CALIBRATION AND VALIDATION FOR ALOS/PALSAR USING PI-SAR

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1. INTRODUCTION

Our research proposal was to calibrate and validate ALOS/PALSAR using the Pi-SAR, an airborne polarimetric SAR system of X-band and L-band developed by the National Institute of Information and Communications Technology (NICT) and the Japan Aerospace Exploration Agency (JAXA). It consisted of three major parts as follows.

(1) To calibrate PALSAR, both radiometricly and polarimetricly, with reflectors (point targets) and natural extended targets, in the same manner as applied to the Pi-SAR/X-SAR and the L-SAR.

(2) To validate PALSAR image data, with emphasis on its incidence angle (antenna pattern) dependency, by comparing with Pi-SAR image data of the area.

(3) To validate digital elevation model (DEM) products of both PALSAR and PRISM, by comparing with Pi-SAR DEM products obtained by the X-SAR cross-track interferometry.

Test sites for the research had been selected all over Japan according to their geographical features (Coast, Dune, Forest, and so on), their accessibility, and the heritage of Pi-SAR observations.

In this report we focus on results of the studies related to the part (1). We have not completed the other parts, due to a change in our circumstances.

2. DEVELOPMENT OF POLARIZATION-SELECTIVE REFLECTORS

While natural extended targets such as forest have been largely used for polarimetric calibration of synthetic aperture radars, it requires some assumptions in target's polarimetric scattering properties and there might be some uncertainty in them. On the other hand, if an appropriate combination of point targets of different polarizaion-selectiveness is available and they have accurate polarimetirc scattering properties and fairly large radar cross-sections, it is more straightforward to use them for polarimetric calibration. We developed polarization-selective corner reflectors for the ALOS/PALSAR.

In a polarimetric SAR, horizontal-polarization (H) antenna and vertical-polarization (V) antenna are used both for transmission and reception, producing four scattering components (Shh, Shv, Svh, and Svv). The measured signals (M) can be expressed with scatteing matrix of the target (S), imbalances of vv components against hh in the transmission system (f_t) and in the reception system (f_r) and their cross-talks (δ), assuming no noises.

$$M = c\ R\ S\ T$$

$$\begin{bmatrix} M_{hh} & M_{hv} \\ M_{vh} & M_{vv} \end{bmatrix} = c \begin{bmatrix} 1 & \delta_{r1} \\ \delta_{r2} & f_r \end{bmatrix} \begin{bmatrix} S_{hh} & S_{hv} \\ S_{vh} & S_{vv} \end{bmatrix} \begin{bmatrix} 1 & \delta_{t1} \\ \delta_{t2} & f_t \end{bmatrix} \quad (1)$$

With appropriate combination of calibration targets of known scattering matrix (S), we can determine the unknown values f_r, f_t; δ_{r1}, δ_{r2}, δ_{t1}, δ_{t2} so that we can obtain true scattering matirix (S) from measured (M). For that purpose, we developed three types of calibration targets:

(1) H-polarization dihedral (Shh=1, Svv=Shv=Svh=0),
(2) V-polarization dihedral (Svv=1, Shh=Shv=Svh=0), and
(3) 45°- rotated dihedral (Shv=Svh=1, Shh=Svv=0).

We had developed those reflectors for the PALSAR, as well as another polarization–selective dihedral shown below for a reference.

(4) 22.5°-rotated dihedral (Shh=Shv=Svv=1, Svh=-1)

They need to be light-weight in order for us to deploy them easily, while they need to be large to provide enough radar cross-sections. We decided the size of its reflector plate to be 1.6 m, 7 times of the PALSAR wavelength (0.236 m), for the all dihedrals. The size of the dihedrals and their radar cross-sections (RCSs) for the PALSAR are shown in Table

1. We made them of styrofoam (base) and an aluminum plate (reflector) to realize a precise and light-weight reflector. To obtain H-only (or V-only) component, we devised an array of horizontally-placed (or vertically-placed) metal strips that reflect only polarization in the same direction as the strips, with Shh=1, Svv=Shv=Svh=0 (or Svv=1, Shh=Shv=Svh=0). They are shown in Fig.1.

Table 1 Size and RCS of Dihedrals

Type	Size	RCS (dBsm)
H-pol (strip)	1.6 m square (~7λ)	34.7 (HH)
V-pol (strip)		34.7 (VV)
45˙-rotated		34.7 (HV, VH)
22.5˙-rotated		31.7 (All)

3. CALIBRATION EXPERIMENT

We participated in the PALSAR calibration and validation (cal/val) activities conducted by JAXA. In the August 2006, we deployed those dihedrals as well as a 1.1m trihedral (Shh=Svv=1, Shv=Svh=0) at an open area in the Tomakomai forested field, Hokkaido, Japan, that is one of our cal/val sites[1]. Location of the calibration targets is shown in Fig.2, along with their pictures and surroundings.

The PALSAR observed them from a descending orbit at 10:14, August 19 (local time) and from an ascending orbit at 21:43, August 22 (local time), both in the polarimetric mode (23.1˚ off-nadia angle). We set azimuth and elevation angles of the reflectors carefully for the each PALSAR datatake.

Coincident to the PALSAR observations, the Pi-SAR (airborne polarimetric L-band and X-band SAR), observed those reflectors for the comparison. The Pi-SAR observation was made on August 19 for the PALSAR descending datatake (simultaneous) and on August 20 for the ascending datatake (two and half days before the PALSAR). The datatakes of the datatakes are summarized in Table 2.

Table 2 Datatakes of PALSAR and Pi-SAR

Datatake	Descending	Ascending
PALSAR observation	10:14 (JST) 19-Aug-2006	21:43 (JST) 22-Aug-2006
Pi-SAR observation	10:24 (JST) 19-Aug-2006	11:31 (JST) 20-Aug-2006
Direction of Target	Az.:103.9˚ El.: 65.35˚	Az.:256.1˚ El.: 64.85˚
Location of Target	Tomakomai, Japan N 42˚43'45" E141˚32'10" (WGS-84)	

4. RESULTS

As for the ascending datatake, a color composite image of Pi-SAR L-band HH (red), VH (green), VV (blue) polarization channels is shown in Fig.3. ("VH" stands for vertical-polarization transmission and horizontal-polarization reception.) All the dihedrals showed polarimetirc properties as expected. The 45˚-rotated dihedral is seen as a bright green point (composed of only VH), while the 22.5˚-rotated dihedral is seen as a bright white point (composed of all HH, VH, and VV). The H-polarization dihedral is seen as a red point (composed of only HH), and the V-polarization dihedral is seen as a blue point (composed of only VV). The trihedral is seen as a purple point, composed of HH (red) and VV (blue).

The corresponding Pi-SAR X-band image is shown in Fig.4. In the image, the H-polarization dihedral displays purple rather than red, meaning the width of metal strips is too large for the X-band not to reflect the V-pol. The V-polarization dihedral also displays purple in the same manner. The 45˚-rotated dihedral is seen as not purely green and the 22.5˚-rotated dihedral as not purely white, probably due to misalignment of the target directions that affects more severely in the shorter wavelength.

The PALSAR image of the ascending datatake is shown in Fig.5. It is color composite of HH (red), HV (green) and VV (blue) power image of Level-1.1 products (sigle-look complex), processed and supplied by JAXA. Although the spatial resolution is coarse and the signal-to-noise ratio is low compared with Pi-SAR, they show all polariztion-selective dihedrals properties as expected. In the upper area (an inset of the upper yellow rectangle), the trihedral is shown as a purple point. In the middle area, the 45˚-rotated dihedral is seen as a green point. In the bottom area, a blue, a red, and a white point (from the top to the bottom) indicates the V-polarization, H-polarization, and 22.5˚-rotated dihedral, respectively. Quantitative analysis of the data is necessary to estimate polarimetric calibration factors of PALSAR, and they should be compared to those estimated by JAXA.

5. REFERENCES

[1] M. Satake, T. Matsuoka, T. Umehara, A. Nadai, S. Uratsuka, and H. Fukuchi, "Polarimetric Calibration Experiment of ALOS PALSAR with Polarization-Selective Dihedrals," Proc. 2007 International Geoscience and Remote Sensing Symposium (IGARSS 2007), Barcelona, p1368, 2007.
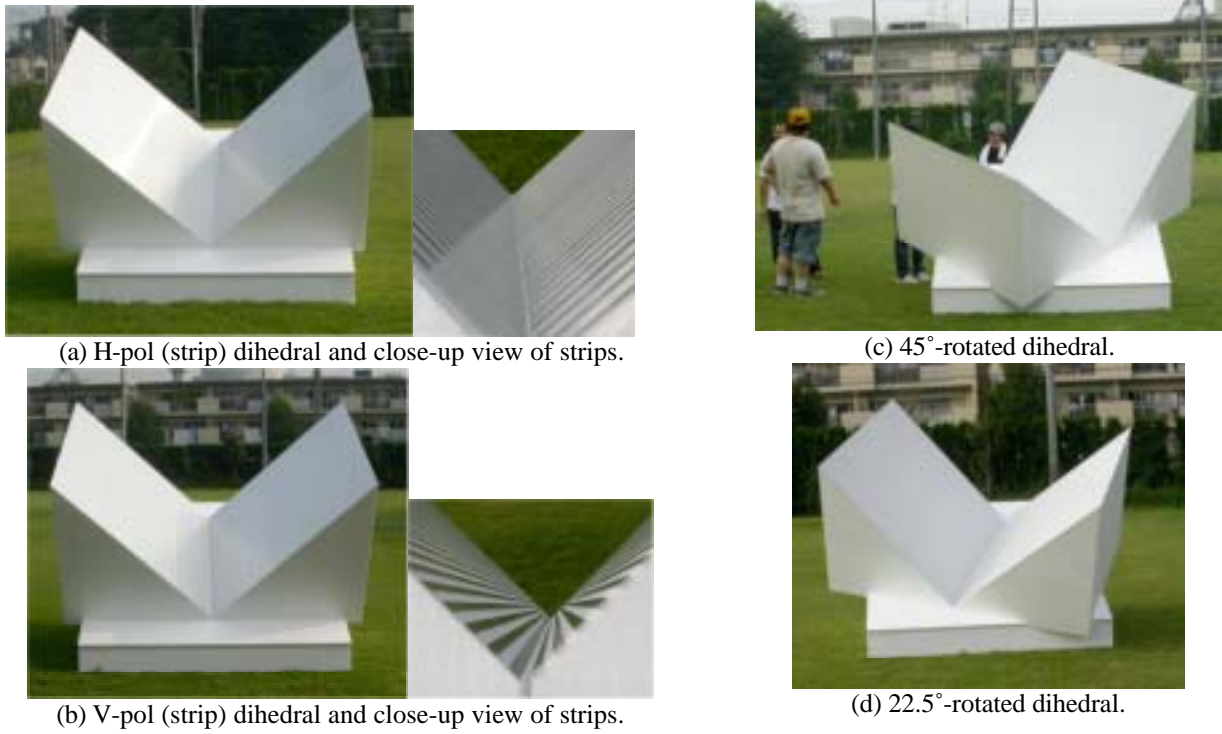
(a) H-pol (strip) dihedral and close-up view of strips.

(c) 45˚-rotated dihedral.

(b) V-pol (strip) dihedral and close-up view of strips.

(d) 22.5˚-rotated dihedral.

Fig. 1 Polarization-selective dihedrals developed for PALSAR.

Fig. 2 Location of calibration targets in the Tomakomai forested field.

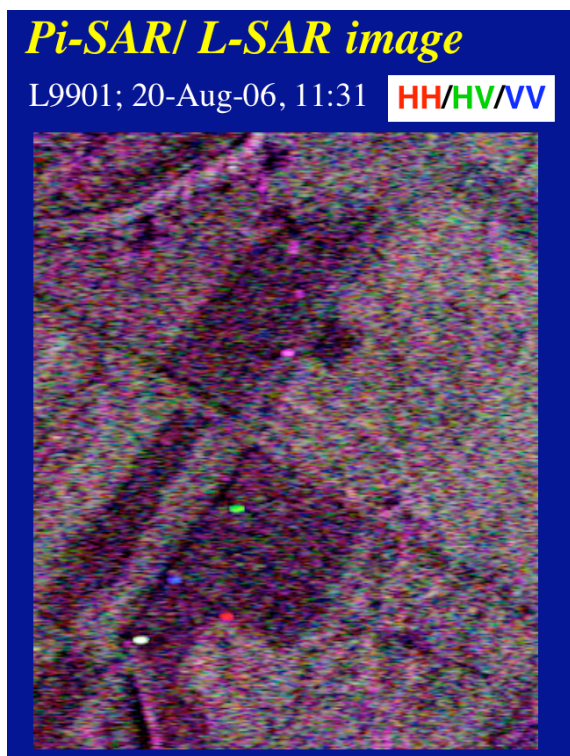**Pi-SAR/ L-SAR image**

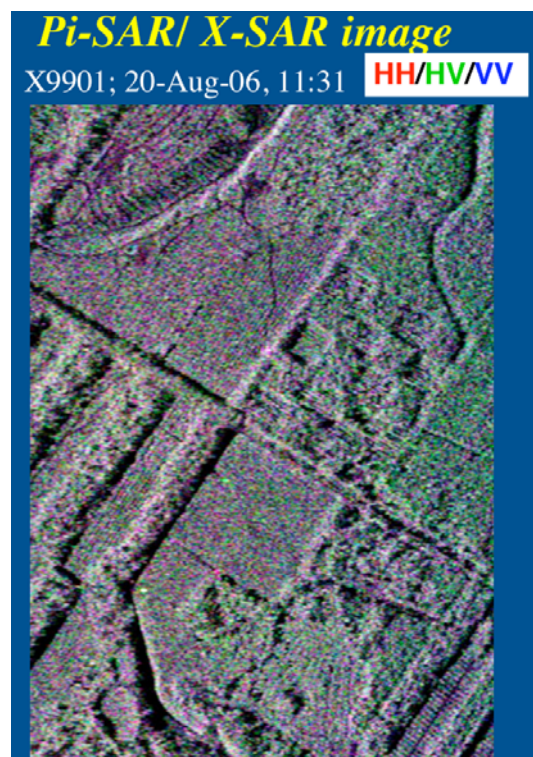L9901; 20-Aug-06, 11:31   HH/HV/VV

Fig. 3 Pi-SAR L-SAR image of calibration targets.

Pi-SAR/ X-SAR image

X9901; 20-Aug-06, 11:31   HH/HV/VV

Fig. 4 Same as Fig.3 but for Pi-SAR X-SAR.

PALSAR images in slant-range
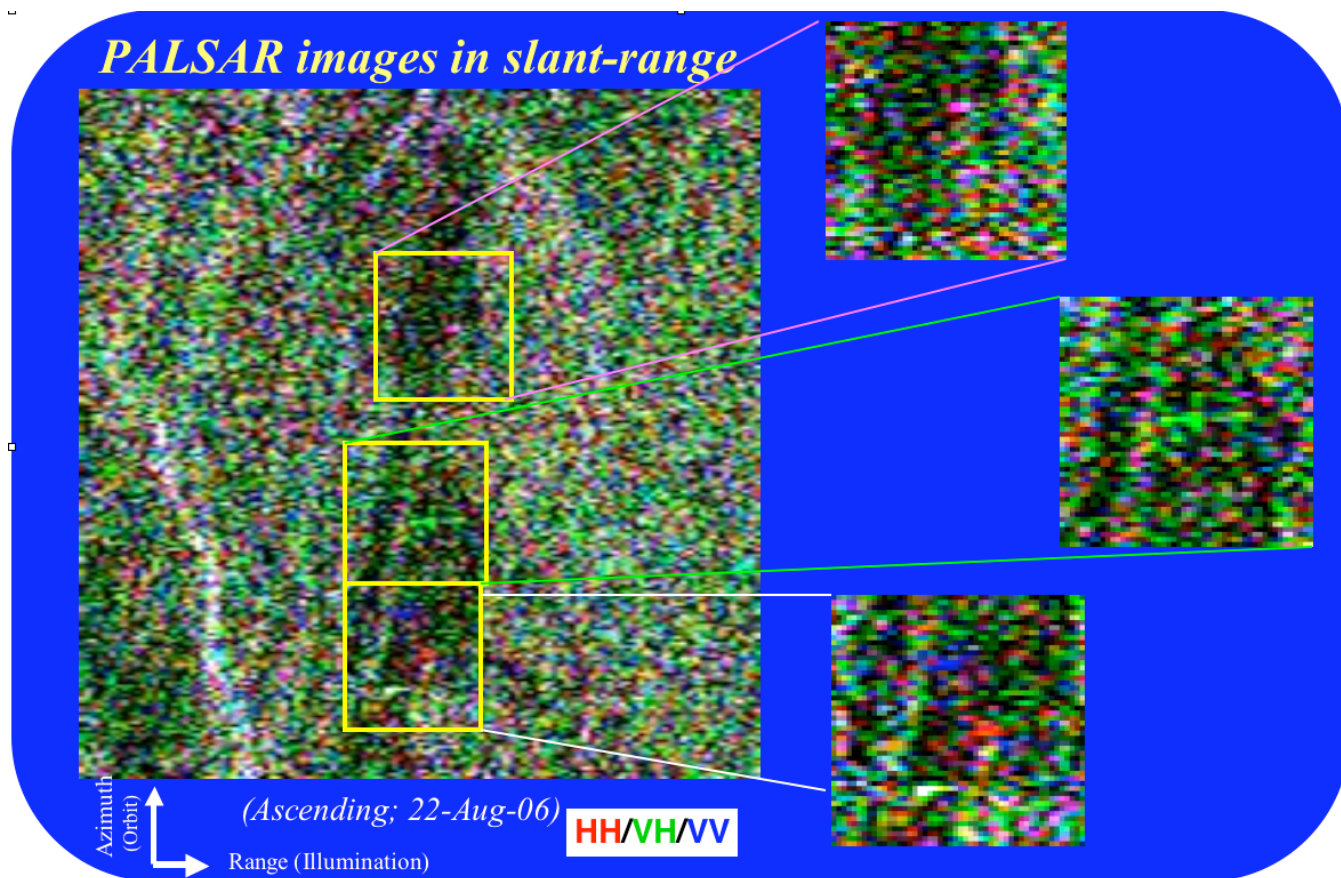
Azimuth (Orbit)

(Ascending; 22-Aug-06)   HH/VH/VV

Range (Illumination)

Fig. 5 PALSAR image of calibration target.