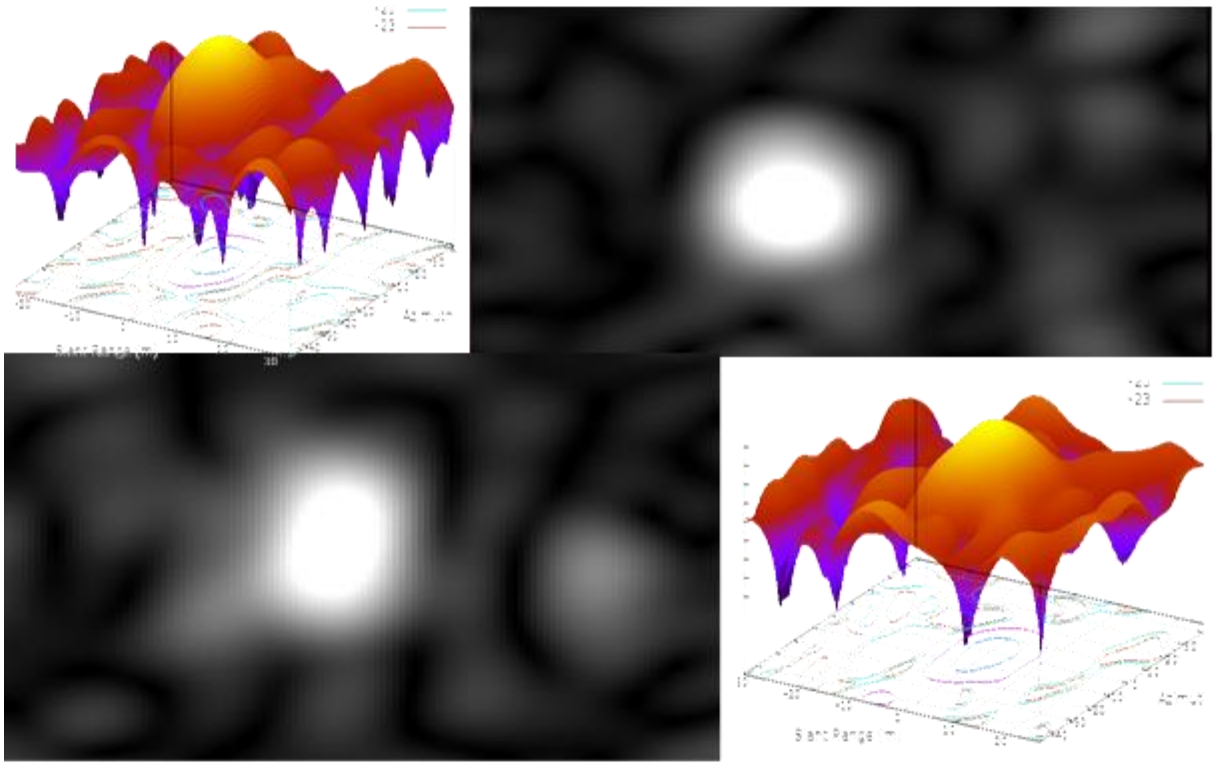
Scientific report SAC/EPSA/ADVG/CVD/CAL-VAL/SR/08/14

Calibration of RISAT-1 SAR Medium Resolution (MRS) Data processed before implementation of DP software update Version-1.3.00



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9. Abstract	This report brings out the results of radiometric calibration of RISAT-1 MRS beam mode data before DP software update Version 1.3.00 was carried out during June 2014. Calibration constant has been computed by deploying corner reflectors and studying its Impulse response for 6 (six) dates for HH polarisation image over Ahmedabad, Jodhpur and Desalpar sites in India. Data quality parameters have also been computed using the point target IRF.
10. Key words	Corner reflector, Corner reflector Deployment, Impulse Response Function, Calibration Constant, Backscattering Coefficient
11. Security Classification	Unrestricted
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Contents

1.0 Introduction

Due to globalisation, today SAR data from different sensors is easily accessible to scientific community worldwide. Each pixel of SAR data contains phase as well as amplitude information. Due to variety of data and bundled information within the data, process of calibration comes into picture. Calibration of SAR data has proven its importance in order to do a quantitative analysis and reach to a meaningful conclusion [1, 2]. Thus, one is able to extend results of studies carried out using one sensor to other [3-5]. This cumulative knowledge base leads to possibilities of developing robust parameter retrieval models for a variety of applications [6-14]. Radiometric calibration of a polarimetric SAR sensor helps in studying polarimetric information content in different frequencies [15]. Polarimetric calibration calls for amplitude as well as phases between different polarisation channels to be calibrated. For a given SAR image, the digital number (DN) is proportional to the received voltage [16]. Therefore, the image intensity I, is proportional to the received power P_r. The process to retrieve SAR backscattering coefficient from the observed SAR image intensity is known as radiometric calibration. [17]. Calibration establishes a relationship between the SAR sensor output and Radar Cross Section (RCS) of a known standard target or distributed target of known RCS [18-20]. Thus, with radiometric calibration, backscattering coefficients values can be compared from different SAR sensors and quantitative information can be obtained.

RISAT-1 is India's first space borne SAR sensor operating at C band. RISAT-1 is not only capable of acquiring data in multi polarisation mode, including quad linear polarisation, but it is also first of its kind to operate in hybrid circular polarimetric mode for earth observation [21,22]. Thus, apart from calibrating the amplitude, polarimetric calibration of the RISAT-1 is also required to be carried out. While calibration of the amplitude will lead to meaningful utilisation of the RISAT-1 system for a large number of applications, calibrated circular hybrid polarimetric data will offer user community to explore potentials of polarimetric SAR data over large geographical areas. SAR calibration can be carried out by analysing standard targets response as well as reference distributed targets analysis [23,24]. Firstly, standard targets like corner reflectors have been deployed to derive radiometric parameters of the data and computing necessary calibration parameters. Along with the exercise of deploying standard targets, reference distributed target can continuously be monitored and any deviation in the radiometry can be analysed to trace out the reason. In case of any deviation in radiometry for the reference distributed target, a rigorous campaign of standard target deployment is essential to be carried out to adjust the calibration parameters. This report details the outcome of calibration exercise carried out for radiometric calibration of RISAT-1 SAR. This document reports the calibration results obtained by studying point target response for the RISAT-1 SAR MRS beam mode data that were processed before implementing the DP update Version-1.3.00.

2.0 RISAT-1 SAR

RISAT-1 is India's first space borne SAR sensor operating at C-band at various beam modes having a number of combinations of linear polarisation modes as well as circular polarisation modes, incidence angle, swath and resolution. **Fig.1** shows schematic diagram of RISAT-1 SAR beam modes. Specifications of RISAT-1 SAR beam modes are given in **Table-1**.

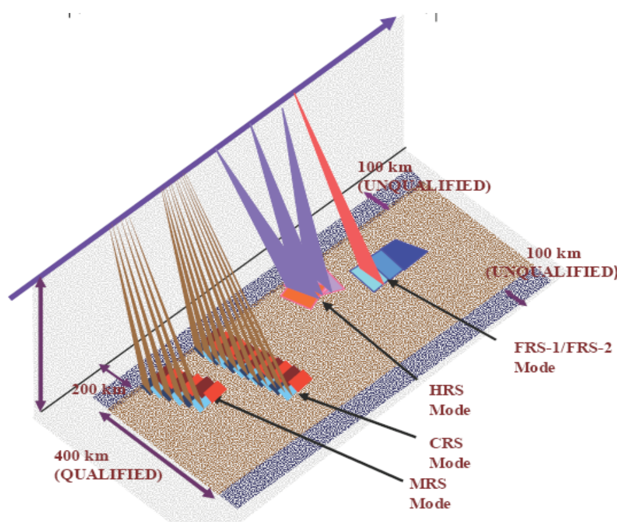

Fig.1: Schematic Diagram showing different beam modes of RISAT SAR

Table-1: Specifications of RISAT SAR Beam modes						
Altitude		536 Km				
Frequency		5.35 GHz				
Imaging Modes		HRS/ *C-HRS*	FRS-1/ *C-FRS-1*	FRS-2/ *C-FRS-2*	MRS/ *C-MRS*	CRS/ *C-CRS*
Swath Coverage		Selectable within 100 – 700 KM off-nadir distance on either side (200 – 600 KM region is qualified, the rest is unqualified)				
Inc angle coverage	Qualified	20^0-49^0 (200-600 Km)				
	Total	10^0-54^0 (100 –700 Km)				
Swath/ Spot Km	*Defined*	10x10	30	30	120	240
	Experimental	100x10	---	---	---	---
Applicable Polarisation combinations		Single/ Dual (co+ cross)/ (CH&CV*	Single / Dual (co + cross) / (CH & CV)*	Quad / (CH&CV)*	Single / Dual (co + cross) / (CH & CV)*	Single / Dual (co + cross) / (CH & CV)*
Resolution (Az x slant range)		1m x 0.7m	3m x 2m	9m x 4m	21-23m x 8m	41-55m x 8m
Minimum sigma naught (dB) *(Qualified Region)*		-16.3	-17	-18	-18	-18
Total no. of beams		*64* on each side of the flight track: total *128*				
Azimuth and Range ambiguity		< -20 dB				

3.0 Study area and data set

Corner reflectors deployment was carried out over grounds of Nirma University and M G Science Institute in Ahmedabad, Gujarat whereas for Jodhpur and Desalpar, corner reflector were deployed in open grounds as described in [25]. A total of 6 (six) data sets of RISAT-1 were acquired for the purpose. Corner reflectors deployment detail is provided in **Table-2.**

Table 2: Details of point target deployment for different beam modes

Sr No	Date	Site	Beam number	Imaging Mode	Incidence Angle	Orbit	Polaris-ation	# of Deployed reflectors
1	22-Feb-13	Jodhpur	87-97	MRS	36.85	4556	HH, HV	1
2	06-Mar-13	Desalpar	87-97	MRS	36.59	4737	HH, HV	4
3	12-Nov-13	Ahmedabad	87-97	MRS	36.84	8525	HH, HV	6
4	07-Dec-13	Ahmedabad	87-97	MRS	36.84	8899	HH, HV	3
5	01-Jan-14	Ahmedabad	87-97	MRS	36.84	9276	HH, HV	4
6	26-Jan-14	Ahmedabad	87-97	MRS	36.85	9653	HH, HV	3

4.0 Methodology

In order to carry out radiometric calibration of SAR, it is required to deploy standard point targets with known Radar cross section accurately pointing towards the SAR sensor over a low clutter region [26, 27]. Once the point targets are imaged, integrated power from two dimensional impulse responses function (IRF) of the point target is to be analyzed for radiometry after removing clutter noise for the standard target response [18-20]. From point target impulse response, apart from deriving calibration constants, range and azimuth spatial resolution, range and azimuth peak side lobe ratio (PSLR), and background-to-peak ratio (BPR) can be computed [12].

Following section gives details of deriving calibration constant and data quality parameters.

Revised calibration constant has been documented in this report, rest of the data quality parameters can be accessed from [30]. Calibration constant can be derived by using the radar equation [28, 29]. Detailed equations used in deriving calibration constant is given in [30].

After deriving the calibration constant, backscattering coefficient σ^o can be derived as

$$\sigma^o(dB) = 10\log_{10}(\mathrm{P_u}) - 10\log_{10}(\mathrm{C}ii) + 10\log_{10}(\sin(\theta_i)) - 10\log_{10}(\sin(\theta_{center})) \qquad (1)$$

Where Pu is the power of distributed area, θ_i is the incidence angle of the distributed area, θ_{centre} is the scene centre incidence angle and C_{ii} is the calibration constant, which can be arrived at using the following equation by studying impulse response function of standard point target as explained in detail in [30].

$$C_{\mathrm{ii}} = \frac{P_{\mathrm{ii}}\delta_r\delta_a}{\sin(\alpha)\ f_{\mathrm{int}}^2\sigma_c\sin(\theta_{center})} \qquad (2)$$

Once the calibration constant is arrived using equation (2), SAR DN values can be converted to the backscattering coefficient for that SAR processor using equation (1).

5.0 Results and Discussion

Corner reflectors [26, 27] have been used to carry out calibration of MRS mode of RISAT-1 SAR intensity data using 6 (six) scenes of HH polarisation. Calibration has been carried out by analysing standard targets response. Firstly, standard targets like corner reflectors have been deployed. **Fig. 2** shows corner reflector mobilization and deployment over the research sites. Reflector responses in RISAT-1 SAR images were analysed to derive radiometric parameters of the data and computing the necessary calibration parameters.

Fig.2: Corner reflector mobilization & deployment

5.1 Calibration Constant Using Point Target Impulse Response

Calibration campaign involving deployment of corner reflector was carried out by calculating the azimuth and elevation angle and pointing to the centre of the beam. Details of number of point targets deployed for each of the 6 (six) dates are given in **Table-2**. As described in the methodology section, RISAT-1 SLC data were taken to frequency domain using FFT and were interpolated in frequency domain with an interpolation factor of 16 in range and 16 in azimuth direction. An inverse FFT resulted in 16x interpolated IRF for the point target. Thus, for all the reflectors, interpolated Impulse Response Function was derived. Hence, there were in all 21 (twenty one) Impulse Response Function (IRF) available. **Fig.3** shows the reflectors captured in the RISAT-1 SAR image.

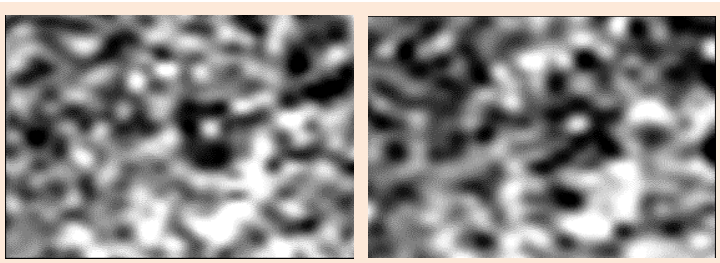

Fig. 3 Corner reflectors as observed in RISAT-1 SAR image

Integrated power from two dimensional impulse responses has been analysed for radiometry after removing clutter noise for the standard target. From point target impulse response, apart from deriving calibration constants, range and azimuth spatial resolution, range and azimuth peak side lobe ratio (PSLR) have been computed. From the interpolated response of the point target, firstly, calibration constant was derived and then the data quality parameters were obtained as given below. **Fig 4** and **Fig 5** show the impulse response for point targets.

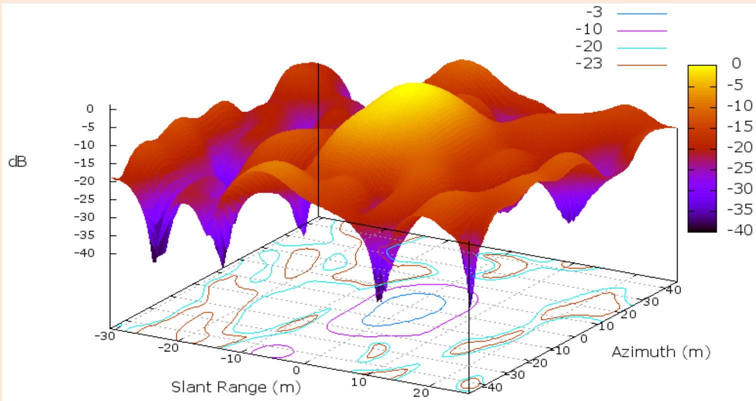

Fig. 5: Point target Impulse response Function for HH polarisation for point target (01Jan2014)

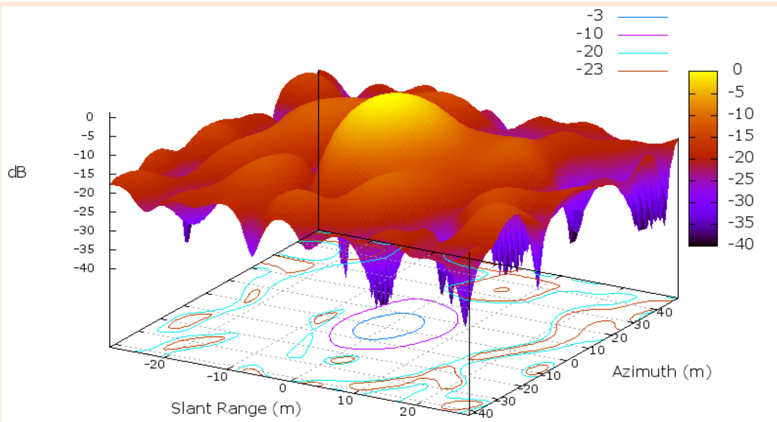

Fig. 4: Point target Impulse response Function for HH polarisation for point target (26Jan2014)

Table 3: Details of point target deployment for different beam modes				
Sl No	**Date**	**Study Area**	**Dr Parul Patel**	**DP**
1	22-Feb-13	Jodhpur	75.45	71.01
2	6-Mar-13	Desalpar	74.77	71.01
3	6-Mar-13	Desalpar	75.46	71.01
4	6-Mar-13	Desalpar	75.44	71.01
5	6-Mar-13	Desalpar	74.60	71.01
6	12-Nov-13	Ahmedabad	75.64	71.02
7	12-Nov-13	Ahmedabad	74.88	71.02
8	12-Nov-13	Ahmedabad	74.96	71.02
9	7-Dec-13	Ahmedabad	76.13	71.04
10	7-Dec-13	Ahmedabad	75.58	71.04
11	1-Jan-14	Ahmedabad	74.11	71.02
12	1-Jan-14	Ahmedabad	75.34	71.02
13	26-Jan-14	Ahmedabad	74.79	71.01
14	26-Jan-14	Ahmedabad	74.73	71.01

After removing clutter noise, the point target impulse response has been used to derive the calibration constant using equation (2). The calibration constants derived for RISAT-1 SAR for each of the point targets are given in **Table-3**. These values are also plotted in **Fig.5** through **Fig.10** with respect to data product values**.**

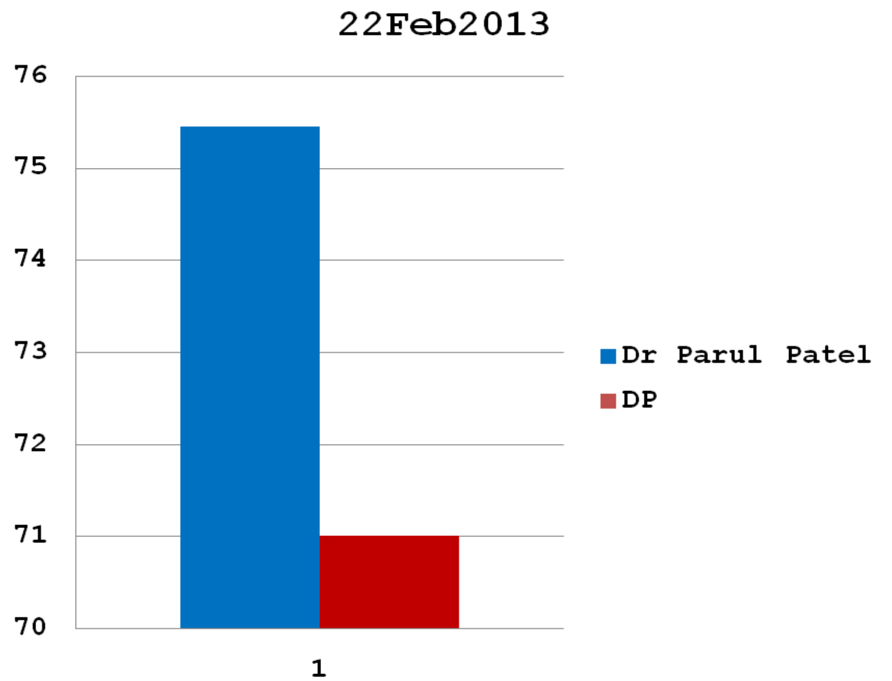

Fig. 5: Calibration Constant using point target impulse response along with that of DP (22February2013, Jodhpur)

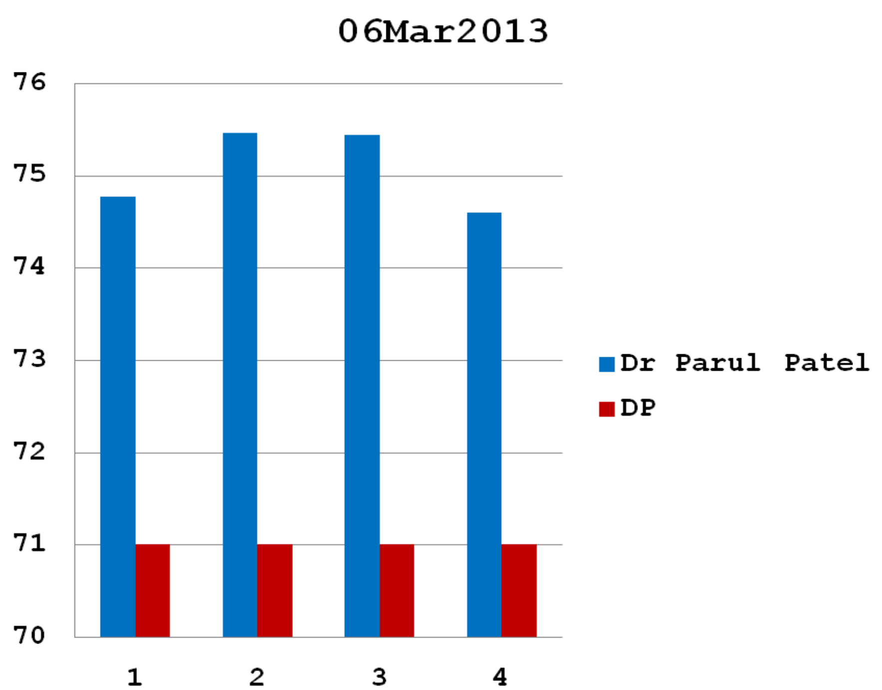

Fig. 6: Calibration Constant using point target impulse response along with that of DP (06Mar2013, Desalpar)

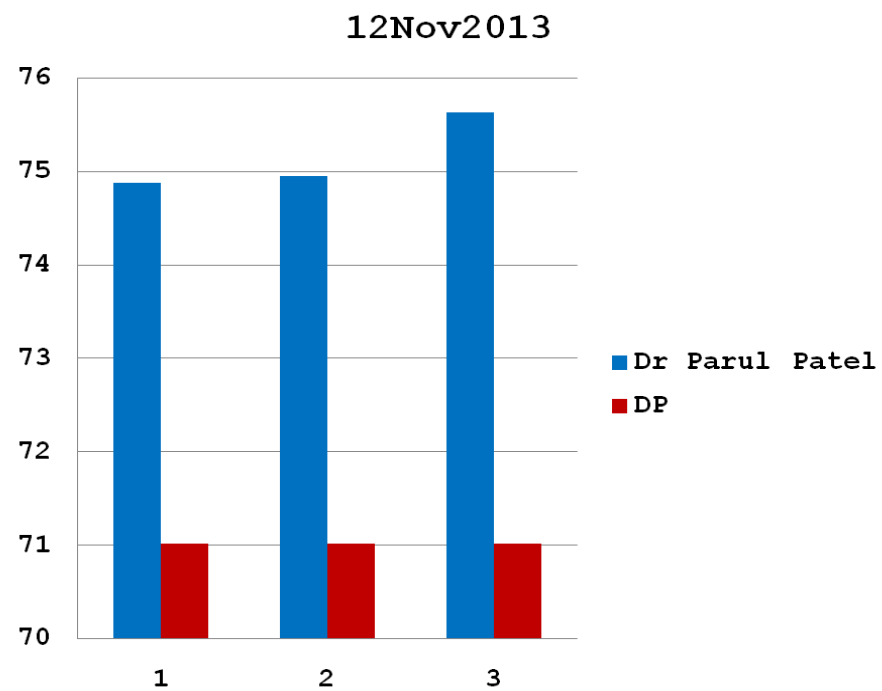

Fig. 7: Calibration Constant using point target impulse response along with that of DP (12Nov2013, Ahmedabad)

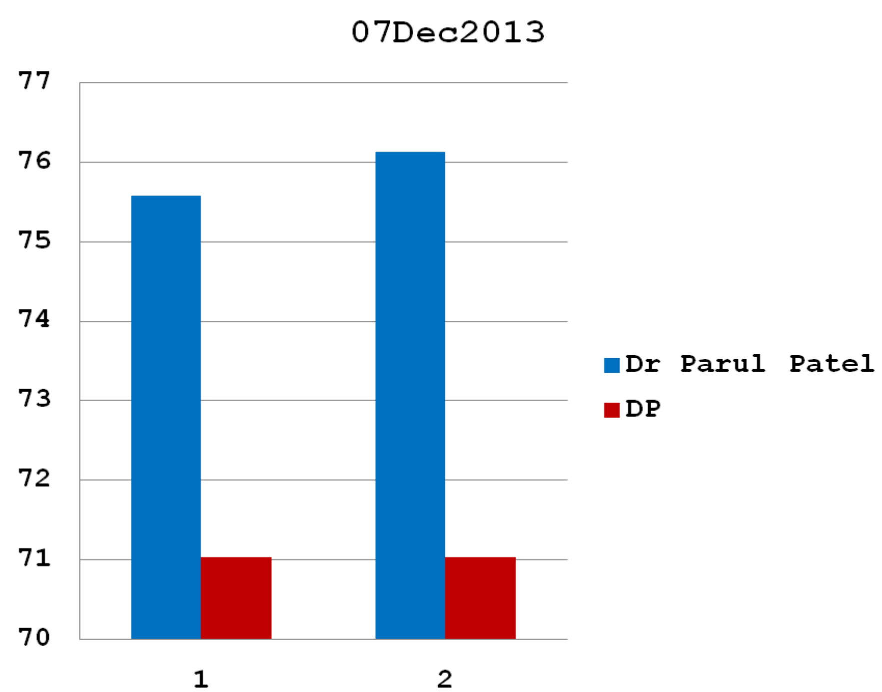

Fig. 8: Calibration Constant using point target impulse response along with that of DP (07Dec2013, Ahmedabad)

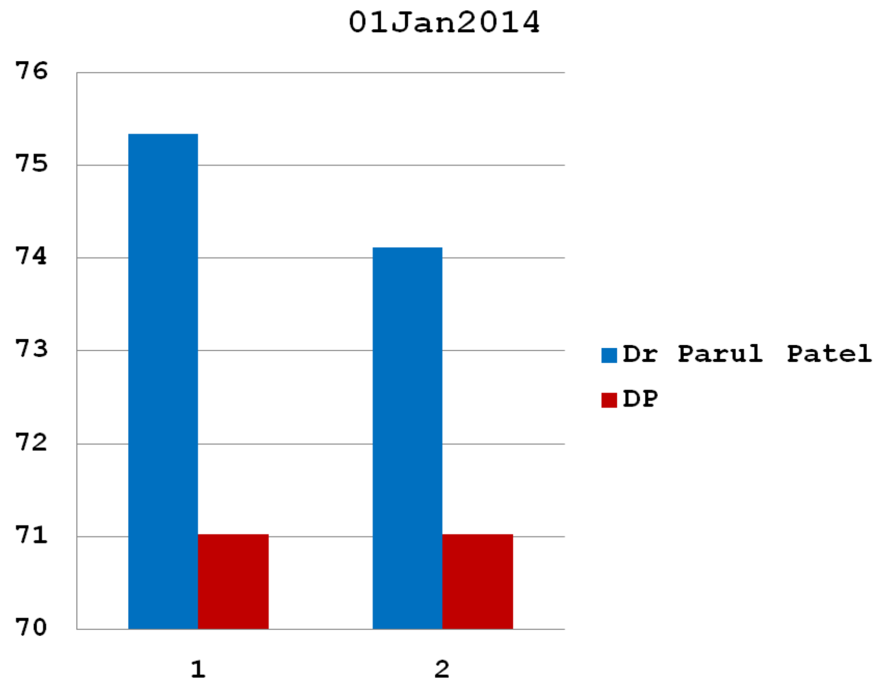

Fig. 9: Calibration Constant using point target impulse response along with that of DP (01Jan2014, Ahmedabad)

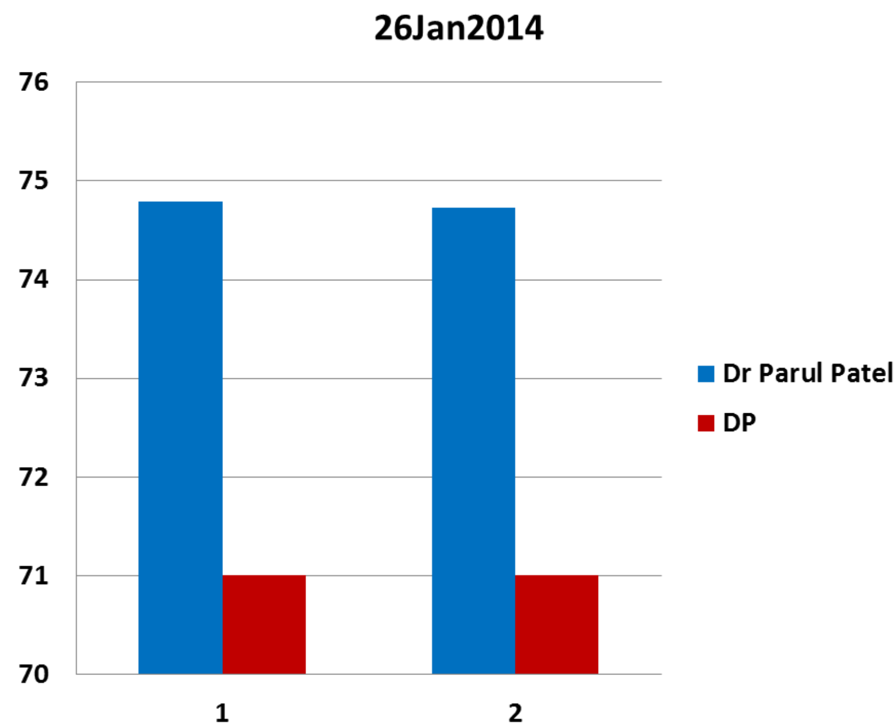

Fig. 10: Calibration Constant using point target impulse response along with that of DP (26Jan2014, Ahmedabad)

A study of **Table-3** and **Fig.5** through **Fig.10** which gives calibration constants derived using point target response and that of DP reveals that the two differs significantly for all the three different study areas Desalpar, Jodhpur as well as Ahmedabad. The reflectors were deployed during February 2013 to January 2014. It can be observed that the Calibration constants derived using point target response and that of the DP provided calibration constant values in the header of the data differed by around 4 dB in general for all the dates during this one year. This difference could be due to uncompensated antenna pattern in the data product.

6.0 Conclusion

This report brings out the results of independent calibration exercise carried out by the team for MRS beam mode data that have been processed before DP update (Version 1.3.00) during June 2014. Point targets were deployed for RISAT-1 SAR calibration for MRS mode. Calibration constant for converting SAR image digital number to backscattering coefficient is computed. The results are based upon 6 (six) date data for HH polarisation with a total of 21 (twenty one) corner reflector responses. It is observed that DP provided calibration constant differs to that of calibration constant derived by independent calibration exercise of deploying corner reflectors and deriving calibration constant based upon their impulse response around 4dB for the MRS beam mode data that have been processed before DP update (Version 1.3.00). This could be attributed to uncompensated antenna pattern. It is planned to evaluate data processed after implementation of the DP update Version 1.3.00.

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