URSI AP-RASC 2019, New Delhi, India, 09 - 15 March 2019

RISAT-1 HRS Mode Data Quality Evaluation

Maneesha Gupta and B. Kartikeyan
Image Analysis and Quality Evaluation Division, SIPG, Space Applications Centre, ISRO, Ahmedabad, 380015

Abstract

This paper presents the data products quality evaluation of High Resolution Spotlight (HRS) Mode of Radar Imaging Satellite (RISAT-1). Sample scenes of Level-2 terrain corrected georeferenced products are acquired in different regions to observe geometric data quality in terms of Location accuracy and Internal Distortion. Further, to evaluate the image and radiometric data quality, parameters such as Background to Peak Ratio (BPRatio), Integrated Side Lobe ratio (ISLR), Peak to Side Lobe ratio (PSLR), Radar Cross Section (RCS) of the Corner Reflector, geometric resolution in the circular polarization mode is observed from the image (Level-1 Single Look Complex products). Results of the analysis are encouraging and meets the specifications. Location accuracy is better than 80m across track and 110m along-track, which is better than the SAR processor specifications. Further, geometric resolution achieved is within the range of 1.18 m for azimuth direction and 0.75 meter for range direction.

1. Introduction

Radar Imaging Satellite (RISAT-1) is the India's first state-of-the-art microwave Synthetic Aperture Radar, launched in 2012 for observing the Earth in all-weather conditions with dawn dusk orbit [1]. RISAT-1 operating in C-band has versatile capacity to image the Earth in variety of resolution and swath requirements. Stripmap (FRS-1/FRS-2) and ScanSAR (CRS/MRS) are the conventional imaging modes. Apart from this, RISAT-1 is the only SAR capable of giving 1 m resolution over 10km x100km spot. It is the first SAR with Hybrid polarimetry for Earth Observation. it has capability of imaging in high resolution sliding spotlight (HRS) mode by suitably pitching and performing mechanical steering of the spacecraft (attitude manipulation) and acquiring data at high range and azimuth resolution. The expected resolution is of the order of ~0.64 in across track and 1 m along track, with a swath of 10 km and an azimuth extent of around 100km. As HRS mode data is acquired by steering spacecraft, introduces Doppler centroid variation in along-track direction, which in turn effects the focusing, and image quality aspects. Further, HRS mode is a significant mode of land imaging, required for specific purpose like surveillance, disaster etc., necessitates ensuring the accuracy and quality of products in terms of geometry, radiometry and image.

In this work, we have taken the sample datasets, acquired in different orbits, beams in circular polarization (RV/RH) over different regions of the world including CalVal sites. Section-2 describes the data summary for analyzing the quality parameters. Section-3 of this paper discusses briefly about the approach and methodology followed by results of the analysis in section-4.

2. Data Summary

The High Resolution Sliding Spotlight mode data of RISAT-1 used for quality evaluation is of four imaging orbits viz. imaging orbit 21507, 20092, 11048, 19764 in 4 different beams. Summary of data used for evaluation is n Table 1. For evaluation of geometric quality, data we used Level-2 terrain-corrected georeferenced product whereas for evaluation of radiometric and image quality, Level-1 Single Look Complex (SLC) product was taken. Product definition is described inn details in [2].

Table 1. HRS Data Products for Quality Evaluation

DOP	Orbit No	Beam No	*Node	Scene No.	#Product Type
22-03-16	21507	42	D	1	L2
22-03-16	21507	42	D	2	L2
22-03-16	21507	42	D	3	L2
22-03-16	21507	42	D	4	L2
22-03-16	21507	42	D	5	L2
22-03-16	21507	42	D	6	L2
22-03-16	21507	42	D	7	L2
19-12-15	20092	32	D	1	L2
19-12-15	20092	32	D	2	L2
19-12-15	20092	32	D	3	L2
19-12-15	20092	32	D	4	L2
19-12-15	20092	32	D	5	L2
19-12-15	20092	32	D	6	L2
19-12-15	20092	32	D	7	L2
28-04-14	11048	30	A	3	L2&SLC
28-04-14	11048	30	A	4	L2&SLC
28-04-14	11048	30	A	5	L2&SLC
27-11-15	19764	47	A	2	L2&SLC
27-11-15	19764	47	A	3	L2&SLC
27-11-15	19764	47	A	4	L2&SLC
27-11-15	19764	47	A	5	L2&SLC

*D-Descending A-Ascending;#L2- Level-2, SLC- Single Look Complex

3. Approach & DQE Parameters

The Quality parameters identified for evaluation of HRS mode data in circular polarizations are discussed here. After SAR antenna acquires the data, the quality of the SAR products depends on the SAR signal processing. As resolution from SAR depends on spacecraft motion, the inaccuracy in Doppler Frequency Modulation Rate and Range Cell Migration affects the azimuth focusing of the image and requires to be monitored from the Level-0 raw data itself [3]. Residue errors if remains will be reflected in product in terms of image quality and geometric accuracies. Thus, to ensure the high-resolution mode product quality, requires evaluation based on identified Quality parameters [3]. The Geometric parameters are evaluated using well-established Data Quality Evaluation Software (DQES) system consisting of pre-processing, reference selection, control point identification on optical & SAR images in semi-automatic mode resulting into error statistics & qualification report [4]. The geometric parameters, which are computed by evaluation software system, are geo-location accuracy, scale variation and internal distortion.

Furthermore, quality of any *SAR image* can be characterized by its response for the point targets. Thus, the performance of the SAR system and the SAR image formation processor can be assessed by estimating the response parameters from the point target. Corner reflectors are the ideal point targets for such characterization. In addition, for radiometric and geometric calibration of HRS data, Corner Reflectors of different types and dimensions were deployed based on the satellite pass information at IMGEOS Cal-Val site, Shadnagar and SAC, Ahmedabad. Basic characteristics for point targets are like geometric resolution, PSLR, ISLR etc. The approach for computation of these parameters is to select the chip of 16 x 16 pixels around the point target (having background to peak ratio better than 30 dB), zoom in Fourier domain by factor of 16, and find the peak of the point target. Based on the peak position, geometric resolution is observed from the half power (3dB down width of the peak profile) and other quality parameters are observed from the 2D (azimuth and range) profiles of the data around point target [5]. The Radiometric Quality is also analyzed to ensure the resolution and speckle in the data [6].

4. Results and Analysis

This section discusses the results of the quality evaluation perform on the HRS mode RISAT-1 data.

4.1 Geometric Data Quality Evaluation

Geometric Data Quality Evaluation (GDQE) was carried out using selective scenes over four places (Ahmedabad, Hyderabad, Paris and Dubai). Geometric parameters were evaluated for the geo reference products with Carto Ortho data (2.5m resolution) for Indian terrain acquisition and L8 OLI Ortho (15m resolution) for global acquisition [Paris and Dubai]. Location accuracy and internal distortions are observed for the sample scenes (15 sample scenes) in both range (across track) and azimuth (along track) directions. Location accuracy is better than 110m, which is better than the expected location accuracy of 300 m. Results are shown in Figure1.

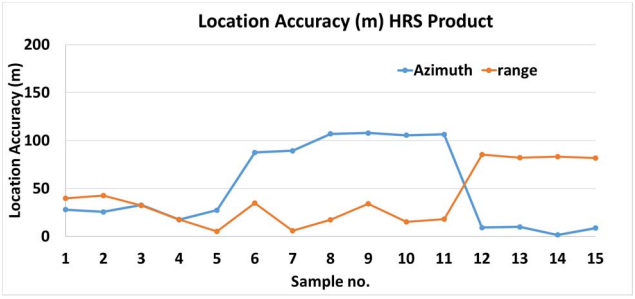

Figure 1. Location Accuracy along and across track (m)

Internal distortion (in pixel) analyzed over the same scenes observed to be less than '8' pixels shown in Figure-2.

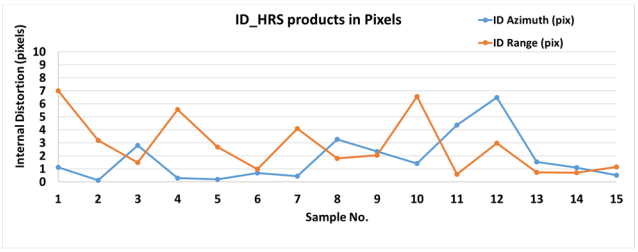

Figure 2. Internal Distortions along and across track (m)

4.2 Image Quality Evaluation

Image Quality based on the Point target analysis is carried out using Level-1 SLC images having Corner reflectors deployed in (a) IMGEOS CALVAL Site on 27th Nov 2015 for the Orbit: 19764 (Figure 3 top) and (b) Ahmedabad SAC ground site on 28 April 2014 for orbit 11048. (Figure 3 bottom) Table 4 gives the details of the corner reflectors deployed over the sites. The background to peak ratio for Shadnagar site is better than 30 dB whereas Ahmedabad BPRatio is around 25 dB suitable for calibration of data.

Table 4. Corner Reflector (CR) details observed in Shadnagar & Ahmedabad scene (L1-SLC) as Point Target

CR.No	CR Size (cm)	CR Shape	Loc	Theoretical RCS
1	75	Square Tr	Shad	35.79
2	75	Square Tr	Shad	35.79
3	40	Square Tr	Shad	24.88
4	40	Square Tr	Shad	24.88
5	20	Square Tr	Ahm	12.83
6	20	Square Tr	Ahm	12.83
7	20	Square Tr	Ahm	12.83

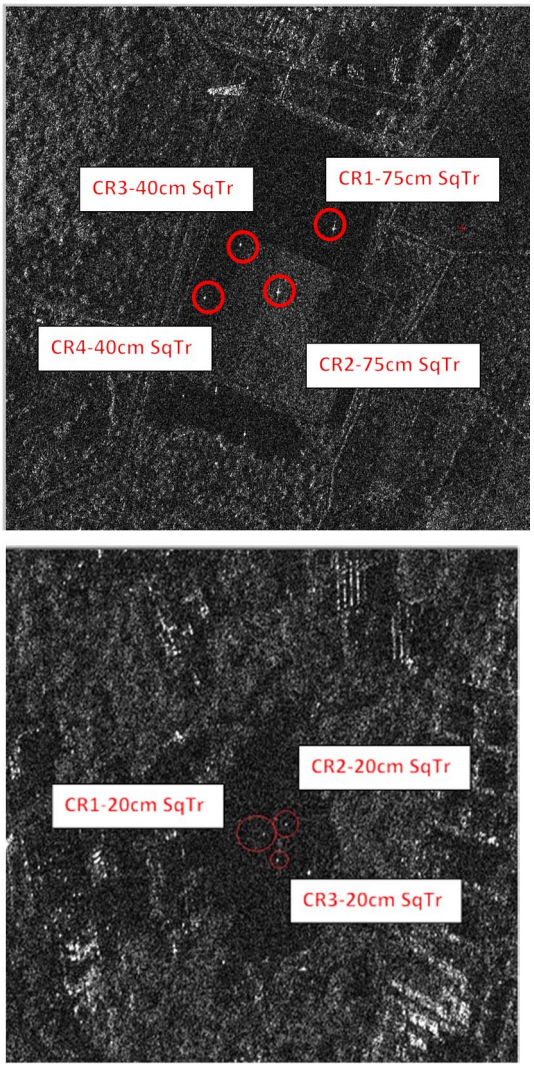

Figure 3. Full Resolution image of (Top) Shadnagar IMGEOS CalVal site [carrying Sq.Tr. 75 cm and 40 cm (Bottom) Ahmedabad scene carrying Sq.Tr. (20 cm CR).

Response in terms of BPRatio (not shown here), PSLR, ISLR, RCS and Resolution are observed for both RH and RV images. To avoid the saturation level, 32-bit SLC products were generated and analyzed for impulse response function of the point targets. Results observed are summarized in table 5. Details of each point target are shown in figure 4.

Table 5. PSLR, ISLR observed from deployed CR's

Parameter	Polarization	Range	Azimuth
PSLR	RV	-17.52	-20.44
	RH	-14.19	-18.45
ISLR	RV	-13.33	-15.05
	RH	-11.56	-13.46

RCS for Shadnagar targets of size 40 cm matches within 0.2 dB whereas CR of size 75 cm are found to slightly off might be due to alignment as Sigma-0 over distributed target is observed which is as expected. RCS for Ahmedabad CRs matches within ~2 dB. This might be due to noise from the background or deployment error.

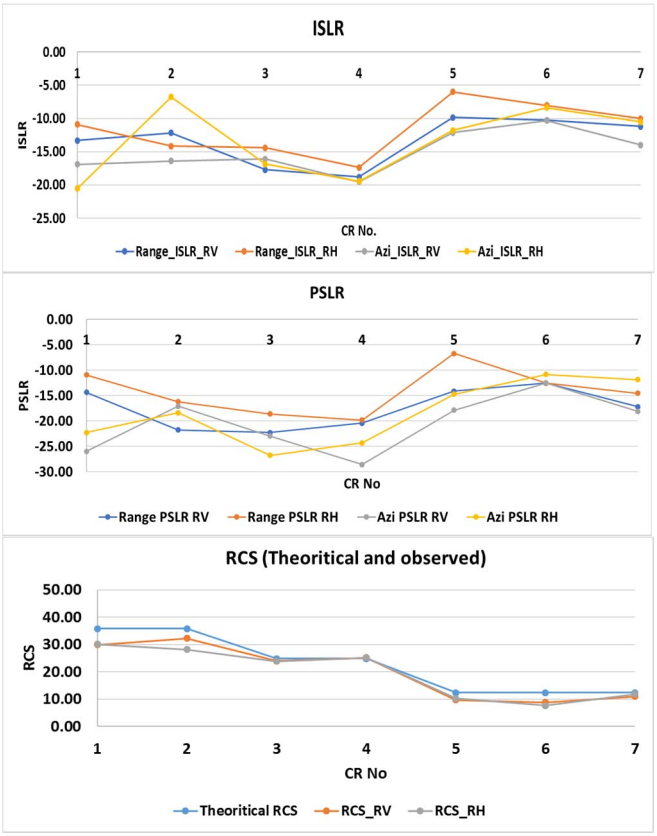

Figure 4. ISLR, PSLR and RCS observed from the CR's observed in Image (RH and RV Polarization)

Geometric resolution describes the sharpness of the response of the main lobe. This is defined as the half power (3 dB) width (in Sample or in time or distance) of the peak profile in both direction. Resolution is observed to be better than 0.7 m in range and 1.1m in azimuth direction as shown in Figure 5.

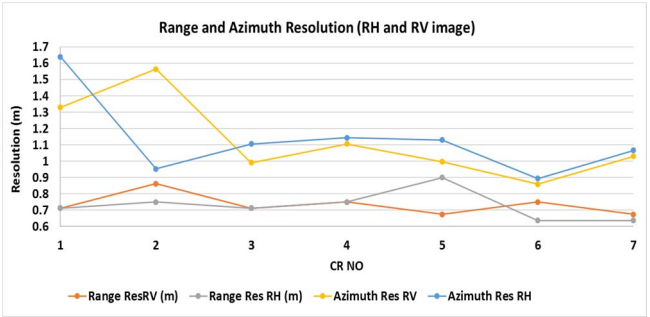

Figure 5. Observed Range and Azimuth Resolution

4.3 Radiometric Data Quality Evaluation

Radiometric data quality evaluation (RDQE) is carried out on Level-1 sample data over Ahmedabad and Hyderabad scenes. Observations are summarized in Table 6.

Table 6. Results of RDQE

Orbit No	Scene No.	Rad. Resolution (dB)		Speckle	
		RV	RH	RV	RH
11049	3	2.7	2.8	0.87	0.86
11049	4	3.45	3.41	1.21	1.19
19765	3	3.38	3.36	1.18	1.18
19765	4	3.3	3.35	1.14	1.15

Radiometric resolution from SLC data is around 3.3 except one scene over Ahmedabad where it is around 2.7/2.8. Similarly, speckle is as expected around 1.18 except the same scene of Ahmedabad where it is less than '1'.

5. Conclusion

HRS product are evaluated for the geometric, radiometric and point target response parameters using standard methodologies. Geometric data quality was observed using 15 sample scenes acquired in different geo locations in defined orbit and beam, using Cartosat-1 and OLI PAN (15 m) as a reference image. The Internal distortion is less than '8' pixels in both Azimuth and Range directions. Location accuracy is found to be better in range (Error better than 90 m) than in Azimuth (Error better than 110 m). Point Target Analysis, it is observed that PSLR, ISLR and spatial resolution in range and azimuth directions are near to the specification for both RH and RV polarizations. Geometric resolution observed is within the range of 1.13 m for azimuth direction and 0.73 meter for range direction. In PSLR observed is -18 to -20 dB & -14 to -17 dB while ISLR is -13 to -15dB and -11 to -14 dB in azimuth and range for RH and RV polarizations respectively. RCS RDQE was carried out on Ahmedabad and Shadnagar scenes. Speckle and Radiometric resolution observed are as expected around 1.1 and 3.3 respectively. The quality parameters are within the acceptable limits and observations suggest that the SAR processor is efficient in generating high-resolution SAR products.

6. Acknowledgements

Authors would like to thank Shri. Dipak K. Das, Director, SAC for the interest in the HRS mode data quality evaluation activity. Authors would like to thank Shri. Debajyoti Dhar, Group Director, Signal & Image Processing Group (SIPG) - SAC for supporting and encouraging this activity. Authors expresses their special gratitude to Shri. M. V. Ramanujam, Head-MDPD/SIPG/SAC and his team for providing the HRS data for Evaluation and valuable discussions. Thanks are due to team IAQD for providing software support.

7. References

1. Tapan Misra, S. S. Rana, N. M. Desai, D. B. Dave, Rajeevjyoti, R. K. Arora, C. V. N. Rao, B. V. Bakori, R. Neelakantan and J. G. Vachchani, "Synthetic Aperture Radar payload on-board RISAT-1: configuration, technology and performance", *Current Science* Vol 104, No. 4, Feb 2013.
2. RISAT-1 data products system Detailed Design review document, RISAT/DP/SAC/DPSG/AIPD/TN-01/Nov2011.
3. Maneesha Gupta, B. Kartikeyan and Santanu Chowdhury, "An approach to evaluate and monitor RISAT-1 SAR from level-0 raw data", , Vol.35, No. 16, 6043-6059, *International Journal of Remote Sensing (IJRS)* [http://dx.doi.org/10.1080/01431161.2014.943323/]
4. RISAT DQE Detailed Design Review & Software Architecture, SAC/SIPA/IAQD/RISAT/TN-60/Nov2011,
5. Maneesha Gupta, Anuja Sharma and B. Kartikeyan, "Image quality assessment of RISAT-1 SAR using trihedral corner reflectors in different beams", Vol 8 No. 2 October 2014, 130-139 in *Journal of Geomatics*,
6. Maneesha Gupta, Anuja Sharma, B. Kartikeyan, "Evaluation of RISAT-1 SAR Radiometric Calibration Using Extended Amazon Rainforest", *Journal of Indian Society of Remote Sensing*, DOI 10.1007/s12524-016-0582-5