SMAP Instrument Baseline

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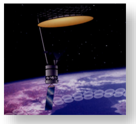


SMAP Instrument Baseline

Key Instrument Requirements for Soil Moisture/Freeze-Thaw

Coverage/Revisit

- 3 days for soil moisture
- 2 days for freeze thaw (at latitudes where applicable)

Incidence Angle

- Constant incidence angle between 35° - 50°.

Radiometer

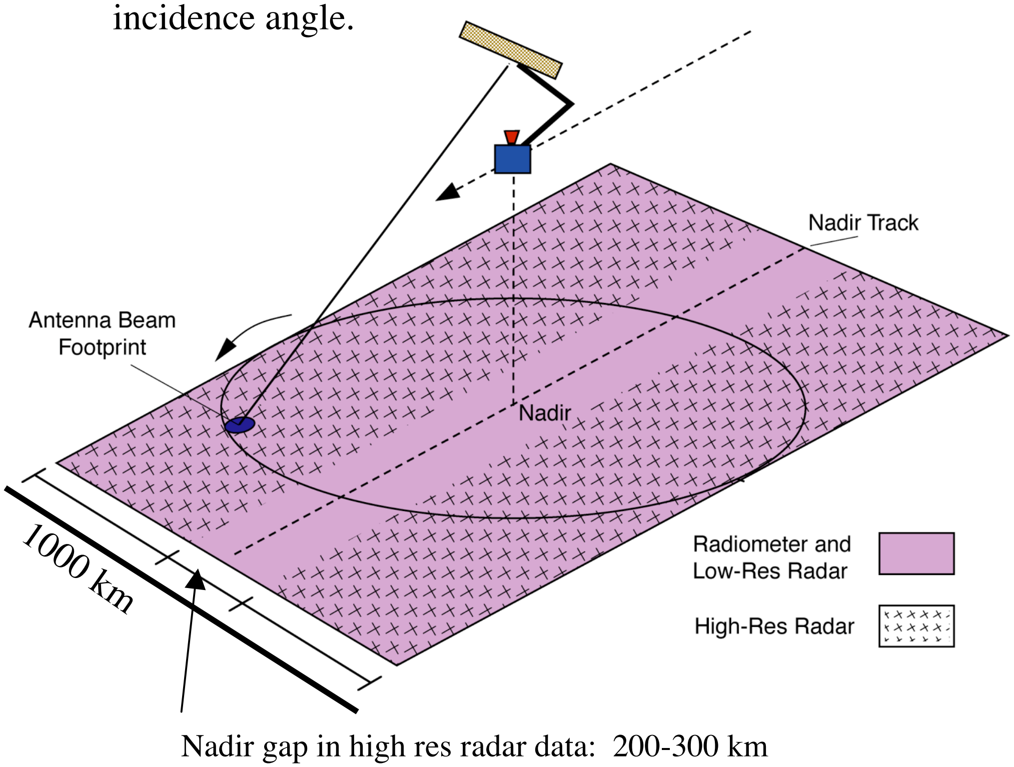
- Frequency: L-Band (1.4 GHz)
- Polarizations: V, H, U
- Resolution: 40 km
- Relative Accuracy: 1.5 K

Radar

- Frequency: L-Band (1.26 GHz)
- Polarizations: VV, HH, HV
- Resolution: 3 km
- Precision (K_p noise): 0.85 dB (worst case, at 3 km resolution)
- Relative Calibration Accuracy: 0.45 dB
- Accuracy requirements met for minimum σ_o of -25 dB.
- Cross-pol (HV) accuracy on "best effort" basis.

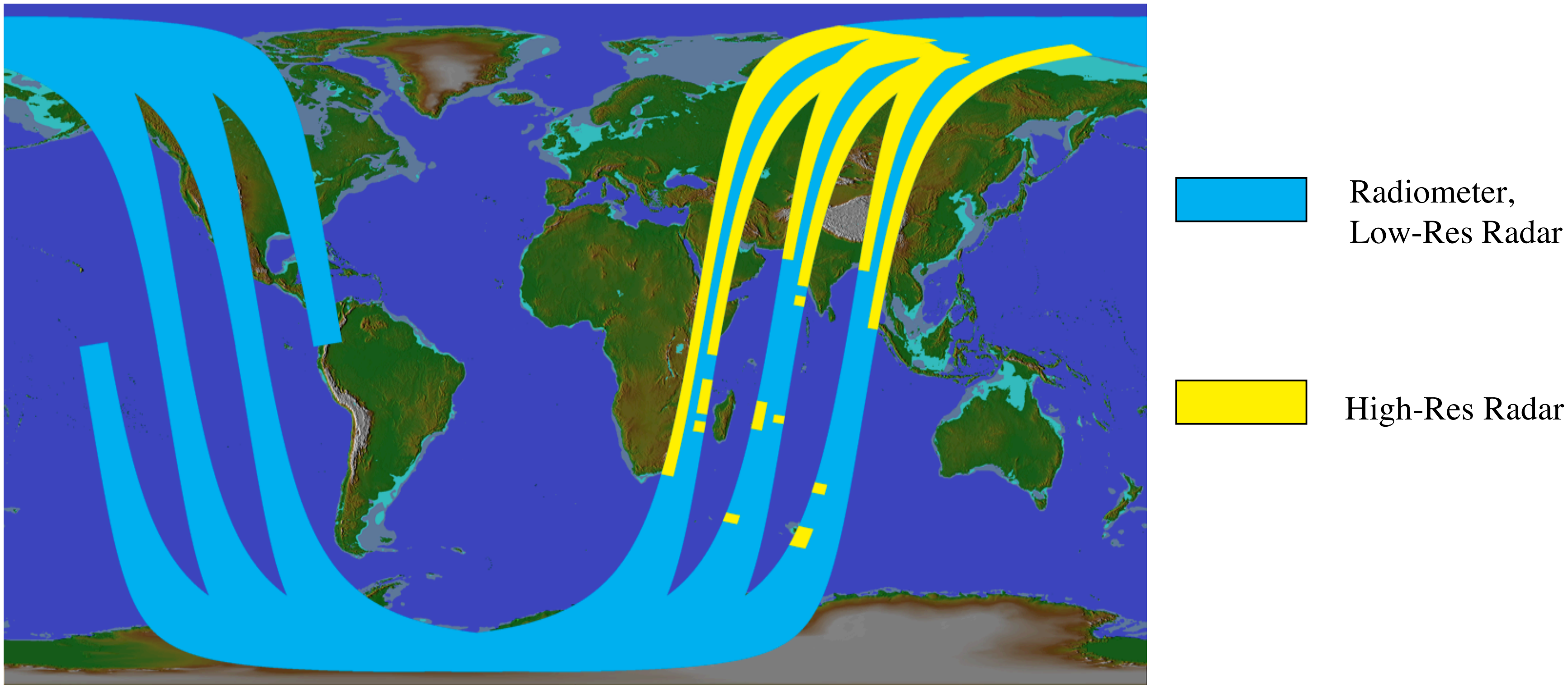
SMAP Instrument Concept

- Orbit: 670 km, sun-synchronous, 6 pm LTAN.
- Instrument Architecture: Radiometer and radar share rotating 6 meter diameter reflector antenna.
- Antenna Beam: 14.6 rpm rotation rate, 40 deg incidence angle.



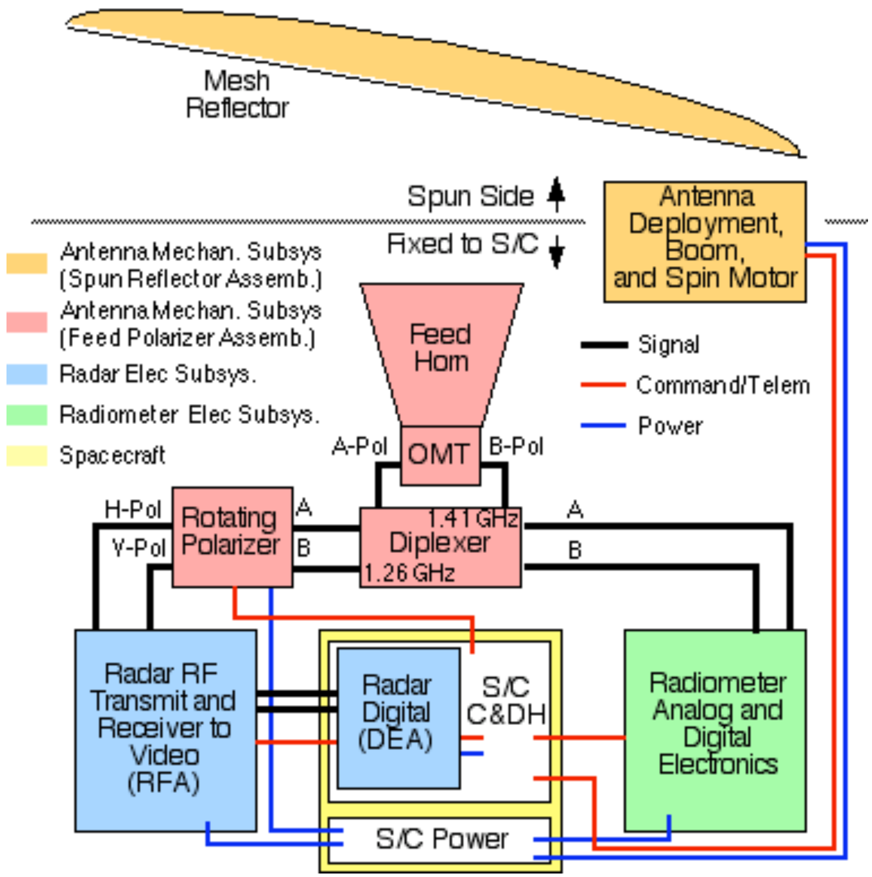
- Radiometer measurements:
  - 40 km real-aperture resolution
  - Made over 360 deg of scan
  - Form full contiguous swath of 1000 km
  - Collected continuously; AM/PM, over land and over ocean
- "Low res" radar measurements:
  - 30 x 6 km real-aperture "slices"
  - Made over forward and aft portions of scan
  - Form full contiguous swath of 1000 km
  - Collected continuously, AM/PM, over land and over ocean
- "High res" radar measurements:
  - Used to generate 1 km gridded product, can be further averaged up to 3 km and 10 km.
  - Made over forward 180 deg of scan only (optional 360 deg collection possible)
  - 1000 km swath with nadir gap of 200-300 km astride spacecraft ground track
  - Collection programmable; baseline to collect over land during AM portion of orbit only

SMAP Coverage



- Three orbit sample shown in image above.
- Low-res radiometer and low-res radar: Using AM revs only, cover entire Earth in 3-days. Average revisit time improves when AM + PM passes are used (but Faraday rotation becomes an issue).
- High-res radar data collection is programmable via ground command. Average revisit time is 3-days over land when only AM revs are used.

Instrument Functional Block Diagram

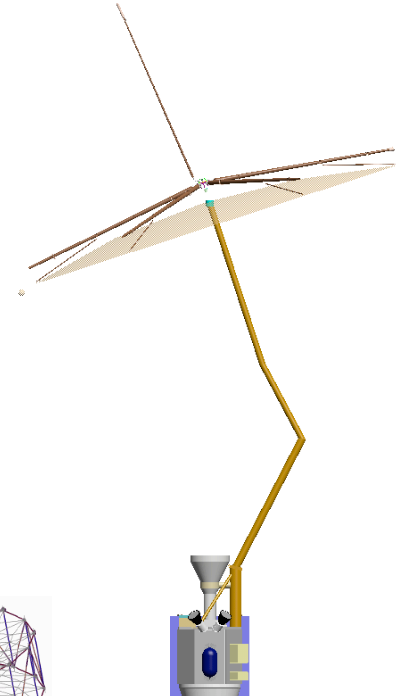


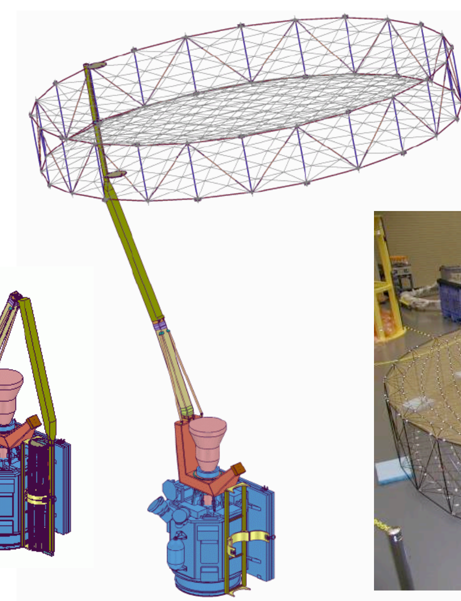
- Antenna Mechanical Subsystem
  - Spun Reflector Assembly (SRA)
  - Feed Polarizer Assembly (FPA)
- Radar Electronics Subsystem
  - Radar RF Electronics Assembly (RFA)
  - Radar Digital Electronics Assembly (DEA)
- Radiometer Subsystem

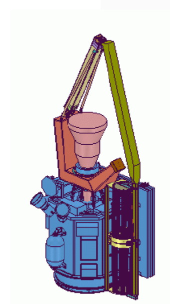
Rotating Reflector

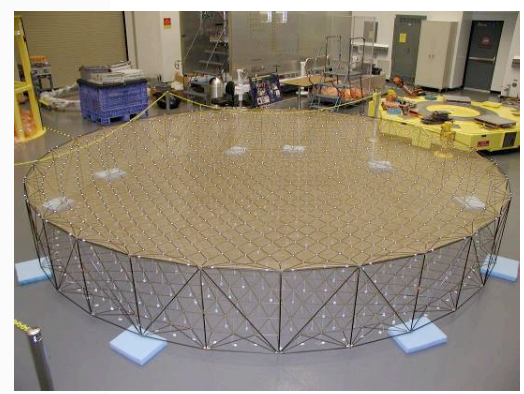
- Key antenna requirements
  - Dual-pol L-Band feed
  - < 2.6 deg BW at 1.4 GHz, >90% beam efficiency.
  - 14.6 rpm rotation rate
  - Deployable mesh material, high reflectivity at L-Band
  - Pointing: 0.3° stability, 0.1° knowledge
  - Rotational Inertia < 150 kg-m^2, CG to 2.5 cm, Inertia Cross Products < 1%, Stiffness > 1 Hz.
- During Hydros risk reduction, two antenna vendors were funded to study adaptations of heritage reflector designs for rotation.
  - "Radial Rib" design with fixed central boom and rotating reflector.
  - "Perimeter Truss" design with rotating reflector and boom.

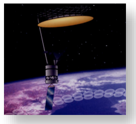
⇒ Both antenna concepts have been demonstrated in simulations to meet requirements in rotating configuration.





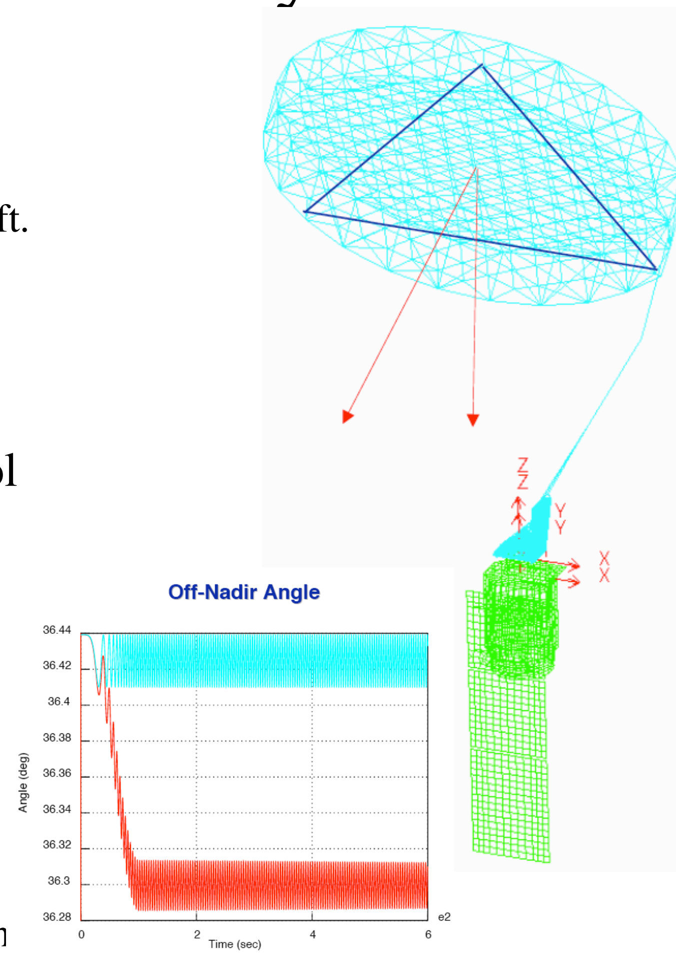






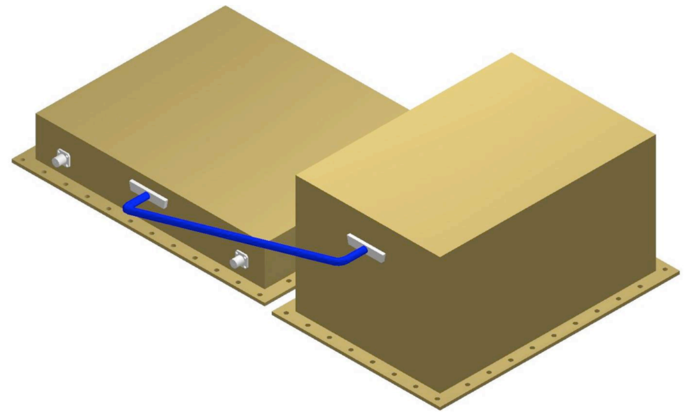
Rotating Reflector Dynamics Analysis

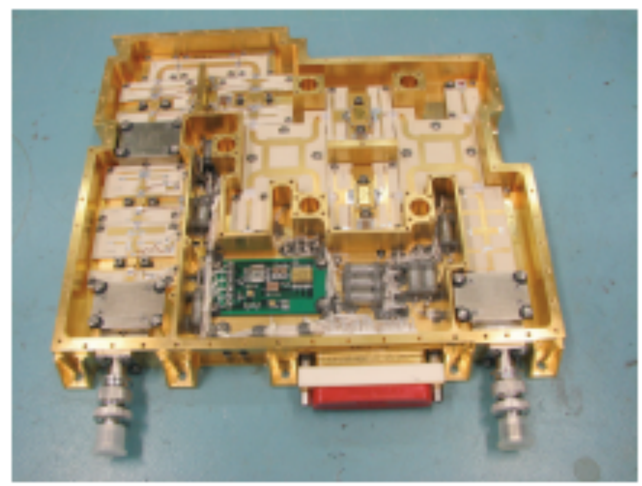
- During Hydros risk reduction and early formulation, dynamics of both antenna concepts assessed by JPL, Boeing.
  - FEM’s received for both antenna concepts, as well as spacecraft.
  - Dynamic simulation included dynamics of entire observatory, including flexible body effects.
  - Impact of perturbations on antenna RF performance also assessed.
- With remaining Hydros funds, spacecraft attitude control system and on-orbit disturbances modeled as well.
- Central conclusions…
  - No high risk issues identified. Observatory behaves in stable fashion.
  - Steady-state observatory performance meets pointing requirements with significant margin.
  - Antenna is in “quasi-rigid” regime and flexible body dynamics not issue. Solar array also behaves as rigid.
  - Observatory level ACS design is required with antenna rotation and momentum compensation in control loop.



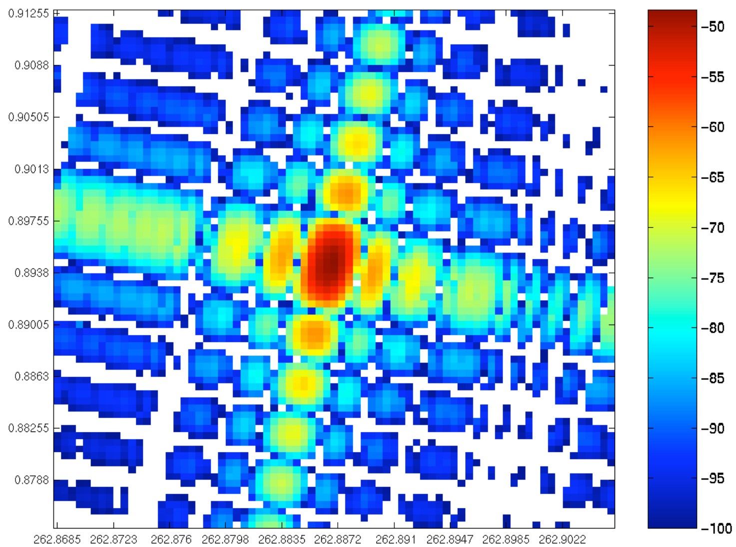
SMAP Radar Electronics

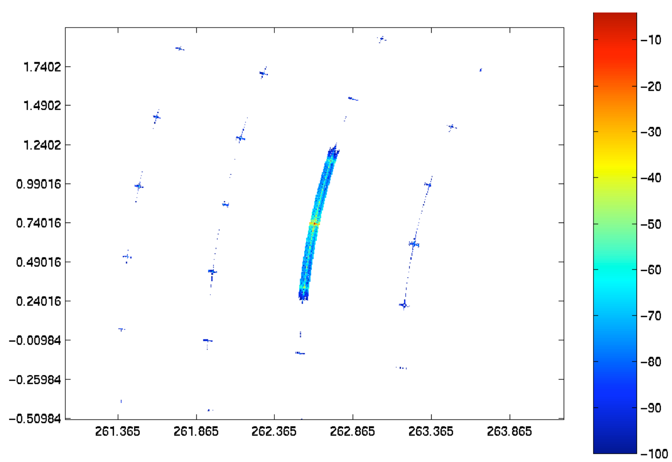
- Radar requirements
  - Dual pol (H,V) with cross-pol (HV)
  - Transmit Pulse: 200 W peak, 1 MHz bandwidth, 40ms pulse length, 3.5 kHz PRF (chosen to be consistent with Aquarius design)
  - High res data processing: A/D, digital filter each channel, BFPQ
  - Low res data processing: simple sum into range bins.
- Radar implementation approach and heritage
  - Transmitter: SSPA from Aquarius
  - Chirp Generator: Aquarius design
  - Loop-back calibration: High heritage from Aquarius
  - Low-risk custom IF electronics and digital processing design for SMAP application.





SMAP Radar High Resolution Performance

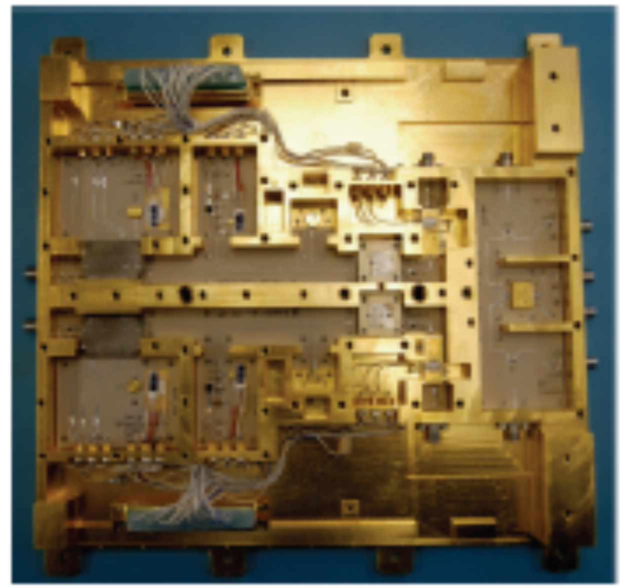


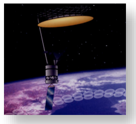


- High-rate radar data collected and telemetered. Processed using low-res, unfocused SAR in ground data processing.
- “Single-look” resolution of 250 m in range and 400-1200 m in azimuth.
- “Multi-look” gridded products of 1 km, 3 km, 10 km, etc. with sufficient accuracy for geophysical retrieval.
- High-res radar processing approach validated with detailed modeling:
  - JPL performance simulation models S/C motion, scanning antenna, SAR processing, resolution, and ambiguities.
  - CSA ground data processing simulation models SAR retrieval, multi-look averaging.
- ***JPL and CSA simulations demonstrate that radar measurement requirements will be met.***

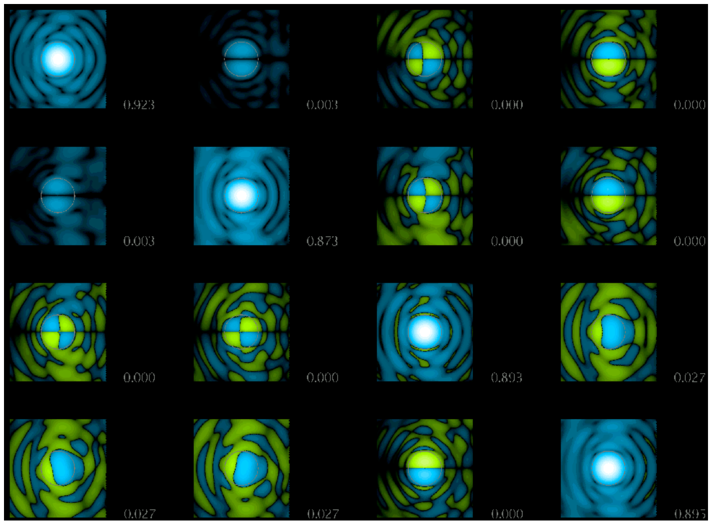
SMAP Radiometer Electronics

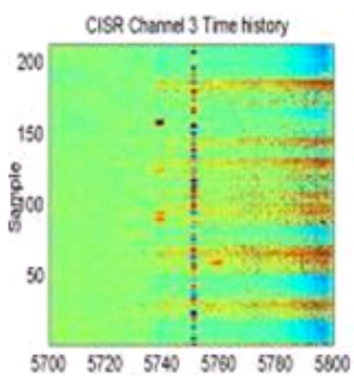
- Radiometer requirements
  - Dual pol (H,V) with third Stokes (U)
  - Internal calibration with Dicke reference load and noise diodes
  - Operates synchronously with radar PRF of 3.5 kHz (chosen to be consistent with Aquarius design)
  - RFI mitigation (primarily against terrestrial radars)
- Radiometer implementation approach
  - Front-end RF from Aquarius
    - Dicke switch, noise diodes, LNA
    - Polarization combiner not needed
  - Back-end RF from Aquarius
  - Custom digital back-end design for polarimetry (4 Stokes) and RFI mitigation (high-rate video, spectrograms, and/or sub-banding with kurtosis)

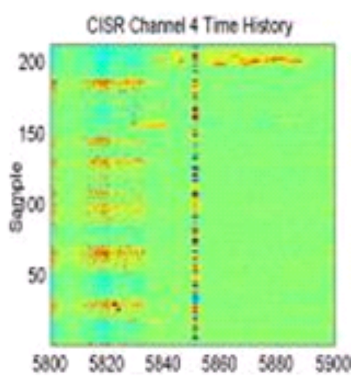




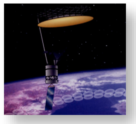
SMAP Radiometer Performance







- Radiometer data collected and telemetered. RFI mitigation applied in ground processing.
- "Single-look" radiometric accuracy of 1.5 K for >90% beam efficiency.
- "Multi-look" product to reduce NEDT.
- RFI mitigation demonstrated in ground-based and airborne experiments
- Radiometer performance predicted using detailed uncertainty analysis:
  - GSFC analysis includes 21 parameters: mainbeam, cross-pol and sidelobe fractions, antenna pointing, NEDT, thermal affects
  - CSA antenna pattern simulations validated by physical scale model
- ***GSFC and CSA simulations demonstrate that radiometer measurement requirements will be met.***



SMAP Instrument Summary

- Stable set of soil instrument measurement requirements that are traceable to science requirements for soil moisture/freeze-thaw.
- Baseline SMAP instrument design (developed during Hydros proposal and early formulation phases) capable of satisfying measurement requirements.
- Significant benefit from conceptual design work performed during Hydros formulation, including focused risk reduction studies on
  - Antenna rotational dynamics
  - Antenna RF performance
  - Feed assembly design
- Significant benefit from heritage and lessons learned on Aquarius:
  - Radar: transmitter, chirp generator, loop back calibration.
  - Radiometer: front-end electronics
- No technology “show-stoppers.” Ready to start SMAP formulation where Hydros left off.
- Key near-term risk reduction activities to perform during formulation:
  - Downselect to single antenna vendor. Perform additional dynamics analyses, including rotating antenna prototype to validate balancing technique.
  - Complete design studies for radiometer digital back-end for RFI suppression.