NISAR S-SAR DBF Calibration

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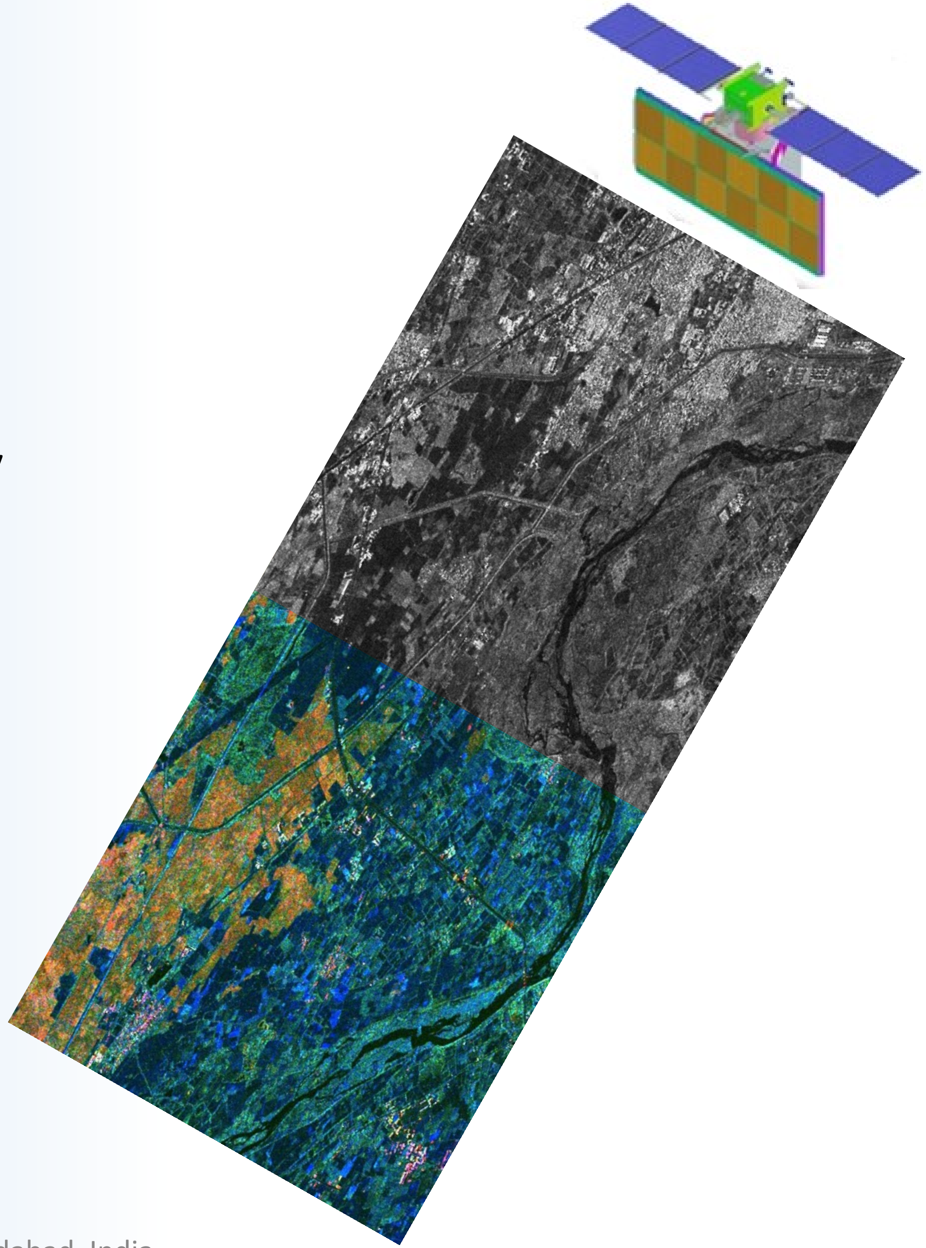
Dated 13/11/2024



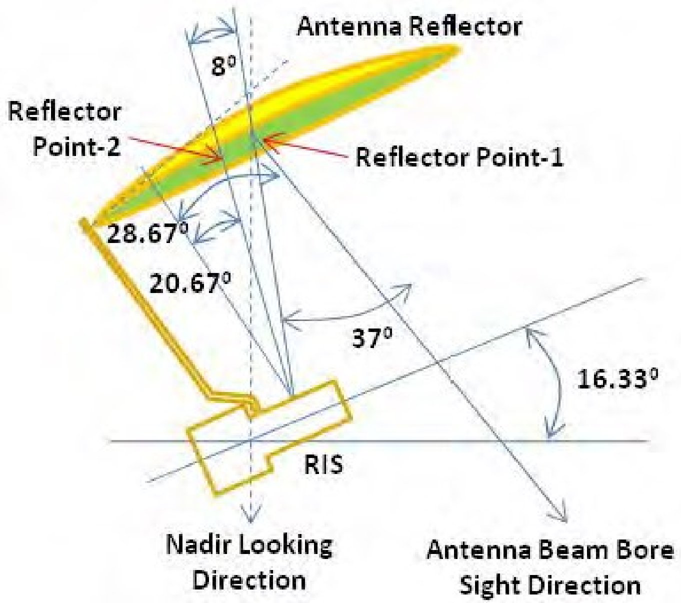
Contents

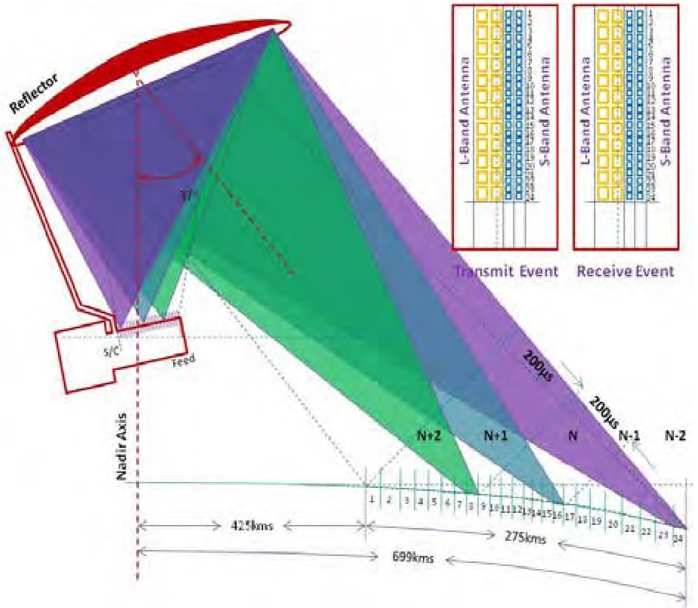
Salient Features of NISAR

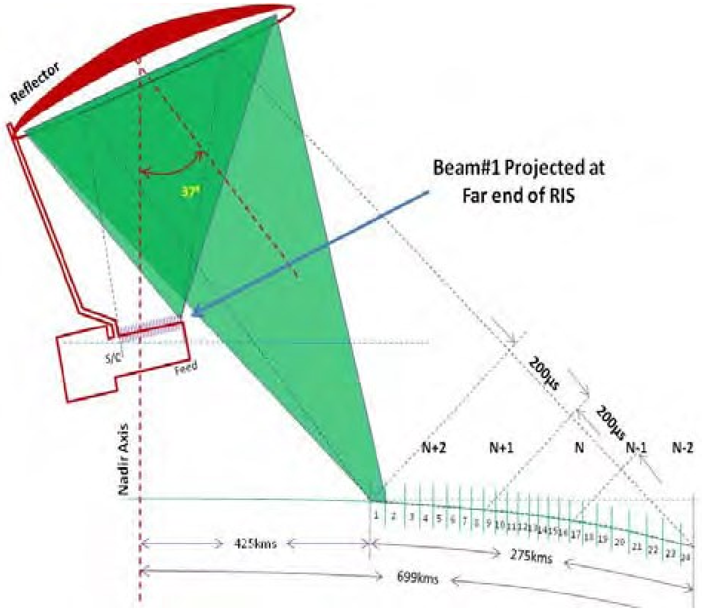
NISAR

- Dual Frequency SweepSAR Mission
- High Resolution (6 m), Wide Swath (240 Km)
- Large Receive Data Window
- 12m Secondary Reflector Antenna
- Digital Beam Forming
- Dead Range Gaps, Staggered PRI

S-SAR SweepSAR Acquisition Strategy







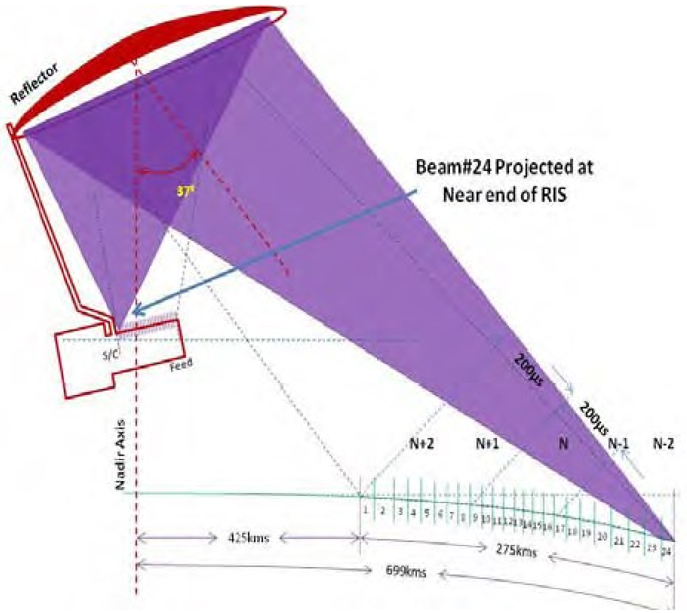
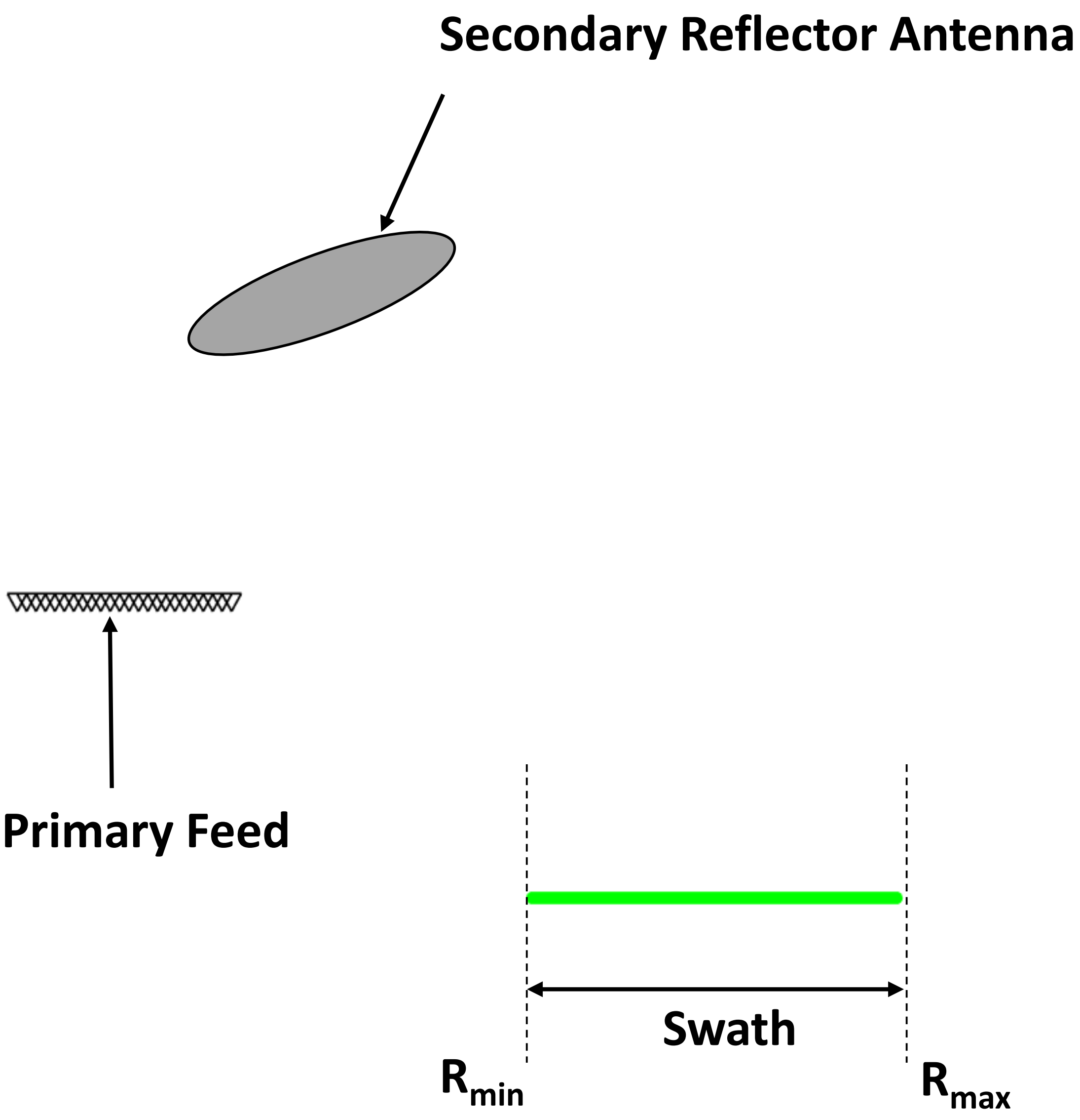


Image Curtesy: S-SAR Payload

Digital Beam Forming

- The SweepSAR mechanism used in NISAR works on the principle of selecting only certain adjacent sub-apertures (at a given time) to be used as Rx channels.
- The phase difference is introduced by the presence of the secondary reflector antenna.
- The data from these channels are phase-equalized by multiplying with complex weighing coefficients and then added.



GIF Curtesy:
S-SAR Payload

Mathematical Background

$u_k(\theta)$ denotes the received signal for the k^{th} TRiM at angle θ,
$g_k(\theta)$ denotes the antenna gain for the k^{th} TRiM at angle θ,
$x(\theta)$ denotes the received signal from swath at the antenna, and
$n(\theta)$ denotes noise.

$v(t)$ is the windowed Rx signal using windowing function $w_k(t)$, and $y(t)$ DBFed output

$\theta(t)$ is a function which converts return time t to the corresponding antenna angle θ.

$q_k(t)$ denotes the weighing coefficients used for phase equalization.

$$u_k(\theta) = g_k(\theta).x(\theta) + n(\theta)$$

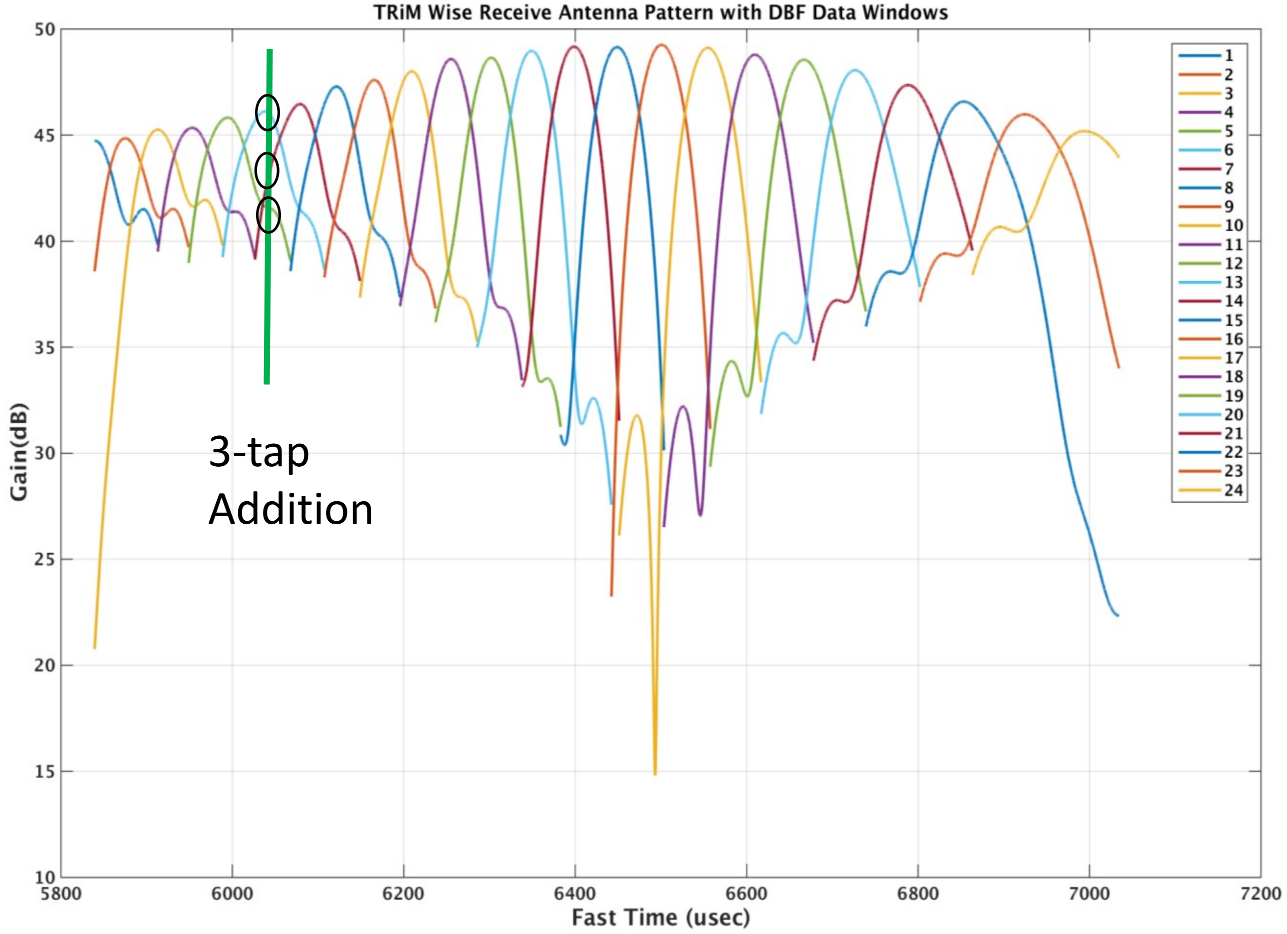
$$q_k(t) = \frac{\overline{g_k\{\theta(t)\}}}{|g_k\{\theta(t)\}|}$$

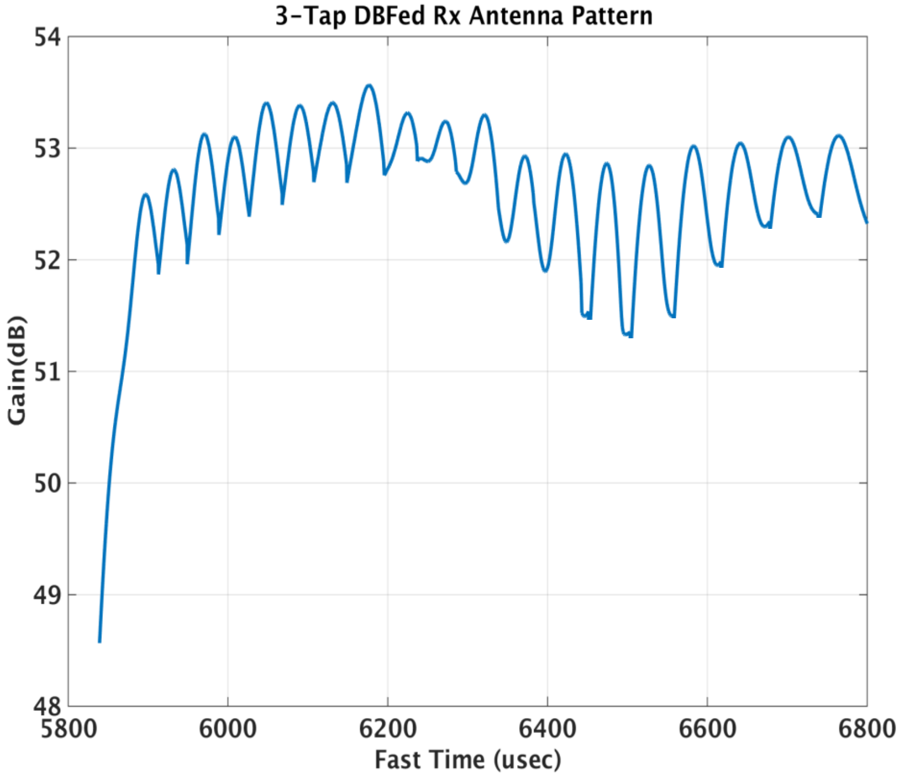
$$v(t) = \sum_{k=1}^{24} u_k\{\theta(t)\}.w_k(t)$$

$$y(t) = \sum_{k=1}^{24} u_k\{\theta(t)\}.w_k(t).q_k(t)$$

S-SAR Antenna Pattern for On –Board DBF & By Pass Mode

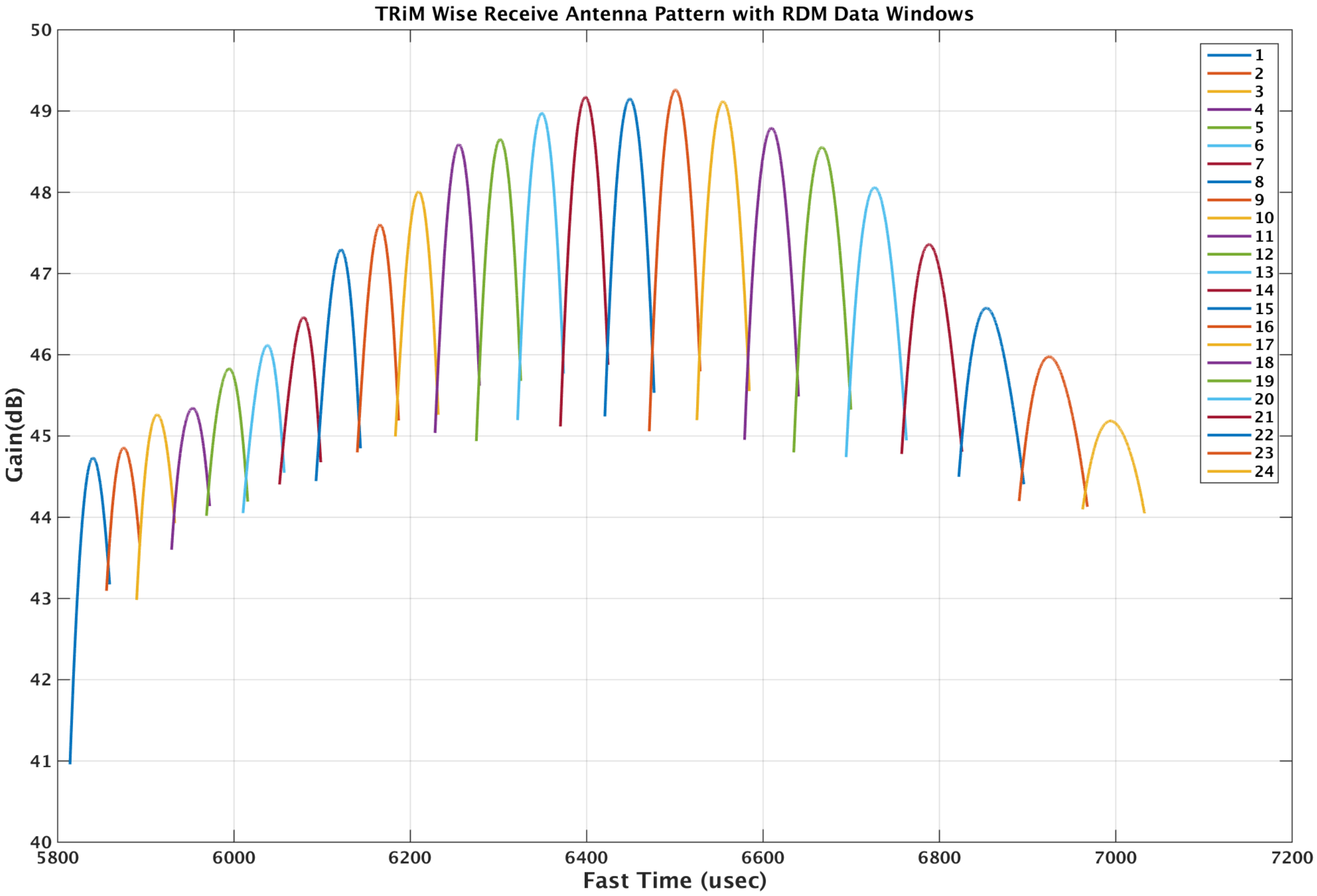
- Nominal mode of data acquisition
- Data windows of channels are computed considering swath overlaps of **three adjacent TRiMs.**
- DBF process **improves SNR** and provides **uniform radiometry across swath**.

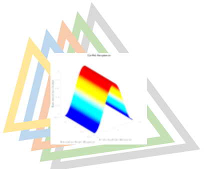




S-SAR Antenna Pattern for RDM Mode

- No On-Board DBF is performed
- ~ 1 Km overlap between adjacent channels
- A Contingency mode
- Will be turned on when DBF chain fails.





Digital Beam Forming Calibration During Commissioning Phase

Factor/Issue	Action/Remarks During Commissioning Phase
Accurate Pointing **(Time to Angle Mapping)**	**Joint Pointing Calibration Exercise with JPL** aims to estimate error in roll, pitch & yaw Using **Null & Doppler Estimates** for different TRIMs
On-Board LUT for Beam Forming Coefficient **(Angle to Coefficient Mapping)**	• Validation using RCID-50 (On –Board DBF) & 51 (On –Ground DBF) over Uniform Backscatter Region in successive cycles. • **On Ground Beam Forming Coefficient** generated using RCID-51 is used to validate RCID-50 **On-Board Beam Forming Coefficient**. • Beam Forming Coefficients are then updated & uploaded On-Board.
Tx & Rx Antenna Pattern Validation	• Using RCID -51 over Uniform Backscatter Region

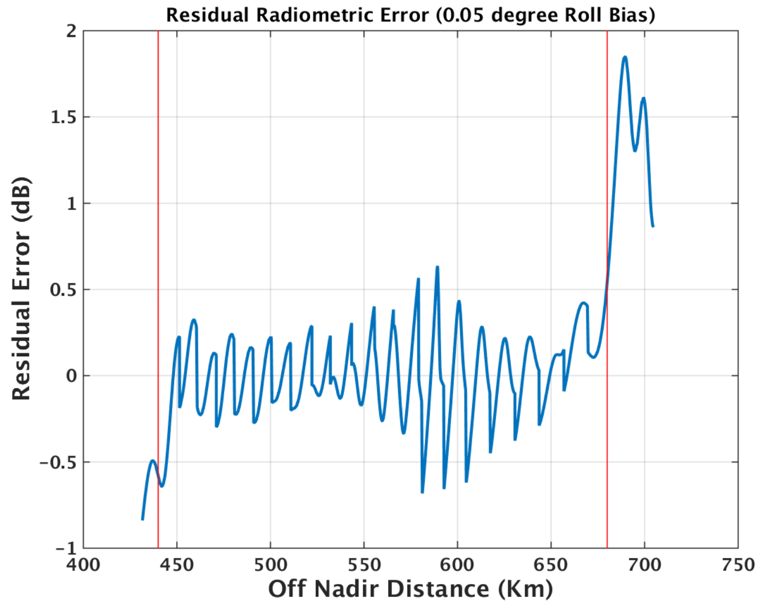
Simulation of Pointing Error on DBF Mode Radiometric Profile

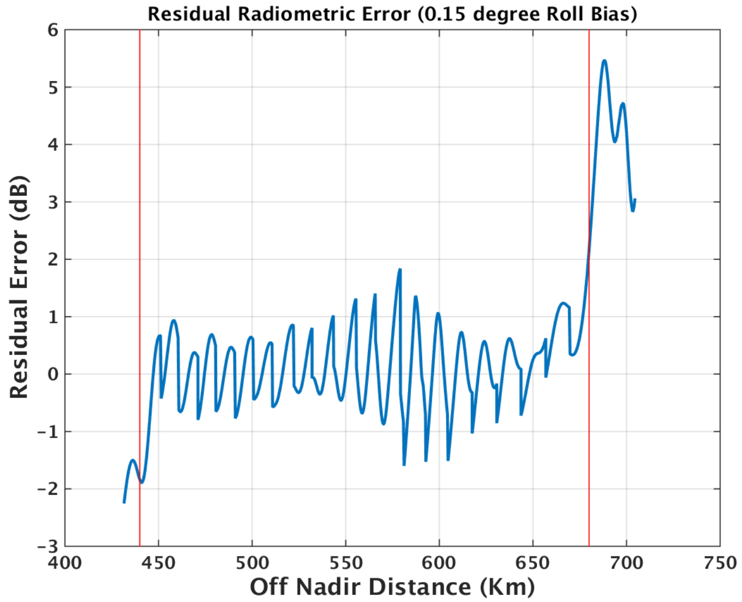
Steps

1. Generating received power profile across swath without any pointing errors
2. Generating received power profile across swath at **different roll errors**
3. Difference between these profiles will give measure of residual radiometric profile

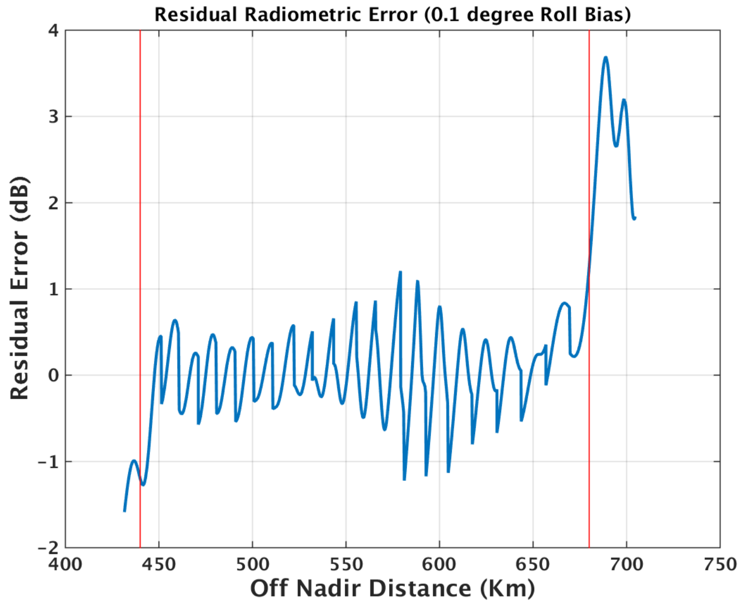
Radar Equation $P_r = \frac{\lambda^3 P_t G_t(\theta_{el},\theta_{az}) G_r(\theta_{el},\theta_{az})}{(4\pi R)^3 L_f L_s} \frac{\sigma^0}{\sin\eta} \frac{c\tau}{2L_a}$					
Where					
c	Light Velocity	299792458 m/s	$G_t(\theta_{el},\theta_{az})$	Transmitted gain	Nominal
σ^0	Backscattering coefficient	Unity	$G_r(\theta_{el},\theta_{az})$	Received gain	Nominal
P_t	Transmitted power	Nominal	λ	Wavelength	.09 m
P_r	Received Power	Evaluated	τ	Pulse width	25 us
θ_{el}	elevation angle	29.5°-41.5°	L_s	System Losses	1
θ_{az}	azimuth angle	0.35	L_f	Fluctuation Losses	1
R	Slant range	890 km -1060 km	η	Incidence Angle	Nominal°
L_a	Azimuth Antenna Length	12			

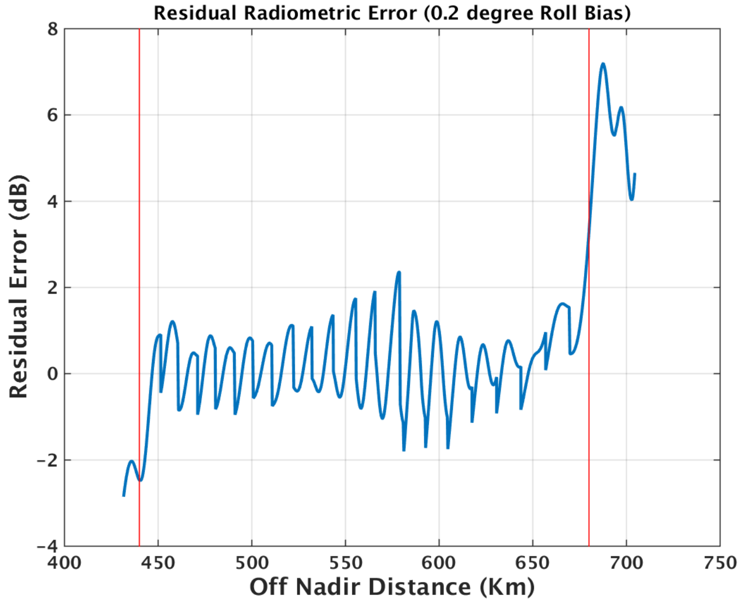
Residual Radiometric Errors Due to Roll Error in DBF Mode



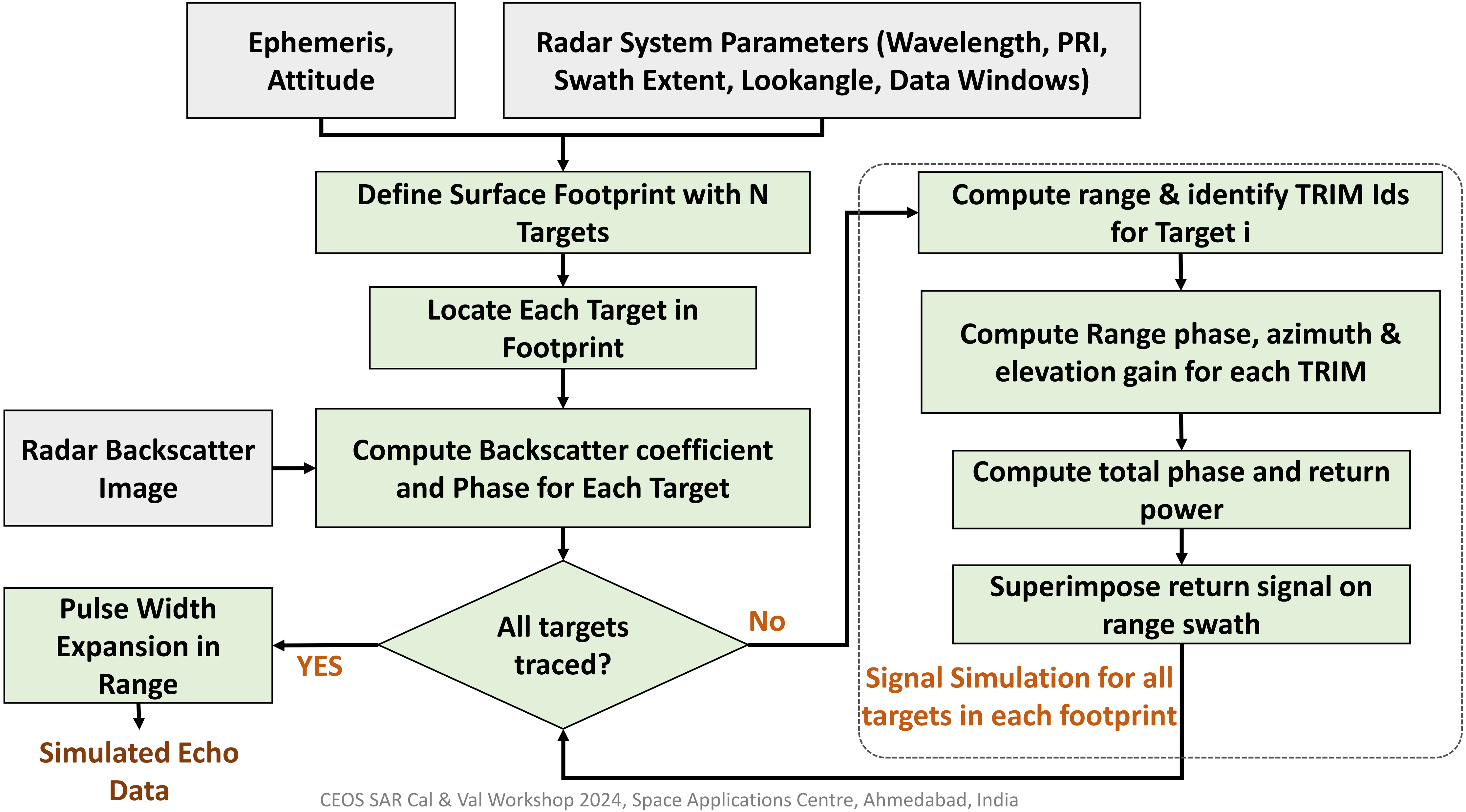


Pointing Error (Degrees)	Pk-Pk Error (In dB)
0.05	1.25 dB
0.1	2.25 dB
0.15	3.5 dB
0.2	4.0 dB





SAR Echo Data Simulation Strategy for Raw Data mode with DBF Data Windows



On Ground Digital Beam Forming

Steps

1. Mapping off fast time (τ) to elevation angle (El) using SAR Geolocation algorithm denoted by $El(\tau)$
2. Calculation of Interpolated Beam Forming Coefficient for each fast time (τ) using Receive Antenna Pattern $G_r(\tau)$
3. Beam Forming

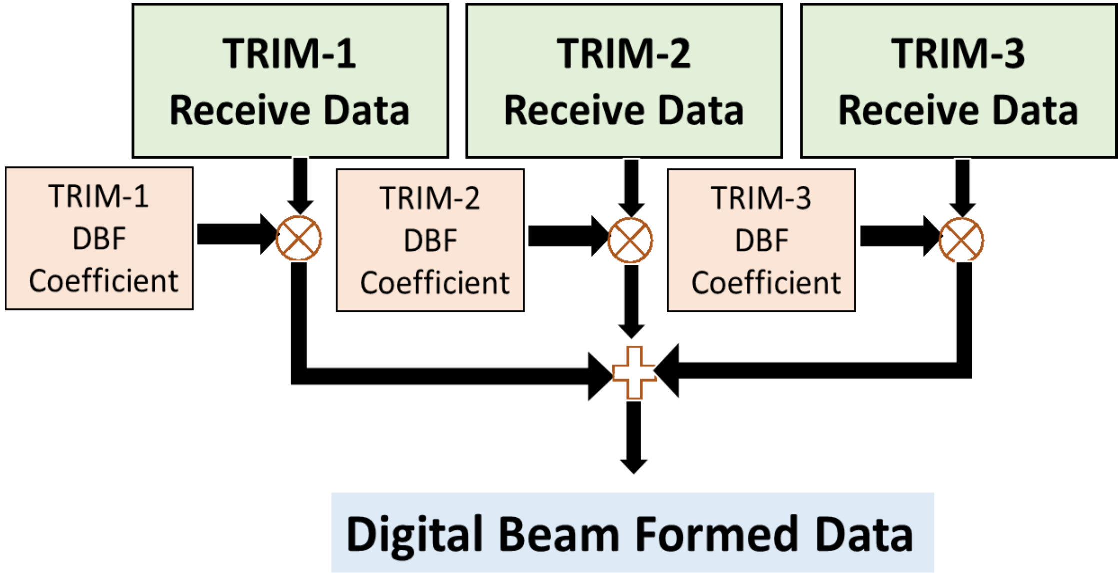
   $y(\tau) = \sum_{k=1}^{24} c_k\{El(\tau)\}^* d_k(\tau)^* w_k(\tau)$

   where,

   $c_k(El(\tau))$ *is the interpolated beam forming coefficient for kth TRIM at fast time* (τ) *, conjugate of complex antenna pattern with unity magnitude*

   $d_k(\tau)$ *is the windowing function for selection of TRIMs for given echo time*

   $w_k(\tau)$ *is the windowing function for selection of TRIMs for given echo time*

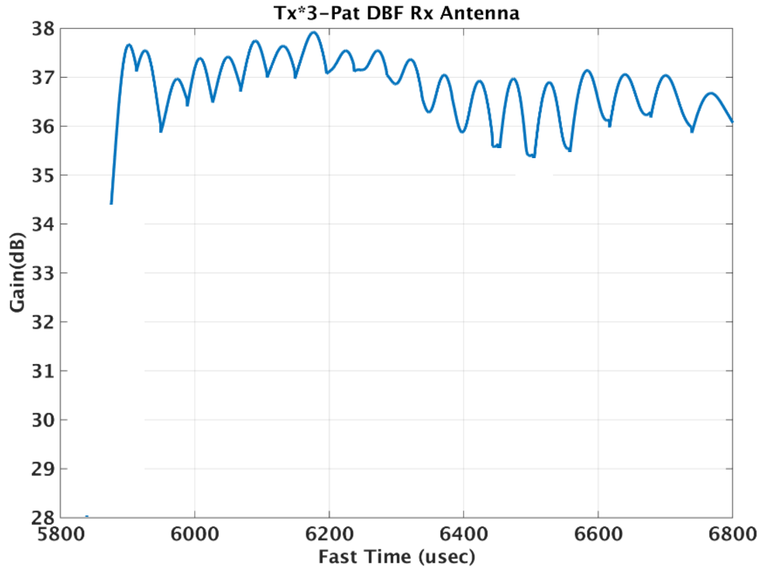


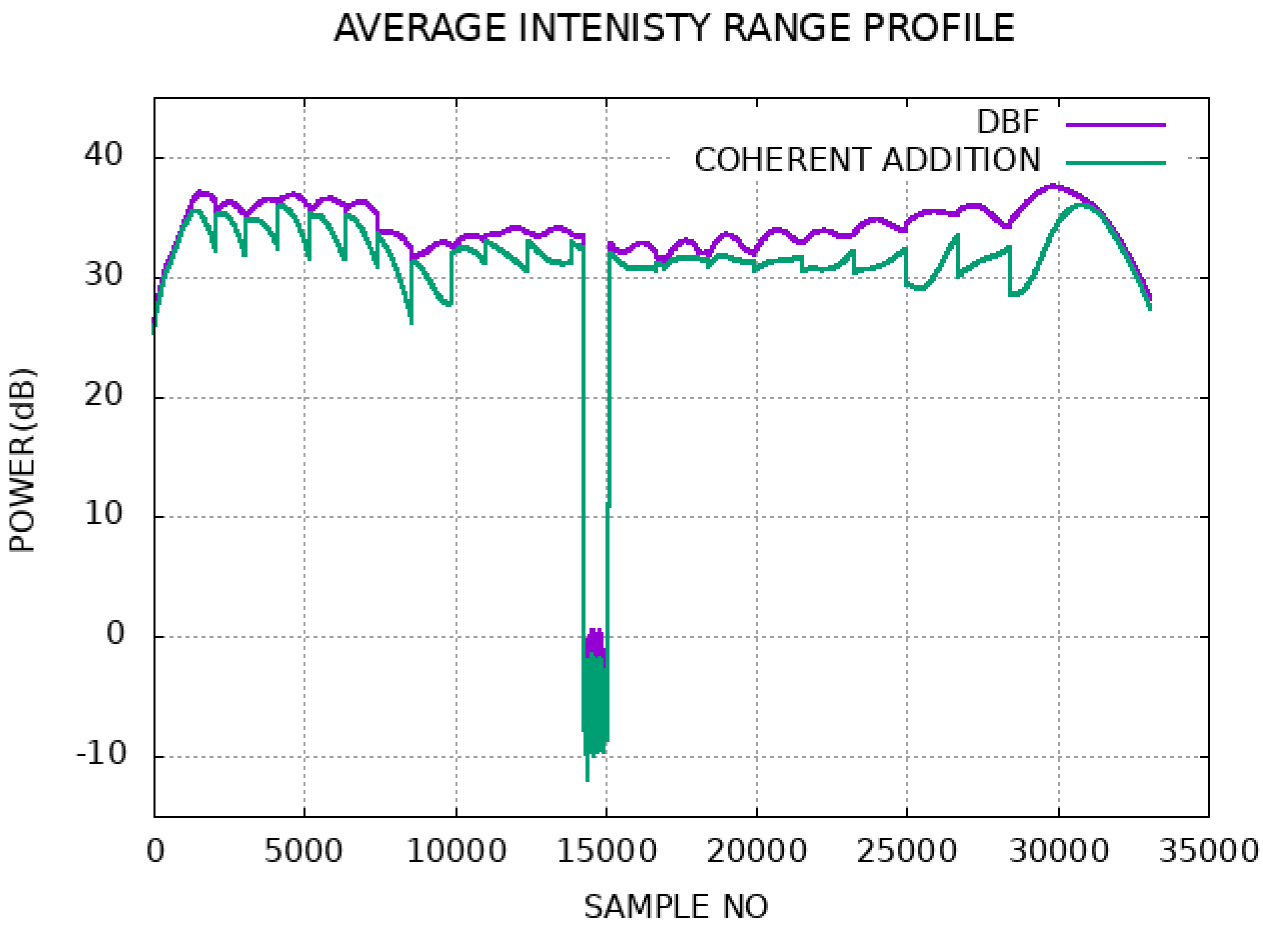
Raw Data Intensity Profiles after Digital Beam Forming

Trim Wise Raw Data was combined using two methods

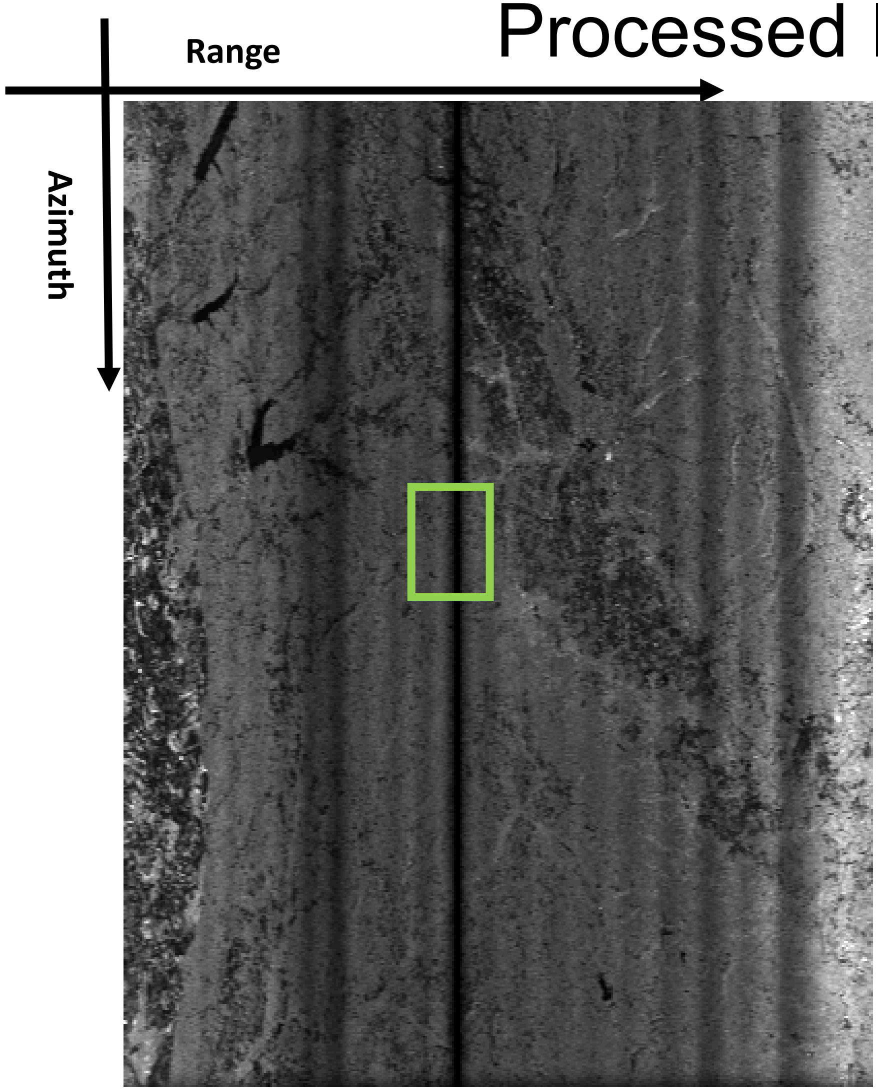
- **3-Tap Digital Beam Forming (i.e. Receive Antenna Pattern Phase Compensation)**
- **3-Tap Coherent Addition (i.e. NO Receive Antenna Pattern Phase Compensation)**

- **Improvement of 1-5 dB in Intensity Profile for 3-Tap DBF case**
- **Relatively Uniform Radiometry across swath in DBF Case**

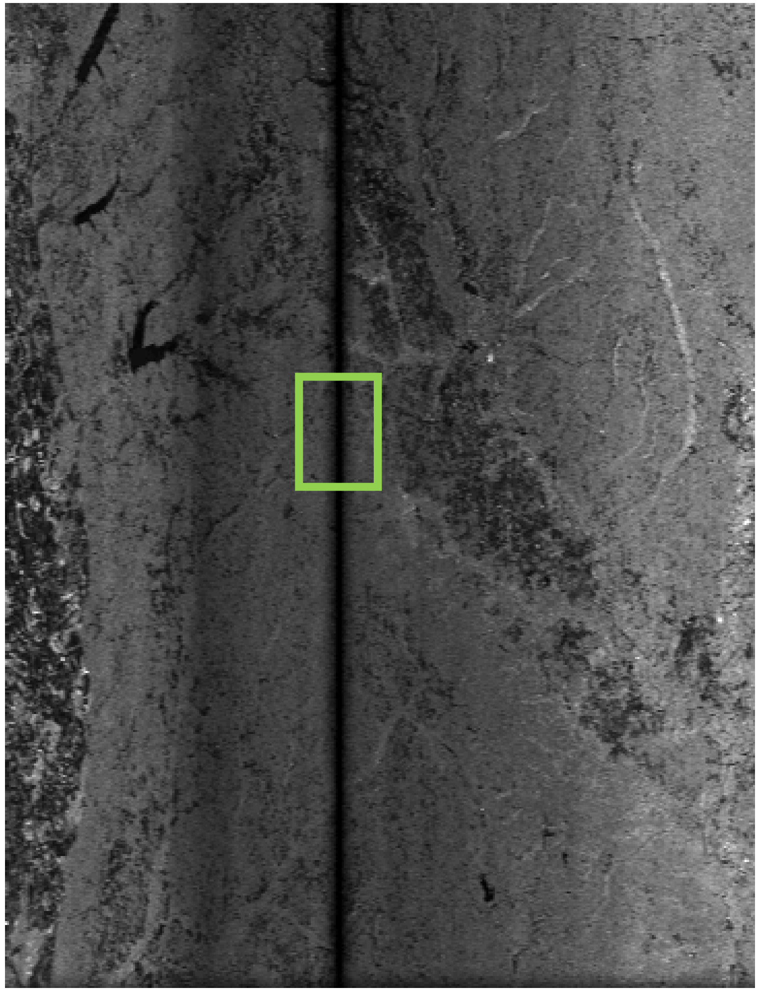




Processed Images



3-Tap Coherent Addition Processed Image (No Antenna Pattern Phase Compensation)



3-Tap DBF Processed Image

Dead Range Gaps at Fix Range Bins for all azimuth pulses

Conclusion

- Digital Beam Forming generates wide swath images at uniform radiometry
- Digital Beam Forming Calibration is done using following methods in Commissioning Phase
  1. Accurate **Time to Angle** Mapping

     Joint Pointing Calibration Exercise
  2. Accurate **Angle to Coefficient** Mapping
     - Nominal DBF Mode & RDM Mode with DBF Data Windows Acquisition over Uniform Backscatter Regions over successive cycle
     - On Ground Beam Forming Coefficient is used to validated On Board beam Forming

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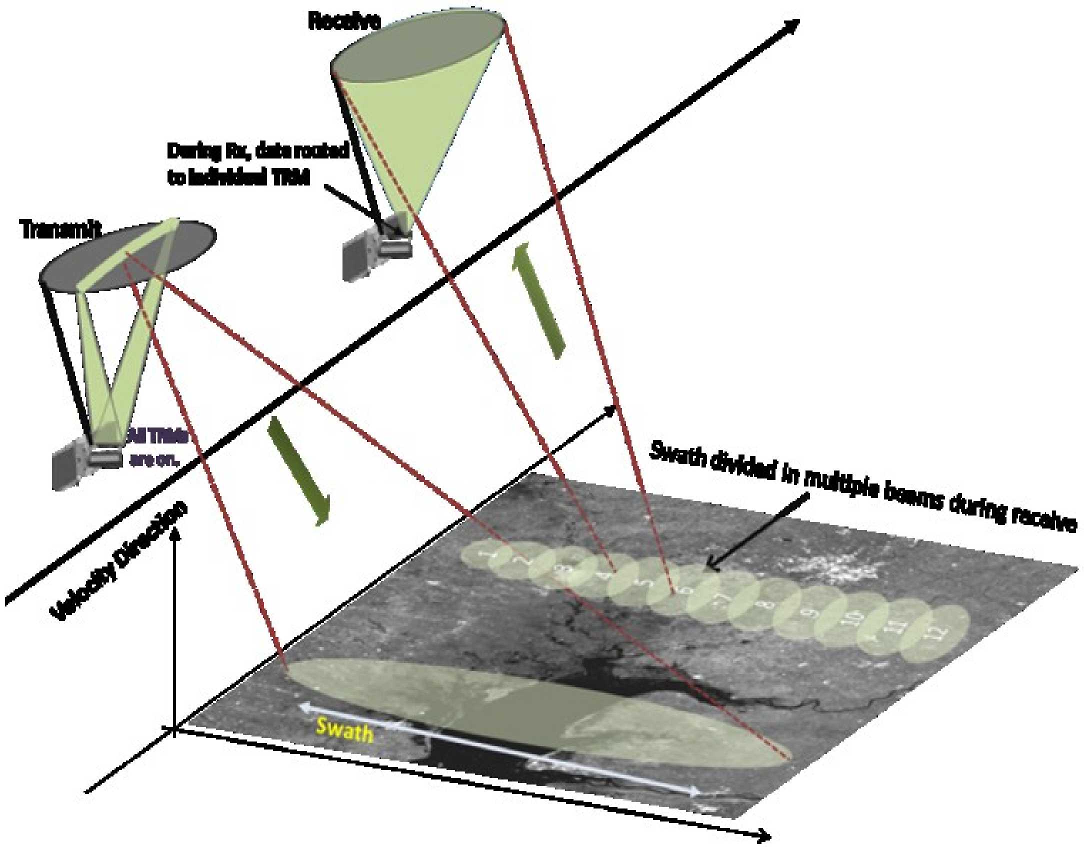
Thanks

backup

NISAR Acquisition Geometry



Major Mission and Acquisition Parameters

Parameters	S-band	L-band
Orbit	747 km with 98° inclination	
Repeat Cycle	12 days	
Time of Nodal Crossing & Look Direction	6 AM / 6 PM & Left Look	
Frequency	3.2 GHz ± 37.5 MHz	1.2575 GHz ± 40 MHz
Available Polarimetric Modes	Single Pol (SP): HH or VV Dual Pol (DP): HH/HV or VV/VH Compact Pol (CP): RH/RV Quasi-Quad Pol (QQP): HH/HV and VH/VV	SP: HH or VV DP: HH/HV or VV/VH CP: RH/RV Quad Pol (QP): HH/HV/VH/VV
Available Range Bandwidths	10 MHz, 25 MHz, 37.5 MHz, 75 MHz	5 MHz, 20 MHz, 40 MHz, 80 MHz (Additional 5 MHz Auxiliary Band for 20 & 40 MHz modes at other end of pass-band)
Swath Width	> 240 Km (except for QQP Mode)	> 240 Km (except for 80MHz BW)
Spatial Resolution	7m (Az.); 3m-24m (Slant-Ra)	7m (Az.); 3m-48m (Slant-Ra)
Incidence Angle Range	33° – 47°	33° – 47°
Noise Equivalent s°	-25 dB (baseline) -20 dB(Threshold)	-25 dB (for required full-swath modes)
Ambiguities	< -20dB for all modes except QQP	< -23dB swath average in SP or DP modes < - 17dB swath average in QP mode
Pointing control	< 273 arc seconds	
Orbit control	< 350 meters	
Data and Product Access	Free & Open	

Salient Features of NISAR

- World's First Dual (L&S) Frequency **SweepSAR** Mission
- High Resolution (6m azimuth) Wide Swath (240 Km) Mission
- Wide Swath is achieved using **Large Receive Data Window**
- High Resolution achieved using 12 m secondary reflector antenna
- Uniform Radiometry across Swath using **Digital Beam Forming**
- Large Receive Data Window, small PRI causes **Dead Range Gaps**
- Distribution of dead range gaps using **PRF Dithering/ Staggered PRI**
- **Resample** the Non Uniformly Sample Azimuth Data to Use RDA