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Site suitability analysis for calibration of RISAT-1 SAR sensor using corner reflectors

Alpana Shukla[1], Mihir Rambhia[1], Gautam Dadhich[2], Shweta Sharma[3] and P.R. Patel[2]
[1]M.G. Science Institute, Ahmedabad
[2]Nirma University, Ahmedabad
[3]Space Applications Centre (SAC), ISRO, Ahmedabad
Email:alpana.botany@gmail.com, mihir.r.93@gmail.com

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Abstract: External calibration is an important activity carried out to eliminate error in the performance of an operational satellite sensor. Calibration procedure to check the radiometric accuracy of the imaging sensor is an important aspect here. This is done either using point target method or distributed target method. In point target method, corner reflector with known radar cross-section is deployed. This target is then observed on the satellite imagery and calibration constant is derived from the obtained backscatter value. In the present study, our aim was to use corner reflectors as point targets to find out the suitability of the site located at Space Applications Centre (SAC), Bopal Campus, Ahmedabad, for performing external radiometric calibration of RISAT-1(Radar Imaging) sensor. Though the site has been previously used for the Fine Resolution (FRS-1) mode calibration, its suitability for Medium Resolution (MRS) mode calibration was unknown. Calibration constants were computed for the FRS-1 image of April 2015 and MRS image of October 2015. The value of calibration constant was found consistent for the various point targets and clutter window sizes in the case of FRS-1 data, but in the case of MRS data, variation was observed for higher window sizes. From the study, it was found that a sufficiently big and uniform background is required for the purpose of calibration. It was further concluded that the site at Bopal is suitable for calibration of FRS image, but, since the resolution of MRS data is low, a bigger site with no buildings in the vicinity would be required for its calibration.

Keywords: RISAT, Radiometric calibration, Site suitability, Signal to clutter ratio, MRS

1. Introduction

RISAT-1 of Indian Space Research Organization (ISRO) is India's first active radar imaging satellite (Misra and Kiran Kumar, 2014). Use of RISAT-1 Synthetic Aperture Radar (SAR) data has increased dramatically due to its broad range of applications and availability of all-weather data. In such a scenario, it becomes crucial to keep a check on the sensor performance and provide users with accurate data. Usually, Corner Reflectors (CR) as point targets are used for the calibration of the SAR images. The Fine Resolution (FRS) -1 mode is having a swath of 25km and very fine spatial resolution, where the pixel size is 3.3m x 2.34m. Medium Resolution (MRS) mode is having a swath of 115km and spatial resolution is in the medium range, i.e. 25m x 8.8m (Misra and Kiran Kumar, 2014).

The objective of this study was to find out the suitable site for the Calibration of FRS-1 and MRS mode of RISAT-1 SAR sensor. Calibration site can be considered appropriate if it satisfies following two minimum requirements (Garthwaite et al., 2015):
1) Calibration constant should remain constant with changing point window and clutter window sizes, as it signifies that area is uniform and free from any external influence.
2) Signal to Clutter Ratio (SCR) should be sufficiently high i.e. greater than 20 dB, as it allows us to distinguish CR from the background clutter energy.

2. Calibration site

The Space Applications Centre (SAC) - Bopal site in Ahmedabad (Latitude-23.045389 N, Longitude-72.452036 E) has been developed for vicarious calibration of high resolution optical as well as SAR sensors. This site has been artificially created by SAC at Bopal campus (fig. 1). The site consists of a very uniform, leveled bare land (see fig. 1 - yellow color) of 115m x 115m area with a very clear brick masonry boundary constructed on all four sides. In this study, Triangular trihedral type of CR are used (Figure 2) having a leg length of 0.9m as a point target. This CR was deployed in the center of a uniform, leveled ground. CR appears as a bright point, whereas the ground appears as a dark patch in the SAR image.

Figure 1: Cal-val site at SAC, Bopal, Ahmedabad (Image Courtesy: Google Earth)

Figure 2: Triangular trihedral corner reflector (Leg Length– 0.9m) deployed on the ground of SAC Bopal campus

3. Methodology

To perform the calibration of the FRS-1 and MRS mode of RISAT-1 SAR sensor, a triangular trihedral type of corner reflector was deployed on the ground of SAC-Bopal Campus, Ahmedabad. This corner reflector was properly aligned to the satellite orientation to reflect all energy back in the direction of active microwave sensor. The response of this target was then identified in the SAR data by recognizing nearby features like lake, roads and buildings. The integral method was used to calculate the total energy intensity of the impulse response of the corner reflector (Gray et al., 1990; Freeman, 1992; Zongmin et al., 2014). The data was processed with the help of GAMMA and ENVI software to obtain the value of calibration constant.

1) SAR image processed in Single Look Complex (SLC) or Ground Range detected (GRD) format using GAMMA software was converted to amplitude image and opened with the help of ENVI software.

2) CR is distinguished in the image as a bright pixel surrounded by uniform dark background (Fig. 3)

3) First of all, Point Target window is selected surrounding the target with the help of Region of Interest (ROI) tool. (Figure 4-a)

   Total pixels in point target (**M**) =

   $$M = m \times m = m^2 \quad \ldots(1)$$

4) Then, four clutter windows are selected on the edges of the point target window, such that no bright point gets added to it (Figure 4-b).

   Total pixels in clutter (**N**) =

   $$N = 4 \times (n \times n) = 4n^2 \quad \ldots(2)$$

5) Digital Number (DN) values for this window are extracted using Statistics (Stats) tool available in the ENVI software.

6) Total intensity of the area M and N is calculated as follows,

   Total Intensity of the point target (**P**) =

   $$P = \Sigma {DN_i}^2 (\text{i = pixels in area M}) \ldots(3)$$

   Total Intensity of the clutter region (**B**) =

   $$B = \Sigma {DN_i}^2 (\text{i =pixels in area N}) \ldots(4)$$

7) Average intensity per pixel of clutter (**C**) will be

   $$C = \frac{B}{N} \quad \ldots(5)$$

8) Background corrected intensity can be calculated by subtracting the contribution of clutter energy according to C,

   Background corrected intensity (**D**) =

   $$D = P - (M \times C) \quad \ldots(6)$$

   Background corrected intensity (**I**) =

   $$I = 10 \times \log_{10} D \; dB \ldots(7)$$

9) Now, Incidence angle at any point of the image is calculated according to Incidence Angle Derivation method (JERS, 2002)

   Incidence angle at Point target (I_{pt}) = θ_i

   Incidence angle at Scene Center (I_{ref}) =Incidence angle as per the Metafile information

10) Following Freeman (1992) and Garthwaite et al. (2014), calibration constant K is calculated as

   $$\mathbf{K} = 10 \times \log_{10} \frac{D \times A \times \frac{\sin I_{pt}}{\sin I_{ref}}}{\sigma_c} \quad \ldots(8)$$

   Radar Cross Section (RCS) of Corner Reflector (σ_c) = 29.49 dB

   Here A (Illuminated Area) is defined as following:

   $$A = LS \times \frac{PS}{\sin I_{pt}} m^2 \quad \ldots(9)$$

   where, Line Spacing (**LS**) = Line spacing in m; and Pixel Spacing (**PS**) = Pixel spacing in m (SAC, 2015).

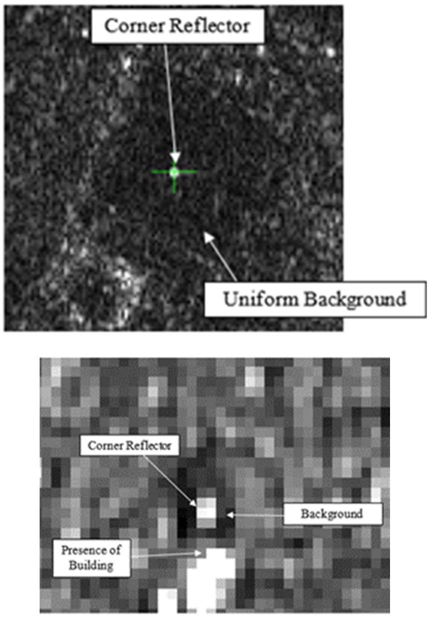

Figure 3: Sigma nought image of 21st April 2015 FRS-1(Top) and 13th October 2015 MRS (Bottom) mode for SAC-Bopal campus (Zoom Scale – 4x)

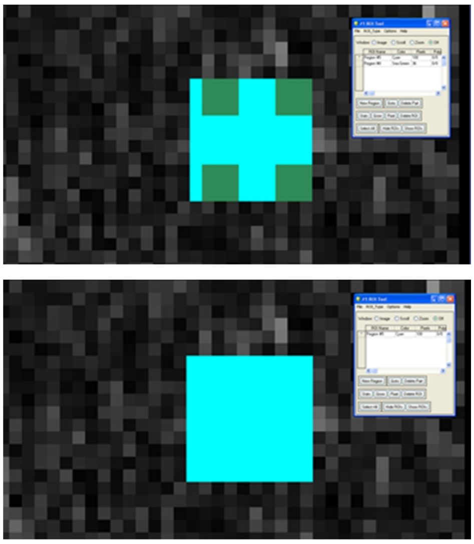

Figure 4: Point window size (a-Top) and clutter window size selected using ROI tool. (b-Bottom) (Zoom Scale – 32x)

4. Data analysis

Calibration constant was calculated for the FRS-1 image of April 21, 2015 and MRS image of October 13, 2015 (Table 1).

Table 1: SAR data used for the study

Date	21-Apr-15	13-Oct-15
Mode	FRS	MRS
Polarisation	RH, RV	HH, HV
Node	Ascending	Descending
Orientation	Left	Left
Beam No.	104	93
Incidence Angle	44.63	35.22

HH–Horizontal transmit, Horizontal receive; HV–Horizontal transmit, Vertical receive; RH–Right-hand circular transmit, Horizontal receive; RV-Right hand circular transmit, Right-hand circular receive

To check the consistency of the results, calibration constant values were computed for various point and clutter window sizes. Ideally, in the case of uniform area, the variation should not be more than 0.5 dB. Fig. 5 and 6 depict impulse response function (IRF) of FRS and MRS data respectively.

It is quite evident from the IRF that the peak of the corner reflector response is not distinct in the case of MRS. Nearby buildings are also visible as bright pixels, which might introduce error for bigger point sizes.

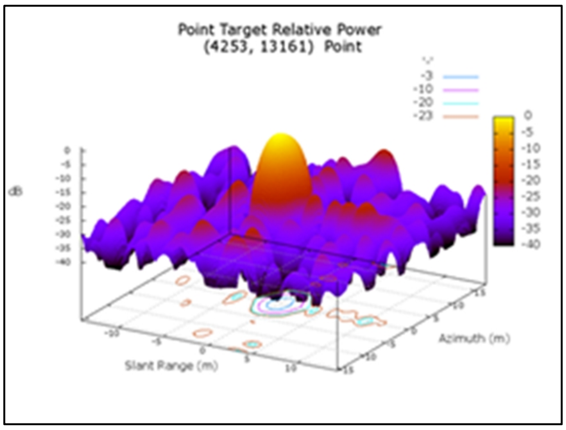

Figure 5: Impulse response function of April 21, 2015 FRS-1 point window size – 16x16; clutter Window Size – 8x8

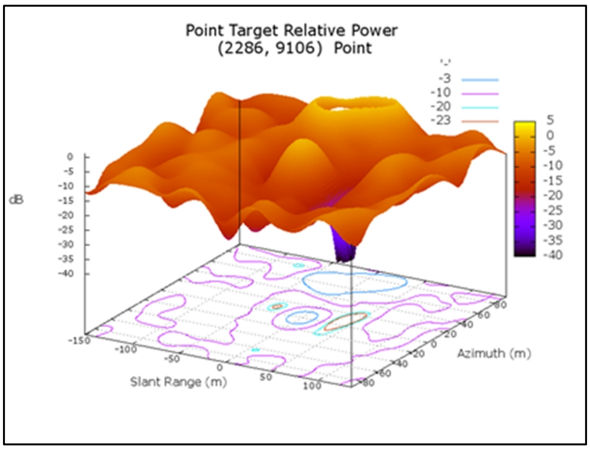

Figure 6: Impulse Response Function of October 13, 2015 MRS Point Window Size – 16x16; Clutter Window Size – 8x8

Table 2: Calibration constant values (K) for FRS-1 data

Case	Point	Clutter	K	SCR
Case1	32x32	16x16	79.489	35.70
Case2	32x32	8x8	79.537	35.92
Case3	16x16	8x8	79.278	35.66
Case4	16x16	16x16	79.266	35.47
Case5	8x8	8x8	79.152	35.54

It can be observed that in the case of FRS image, the value of calibration constant was found to be quite consistent (Table2, Figure 7) with changing different point window size as well as clutter window size. Average calibration constant was found equal to 79.344 (Case 1 to 5). Standard deviation was found to be 0.1623, which is quite low and can be considered satisfactory.

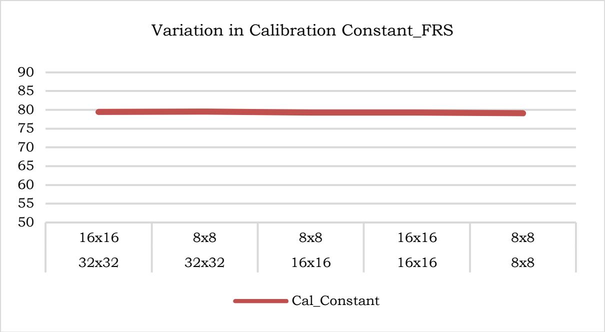

Figure 7–Variation in SCR value with change in Point window size and Clutter window size for FRS data

Contrary, in the case of MRS data, with a change in window sizes, huge variations were obtained in the value of calibration constant. (Table 3, Figure 8) The standard deviation was found to be 4.37, which is very high, indicating inconsistency.

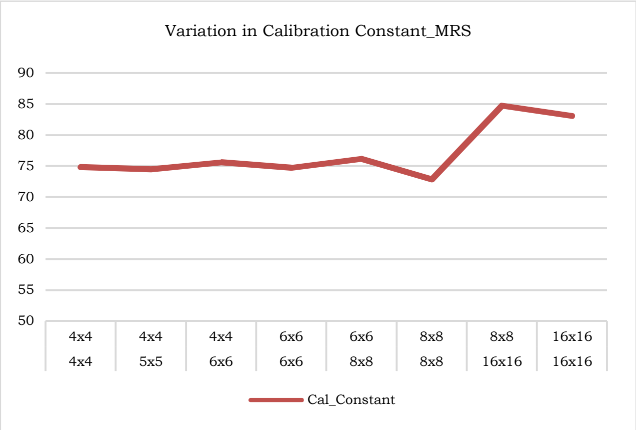

Figure 8: Variation in SCR value with change in Point window size and Clutter window size for MRS data

Table 3: Calibration constant values (K) for MRS Data

Case	Point	Clutter	K	SCR
Case1	4x4	4x4	74.86	**16.86**
Case2	5x5	4x4	74.461	**16.46**
Case3	6x6	4x4	75.594	**17.6**
Case4	6x6	6x6	74.718	**15.61**
Case5	8x8	6x6	76.167	**17.06**
Case6	8x8	8x8	72.871	**12.23**
Case7	16x16	8x8	84.774	**24.13**
Case8	16x16	16x16	83.124	**21.28**

From the study, it was observed that as the FRS-1 mode has a higher resolution, the site has sufficiently large and uniform background for the CR. As a result, the value of calibration constant remains consistent with different point window sizes as well as clutter window sizes. While in the case of MRS data, huge variations were observed in the value of calibration constant, and it is inferred as inconsistent. This inconsistency could be due to the effect of building present in the vicinity of the CR in the lower resolution of the image. To overcome this error, only case 1 (i.e. having point window size of 4) can be considered as reliable and the value obtained is 74.860.

Parameters like uniform and large area, absence of buildings or man-made structures in the vicinity, low moisture content of soil, leveled terrain, good accessibility and absence of human movements should be considered while selecting the calibration site. From this study, it could be suggested that this site in Bopal is suitable for FRS-1 data calibration purpose but a bigger uniform site with no building in the vicinity should be found for MRS data calibration.

Conclusion

From this study, it was observed that the site in Bopal is suitable for FRS-1 data calibration purpose but not for MRS mode. A bigger uniform site with no building in the vicinity should be developed for MRS data calibration.

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References

Freeman, A. (1992). SAR Calibration: An Overview. IEEE Transactions on Geo science and Remote Sensing, 30, 6, pp. 1107-1121.

Garthwaite, M.C., S. Nancarrow, A. Hislop, M. Thankappan, J.H. Dawson and S. Lawrie (2015). The Design of Radar Corner Reflectors for the Australian Geophysical Observing System: a single design suitable for InSAR deformation monitoring and SAR calibration at multiple microwave frequency bands. Record 2015/03. Geoscience Australia, Canberra

Gray, A.L., P.W. Vachon, C.E. Livingstone and T.I. Lukowski (1990). Synthetic Aperture Radar Calibration using Reference Reflectors, IEEE Trans. Geo science and Remote Sensing, GE-28, No.2, pp. 374 - 383.

JERS (2002). SAR PRI Products Calibration (March 2002). TN-01-0005, Issue-2, ESRIN

Misra, T. and A.S. Kirankumar (2014). RISAT-1: Configuration and performance evaluation. General Assembly and Scientific Symposium (URSI GASS), 2014 XXXIth URSI, vol. no., pp.1,4, 16-23 Aug. 2014.

Zongmin, F., H. Lei, T. Zhihua, L. Jiuli and Z. Liangbo (2014). Airborne SAR radiometric calibration using

SAC (2015). RISAT-1 Data products formats (September 2015), Space Applications Centre, Ahmedabad.

point targets. IOP Conf. Series: Earth and Environmental Science, 17, 1, 012186.