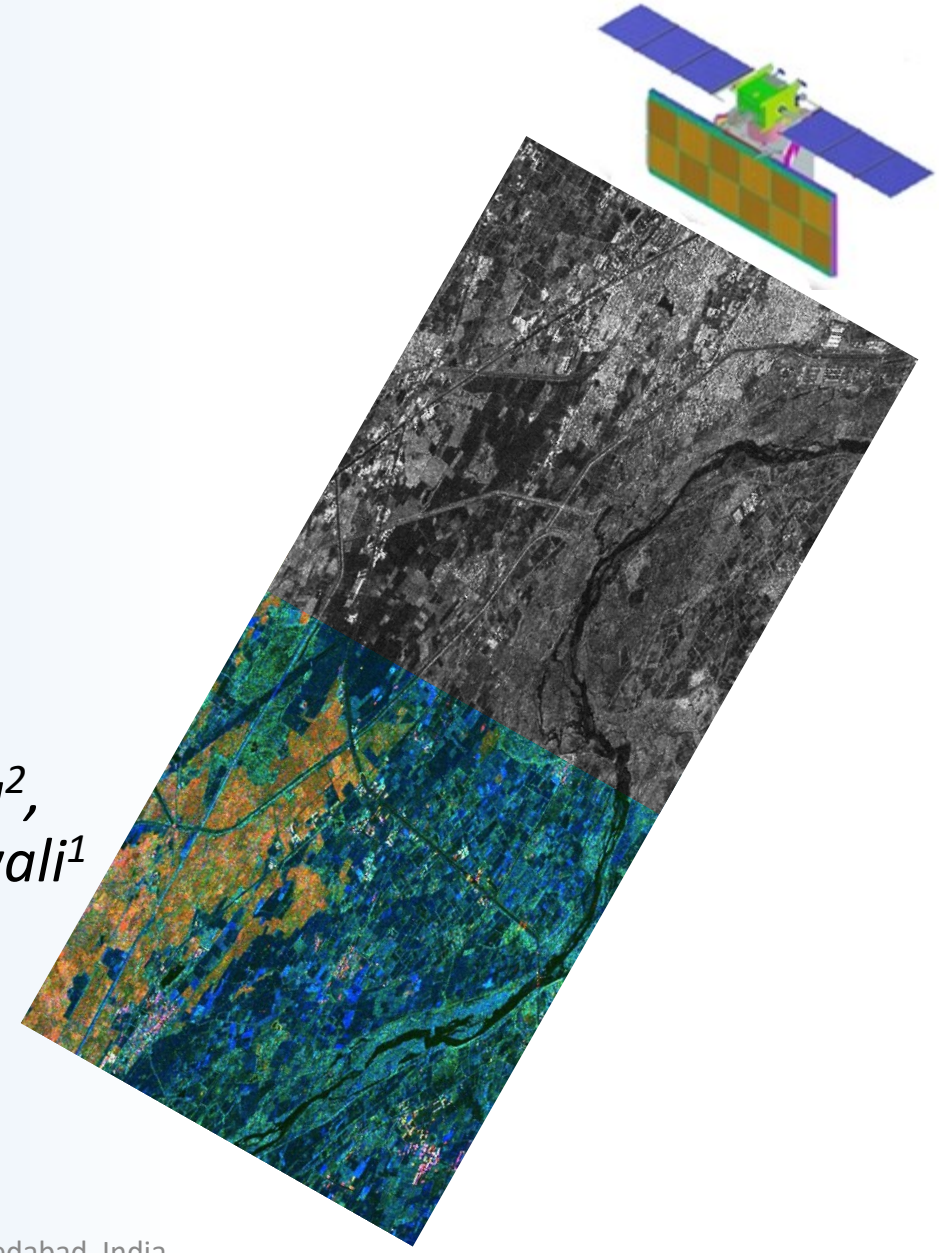
Radiometric and Polarimetric Characterization of ISRO's Multi-Band Active Radar Calibrator



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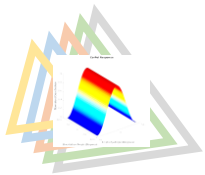
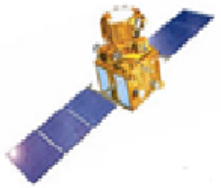
National Remote Sensing Centre[1]/ Space Application Centre[2]
Indian Space Research Organization,
Department of Space,

Presentation at a Glance

- Indian Space Programme
- ISRO Cal-Val Activities
- Multi-Band ARC
  - Salient Features of ARC
  - System design and Specifications
- Strategy of Calibration exercises in Multiple Frequencies
- EOS-04 C-band Analysis Results
- NovaSAR S-band Analysis Results
- ISRO’s X-band Analysis Results
- Conclusion
- References



Indian Space Programme



Strategic User Stations

- Acquisition Planning
- Meeting User Demand

Design, Implementation

Reviews, Testing, Approvals

Satellite Conceptualization

- Assimilation of user feedback/ requirements
- Global Scenario
- Studies for Satellite Configuration finalization
- Payload Acquisition Planning

Launch

Calibration, Performance & Quality Reviews

Initial Orbit Phase

- Mission Performance Analysis and Data product Quality Evaluation
- Calibration & Validation
- Acquisition Planning

Maintenance of Spacecraft and Payload Quality

Operational Phase

- Acquisition Planning as per user demand
- Data Products Generation
- Quality Control & Assurance
- Product Dissemination

End Of Life

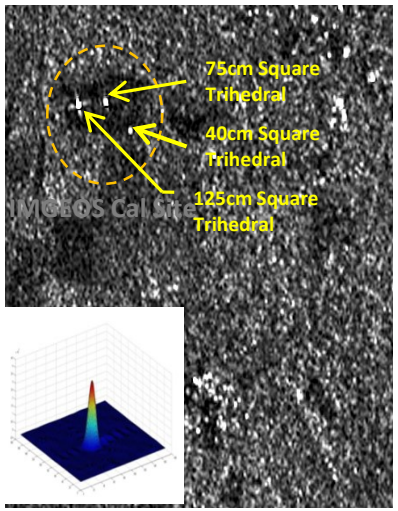
ISRO's Cal-Val Sites

ISRO has established permanent and campaign mode Calibration Sites with an objective:

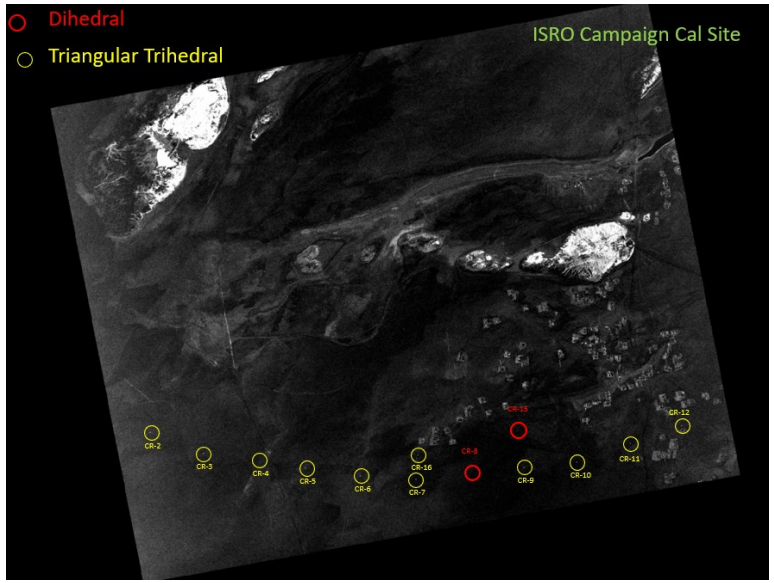
- To perform radiometric, geometric and polarimetric calibration of space borne and airborne SAR sensors operating in:
  - Multi-frequency (L, S, C and X bands)
  - Multi-polarizations (Single/Dual/Hybrid/Full Pol)
- To derive SAR Image Quality Metrics for data product validation

Permanent Sites: NRSC-IMGEOS, SAC-Ahmedabad, Antarctica
Campaign mode Sites: Desalpur, Amarapur, IIST Campus

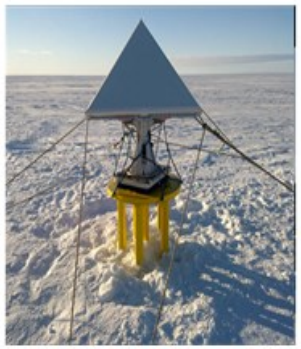
EOS-04 Fine Resolution Stripmap data



Impulse Response Function for point target

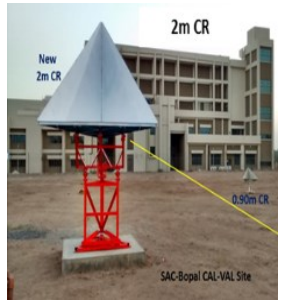


CRs deployed in ISRO Cal Site in Campaign Mode



CR deployed at Antarctica during 2021-2022

Orientation of 100cm Dihedral CR



CRs deployed at SAC/ISRO

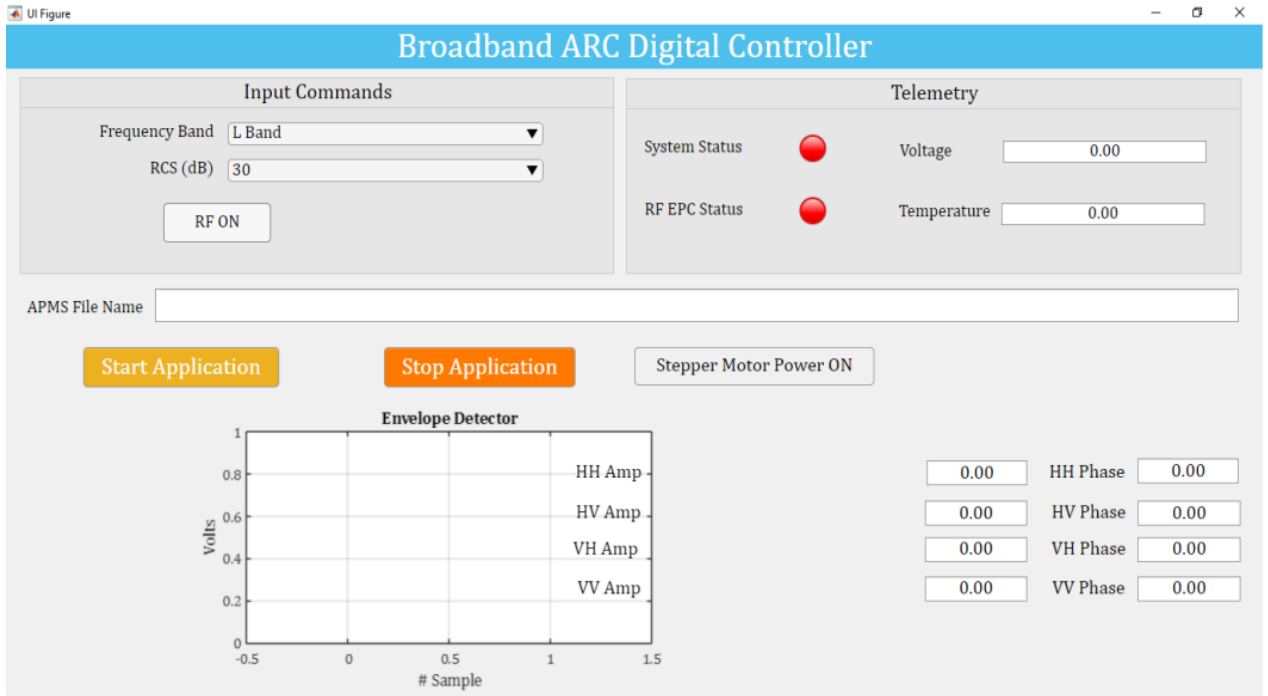
Multi-band Active Radar Calibrator

- To support Calibration and Validation of various SAR missions operating in various frequency bands and polarizations, an Active Radar Calibrator (ARC) also known as Transponder was developed by SAC, ISRO
- Active Radar Calibrators (ARC) are electronic RF systems which has variable RCS values to support calibration of various SAR spatial resolutions.
- Salient Features of ARC:
  - Highly stable RCS by the temperature control of the ARC system
  - Monitoring and analyzing the SAR signal from a satellite by using the Digital Receiver
  - Polarimetric ARC functionality - a valuable tool for phase calibration

Multiband Transmit and Receive Antenna Module: ARC Antenna is a broadband, shared aperture, dual polarized, low profile and light weight multilayer planar antenna operating at L, S, C and X band frequencies. The isolation between Tx and Rx antennas is better than 60 dB.

Major subsystems for ARC:

1. Multiband Transmit and Receive Antennas.
2. Multiband RF Receiver
3. Digital Controller
4. Steering Mechanism and AIT elements



Design Parameter	Specifications
Frequency Band	L Band: 1.25 GHz ± 50 MHz S Band: 3.20 GHz ± 50 MHz C Band: 5.40 GHz ± 125 MHz X Band: 9.60 GHz ± 375 MHz
RCS Range	L Band: 10 to 42 dBm^2 S Band: 10 to 42 dBm^2 C Band: 10 to 47 dBm^2 X Band: 10 to 28 dBm^2 (In Steps of 2 dB)
Polarization	HH, VV, HV, VH, HH + HV, VV + VH, Full Pol., Circular Pol.
Mechanical Mount	Motorized steerable structure with steering steps of 0.5 deg.
Elevation Angle Range	0 – 90 deg.
Azimuth Angle Range	0 - ± 180 deg.
Input Power	Maximum: -40 dBm
RCS Repeatability	< ±0.2 dB
Phase Repeatability	± 3°
Commanding Interface	USB, LAN
Supply Voltage	24 VDC, 10 Ah
Operating Temperature Range	-10 deg. to 50 deg.

ARC Calibration Strategy in Multiple Frequencies

- EOS-04, NovaSAR and RISAT-2B Series corresponding to C, S and X bands were planned over NRSC Shadnagar IMGEOS Cal-Val Site
  - EOS-04 in C-band
  - NovaSAR in S-band
  - ISRO's RISAT X-band
- ARC has been deployed along with Square Trihedral Corner Reflectors(CRs) at IMGEOS Cal- Val site to perform cross validation of point target analysis results.











Cal-Val Analysis using Multi-band ARC

- ✓ Response from ARC and corner reflectors are identified across the polarizations.
- ✓ Detailed point target analysis has been performed with in-house developed SARCalTool to measure image quality metrics of the SAR system.
- ✓ The quality parameters of an Impulse Response Function of point target like Peak Side Lobe Ratio (PSLR), Integrated Sidelobe Ratio (ISLR), Spatial Resolution and Radar Cross Section of ARC and CR are measured.
- ✓ Apart from that, the polarimetric quality parameters corresponding to EOS-04 Full polarimetric data are also derived to ascertain the preliminary results with the specifications.

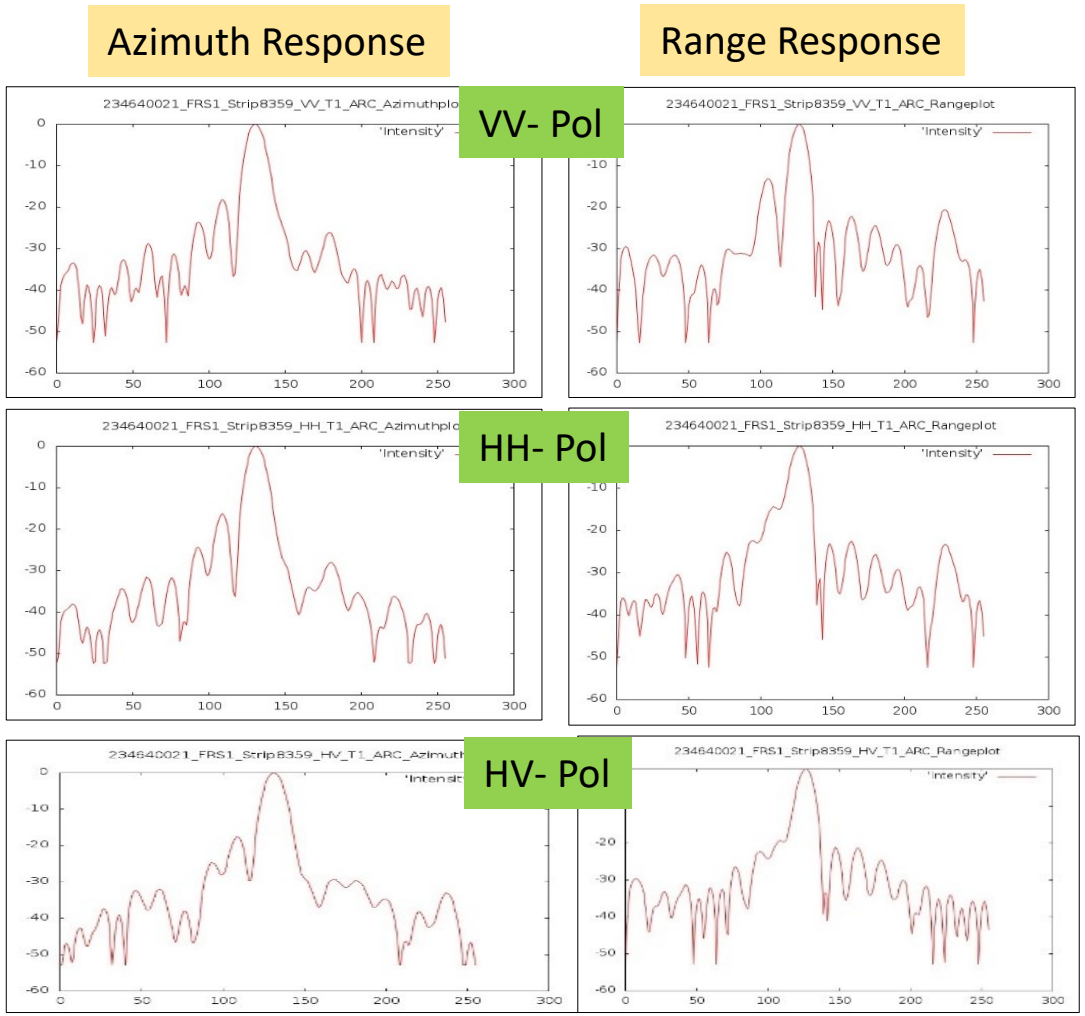
	Target	Co Pol Channel Imbalance	Co Pol Phase Imbalance	Cross Pol Channel Imbalance	Cross Pol Phase Imbalance
26th May 2023	ARC	0.979768	-1.982195	1.021099	4.492874
	75cm Square Trihedral	0.979560	-6.646094	---	--
14th Nov 2023	ARC	1.020856	12.38792	1.040815	-6.13621
	75cm Square Trihedral	1.017188	12.56012	---	--

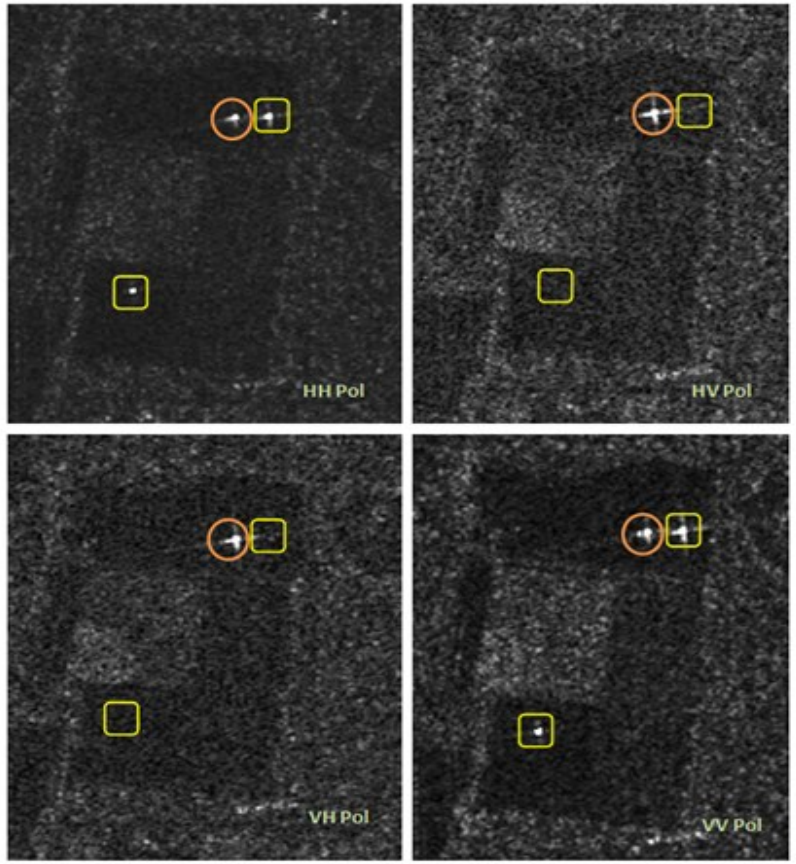
Point Target Analysis of ARC in EOS-04 C-band

- ARC and Corner reflectors are visible in co-polarization as expected w.r.t its scattering matrix properties.
- ARC is clearly visible in cross polarization also enabling to perform Polarimetric calibration.

Impulse response function of ARC in Co-Polarization

Impulse response function of ARC in cross polarization



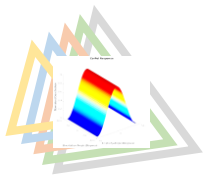


EOS-04 Image acquired over IMGEOS Cal Site in FRS-1 mode in Full Pol on 26/05/23

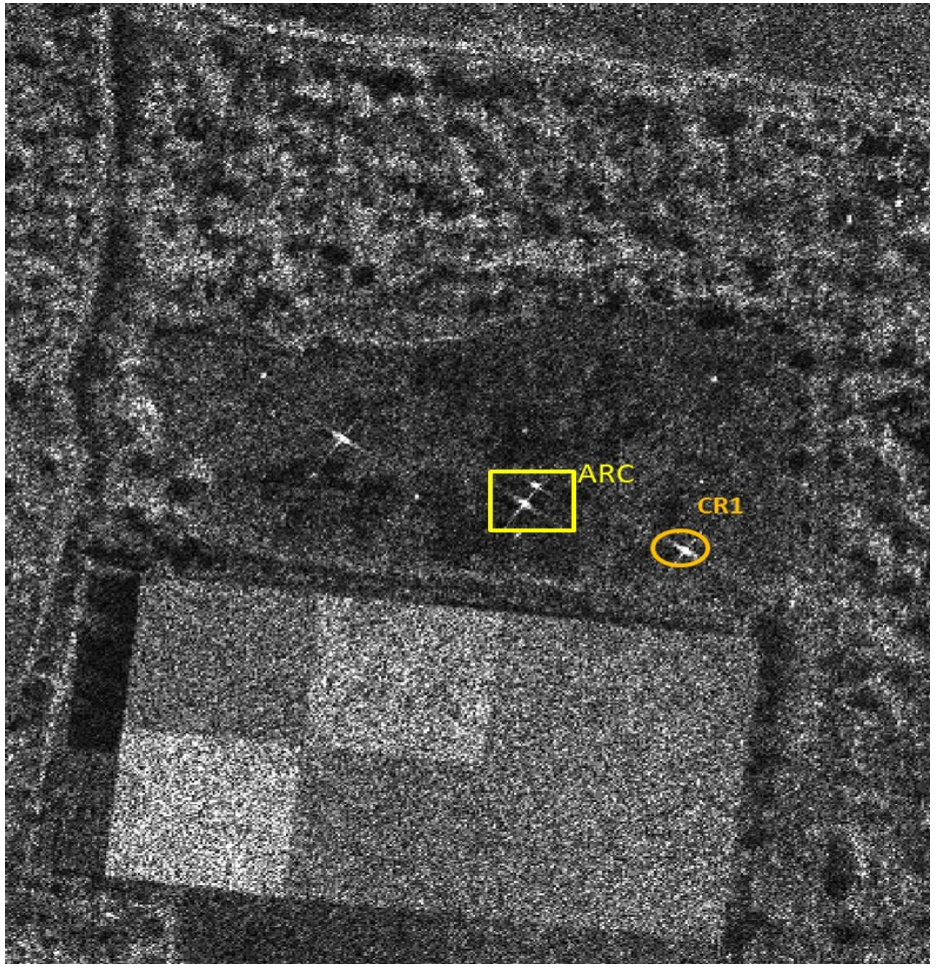
- Active Radar Calibrator
- Square Trihedral Corner Reflector

ARC Analysis for C-Band, RCS Set to 38dBsm

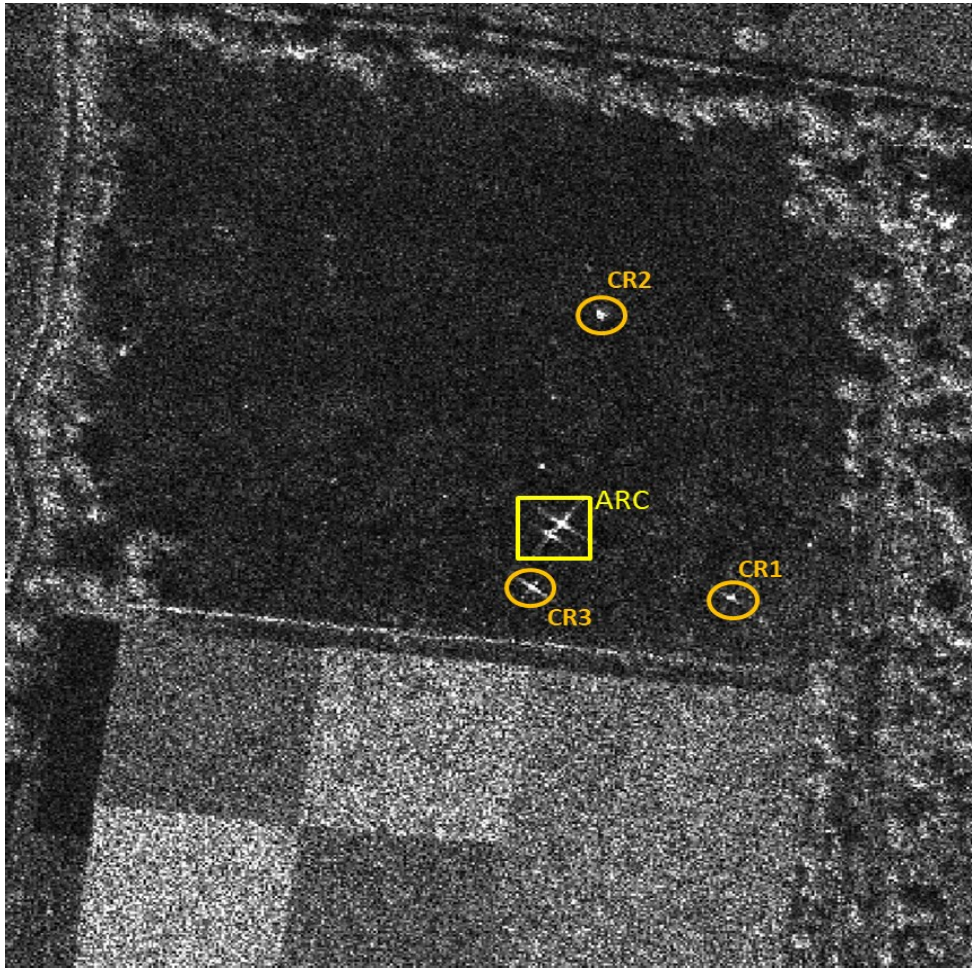
Date of Pass	Target	Pol	Peak DN value	Background to Peak Ratio(dB)	Theoretical RCS(dBsm)	Measured RCS (dBsm)
26th May 2023	ARC	HH	41566	-35.65	38	35.96
	ARC	VV	43869	-37.15	38	35.94
	ARC	HV	42620	-39.7	38	36.49
	ARC	VH	43863	-39.54	38	35.99
	75cm Square Trihedral	HH	24623	-31.2	35.8 (RCS characterized is 33.8)	33.48
	75cm Square Trihedral	VV	23662	-31.11	35.8 (RCS characterized is 33.8)	32.99
14tH Nov 2023	ARC	HH	33348	-31.1	38	33.58
	ARC	VV	32419	-32.74	38	33.77
	ARC	HV	32894	-33.58	38	34.2
	ARC	VH	32783	-33.93	38	33.67
	75cm Square Trihedral	HH	33456	-28.54	35.8 (RCS characterized is 33.8)	33.76
	75cm Square Trihedral	VV	32801	-28.54	35.8 (RCS characterized is 33.8)	33.75



ARC Response in X-band data

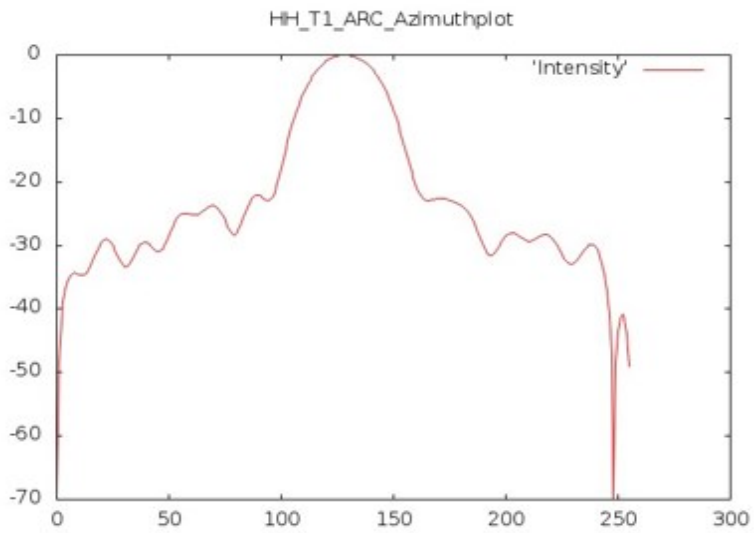


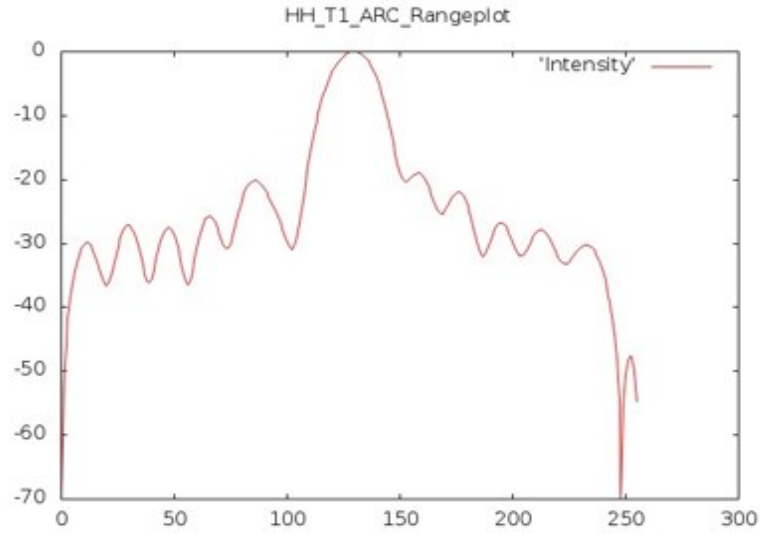
Descending , Right



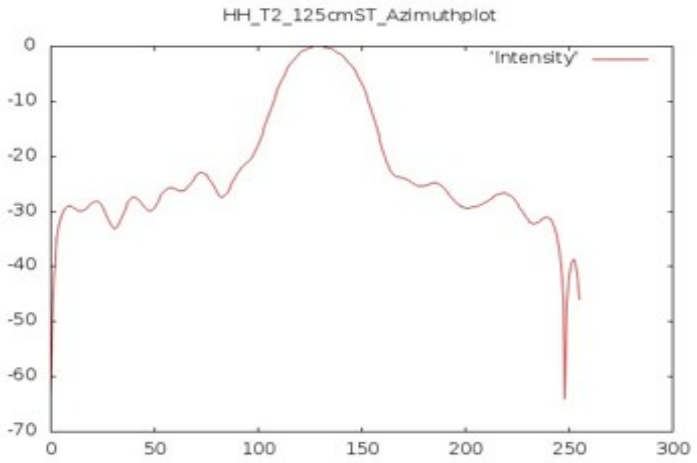
Descending , Left

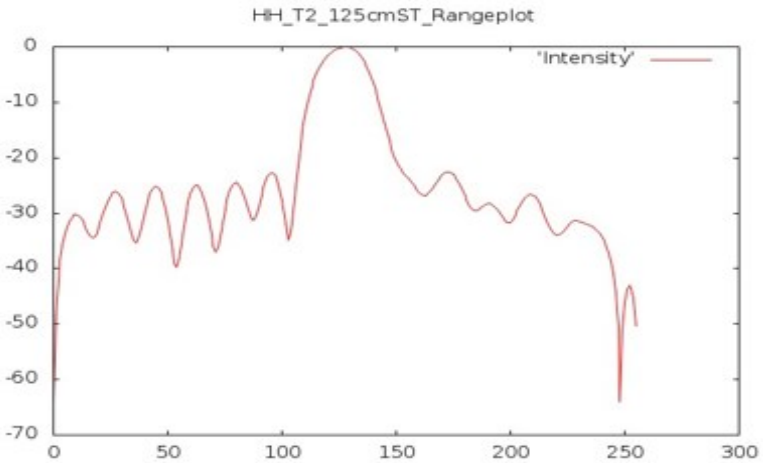
Multi-band ARC in S-band (NovaSAR)



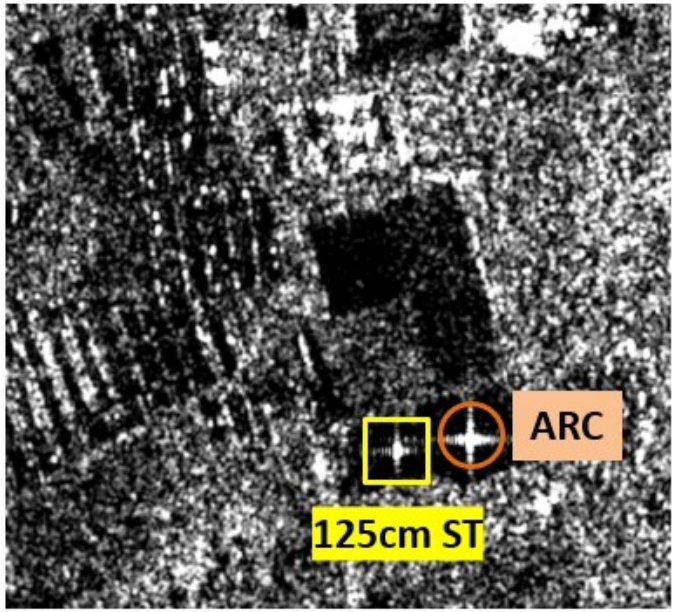


Impulse response function of ARC in HH Pol





Impulse response function of 125cm Square Trihedral in HH-Pol



NovaSAR data in HH polarization

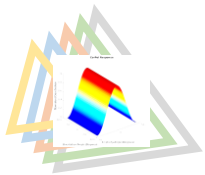
Acquisition Date: 4/7/2023

Derived RCS with ARC and Corner Reflector for NovaSAR

DOP	Target	Pol	Peak DN value	Background to Peak Ratio (dB)	Theoretical RCS (dB)	Measured RCS (dB)	K from Product	Derived K value
4/7/2023	ARC	HH	5431	-41.39	46	41.7	100000	78415.48
	125cm Square Trihedral	HH	2828	-34.53	40.2	36.09	100000	81943.32
10/11/23	ARC	HH	8263	-41.09	46	44.81	100000	75984.63
	125cm Square Trihedral	HH	3361	-31.24	40.2	37.42	100000	52750.5

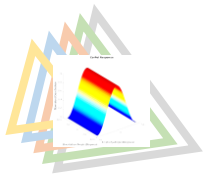
Image Quality metrics derived from ARC and CR for NovaSAR

DOP			Azimuth			Range		
	Target	Pol	PSLR (dB)	ISLR (dB)	Resolution (m)	PSLR (dB)	ISLR (dB)	Resolution (m)
4/7/2023	ARC	HH	-22.12	-19.27	9.06	-18.96	-16.19	5.94
	125cm Square Trihedral	HH	-22.96	-20.49	9.06	-22.55	-18.34	6.25
10/11/23	ARC	HH	-22.44	-19.34	7.81	-14.52	-14.36	6.25
	125cm Square Trihedral	HH	-23.94	-19.39	7.5	-21.78	-17.7	6.25



Summary:

- Multi-band ARC designed by SAC/ISRO team was deployed at NRSC-IMGEOS Microwave Cal-Val Site to carry out SAR Cal-Val exercises at C, X, S and L band frequencies.
- Parallelly, Square Trihedral corner reflectors are also deployed in NRSC-IMGEOS Cal site along with ARC for the purpose of cross validation of the results.
- EOS-04, NovaSAR and X-band SAR corresponding to C, S and X bands were planned over IMGEOS Cal site.
- The Image quality parameters from point target like Peak Side Lobe Ratio (PSLR), Integrated Sidelobe Ratio (ISLR), Spatial Resolution and Radar Cross Section of ARC and CR are measured.
- The polarimetric quality parameters corresponding to EOS-04 Full polarimetric data are also derived to ascertain the results with the specifications.
- The results indicates that proper functionality of multiband ARC for X, C and S operating frequency bands.



References:

[1] Swati Shukla, Yogendra Sahu, Vinit Kumar, Deepa Sharma, Shweta Sharma, Avadhesh Pandey, Sunil Kumar, Shikhar Gupta, Raghav Mehra, J Rao, Pankaj K Nath, Rakesh Bhan, CVN Rao "Design and Characterization of a Multiband Polarimetric Active Radar Calibrator at L, S, C and X Band" at URSI - RCRS 2022, IIT (Indore), India, 1 - 4 December, 2022.

[2] https://bhoonidhi.nrsc.gov.in/bhoonidhi_resources/help/docs/EOS_04_Data_Products_Format_Document.pdf

[3] P. V. Jayasri, K. Niharika, S. H. Priya, CVR Sarma, HSV. Usha Sundari, EVS Sita Kumari, "RISAT-1 SAR External Calibration – A Summary", InGARSS, pp. 82-85, doi: 10.1109/InGARSS48198.2020.9358959.

[4] K.Niharika and P.V.Jayasri and S.GowriSankar, Y.Ramu, Usha Sundari Ryali, B.Santhisree, E.V.S. Sita Kumari, Vinod M. Bothale, "Characterization of S-Band SAR Data as a Precursor to NISAR," 2021 IEEE International India Geoscience and Remote Sensing Symposium (InGARSS), Ahmedabad, India, 2021, pp. 344-347, doi: 10.1109/InGARSS51564.2021.9792067.

Acknowledgements:

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Thank you