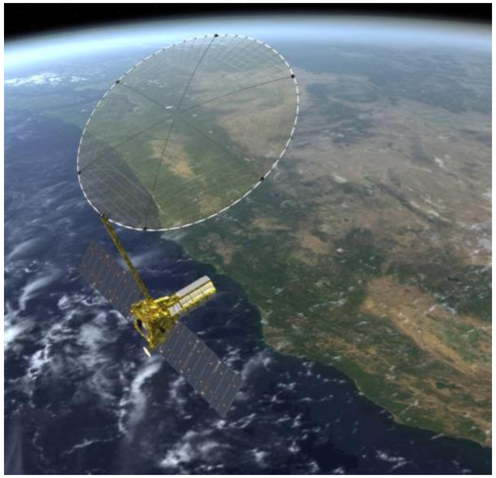



Outline

- Two Wide-swath Imaging Techniques – SIR-C ScanSAR vs. NISAR SweepSAR
- System Sensitivity Comparison between SIR-C and NISAR L-SAR systems with implemented system parameters
- Hardware implementation and Capability Comparison
- Issues SweepSAR-architecture system requires to address

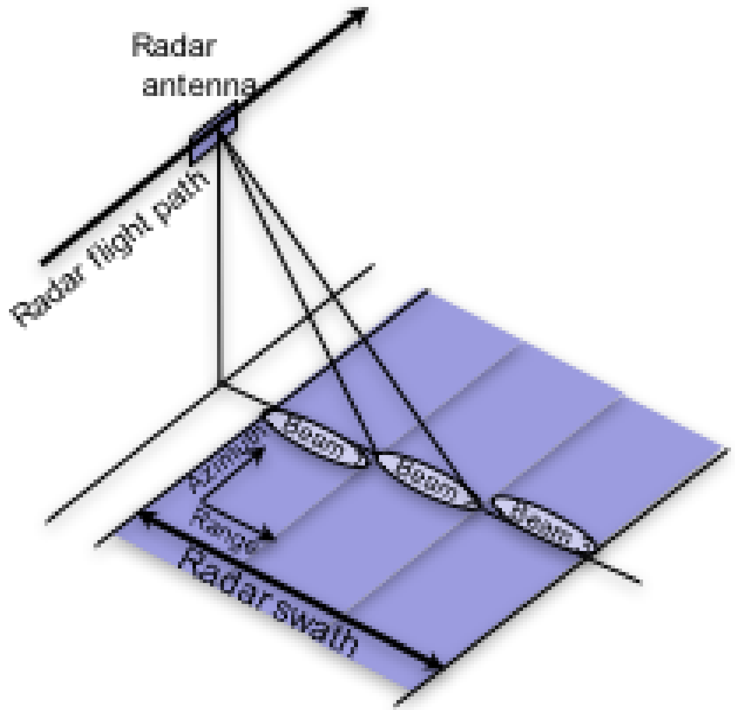
SIR-C/X-SAR and NISAR L-SAR Systems: Historical Background

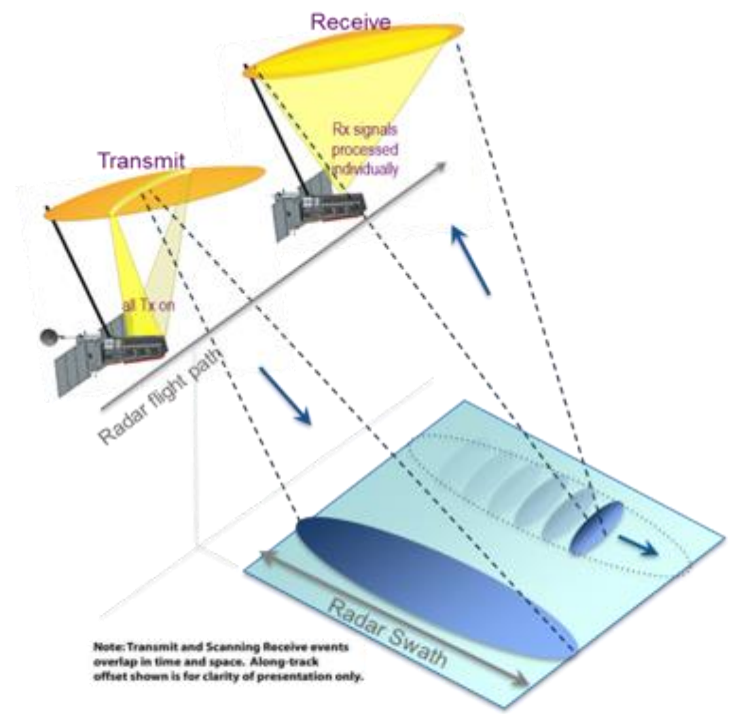


- SIR-C/X-SAR Radar was a three-frequency SAR system of which NASA/JPL L-band/C-band systems utilizing planar active phased array antennas and using ScanSAR technique for wide swath imaging. (DLR X-band system used slotted-waveguide antenna with tilting mechanism for pointing.)
  - SIR-C/X-SAR were flown on Shuttle Endeavour twice in Apr. and Oct. 1994 as SRL-1 and SRL-2
  - SIR-C/X-SAR C-band and X-band radar systems were modified to a dual-frequency fixed baseline SAR interferometer and flown as SRTM/X-SAR also on Shuttle Endeavour in Feb. 2000
- NISAR dual-frequency SAR SAR System traces back to JPL/DLR joint DESDynI/Tandem-L Mission in Apr. 2008-Apr. 2011, which baselined the use of a reflector with arrayed feed antenna to implement SweepSAR technique dedicated to wide-swath imaging. (ISRO provides S-band SAR system.)
  - SweepSAR technique can be implemented utilizing a planner active phased array but was determined to be technical resources and cost inferior comparing to using a reflector with arrayed feed antenna.

ScanSAR vs. SweepSAR (1 of 2)

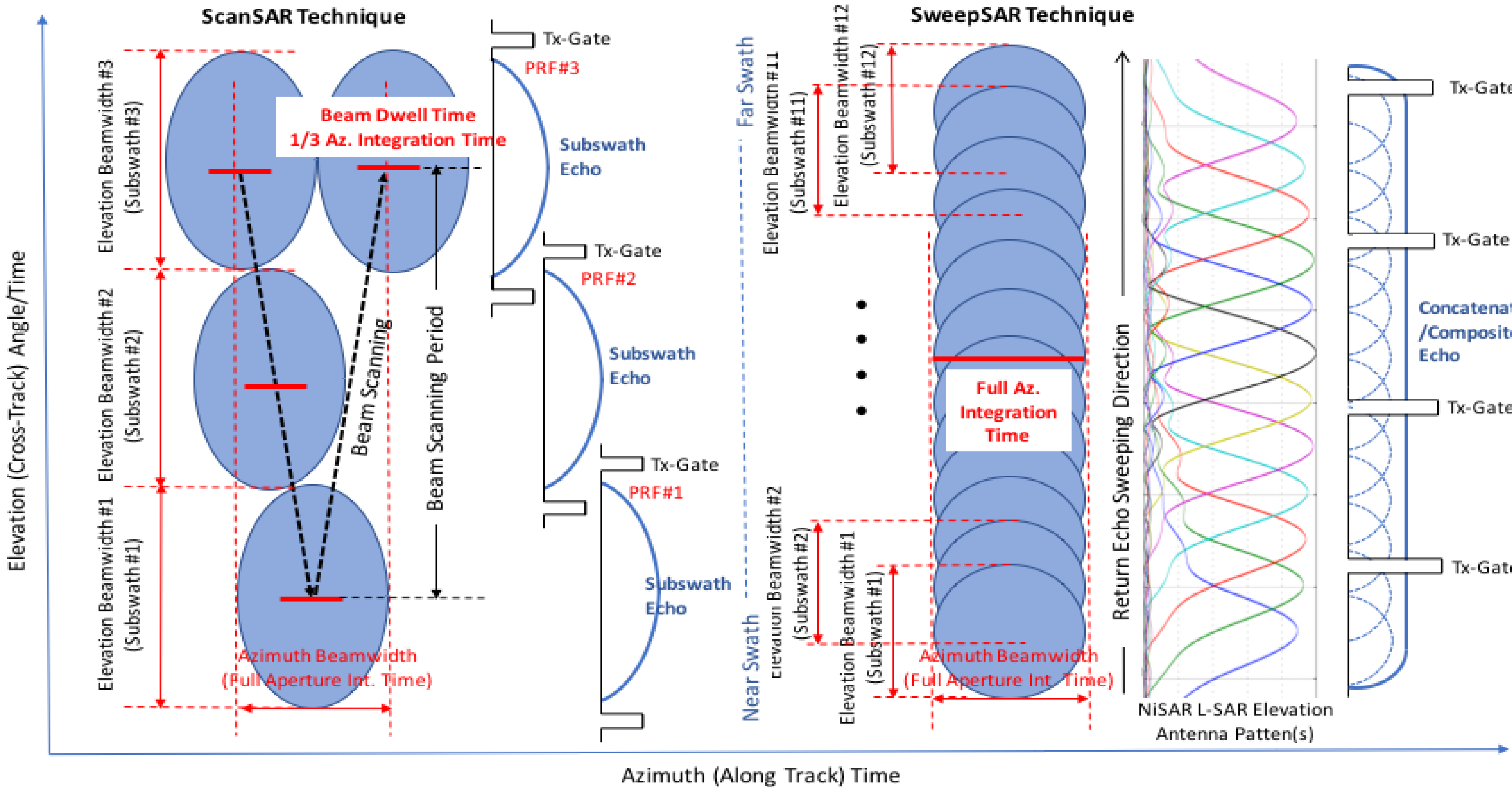
- ScanSAR electronically (by controlling the phasing of the phased array) scans a single beam in cross-track (elevation) to illuminate each subswath cyclically
- SweepSAR uses multiple sub-beams in cross-track (elevation) with each sub-beam illuminating overlapped sub-swaths for wide-swath imaging



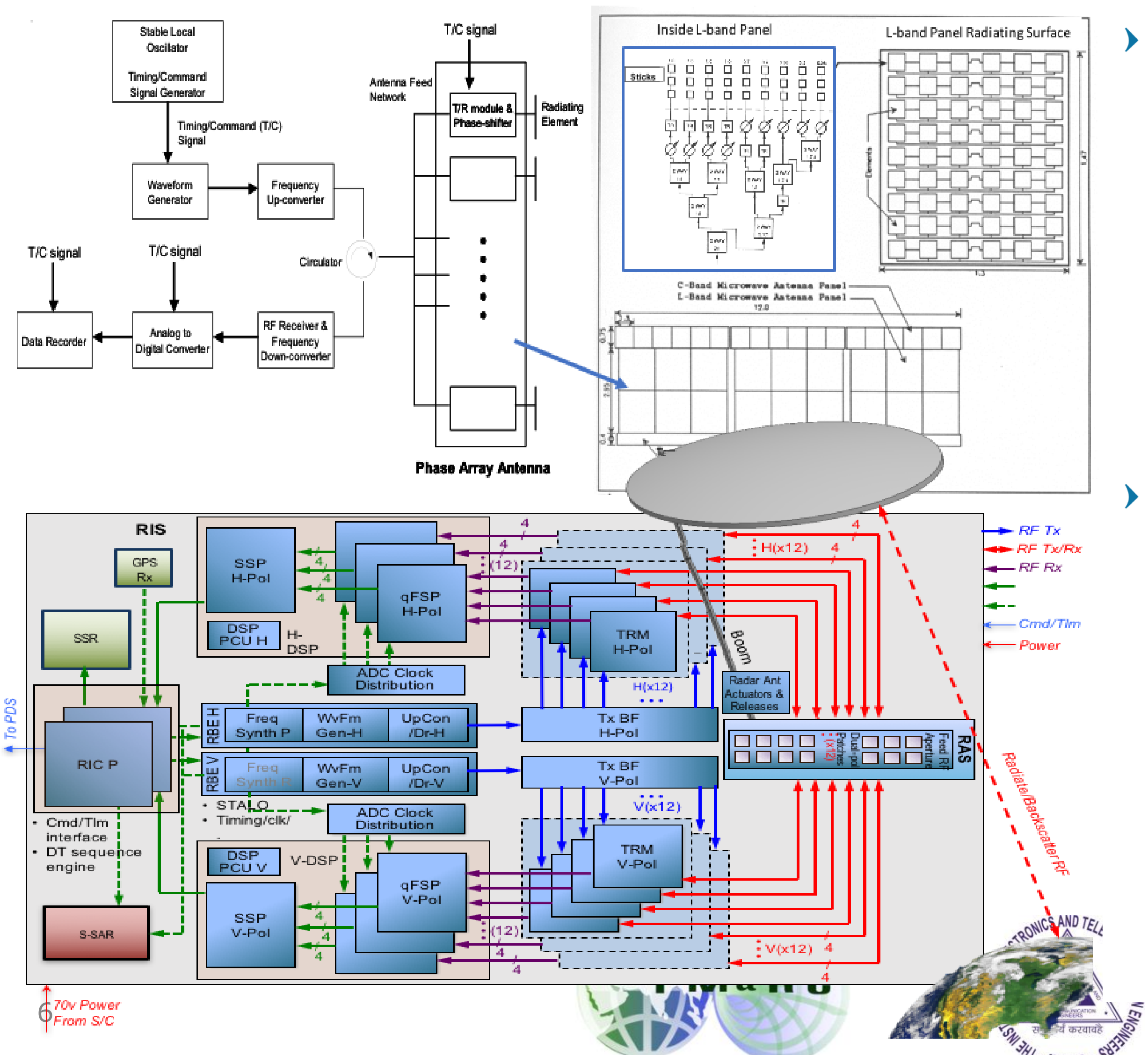


ScanSAR vs. SweepSAR (2 of 2)

- ScanSAR electronically (by controlling the phasing of the phased array) scans a single beam in cross-track (elevation) to illuminate each subswath cyclically
- SweepSAR uses multiple sub-beams in cross-track (elevation) with each sub-beam illuminating overlapped sub-swaths for wide-swath imaging



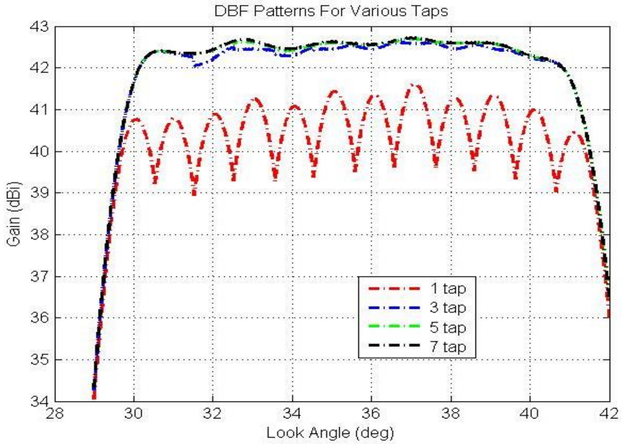
SIR-C/X-SAR and NISAR L-SAR Systems: System Functional Diagram



- SIR-C L-SAR Planar Active Phased Array
  - Aperture size: 3.0 mx12.0 m
  - Arranged in 2 (elevation) x 9 (azimuth) panels configuration
  - Each panel: 9 dual-pol radiating sticks; 14 TRMs (7 per polarization)
  - 3 coax 1-to-18 cooperate feed networks (1 per pol+BITE)
- NISAR L-SAR Reflector & Arrayed Feed
  - Aperture size: 12m diameter
  - 2m Feed: 2x12 dual pol radiating elements segmented in 6 tiles
  - 24 120W TRMs direct feed to the feed tiles (12 per polarization)
  - 2 coax 1-12 transmit feed network connecting driver to each TRM (1 per polarization)

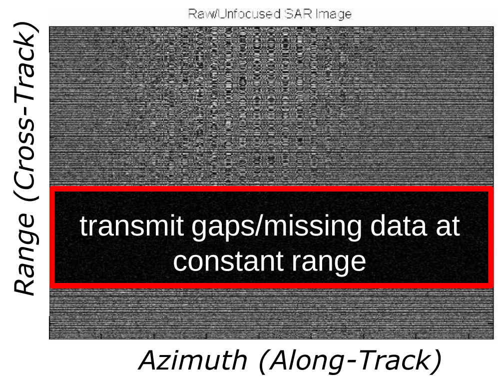
System Sensitivity Comparison

- Radar receive power: $P_r = \frac{P_t G_t \sigma A_e}{(4\pi)^2 R^4} = \frac{P_t A_e^t \sigma A_e^r}{4\pi\lambda^2 R^4}$
- For a given range and ignoring antenna efficiency,
  - NISAR reflector aperture (113m^2) is 3 times larger than that of SIR-C L-SAR (36m^2), resulting in about ~ 9dB better two ways.
  - NISAR azimuth integration time is 3 times longer than that of SIR-C L-SAR 3-subswath ScanSAR mode, another ~4.5dB better
  - NISAR SweepSAR each sub-beam illuminates overlapping subswaths; if digital beam forming is performed correctly, the power received from each subswath can be as much as ~ 6dB better than SIR-C ScanSAR edge of the subswath
  - However, for each subswath, SIR-C L-SAR radiates entire T/Rs of full array at 4.4KW, while NISAR each subswath was radiated with one T/R at 120W, losing out by ~15dB
- Overall, NISAR L-SAR system can be ~2dB (varying cross-range) more sensitivity than SIR-C L-SAR System but NISAR antenna efficiency is worse than that SIR-C antenna, having more loss
- Both systems can increase its sensitivity by having more powerful TRMs but may hit thermal constraints (limiting radar datatake duration/orbital duty cycle) and multipaction issues (for TRM and feed tiles)

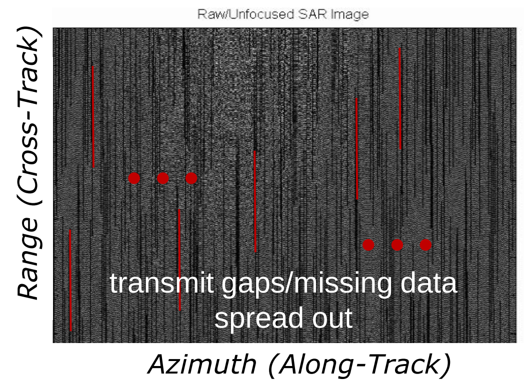


Overall Comparison

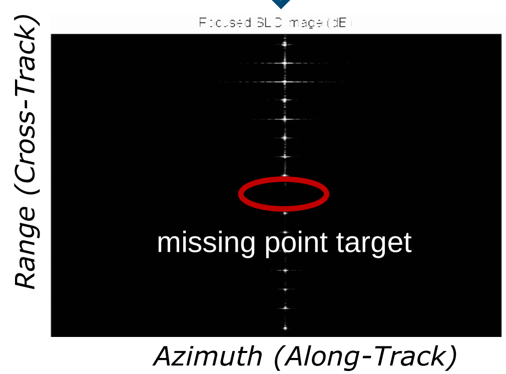
- The biggest advantage of SweepSAR/reflector+feed over ScanSAR/planar phased array is in its more efficient in using the aperture, more economic in mass, and easier to add one more frequency (as we do, adding S-SAR).
- However, SweepSAR requires more complicated on-board digital beam forming processing to bring out its sensitivity.
- SweepSAR also creates transmit gaps if operated with single PRF; PRF dithering will remove the gaps with slightly reduction in SNR.



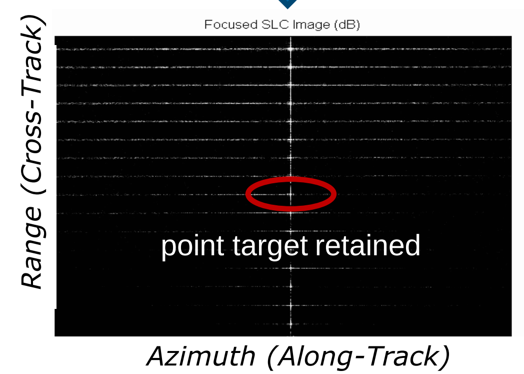
(1a) Raw data with transmit gaps if constant PRF



(2a) Raw data with transmit gaps spread out if random dithering PRF



(1b) Processed image missing a point target if constant PRF



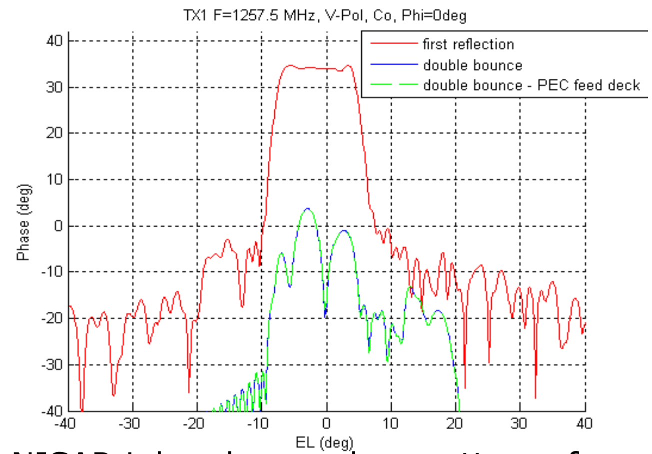
(2b) Processed image with all point targets if random dithering PRF

Other Differences between SIR-C L-SAR and NISAR L-SAR

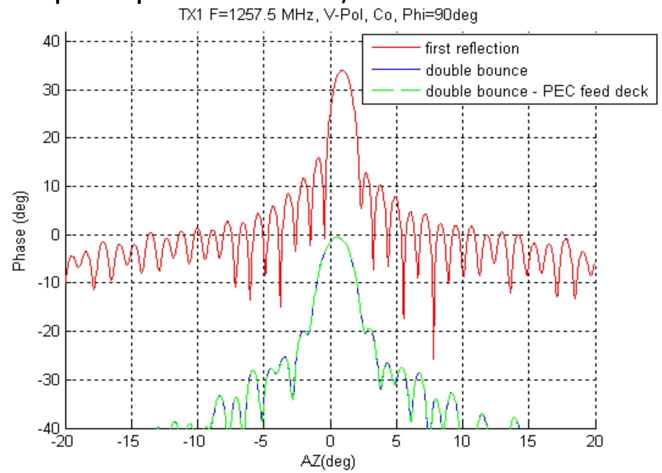
- Due to its antenna configuration, SIR-C L-SAR antenna can be steered in azimuth operated in Spotlight mode; NISAR antenna arrayed feed does not allow azimuth steering and to accommodate dual frequency feeds, L-SAR beam and S-SAR beam are squinted in azimuth.
- NISAR L-SAR includes in internal calibration signal routing in the TRMs; SIR-C L-SAR had provision of coupling signals from the antenna panels and routed to the radar receiver.
- NISAR L-SAR system implements split spectrum waveform radiation (two waveforms at different center frequencies and radiated successive in time) to allow for ionospheric TEC estimate to remove.
- NISAR implements compact pol configuration, with which both H-pol TRMs and V-pol TRMs are driven and radiated out from the antenna in circular polarization.
- NISAR L-SAR system directly digitizes L-band signals received by the TRMs, followed by complete digital processing and data handling as a digital receiver; SIR-C received signals got down-converted to intermediate/baseband before being digitized.

Other Issues NISAR System Has to Contend with

- The feed (and supporting payload structure) is within field of view of the reflector
  - Affect the reflector patterns and increase slightly ambiguity/background (see reflector first and 2nd bounced patterns at right.)
  - Increase externally mounted assemblies exposure to high power near field radiation from the feed direct and from the reflector reflected.
- The deployed reflector blocks FOV of other preferred zenith looking subsystems, such as S-TT&C antenna, star sensors, necessitating reconfiguration or possible redesign
- The antenna patterns seems to be more susceptible to thermal distortion, affecting pointing stability and focus
- Structures in the FOV of reflector/feed may induce passive intermodulation when both SAR systems are transmitting



NISAR L-band secondary patterns from first reflection and second reflection; top: V-pol elevation, bottom: azimuth



Summary

- NISAR L-SAR system (and S-SAR system) implements new SweepSAR architecture/technique which provides more effective and efficient wide-swath-imaging capability
- SweepSAR requires digital beam forming and PRF dithering
- Different but more advanced technologies are being used; newer capabilities are added while just focusing on wide-swath capability.
- The antenna subsystem created issues that must be mitigated

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