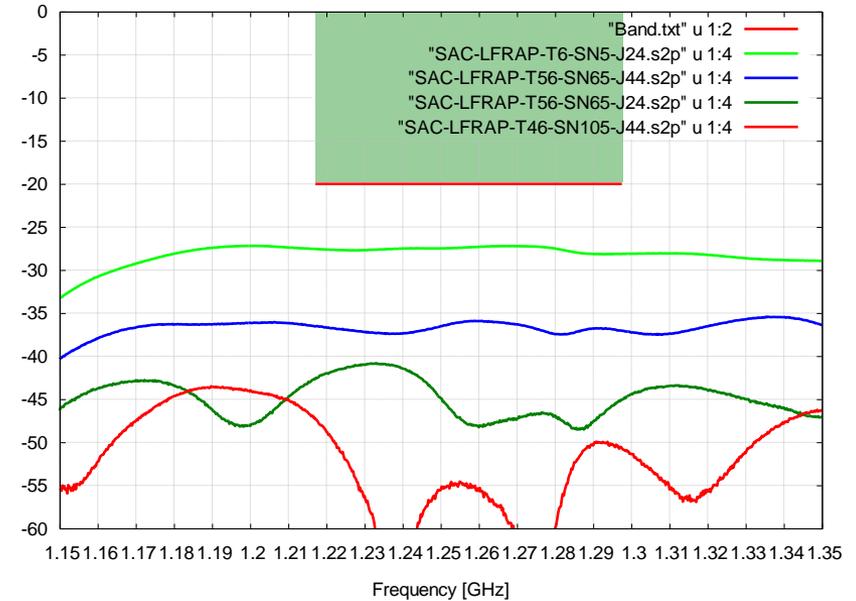


## Coupling between beams measured with L-Band antennas and S-Band mock-up

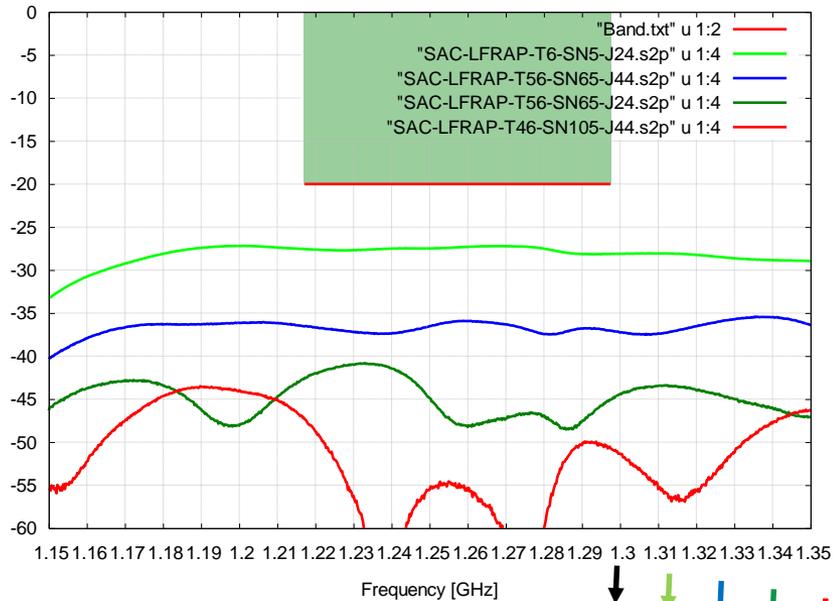
JPL



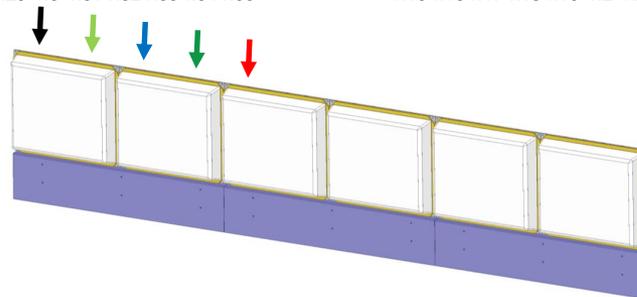
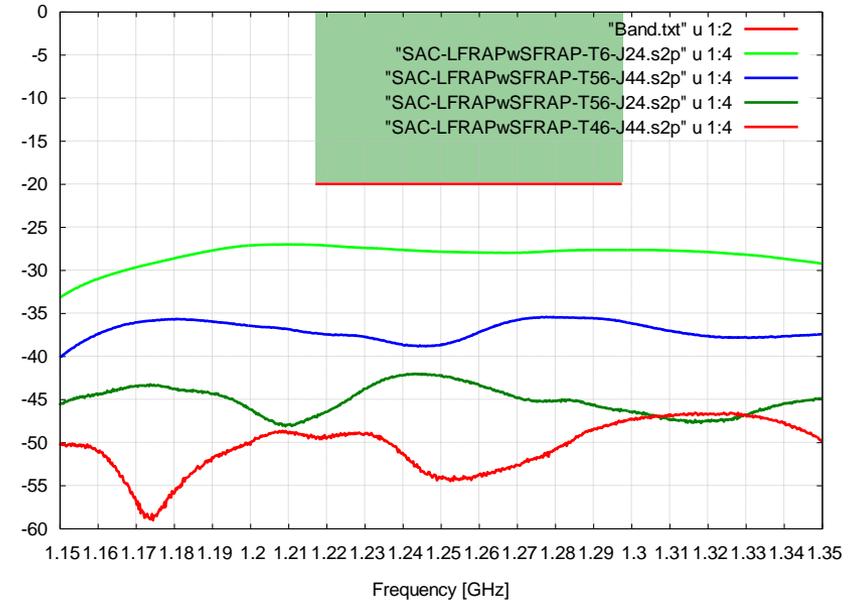
SAC



## Without S-FRAP

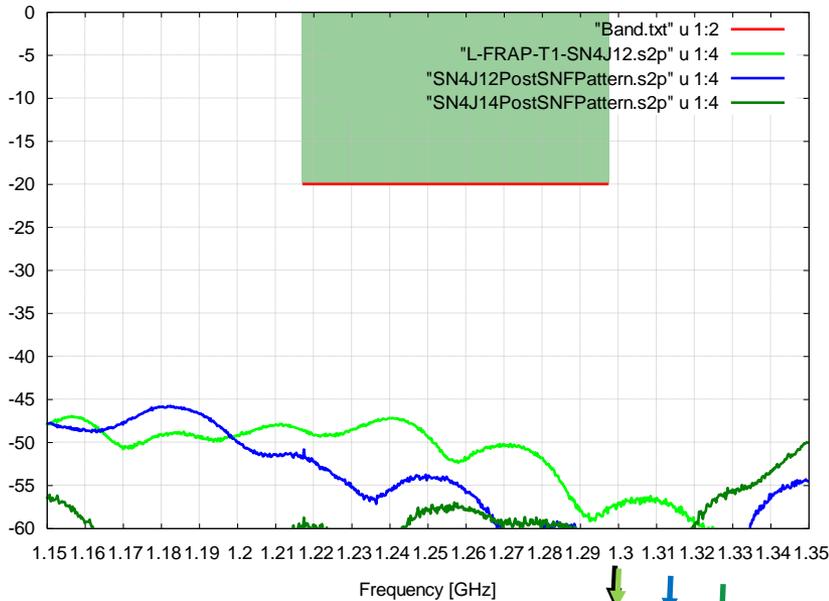


## With S-FRAP

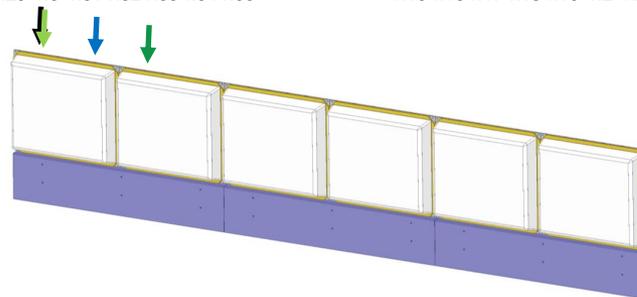
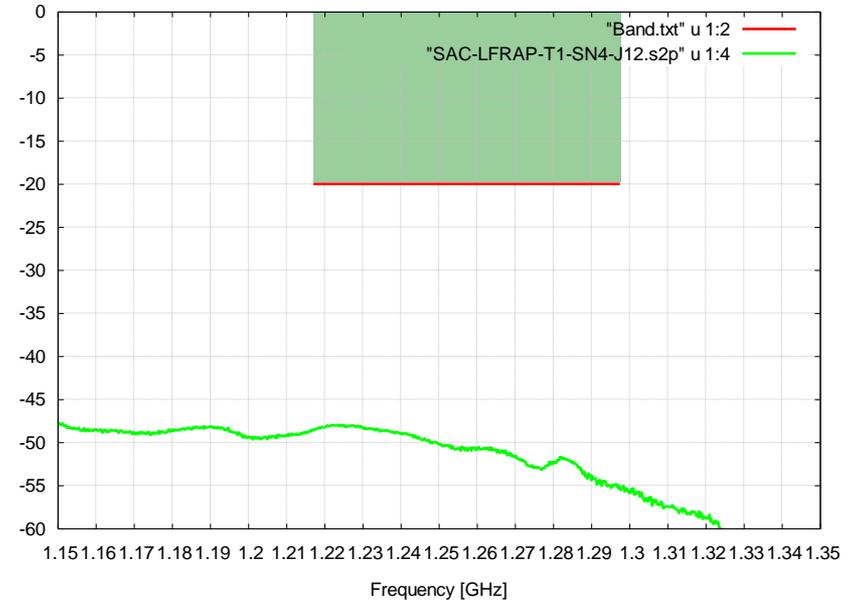


Coupling between beams measured with L-Band antennas and S-Band mock-up

JPL

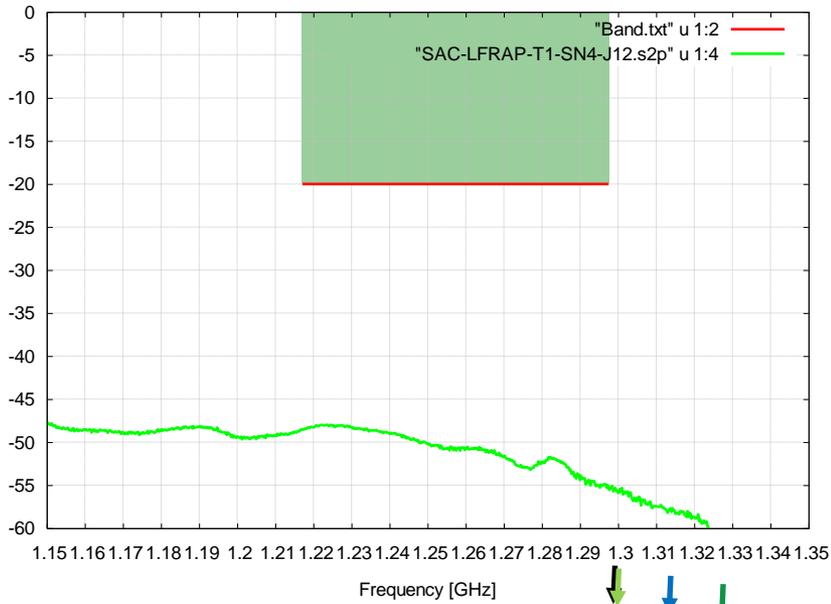


SAC

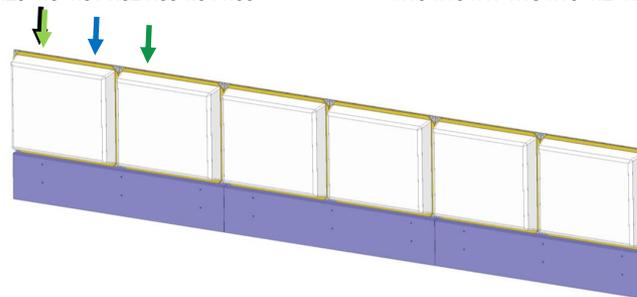
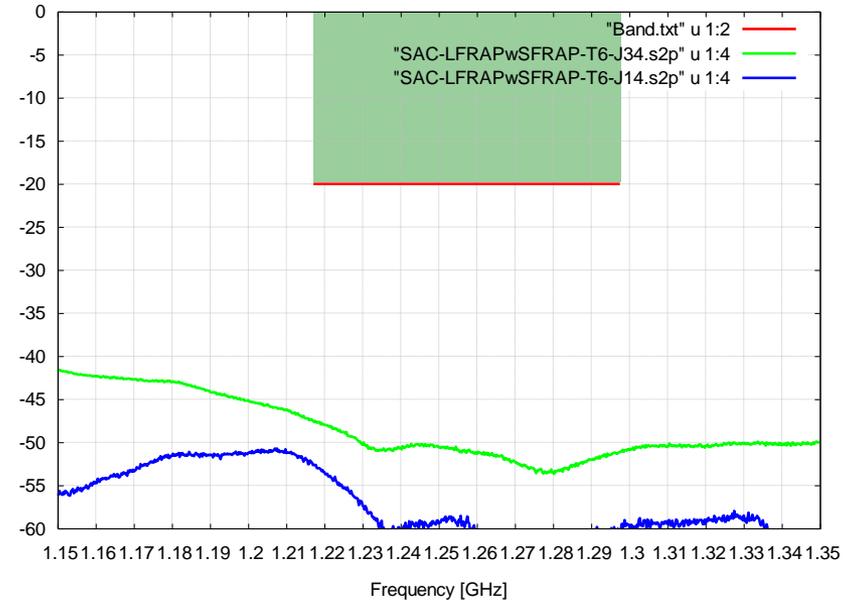


# Coupling Between Beams – CX-Pol

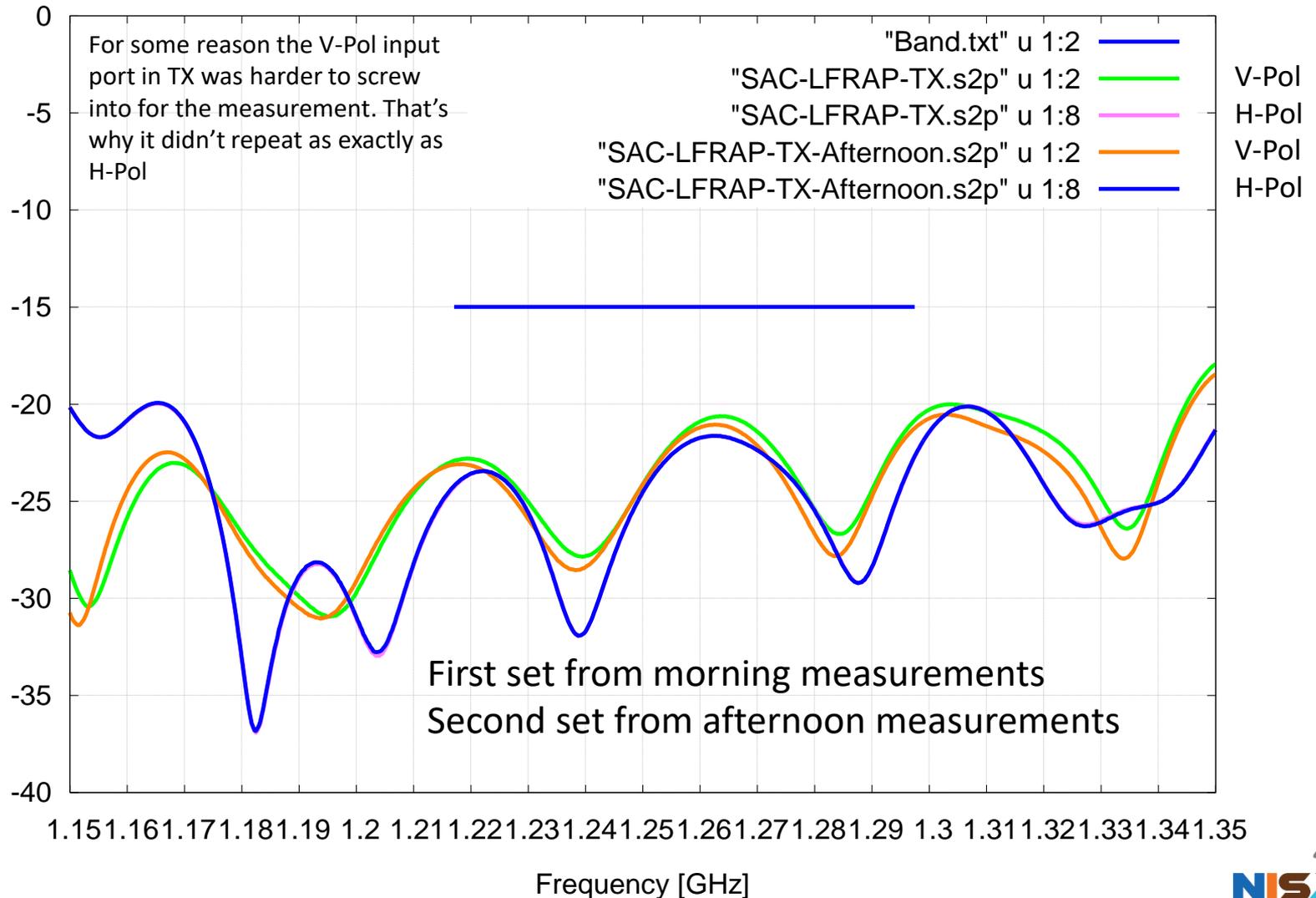
Without S-FRAP

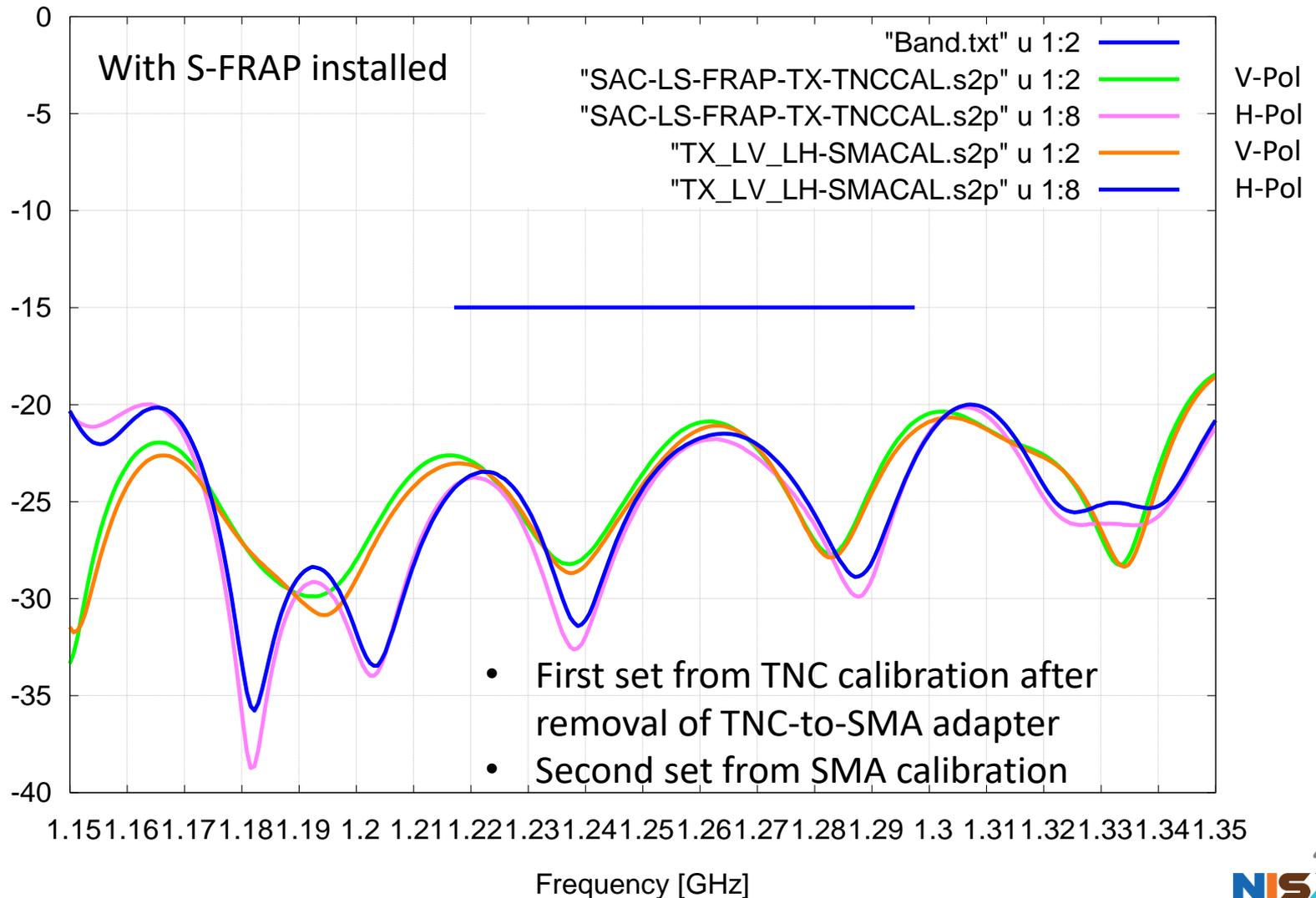


With S-FRAP



# Return Loss of TX Beams





- A complete EM L-FRAP was built and measured at JPL
- A feeding network based on phase-matched coax cables and power dividers was used to simulate the correct phase of each TRM in the flight configuration
- The antenna was then disassembled and shipped to India
- Once at SAC, it was assembled and tested again in order to verify its integrity
- The EM S-FRAP was then installed in place of its mock-up to verify that there was no significant cross-coupling between the two antennas
- The shown results prove the integrity and robustness of the design



## Back-up

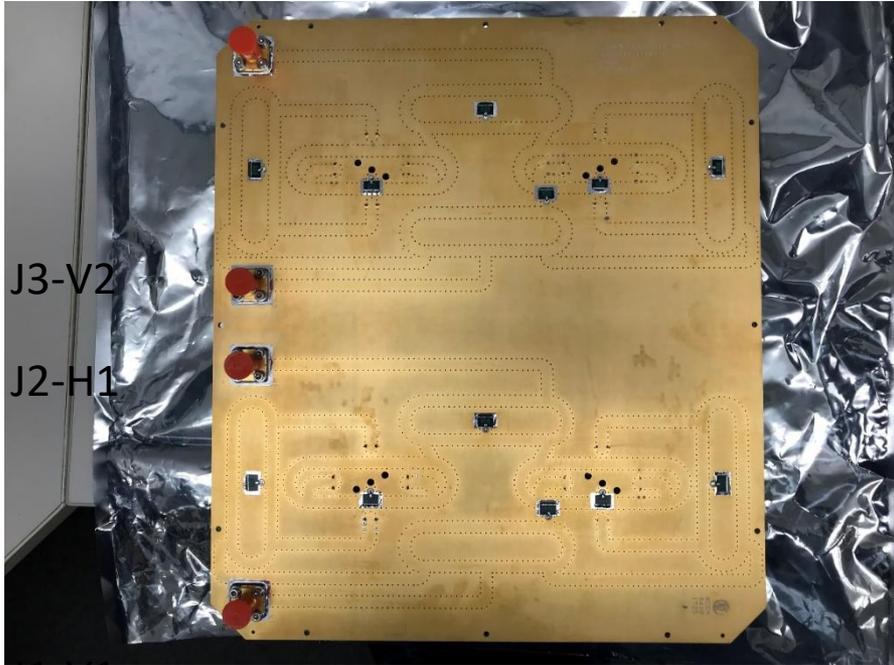
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# SN12 “Connectorized” Board

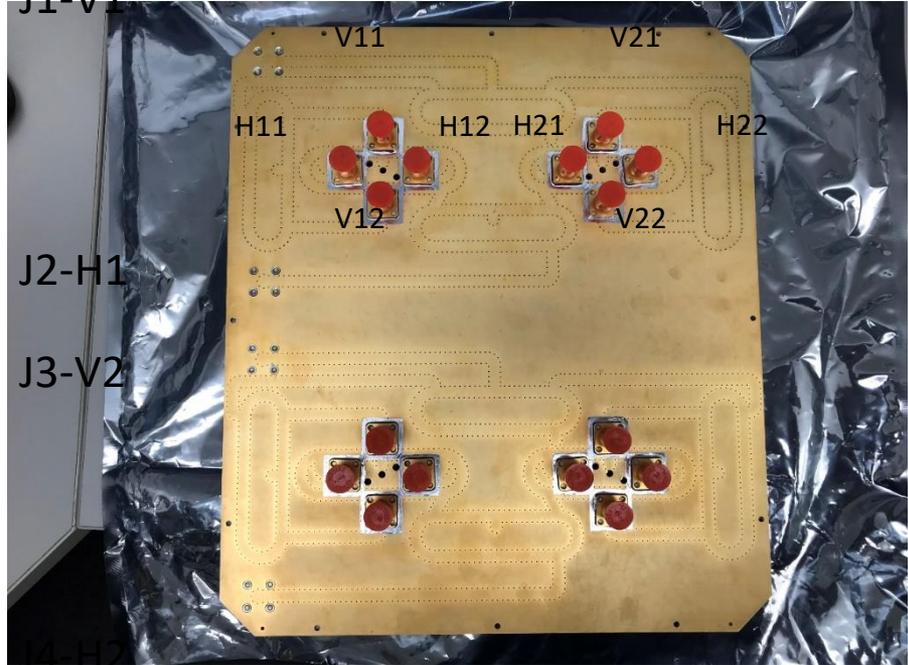
Bottom

Top

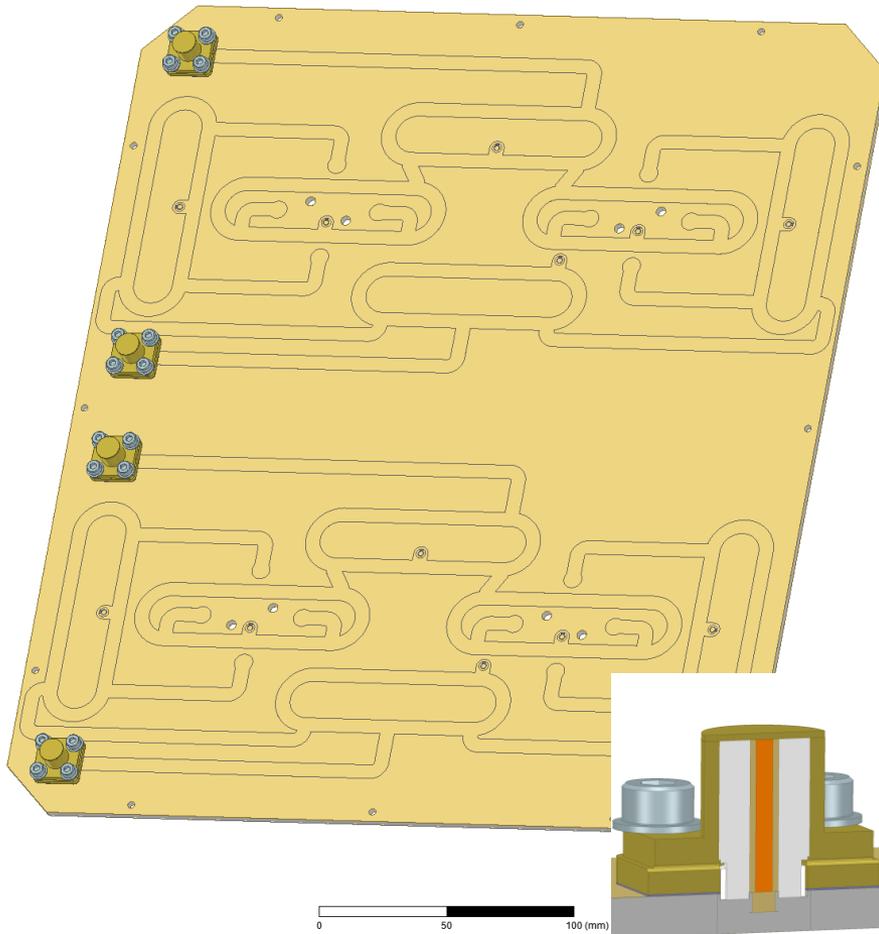
J4-H2



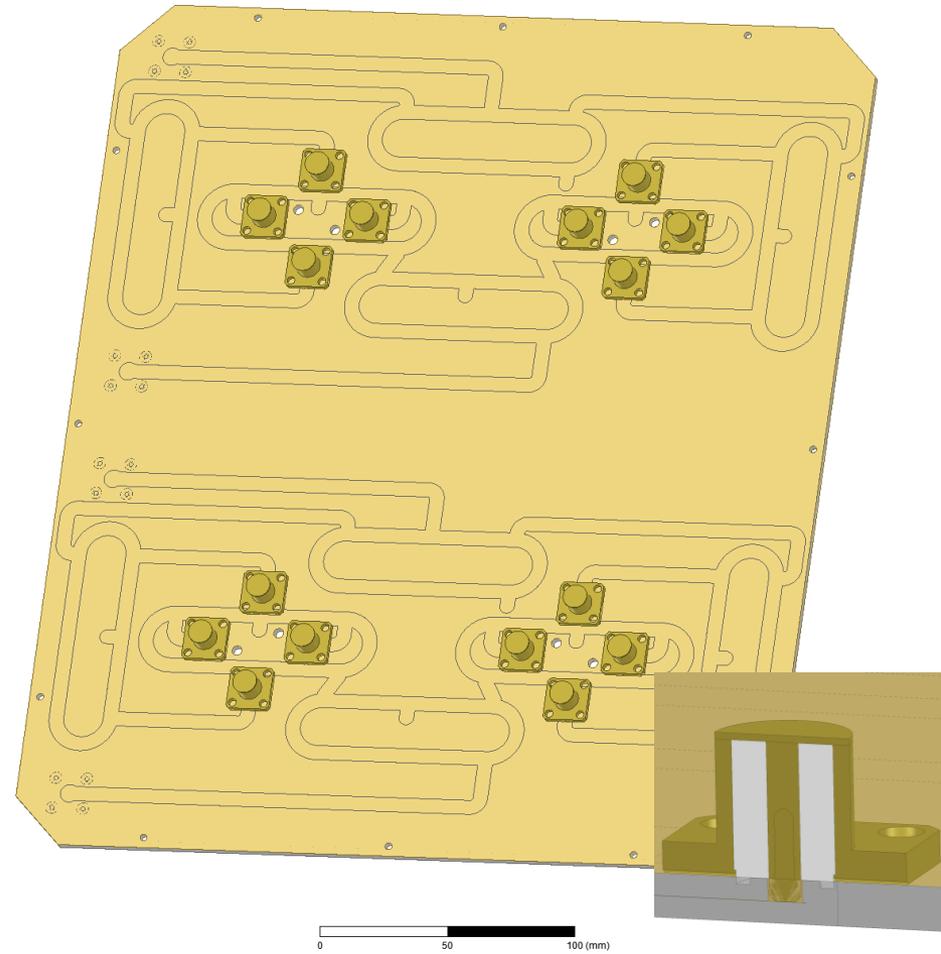
J1-V1



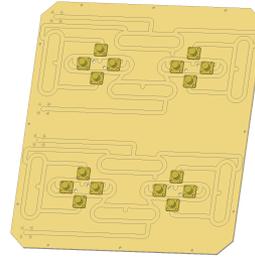
Bottom



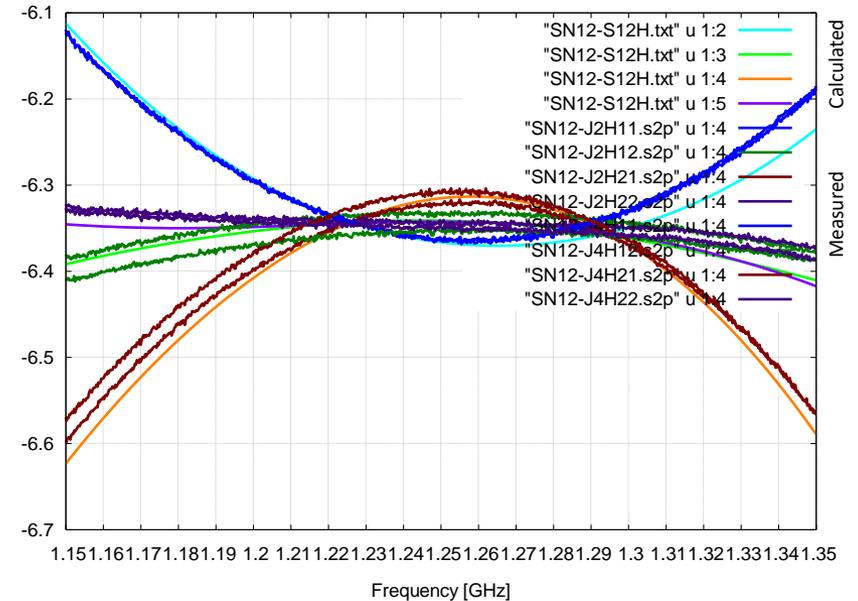
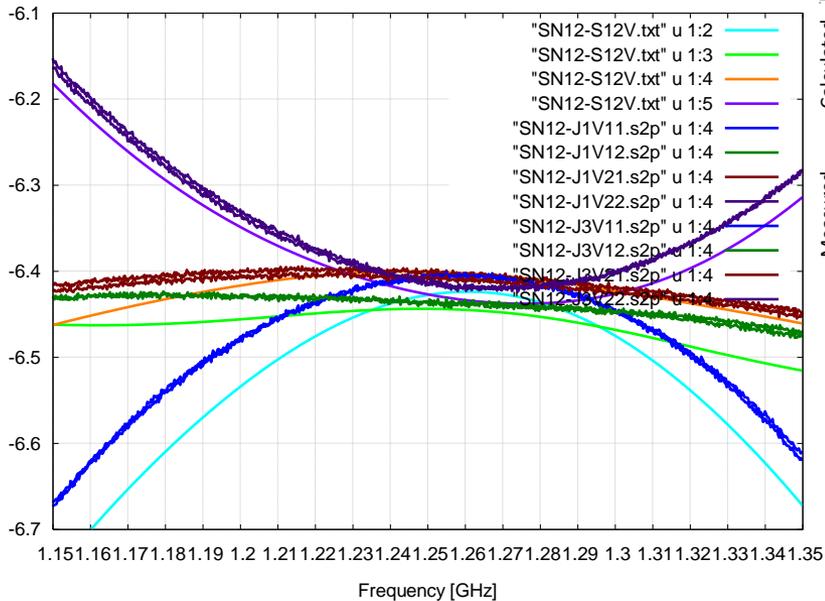
Top



V-Pol



H-Pol



- Note: Rogers 6002 nominal  $\tan \delta$  is 0.0012. In this case I used 0.0018 to get this match with the measurements. In the past I used 0.0024. It appears that this last board is a little less lossy than the prototype boards
- Also, measurements from both sides of the board are reported in the plots. Note the consistency of the results