Study on Absolute Calibration Coefficient Improvement for ALOS PALSAR Data after Initial Calibration Check

K. Nakamura, S. Kodama, Y. Takeyama, and M. Matsuoka
National Institute of Advanced Industrial Science and Technology, Japan

Abstract—The Advanced Land Observing Satellite (ALOS) was launched in 2006, carrying the Phased Array type L-band Synthetic Aperture Radar (PALSAR). Although three years have passed from the start of ALOS PALSAR observation, we know the PALSAR is in operation with greatly stable operation. However, we need to monitor its performance for the future sustainable operation in order to evaluate the temporal sensitivity variations of the PALSAR sensor and keep the calibration coefficient quality and its improvement. To achieve this goal, AIST (National Institute of Advanced Industrial Science and Technology) kicked off the PALSAR calibration and validation campaign in 2007. We especially focus on cross-polarization calibration and aim to propose an improved backscattering coefficient by evaluating the absolute calibration coefficient accuracy is evaluated, which is calculated for each polarization based on the ground-truth. In the calibration observations, we used two triangular trihedral corner reflectors (CRs) of size 2 m and 3 m for the like-polarization and our inbuilt prototype rotatable rectangular dihedral CR was used for the cross-polarization.

1. INTRODUCTION
The Advanced Land Observing Satellite (ALOS) was launched by Japanese Aerospace Exploration Agency (JAXA) in 2006, which has the Phased Array type L-band Synthetic Aperture Radar (PALSAR) on board as a follow-on of the Japanese Earth Resources Satellite-1 (JERS-1). The development of the PALSAR is a joint project between Ministry of Economy, Trade and Industry (METI) and JAXA.

The PALSAR observation for calibration and validation (Cal/Val) campaign was conducted half year after the launch by developing corner reflectors (CRs) were deployed all over the world [1]. Although three years have passed from the start of ALOS PALSAR observation, the PALSAR is operating under a very stable condition. However, we may as well continuously monitor the temporal sensitivity variations of the PALSAR sensor for the future sustainable operation.

National Institute of Advanced Industrial Science and Technology (AIST) has been studying the remote-sensing based natural resource survey. One of the research targets is the soil moisture estimation under vegetation and forest cover. In order to better estimate soil moisture and above ground biomass, the calibration coefficient quality should be controlled during the mission. To achieve this goal, we, in AIST, started the PALSAR Cal/Val campaign of AIST. Since the AIST Cal/Val campaign is not just for by AIST, we have been promoting joint activities for the PALSAR calibration observation and the campaign was launched under the cooperation with other agencies.

We especially focus on the cross-polarization calibration based on the ground-truth because the conventional calibration depends only on computationally approach using Quegan method [2]. We therefore developed a prototype of rotatable dihedral CR and the trial observations were carried out using the CRs during the year of 2008. We aim to propose an improved backscattering coefficient as the absolute calibration coefficient accuracy, and the evaluation is made for each polarization data based on ground truth.

2. DATA ACQUISITION
As mentioned above, we promoted joint activities for this PALSAR calibration observation campaign with other agencies and institutes. Currently, the AIST Cal/Val campaign is designed under cooperation with four Japanese universities: Gifu University, Nagasaki University, National Defense Academy of Japan and Nihon University, and Earth Remote Sensing Data Analysis Center (ERSDAC). We also joined the JAXA ALOS Calibration and Validation Science Team (CVST). This paper describes initial results of the calibration observations by AIST and four universities.

Our campaign was planned in accordance with the ALOS systematic observation strategy, which was started in November 2007. The direction and elevation angles to install the CRs were predicted.
Figure 1: AIST PALSAR Cal/Val campaign was performed using the following CRs. (a) 2 m triangle side trihedral CR. (b) 3 m triangle side trihedral CR. (c) Non-rotated 2 m square side dihedral CR. (d) 45° rotated 2 m square side dihedral CR. by the nominal orbital parameters of ALOS. Two triangular trihedral CRs of size 2 m and 3 m and a 2 m square dihedral CR were used for sixteen, four and four observations respectively for the $HH$-polarization. We also carried out the calibration observations for the $HV$-polarization in three times. Our deployable CRs are shown in Figure 1.

3. DATA ANALYSIS AND RESULTS

This paper presents the results of the calibration by AIST and four universities from November 2007 to October 2008. Currently, calibrated single-look complex data (level 1.1 products) are processed and distributed by ERSDAC. The calibration accuracy was evaluated using the integral method [3] was applied to evaluate the calibration accuracy. This method has the characteristics of e.g., less affected by the focus process. The radar cross section (RCS) from a CR in the uniform background region $\sigma_{obs}$ is calculated as follows:

$$
\sigma_{obs} = \left( \sum_{i,j} a_{p,ij}^2 - \frac{N_p}{N_u} \sum_{i,j} a_{u,ij}^2 \right) \frac{\delta_r \delta_a}{\sin \theta} \frac{CF}{\delta_r \delta_a \sin \theta} \frac{CF}{\delta_r \delta_a \sin \theta}
$$

(1)

where $CF$ is the absolute calibration coefficient derived by ERSDAC, $a_{p,ij}^2$ and $a_{u,ij}^2$ are respective image amplitudes of the uniform area including the contains CR and the same background uniform area associated with pixel $ij$ containing $N_p$ and $N_u$ pixels, $\delta_r$ and $\delta_a$ are the image slant-range and azimuth sampling distances in the image, and $\theta$ is the incidence angle at the CR.

The calibration accuracy can be evaluated by the ratio $\sigma_{obs}$ to the theoretical RCS $\sigma_{theory}$. If the difference between $\sigma_{obs}$ and $\sigma_{theory}$ (in the logarithm ratio in dB expression) is 0, the calibrated product agrees with $\sigma_{theory}$. Figures 2(a)–(c) show the results of the accuracy for the
**HH**-polarization from the trihedral CR in Fine Beam Single polarization (FBS), Fine Beam Dual polarization (FBD), and Polarimetric (PLR) modes, respectively. The off-nadir angles are 34.3° in the FBS and FBD modes and 21.5° in the PLR mode. The mean of the difference values from the

![Graph](image)

Figure 2: Difference of RCS between the theoretical values and those based on the observed CRs. The integral method [3] was applied to SLC data processed by ERSDAC to extract the observed values, (a) FBS mode, (b) FBD mode, (c) PLR mode. Open and solid symbols indicate the ascending and descending orbits of ALOS satellite, respectively. Circles and diamonds correspond to the 2 m triangular trihedral CR (see Figure 1(a)), and triangles are the 3 m triangle side trihedral CR (see Figure 1(b)), respectively. Data with dashed circle, square and triangle are the abnormal values due to heavy rain, installation error, and misplacement of CRs.

![Graph](image)

Figure 3: Difference of RCS between the theoretical values and those by observed CRs. Integral method [3] was applied to SLC data processed by ERSDAC in deriving the observed values, (a) **HH**-polarizations in FBS and FBD modes, (b) **HV**- and **VH**-polarizations in PLR mode. Open and solid symbols indicate the ascending and descending orbits of ALOS satellite, respectively. The 2 m square dihedral CR was used for all observations. Circles and triangles are for **HH**-polarization using the non-rotated 2 m dihedral CR (see Figure 1(c)), and squares and diamonds are for **HV**- and **VH**-polarizations using the 45° rotated 2 m dihedral CR (see Figure 1(d)), respectively.
triangular CRs and the standard deviation are $-0.64 \text{ dB}$ and $1.13 \text{ dB}$, respectively. If we assume that the abnormal value is less than $-1.4 \text{ dB}$, caused by installation errors and bad weather condition, the mean and standard deviation become $-0.13 \text{ dB}$ and $0.65 \text{ dB}$, respectively. The mean of the difference values between the FBS and FBD modes is $0.19 \text{ dB}$.

The PLR mode data allow us to validate the calibration accuracy for the $VH$-polarization. In Figure 2(c), there are large errors of the like-polarization in August data because of the incorrect installation. While, the correct installation was made for the October data, the $HH$-to-$VV$ backscattering ratio becomes $0.28 \text{ dB}$.

Figure 3 shows the calibration accuracy derived from the observation using the dihedral CR in all polarization modes of PALSAR. The off-nadir angles are $34.3^\circ$ of the FBS and FBD modes and the calibration accuracy for the $HH$-polarization are shown in Figure 3(a). The mean difference value from the non-rotated dihedral CRs and the standard deviation are $-2.32 \text{ dB}$ and $0.37 \text{ dB}$, respectively. Since the large bias might have been caused by the incorrect positioning of the direction and/or elevation angles of the dihedral CR, this CR require more strict and precise installation.

Figure 3(b) shows the calibration accuracy for the cross-polarization in the PLR mode in which solid and open symbols indicate off-nadir angles of $21.5^\circ$ and $23.1^\circ$, respectively. The mean difference values and the standard deviation are $-2.08 \text{ dB}$ and $0.54 \text{ dB}$ for the $HV$-polarization, and $-4.11 \text{ dB}$ and $0.60 \text{ dB}$ for the $VH$-polarization, respectively. In this study, the imbalance between the $HV$- and $VH$-polarizations was found. The mean $HV$ to $VH$ backscattering ratio was $2.04 \text{ dB}$ and the average phase difference of the $HV$- and $VH$-polarizations was $0.83^\circ$.

4. CONCLUSIONS

AIST kicked off the PALSAR Cal/Val campaign, which was conducted under cooperation with Gifu University, Nagasaki University, National Defense Academy and Nihon University, and ERSDAC. We also join the JAXA ALOS CVST.

The calibrated products derived by ERSDAC were examined by using the triangular triangle CRs. As the results, the mean difference between $\sigma_{\text{obs}}$ and $\sigma_{\text{theory}}$ and standard deviation were $-0.13 \text{ dB}$ and $0.65 \text{ dB}$ respectively for the $HH$-polarization in all modes. The standard deviation is almost comparable to the JAXA standard product. However, as to the calibration accuracy for the cross-polarization using the prototype rotatable dihedral CR, the mean values of backscattering coefficient and phase difference between the $HV$- and $VH$-polarizations were found to be $2.04 \text{ dB}$ and $0.83^\circ$, respectively. Thus, a clear imbalance between the $HV$- and $VH$-polarizations was clearly found.

In future, we continue deploying CR observations and the polarimetric calibration will be carried out in order to solve the imbalance between the $HV$- and $VH$-polarizations. We will also consider the effect of Faraday rotation on the calibration coefficients [4].

ACKNOWLEDGMENT

The authors thank Assist. Prof. Moriyama of Nagasaki University, Prof. Wakabayashi of Nihon University, Prof. Kimura of Gifu University and Prof. Ouchi of National Defense Academy for their assistance with this study. We also wish to thank the students of Nagasaki University, Nihon University, Gifu University and National Defense Academy for their assistance in the CR observations. Ms. Arioka, Dr. Okuyama and Dr. Kamei are appreciated for their assistance in the AIST observation. METI and JAXA retain ownership of the original ALOS PALSAR data, which were distributed by ERSDAC. This research was partially supported by research and development of remote sensing technology for non-renewable resources by METI.

REFERENCES