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ASSESSMENT OF SMALL PASSIVE CORNER REFLECTORS FOR GEOMETRIC CORRECTION OF RADARSAT FINE MODE SAR DATA

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ABSTRACT

A study was conducted to assess the applicability of using small, passive corner reflectors for geometric correction of RADARSAT Fine Mode SAR data. Five 1-m width trihedral corner reflectors were constructed, using aluminum plates, and deployed. The geographic locations of the reflectors were measured using differential GPS. The performance of the corner reflectors was evaluated by analyzing the RADARSAT Fine Mode SAR data. The results obtained indicate that the small, passive, trihedral corner reflectors are sufficient to near saturate backscatter information of a ground pixel, making them identifiable as point targets in the SAR image. At 29 dB larger than the power scattered from the background area, the corner reflectors could be readily identified. Contrast enhancement of the SAR image was necessary to identify the corner reflectors when the difference between the power scattered from the reflector's resolution cell and the background targets narrows down to 12 dB. Below 12-dB difference, it becomes fairly difficult to identify exact locations of the corner reflectors in the image. Geometric correction of the SAR data using the GPS locations of 5 corner reflectors was satisfactory, with a RMS error of less than half a pixel.

1. INTRODUCTION

Recent advances in satellite remote sensing have seen the development of synthetic aperture radar (SAR) satellites e.g., ERS-1/2, RADARSAT, ENVISAT. Their capability to obtain information independent of weather conditions and external illumination source have made them potentially important, particularly in the tropics where persistent cloud cover limits the use of data from optical and near infrared satellite sensors. However, the coherent imaging of radar systems results to speckles, creating a "salt and pepper" appearance in radar images. The presence of speckles in radar images makes it relatively difficult to identify point targets, with known geographic locations, needed for geometric correction. Passive corner reflectors are often installed for this purpose.

The triangular trihedral design is the most popular corner reflector (Curlander and McDonough, 1991). Corner reflectors designed at the NASA's Jet Propulsion Laboratory (IGPP, 2000) and at the Alaska SAR Facility (ASF, 2000) are large, measuring 2.4 meters on the short edge. Using large reflector may result in increased radar cross section, but will also lead to increased construction and deployment errors (Curlander and McDonough, 1991). The questions then are: (a) will a small, passive, trihedral corner reflector be easily identifiable in RADARSAT Fine Mode SAR data? (b) are small corner reflectors sufficient to geometrically correct RADARSAT Fine Mode SAR data? and (c) what will be the ideal site to set up the reflectors? A number of factors have to be considered when deploying the reflectors, including the backscatter from the surrounding target area, pointing angle relative to the radar, and the contribution from multipath.

2. CORNER REFLECTOR DESIGN

Considering the high azimuth and range resolutions (~9 m) of Radarsat Fine Beam Mode data, a small (1-m width) trihedral corner reflector was presumed sufficient to saturate backscatter information of a ground pixel. The small corner reflector design does not only minimize plate curvature of the side panels, but also provides easy mobility in transporting the reflectors to the field sites.

The reflector consists of 3 sides of triangular aluminum panels (Figure 1). Each panel has a small hole on it to drain rainwater and minimize the effect of strong wind. The longest side of each triangular panel is reinforced with angular bar to minimize surface curvature. The panels are then attached perpendicular (90 degrees rigorous) to each other by bolts and nuts.

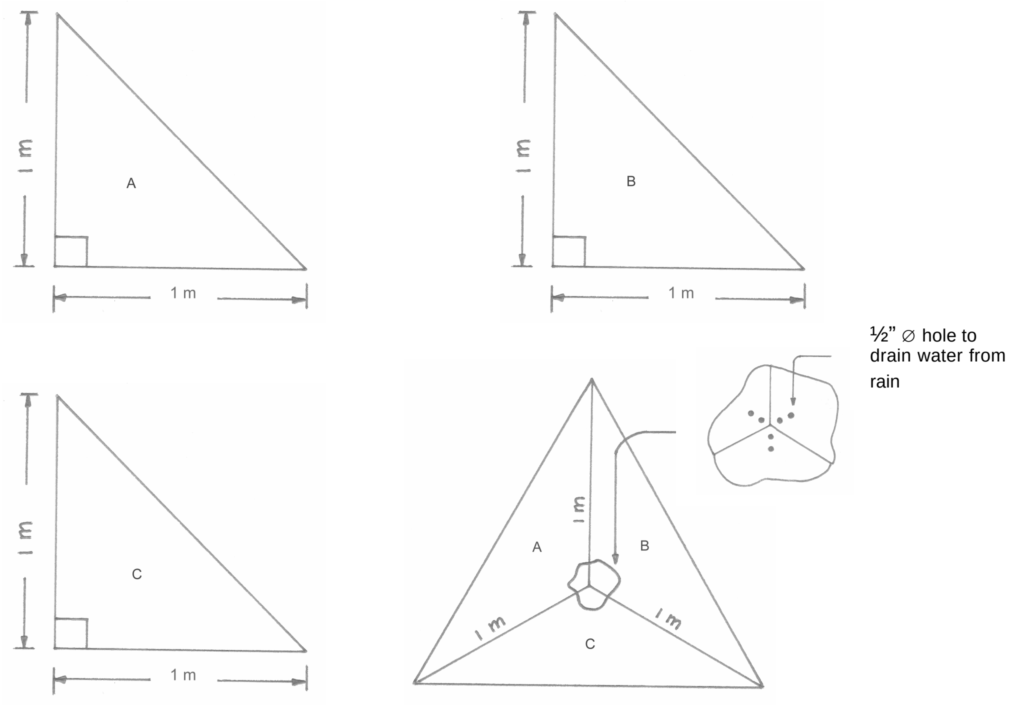


Figure 1. Main components of the corner reflector showing the dimensions of the 3 triangular aluminum panels and detail of the water drain.

The corner reflector is also equipped with base accessories (Figure 2) and parallel bar component (Figure 3) to support the reflector when set at certain directions relative to the radar: (a) perpendicular to the satellite’s flight direction and (b) facing the sensor at a pointing or tilt angle, which is based on the incidence angle at the center of the image swath.

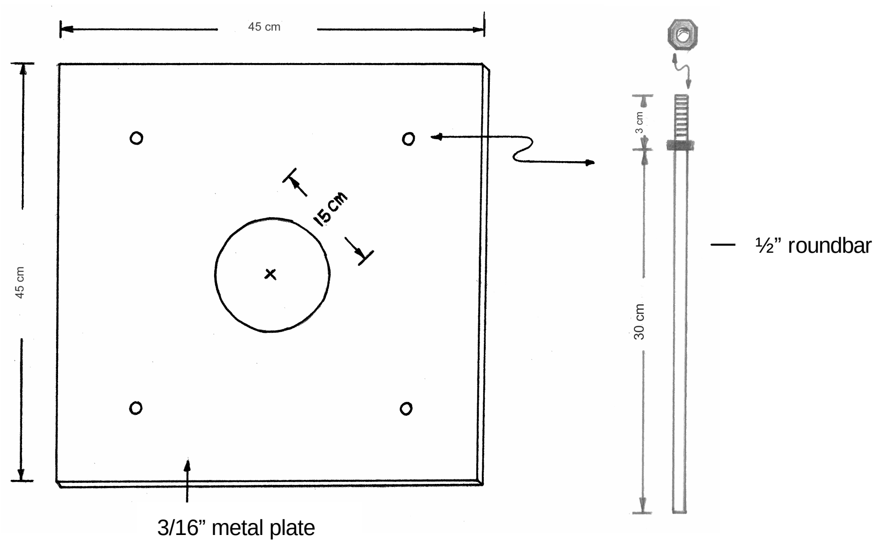


Figure 2. Details of the base accessories

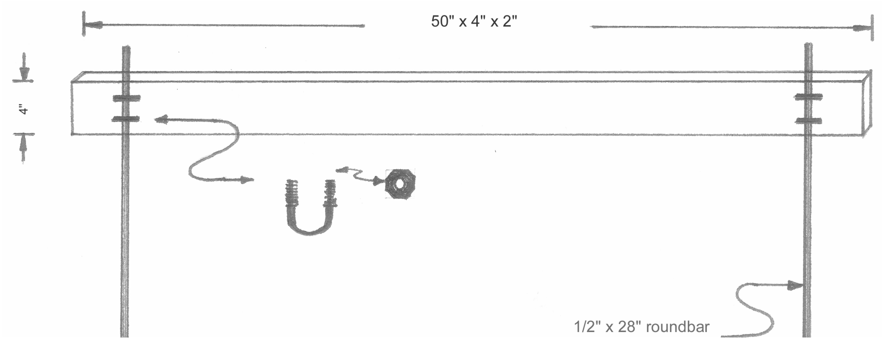


Figure 3. Details of parallel bar component

2.1 Installing the Corner Reflector

Preliminary locations were selected in areas commonly covered by both ascending and descending SAR images (Table 1), followed by field inspection to verify the suitability of the sites. Areas that are at least 100 meters away from objects with potential "reflector" effect and those where backscatter contribution from its land cover is presumably small were finally selected as deployment sites.

Table 1. Data specifications of the 2 RADARSAT Fine Mode SAR data

	RADARSAT SAR data 1	RADARSAT SAR data 2
Acquisition date (local time)	29 January 2001	11 February 2001
Ascending/descending	Ascending	Descending
Orbit number	79-158A	79-336D
Center incidence angle	38.41	37.61
Lat./Long. Of image center	14 03'N 100 34'E	14 07'N 100 28'E
Lat./Long. Of NW corner	14 14'N 100 19'E	14 23'N 100 18'E
Lat./Long. Of NE corner	14 19'N 100 43'E	14 18'N 100 43'E
Lat./Long. Of SW corner	13 47'N 100 24'E	13 56'N 100 13'E
Lat./Long. Of SE corner	13 52'N 100 49'E	13 51'N 100 37'E

Source: RSI RADARSAT Technical Proposal, November 2000

Precise orientation of the reflectors relative to the radar was carefully measured. The reflectors were oriented perpendicular to the satellite's flight direction (Figure 4). The pointing angle (or tilt angle) of the corner reflector was adjusted relative to the radar's incidence angle. The corner reflector is positioned in the rain-catcher position by tilting it backward at an angle of 6.59^o for 29 January 2001 ascending mode and 7.39^o for 10 February 2001 descending mode. Figure 5 illustrates the correct positioning of the pointing angle of the reflector.

(4a) ascending

(4b) descending

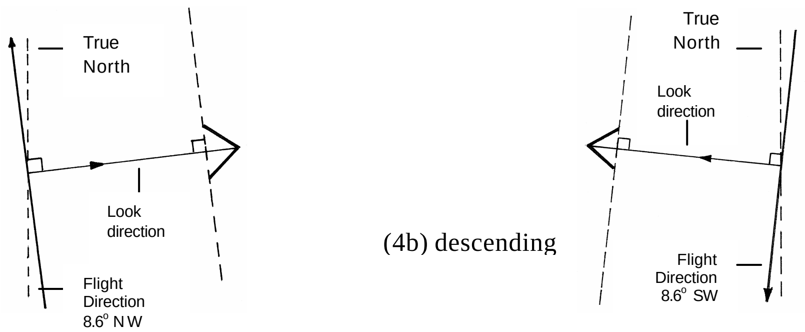


Figure 4. Positions of corner reflectors for ascending and descending modes

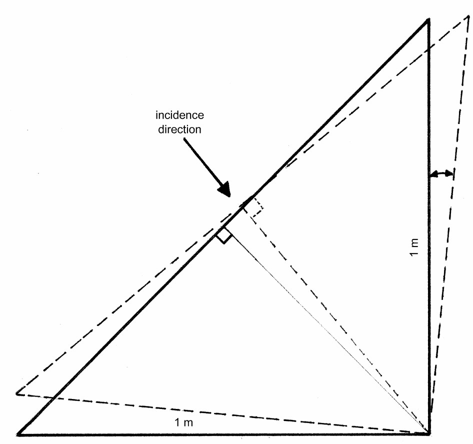


Figure 5. Pointing angles for ascending and descending acquisition modes

3. ANALYZING SAR DATA FOR PERFORMANCE OF CORNER REFLECTORS

The SAR data were corrected for LUT scaling and incidence angle variation following the procedures outlined for extracting sigma nought from RADARSAT CDPF products (ALTRIX Systems, 2000). The corrected amplitude data were rescaled to a calibration constant of $K=3x10^8$ (Intensity) in order for the data to fit within the unsigned integer range.

The corner reflectors could be readily identified in the descending Radarsat image (Figure 6) after applying interactive linear stretching of the output display. In one location, the corner reflector could be identified easily against a dark background (-21db) without applying any linear stretch to the output display. The backscatter values of the reflector's resolution cell and the background target were calculated (Table 2).

Table 2. Backscatter measurement of the reflector's resolution cell and background target.

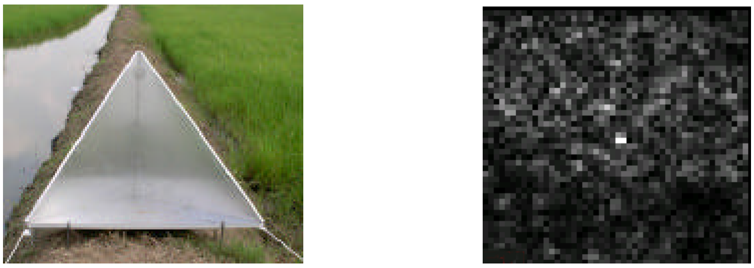
Corner Reflector		Backscatter from Reflector Resolution Cell (dB)	Backscatter from Background Target (dB)	Visibility of Reflectors
Ascending	1	9.34	-3.21	Visible after contrast stretching
	2	---	--2.78	Uncertain
	3	---	-4.96	Uncertain
	4	9.50	-1.53	Visible after contrast stretching
	5	---	-3.22	Uncertain
Descending	1	8.53	-21.22	Visible
	2	9.89	-2.19	Visible after contrast stretching
	3	9.48	-3.14	Visible after contrast stretching
	4	9.21	-5.08	Visible after contrast stretching
	5	9.48	-2.98	Visible after contrast stretching

The locations of 3 corner reflectors could not be identified in the ascending SAR image. This is due to errors in the orientation of the reflectors and the presence of multipath. Errors in the orientation of the reflector considerably reduced the backscatter of the reflector's resolution cell, resulting in the absence of a bright target in the image. While the presence of multipath, such as nearby housing structures and power lines, confuses which bright target in the image is the reflector.

The reflectors were re-oriented for the descending image acquisition, with reflectors 1 and 2 relocated to adjacent fields distant from multipath source and with potentially smaller background power. Fields with smooth surface and flooded paddy fields are ideal candidates. The backscatter from the reflectors' resolutions cells averaged 9.3 dB. At 29 dB larger than the power scattered from the background area, corner reflector 1 could be readily identified (Figure 6a). Contrast enhancement of the descending SAR image was necessary to identify corner reflectors 2 to 5, where the difference between the power scattered from the reflector's resolution cell and the background targets narrows down to 12 dB (Figures 6b to 6e). Below 12-dB difference, it becomes uncertain and fairly difficult to identify exact locations of the corner reflectors in the image.

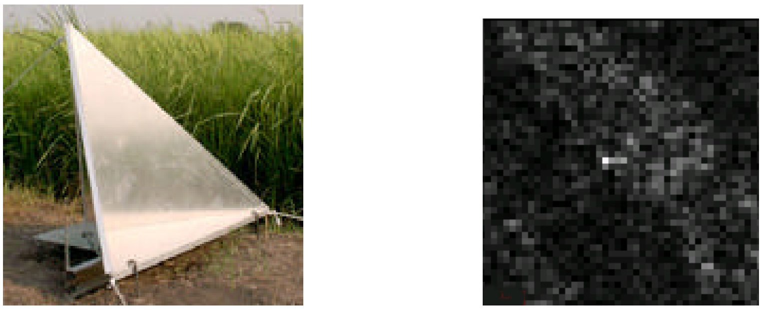
(6a) Reflector No. 1

Reflector : 8.53 dB
Background : -21.22 dB



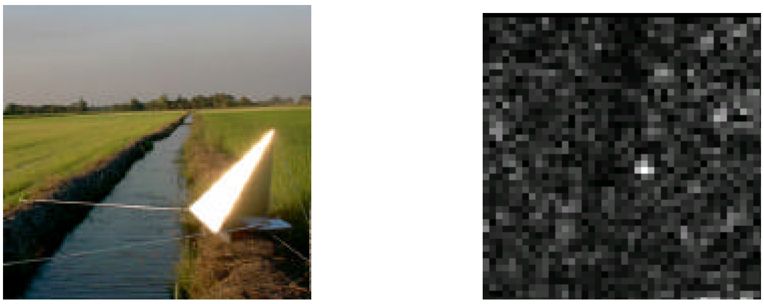
(6b) Reflector No. 2

Reflector : 9.89 dB
Background : -2.19 dB



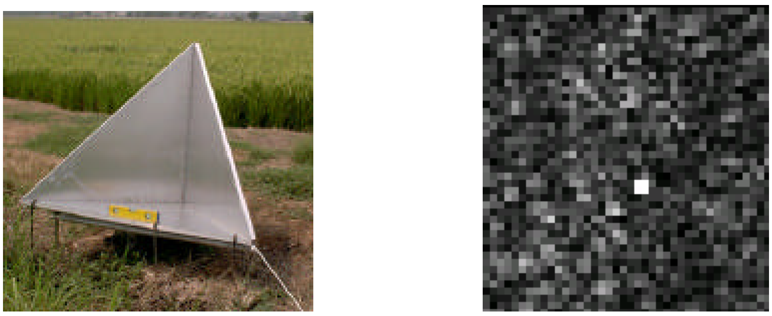
(6c) Reflector No. 3

Reflector : 9.48 dB
Background : -3.14 dB



(6d) Reflector No. 4

Reflector : 9.21 dB
Background : -5.08 dB



(6e) Reflector No. 5

Reflector : 9.48 dB
Background : -2.98 dB

Figure 6. Field locations of corner reflectors and their corresponding views in the descending SAR image

3.1 Geometric Correction

Geometric correction, using the GPS locations of 5 corner reflectors, was made on the 11 February 2001 ascending SAR data. The result was satisfactory, with RMS errors less than half a pixel.

Table 3. Ground control points using the locations of corner reflectors

GCP Station	Cell x	Cell y	Easting	Northing	RMS
1	4800.93	4087.12	666840.84	1563299.43	0.28
2	6043.74	5886.74	672284.00	1550760.24	0.25
3	6430.00	1748.00	679653.11	1575678.92	0.11
4	1965.25	4145.02	649383.84	1566364.13	0.15
5	3549.04	7607.75	654909.69	1543218.12	0.17

4 CONCLUSIONS

The small, passive, trihedral corner reflectors could be identified in the SAR image as bright point targets. At an average backscattered power of 9.3 dB, the reflectors could near saturate backscatter information of a ground pixel. While small reflectors offer minimal construction errors and easy mobility, precise orientation is necessary to optimize backscatter from the reflectors' resolution cells. Factors other than the precise orientation of the reflectors have also to be considered. Background targets should be at least 12 dB lesser than that of the reflector's resolution cell, otherwise it would be fairly difficult to identify the reflectors in the image. Flooded paddy fields and fields with smooth surface, where backscatter contribution is about -21 dB or less, are ideal deployment sites. The deployment sites should be free from multipath contribution and should be located distant from power lines and housing structures.

Finally, geometric correction of RADARSAT Fine Mode SAR data using the locations of 5 small, passive, trihedral corner reflectors was satisfactory.

5. ACKNOWLEDGEMENT

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