Polarimetric Calibration Using Polarization Orientation Angles of Built-up Areas

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Abstract

A new polarimetric calibration method using polarization orientation angle shifts at built-up areas and standard calibrators is studied. Calibration matrices were derived from datasets of the Gifu and the JAXA Tomakomai calibration sites, which are almost the same as those by JAXA. Faraday rotation angels in observed datasets can be estimated. Two estimated Faraday rotation angles were reasonable.

Keywords: PALSAR, polarimetric calibration, polarization orientation angle, Faraday rotation.

1. INTRODUCTION

The Phased Array type L-band Synthetic Aperture Radar (PALSAR) offers fully polarimetric data to the remote sensing society. In the ALOS/PALSAR mission, polarimetric SAR data calibration is important to ensure accurate extraction of geophysical parameters, such as, soil moisture, surface roughness, and biomass. The calibration algorithms proposed by van Zyl [1] and the more general approach proposed by Quegan [2] are presently standards for phase and cross-talk calibration of polarimetric data.

Recently polarimetric orientation angle shifts in built-up areas are reported [3]. In this research, a new polarimetric calibration method using polarimetric orientation angles are proposed.

2. RADAR SYSTEM MODEL

Nonreciprocal radar system model including Faraday rotation is assumed as follows.

$$\begin{aligned}\mathbf{O} &= \mathbf{RFSFT}+\mathbf{N}\\ &= \begin{bmatrix} r_{11} & r_{12}\\ r_{21} & r_{22}\end{bmatrix}\begin{bmatrix}\cos\Omega & \sin\Omega\\ -\sin\Omega & \cos\Omega\end{bmatrix}\begin{bmatrix} S_{hh} & S_{hv}\\ S_{vh} & S_{vv}\end{bmatrix}\begin{bmatrix}\cos\Omega & \sin\Omega\\ -\sin\Omega & \cos\Omega\end{bmatrix}\\ &\cdot\begin{bmatrix} t_{11} & t_{12}\\ t_{21} & t_{22}\end{bmatrix}+\begin{bmatrix} n_{hh} & n_{hv}\\ n_{vh} & n_{vv}\end{bmatrix}\end{aligned} \tag{1}$$

where **O** is the observed scattering matrix, **F** is one-way Faraday rotation matrix, **S** is the Scattering matrix, **R** and **T** are the receive and transmit distortion matrices, respectively, **N** is the noise matrix.

Eq. 1 can be rewritten as

$$\mathbf{O}=\tilde{\mathbf{R}}\mathbf{S}\tilde{\mathbf{T}}+\mathbf{N}=\begin{bmatrix}\tilde{r}_{11} & \tilde{r}_{12}\\ \tilde{r}_{21} & \tilde{r}_{22}\end{bmatrix}\begin{bmatrix} S_{hh} & S_{hv}\\ S_{vh} & S_{vv}\end{bmatrix}\begin{bmatrix}\tilde{t}_{11} & \tilde{t}_{12}\\ \tilde{t}_{21} & \tilde{t}_{22}\end{bmatrix}+\begin{bmatrix} n_{hh} & n_{hv}\\ n_{vh} & n_{vv}\end{bmatrix} \tag{2}$$

$$\begin{aligned}\tilde{\mathbf{R}}=\mathbf{RF}&=\begin{bmatrix} r_{11}\cos\Omega - r_{12}\sin\Omega & r_{11}\sin\Omega + r_{12}\cos\Omega\\ r_{21}\cos\Omega - r_{22}\sin\Omega & r_{21}\sin\Omega + r_{22}\cos\Omega\end{bmatrix}\\ \tilde{\mathbf{T}}=\mathbf{FT}&=\begin{bmatrix} t_{11}\cos\Omega + t_{21}\sin\Omega & t_{12}\cos\Omega + t_{22}\sin\Omega\\ t_{21}\cos\Omega - t_{11}\sin\Omega & t_{22}\cos\Omega - t_{12}\sin\Omega\end{bmatrix}\end{aligned} \tag{3}$$

where $\tilde{\mathbf{R}}$ and $\tilde{\mathbf{T}}$ are the equivalent receive and transmit distortion matrices including the Faraday rotation effect respectively.

3. POLARIZATION ORIENTATION ANGLE SHIFTS IN BUILT-UP AREAS

The polarization orientation angle is defined by the angle between the major axis of the polarization ellipse and the horizontal axis. It is known that terrain slopes induce the polarization angle shift θ, which is the angle that rotates the incidence plane about the line of sight to the surface normal by the following equation [4]:

$$\tan\theta=\frac{-\tan\omega}{-\tan\gamma\cos\phi+\sin\phi} \tag{4}$$

where $\tan\omega$ is the azimuth slope, $\tan\gamma$ is the slope in ground range direction, and ϕ is the radar look angle. Note that in this paper the sign of the $-\tan\varpi$ is opposite to the definition in [4].

For Bragg scattering surfaces, the orientation angle by circular polarizaztion method is [4]

$$\theta=\mathrm{Arg}\left(-\left\langle \tilde{S}_{rr}\tilde{S}_{ll}^{*}\right\rangle\right)\big/4\quad. \tag{5}$$

Polarization onentation angle shifts occur in built-up areas, and they are explained by the double-bounce from a building wall and the ground [3]. The Polarization orientation angle of a built-up area becomes

$$\tan\theta=-\tan\alpha/\cos\phi \tag{6}$$

where α is the rotation angel of the vertical wall from the azimuth direction (more strictly, the perpendicular direction to the radar incidence), and ϕ is the radar look angle as

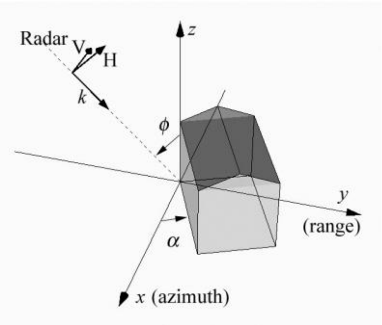


Figure 1. Schematic diagram of the radar imaging geometry to relate the orientation angle to a wall angle.

shown in Figure 1.

4. POLARIMETRIC CALIBRATION USING BUILD-UP AREAS

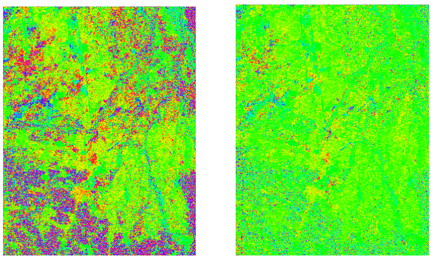
In this study, firstly the equivalent distortion matrices (Eq.3) for each calibration site dataset are determined. Secondary from several pairs of them, the system distortion matrices and Faraday rotation angles of each dataset are separated. The equivalent distortion matrices for each dataset is determined to satisfy the following conditions after calibration:

1. Two polarization angles in built-up areas from a set of (HH, HV, VV) and a set of (HH, VH, VV) are same.
2. Correlation between co-polarization and cross-polarization is small for surface scattering surfaces.
3. The response of a corner reflector calibrator is balanced between co-polarizations.

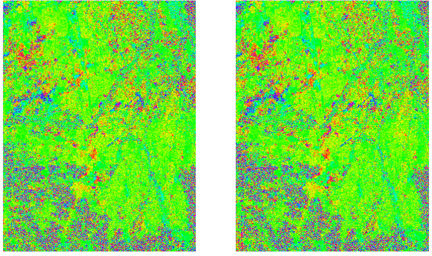
The simulated annealing algorism is applied in this study. Built-up areas have strong backscatter and are robust to noise. Therefore the proposed method has an advantage over other methods that do not use built-up areas as calibration targets.

5. PLELIMINARY RESULT OF ALOS PALSAR CALIBRATION

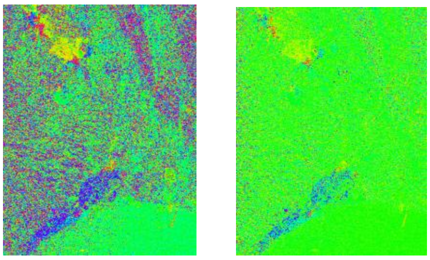
So far two calibration site datasets, Gifu data of nigh in 11 June 2006 and Tomakomai data of day in 19 May 2006, were used. In Gifu site, a 2.0 m trihedral corner reflector and a 1.0 m by 3.6 m flat plate were deployed. In Tomakomai site, a 3.0 m trihedral corner reflector was deployed by JAXA.



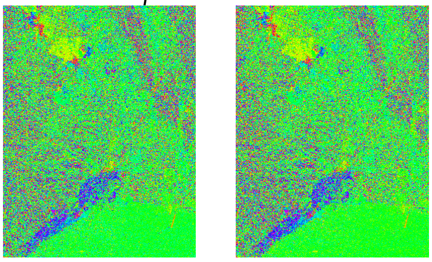
Before Calibration



After calibration
(a) Gifu



Before Calibration



After calibration
(b) Tomakomai

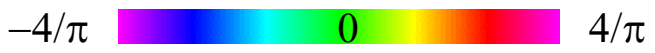


Figure 2. Polarization orientation angel images. (a) before calibration and (b)after calibration. In each pair, the left is from a combination of HH, HV and VV, and the right is from that of HH, VH and VV.

JAXA L1.1 products were provided. Calibration of L1.1 was removed by applying the system distortion matrix parameters in the leader file. The separated system distortion matrices by the proposed method are

$$\mathbf{R} = \begin{bmatrix} 1 & -0.045 + j0.008 \\ 0.024 + j0.003 & 0.720 + j0.012 \end{bmatrix}, \quad (7)$$

$$\mathbf{T} = \begin{bmatrix} 1 & 0.024 + j0.028 \\ -0.028 + j0.002 & 0.902 + j0.422 \end{bmatrix}$$

Separated Faraday rotation angles are –0.62 and –1.47 degrees for Gifu and Tomakomai sites respectively.

Figure 2 shows polarization orientation angel images before and after calibration from Gifu dataset. After calibration, two images correspond well. This suggests that calibration is done well. Table 1 shows CR peak response after calibration, and means that a good balance of co-polarizations and a good isolation of cross-polarizations after calibration.

Table 1. CR peak response after calibration

	Gifu	Tomakomai
|HH/VV| [dB]	0.13	0.14
|HV/VV| [dB]	-39.8	-38.9
|VH/VV| [dB]	-44.8	-34.3

5. CONCLUSION AND FUTURE WORK

Distortion matrices of ALOS/PALSAR after removing Faraday rotation effects were estimated from Gifu and Tomakomai datasets by using polarization orientation angles of built-up areas and a ground calibrator. Their diagonal terms are similar to those by JAXA, but off-diagonal terms have small differences. Faraday rotation angle can be estimated by Freeman method after calibration. This will improve calibration accuracy. In future work, distortion matrices will be updated by adding more calibration site datasets under an assumption of stable PALSAR system. In addition, estimated Faraday rotation angles will be evaluated.

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