Polarimetric calibration method including Faraday Rotation compensation using passive two reference reflectors

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1. Introduction

Advanced Land Observing Satellite (ALOS) was launched by Japan Aerospace Exploration Agency (JAXA) in January 2006. The ALOS loads Phased Array type L-band Synthetic Aperture Radar (PALSAR) that is the world-first spaceborne full polarimetric radar utilizing horizontally and vertically polarized L-band microwaves both in transmission and reception. Full-Polarimetric SAR is quite useful so that it can measure a scattering matrix of a target with 4 polarization combinations in transmission and reception (HH, HV, VH, VV). However, to utilize Full-Polarimetric SAR data, it is necessary to estimate and remove antenna distortion. In addition, it is very important to estimate and remove Faraday Rotation effect because of orbital altitude and observing wavelength of PALSAR. This Faraday Rotation effect may affect significant data error when the sun activity is active[1].

In this paper we propose polarimetric calibration method to remove both antenna distortion and Faraday Rotation effect by using two passive reference reflectors; a polarization-preserving and a polarization-rotating. We compare the results with those obtained using two reference reflectors; a passive polarization-preserving reflector and an active polarization-rotating reflector. Then we confirm the validity of our polarimetric calibration method and passive polarization-rotating reflector.

2. Polarimetric Calibration Method [2]

Measured scattering matrix M is assumed to be a combination of receiving and transmitting distortion matrices of the radar antenna R and T, one-way Faraday rotation matrix F, and true scattering matrix S as shown in equation (1).

$$M = R^T \bullet F \bullet S \bullet F \bullet T$$

$$\begin{pmatrix} M_{hh} & M_{hv} \\ M_{vh} & M_{vv} \end{pmatrix} = \begin{pmatrix} 1 & C_2 F_R \\ C_1 & F_R \end{pmatrix}^T \begin{pmatrix} \cos\Omega & \sin\Omega \\ -\sin\Omega & \cos\Omega \end{pmatrix} \begin{pmatrix} S_{hh} & S_{hv} \\ S_{vh} & S_{vv} \end{pmatrix} \begin{pmatrix} \cos\Omega & \sin\Omega \\ -\sin\Omega & \cos\Omega \end{pmatrix} \begin{pmatrix} 1 & C_2 F_T \\ C_1 & F_T \end{pmatrix} \tag{1}$$

where R and T are expressed by cross-talk factor $C_{1,2}$ and channel imbalance $F_{R,T}$, and Ω is the one-way Faraday Rotation angle. Moreover we also assume two reflectors' scattering matrices (polarization-preserving = S_{pres}, polarization-rotating = S_{rot}) which are used for calibration algorithm as follows:

$$S_{pres} = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} \quad , \quad S_{rot} = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix} \tag{2}$$

The one-way Faraday Rotation angle Ω is calculated from measured scattering matrix of polarization-preserving reflector, and written as equation (3).

$$\Omega = \frac{1}{2}\tan^{-1}\left(-\frac{M_{vh}^{pres}\cdot M_{hv}^{pres}}{M_{hh}^{pres}\cdot M_{vv}^{pres}}\right)^{\frac{1}{2}} \tag{3}$$

Then the others unknown quantity ($C_{1,2}$ and $F_{R,T}$) are written as equations (4) and (5).

$$F_R = \sqrt{\frac{M_{vv}^{pres}}{M_{hh}^{pres}}\cdot\frac{M_{vh}^{rot}}{M_{hv}^{rot}}} \quad , \quad F_T = \frac{M_{vv}^{pres}}{M_{hh}^{pres}} \Big/ F_R \tag{4}$$

$$C_1 = \frac{1}{2M_{hh}^{pres}}\cdot\left(\frac{M_{hv}^{pres}F_R + M_{vh}^{presi}F_T}{F_R F_T + \dfrac{M_{vv}^{rot}}{M_{hh}^{rot}}}\right) \quad , \quad C_2 = \frac{1}{2M_{hh}^{pres}}\cdot\left(\frac{M_{hv}^{prei}}{F_T} + \frac{M_{vh}^{pre}}{F_R}\right) - C_1 \tag{5}$$

Now we consider two cases of the polarimetric calibration method. In case A, we use two passive reflectors; Trihedral reflector as polarization-preserving one and a Twisted reflector as a polarization-rotating one. In case B, we use a Trihedral reflector as a polarization-preserving and a Polarimetric Active Radar Calibrator (PARC) as an active polarization-rotating. In both cases we evaluate calibration results by using Plate as an evaluation reflector. Figure 1 shows 4 reflectors used for calibration and evaluation. These reflectors' properties are shown in Table 1.

(a) Trihedral (b) Twisted (c) Plate (d) PARC

Figure 1 Reference reflectors

Table 1 Properties of reference reflectors

Reflector Type	Scattering matrix	Size	Radar Cross-section [dBm2]	Active / Passive
Trihedral	$\begin{pmatrix}1 & 0\\ 0 & 1\end{pmatrix}$	1.2m square	31.47	Passive
Twisted	$\begin{pmatrix}0 & 1\\ 1 & 0\end{pmatrix}$	2m square	35.58	Passive
PARC	$\begin{pmatrix}0 & 1\\ 1 & 0\end{pmatrix}$	1m square	40.8	Active
Plate	$\begin{pmatrix}1 & 0\\ 0 & 1\end{pmatrix}$	2m square	35.58	Passive

The Twisted reflector reflects cross-polarization against incident polarization due to 45 degrees slanting metal grid and aluminum plate at backside as shown Figures 2 and 3. This reflector can be easily made at low price and has stable property.

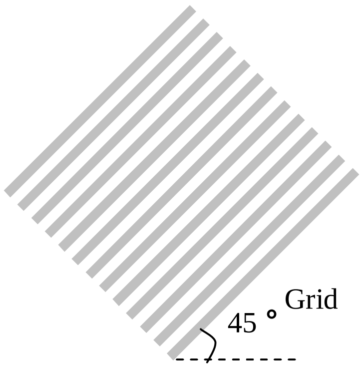


Figure2 Twisted reflector

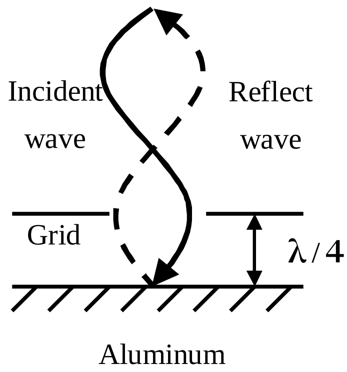


Figure 3 Principle of Twisted reflector

3. Polarimetric Calibration Result

Those reflectors mentioned in the last section were deployed on very wide and frat open field in suburban area of Musashimurayama, Tokyo in October 2006.

Observed PALSAR image of HH, HV, VV polarization channels (HH - red, HV - green,VV - blue) are shown in Figure 4. In our calibration experiment, we deployed 8 reflectors in total.

Since the PALSAR data obtained from JAXA has been calibrated by JAXA without Faraday Rotation sompesation, we recover uncalibrated data (Un-cal) from the obtained one. Then we apply our calibration method to the uncalibrated data. Figure 5 shows polarization signatures of Plate as a calibrated result. The channel imbalance and the cross-talk level of Plate are shown in Figures 6 and 7.

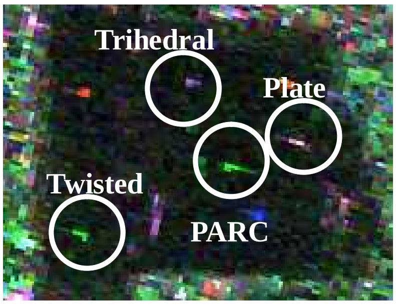
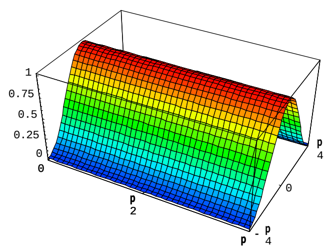
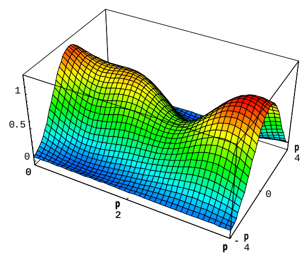


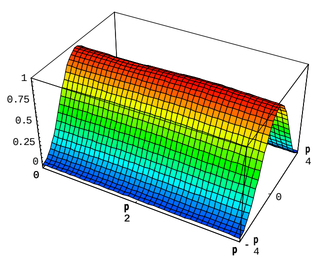
Figure 4 Reflectors' location



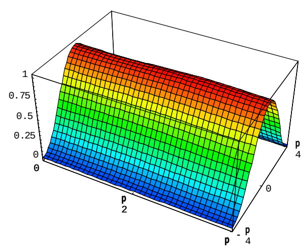
(a) Ideal



(b) Un-cal



(c) Case A



(d) Case B

Figure 5 Polarization signature of Plate

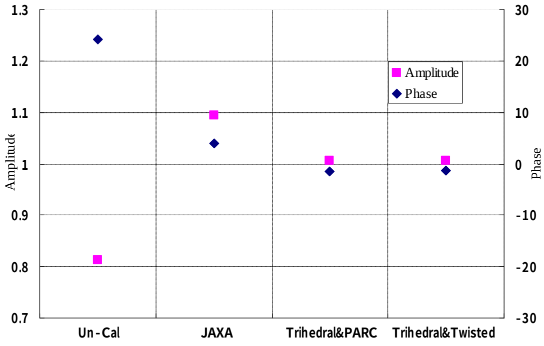


Figure 6 Channel imbalance

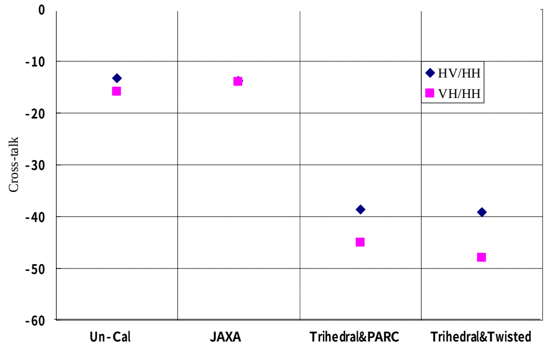


Figure 7 Cross-talk

According to Figure 5, calibrated results of both case A and B show good signatures. The validity of our calibration method also can be seen in both Figures 6 and 7 in which good channel imbalance and cross-talk isolation of Plate are shown.

Furthermore, we can estimate Faraday Rotation angle. Firstly, we derive the angle from equation (3) as an iteration value. Finally, we estimate the angle as 5.79 degrees in Case A and 5.71 degrees in Case B. In both cases, the estimated angle is nearly the same as about 6.5 degrees which are derived theoretically using equation (6).

$$\Omega = \frac{K}{f^2} \int TEC \times B \cos \phi dr \quad [rad] \tag{6}$$

where K is a constant, f is an observation frequency, TEC is total electron content in TEC unit, B is magnetic flux density, and ϕ is an angle between an electric wave vector and a magnetic field one.

4. Conclusion

We tried polarimetric calibration for ALOS PALSAR data with two calibration cases; using Trihedral and PARC as Case A, and Trihedral and Twisted as Case B. In both cases, calibration results show the validity of the calibration methods. It is shown that even passive Twisted reflector can provide reasonable calibration precision like active PARC. We also estimated the Faraday Rotation angle, and the angle is reasonable in comparison to the theoretical one.

Acknowledgement

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References

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