Calibration of UAV SAR Images Using Corner Reflectors: Addressing Phase and Radiometric Inconsistencies

Shubham Raj, Satyam Agnihotri, Sushant Shekhar, Somalin Nath, Onkar Dikshit

National Centre for Geodesy, IIT Kanpur, India

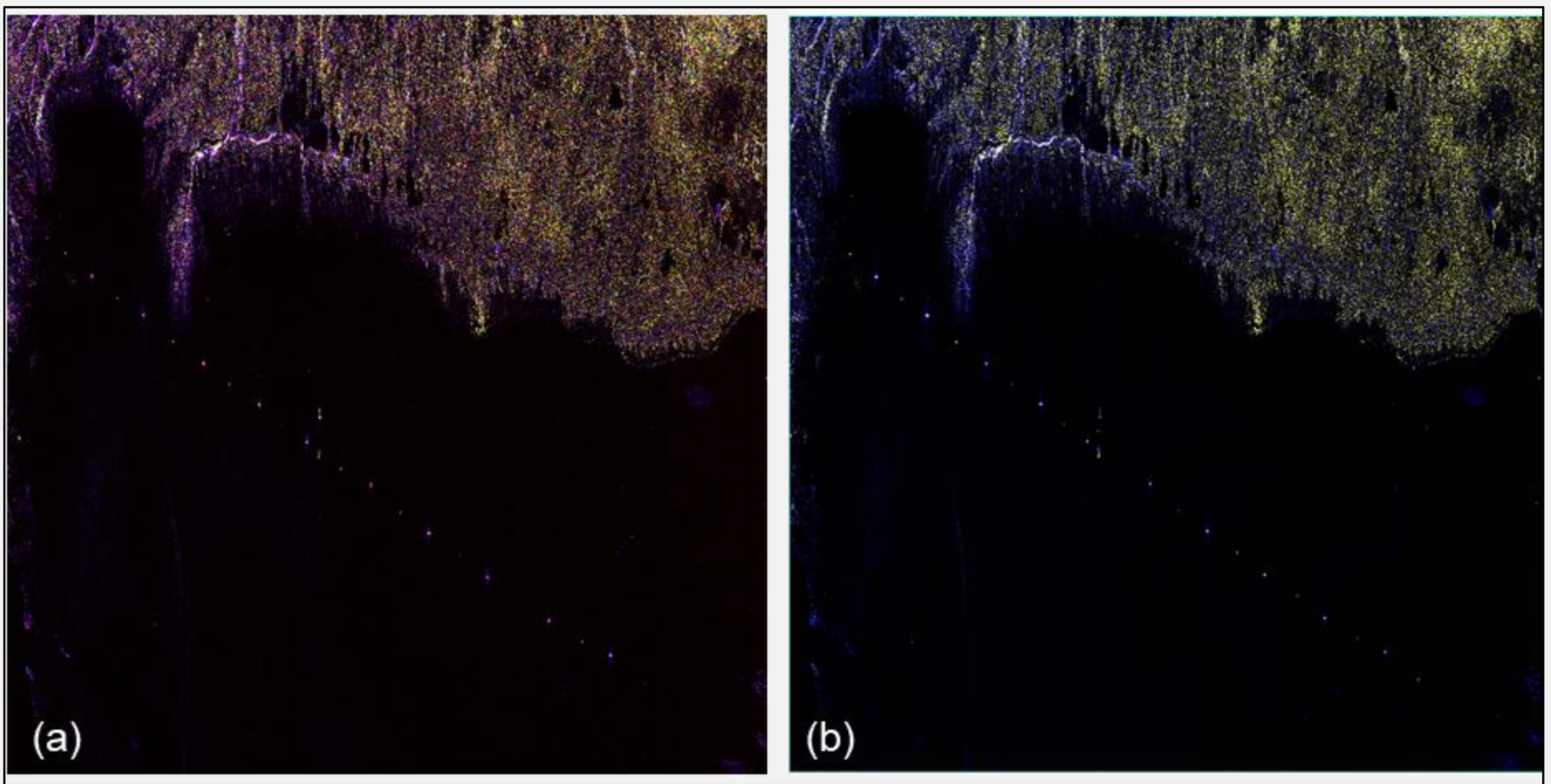
Email : nsomalin@iitk.ac.in

Background:

Conventional SAR systems measure the power of incoming echoes, influenced by scene brightness temperature and thermal noise, which must be converted into consistent radiometric units in terms of radar cross-section (RCS).

Phase inconsistencies, if unaddressed, can result in polarization state errors, leading to channel imbalance and cross-talk.

The study outlines a systematic approach to calibrate SAR systems by addressing both radiometric and phase inconsistencies using corner reflectors.



(a) Pauli decomposition of uncalibrated UAVSAR SLC image, and (b) calibrated UAVSAR SLC image

Radiometric and Phase Calibration of SAR Images using Corner Reflectors

The approach has been made to calibrate SAR systems by addressing both radiometric and phase inconsistencies using corner reflectors. Conventional SAR systems measure the power of incoming echoes, influenced by scene brightness temperature and thermal noise, which must be converted into consistent radiometric units in terms of radar cross-section (RCS) (Basavaraju et. al., 2021; Maiti et. al., 2020; Van Zyl, et. al., 1987, 1992) . Phase inconsistencies, if unaddressed, can result in polarization state errors, leading to channel imbalance and cross-talk.

The Scattering Matrix for radiometric calibration:

$$S_{cr} = \frac{k_o l^4}{\sqrt{12\pi}}\begin{bmatrix}1 & 0\\0 & 1\end{bmatrix} \qquad \text{Eq. 1}$$

$$\sigma_{cr} = \frac{4\pi l^4}{\lambda^2}\left[cos\theta + sin\theta(sin\emptyset + \cos\emptyset) - \frac{2}{cos\theta + sin\theta(sin\emptyset + cos\emptyset)}\right]^2 \qquad \text{Eq. 2}$$

$$\text{Amplitude constant, A} = \left(\frac{Measured\ RCS}{Theoritical\ RCS}\right)_{cr} \qquad \text{Eq. 3}$$

The Cross Talk Correction calculated using the following Ainsworth Model (Ainsworth and Famil, 2006):

$$\begin{bmatrix}O_{hh}\\O_{vh}\\O_{hv}\\O_{vv}\end{bmatrix} = (t_{vv}r_{vv})\begin{bmatrix}k^2\alpha^2 & vk & wk\alpha^2 & vw\\ zk^2\alpha^2 & k & wzk\alpha^2 & w\\ uk^2\alpha^2 & uvk & k\alpha^2 & v\\ uzk^2\alpha^2 & uk & zk\alpha^2 & 1\end{bmatrix}\begin{bmatrix}S_{hh}\\S_{vh}\\S_{hv}\\S_{vv}\end{bmatrix} \qquad \text{Eq. 4}$$

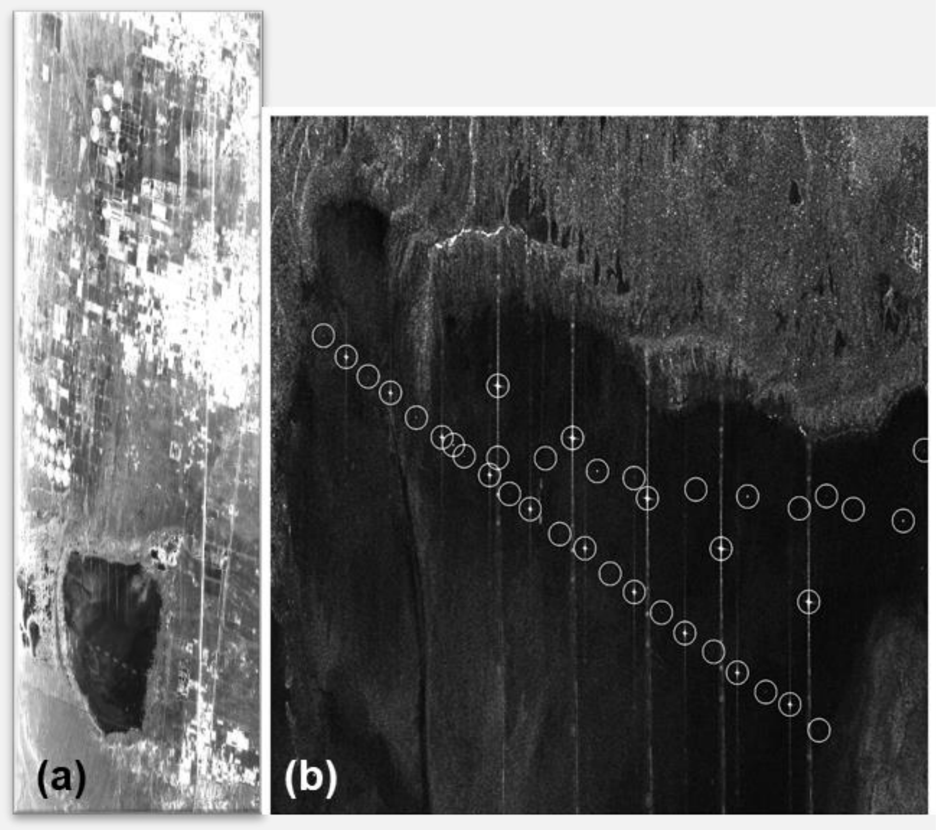
Where, α and k are channel imbalance parameters; u, v, w, z are cross talk parameters

Number of constraints using reciprocity = 5

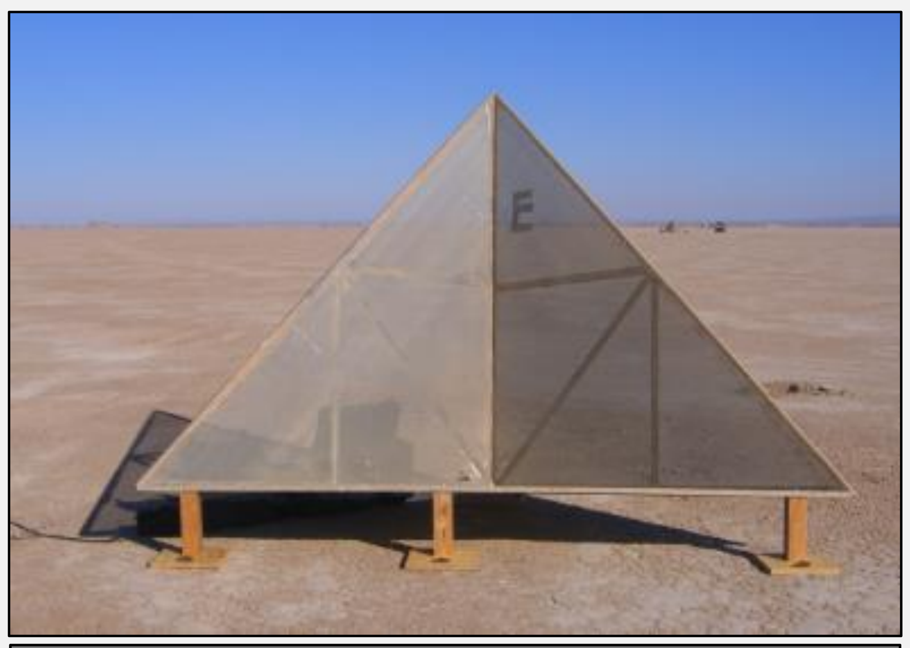
$(\sigma_{hvhv} = \sigma_{vhvh}\ ;\ \sigma_{hvhv} = \sigma_{vhvh}\ ;\ Im(\sigma_{vhhv}) = 0\ ;\ \sigma_{hvhh} = \sigma_{vhhh}\ ;\ \sigma_{hvvv} = \sigma_{vhvv})$

Study Area:

For the calibration of UAVSAR data (Figure 5), we used Corner Reflectors (CRs) deployed at the Rosamond Corner Reflector Array (RCRA) site, located near the south beach of Rosamond Dry Lake Bed, California. The whole array consist of triangular trihedral corner reflectors out of which 31 are 2.4m CRs.



(a) Uncalibrated UAVSAR data of Rosemond test site, and (b) array of CR for the calibration

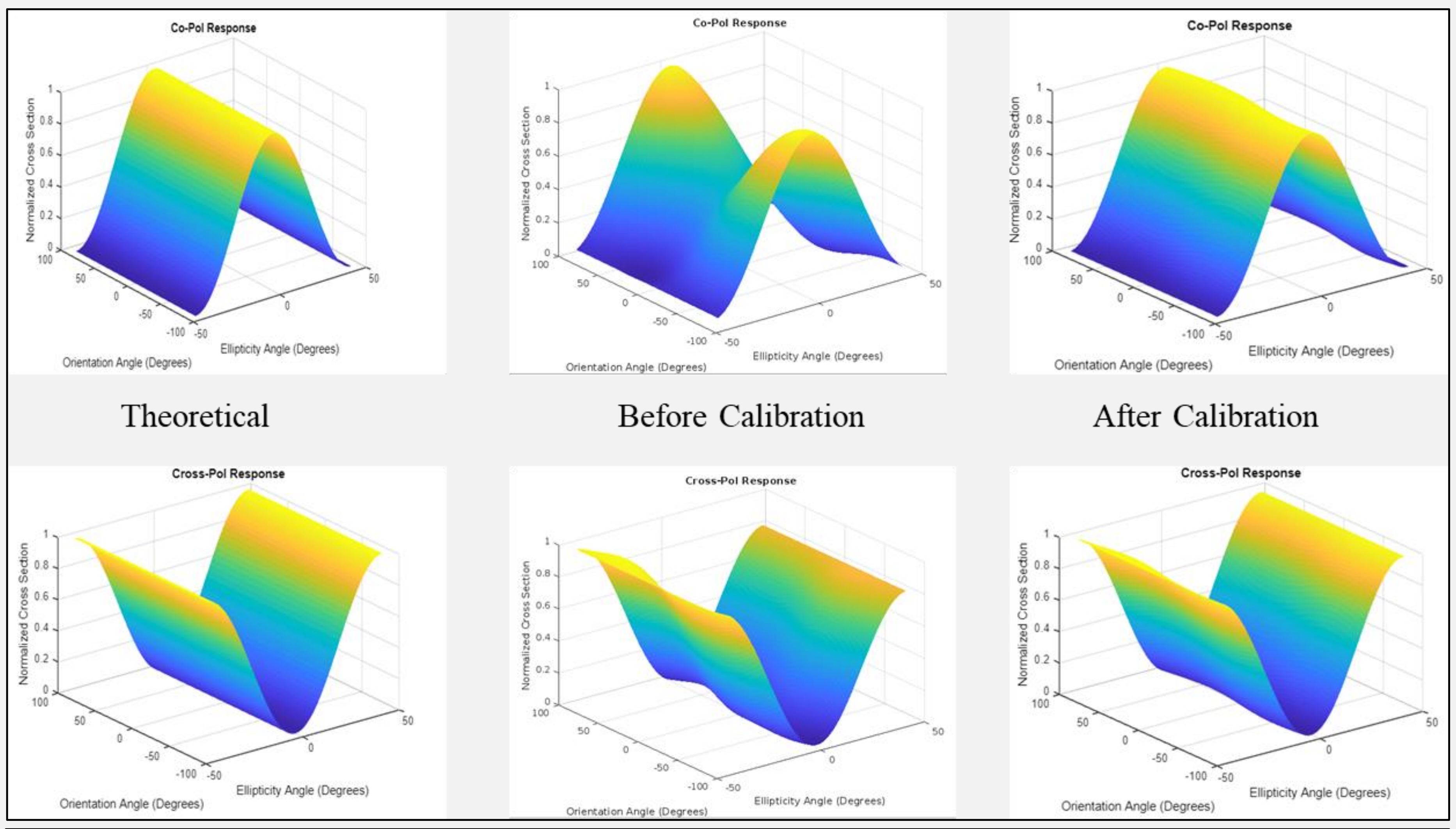


2.4 m trihedral corner reflector located at Rosamond

The theoretical radar cross-section of a corner reflector for Rosemond area was calculated, considering its dimensions, wavelength, azimuth angle, and incidence angle. This theoretical RCS is essential for validating the radar's measurements.

Table 1: Radiometric calibration parameters

Length	Theoretical RCS	Measure RCS	Calibrated RCS
2.4384	49.884084	21.141762	49.884082
2.4384	50.927407	25.948898	50.927407
2.4384	50.995322	24.407278	50.995322
2.4384	50.929408	26.061499	50.929409
2.4384	49.223987	23.547672	49.223988
2.4384	48.422398	24.501144	48.422400
2.4384	47.618361	23.141615	47.618359
2.4384	47.592091	25.837290	47.592089
2.4384	47.285516	24.233007	47.285517
2.4384	45.991987	25.079107	45.991986



Results for UAV SAR data calibration using Corner Reflectors

Conclusion:

The results indicates a clear enhancement in the quality of SAR data, as evidenced by the comparison of images before and after calibration. The CRs significantly improved both radiometric and phase calibration of SAR images.

References:

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- S. Quegan, "A unified algorithm for phase and crosstalk calibration of polarimetric data-theory and observations," IEEE Trans. Geosci. Remote Sens., vol. 32, no. 1, pp. 89–99, Jan. 1994.
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