ALOS PALSAR Products Verification

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Abstract— **ALOS, an enhanced successor of the Japanese Earth Resources Satellite 1 (JERS-1), was launched from JAXA's Tanegashima Space Center in January 2006. An important contribution to the ALOS mission is the verification of PALSAR products to be distributed by the European ADEN node using the PALSAR processor developed by JAXA. A total of 28 ALOS PALSAR products have been analysed with respect to radiometric, geometric and polarimetric quality (including effects of Faraday rotation caused by the ionosphere) and a summary of the results is shown in this paper.**

ALOS PALSAR, product quality assessment, radiometry, geometry, polarimetry, Faraday rotation.

I. Introduction

ALOS, an enhanced successor of the Japanese Earth Resources Satellite 1 (JERS-1), was launched from JAXA's Tanegashima Space Center in January 2006. ALOS operates from a sun-synchronous orbit at 691 km, with a 46-day recurrence cycle carrying a payload of three remote sensing instruments: the Panchromatic Remote Sensing Instrument for Stereo Mapping (PRISM), the Advanced Visible and Near-Infrared Radiometer type 2 (AVNIR-2) and the polarimetric Phased Array L-band Synthetic Aperture Radar (PALSAR). The PALSAR sensor has the capacity to operate with a wide range of off-nadir angles and resolutions in a single-, dual-, and quad-pol mode.

As part of the ALOS calibration & validation activities, ESA has undertaken some activities to assess the quality of PALSAR data and in particular, the verification of PALSAR products to be distributed by the European ADEN node using the PALSAR processor developed by JAXA. Under contract to ESA/ESRIN, the Microwaves and Radar Institute at the German Aerospace Center (DLR) Oberpfaffenhofen and its partners BAE Systems Advanced Technology Centre and CREASO GmbH developed a quality assessment tool (CALIX) for the verification of standard ALOS PALSAR products and also provided support for the verification of ALOS PALSAR data quality. In addition, a set of corner reflectors and transponders have been deployed at the DLR test site in Oberpfaffenhofen throughout the whole commissioning phase to allow an accurate measurement of the basic product quality parameters. The quality assessment features of the CALIX software include a product reader, antenna pattern estimation, point target analysis, distributed target analysis, geometric analysis and polarimetric analysis. Results obtained with CALIX on a set of products acquired over the DLR test site will be presented in this paper. Hereby we will concentrate on radiometric, geometric and polarimetric data quality. Since PALSAR is the first fully polarimetric spaceborne L-band sensor, propagation effects are important new issues to be addressed. The main challenge is to assess the influence of the ionosphere on the polarisation. Two different approaches for estimating the Faraday rotation angle have been applied and the results are here compared.

II. Product Header Analysis

Analysis has been performed on the PALSAR product headers with the following observations: (i) the slant range complex Level 1.1 product header does not include image corner lat/long values and platform heading and (ii) for Level 1.1 products, the near, mid and far swath incidence angles are not consistent with each other (this is not the case for the corresponding ground range detected Level 1.5 products). Both issues are known to JAXA and will be solved in a future release of the JAXA processor.

III. Image Quality Assessment

The image quality of PALSAR products has been assessed via the impulse response function (IRF) produced by the six DLR corner reflectors deployed at the DLR test site. IRF parameters such as the spatial resolution and sidelobe ratios have been derived. Fig. 1 shows the IRF for the DLR corner reflector at Gilching from a single polarisation product (after resampling the data by a factor of 8).

Table I gives the average azimuth and range spatial resolution, integrated sidelobe ratio (ISLR), peak sidelobe ratio (PSLR) and spurious sidelobe ratio (SSLR) for 6 Level 1.5 PALSAR products. The three product types are single polarisation, FBS, dual polarisation, FBD, and quad polarisation, PLR. The first PLR measurement is for HH polarisation and the second for VV polarisation. The measured spatial resolutions for the FBS and FBD products are slightly larger than their theoretical values while they are comparable for the PLR products. The spatial resolution measurements indicate that these products are undersampled in both azimuth and range (except for PLR products in range). For data to be adequately sampled in Level 1.5 products the pixel size should be half the spatial resolution (the FBS pixel size is 6.25m while the FBD and PLR pixel size is 12.5m). The ISLR is reasonable for the FBS and FBD product type but is higher for the PLR products. The PSLR and SSLR values are reasonable. Note that all the DLR corner reflectors are saturated which, along with the undersampling, contributes to the properties of Level 1.5 IRFs.

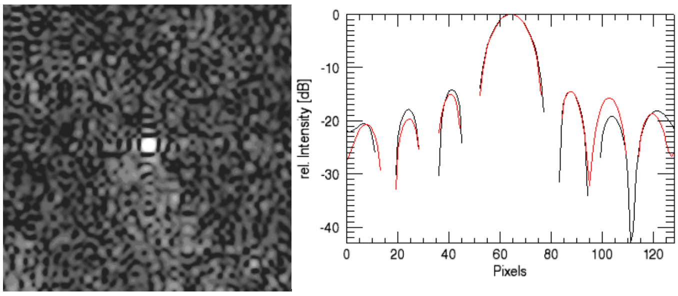

Figure 1. Resampled image and IRF slices in range (black line) and azimuth (red line) from PALSAR Level 1.5 product ALPSRP028420950, FBS, 20060806, 21:39:59.7.

TABLE I. PALSAR LEVEL 1.5 IRF PARAMETERS

Acq Date	Prod Type	Azi Res (m)	Range Res (m)	ISLR (m)	PSLR (m)	SSLR (m)
06/08/06	FBS	8.77	9.88	-4.9	-8.6	-13.0
01/08/06	FBS	8.93	10.66	-3.0	-7.8	-13.5
14/07/06	FBD	16.54	16.15	-7.5	-8.6	-12.3
23/05/06	FBD	18.00	18.52	-7.6	-10.7	-12.6
06/09/06	PLR	16.67	22.34	-1.1	-6.0	-12.7
06/09/06	PLR	16.50	26.44	-1.2	-8.4	-12.7
15/11/06	PLR	18.00	27.34	-0.1	-7.7	-10.0
15/11/06	PLR	17.10	26.69	0.9	-7.5	-10.6

Table II gives the IRF measurements for 6 Level 1.1 products. For this product type all the DLR corner reflector IRFs are not saturated and the data is adequately sampled. The spatial resolution measurements are comparable with their theoretical values and the sidelobe ratios are lower than the corresponding Level 1.5 measurements.

IV. RADIOMETRIC QUALITY ASSESSMENT

The relative radiometric calibration between Level 1.5 and Level 1.1 products has been assessed by comparing the radar cross-section of the whole scene and selected distributed targets. For the same set of products as in Table 1 the global rcs of corresponding Level 1.1 and 1.5 products give rcs differences of less than 1dB while for a user selected distributed targets of Lake Starnberg and a wood near DLR of less than 0.3dB.

TABLE II. PALSAR LEVEL 1.1 IRF PARAMETERS

Acq Date	Prod Type	Azi Res (m)	Range Res (m)	ISLR (m)	PSLR (m)	SSLR (m)
06/08/06	FBS	4.74	4.78	-6.3	-12.5	-19.7
01/08/06	FBS	4.52	4.71	-7.0	-11.9	-21.7
14/07/06	FBD	4.49	9.59	-7.5	-13.5	-21.2
23/05/06	FBD	4.45	9.61	-8.2	-13.6	-21.5
06/09/06	PLR	4.48	9.63	-5.2	-12.7	-17.2
06/09/06	PLR	4.44	9.85	-5.3	-14.0	-14.7
15/11/06	PLR	4.58	9.77	-5.4	-11.6	-16.7
15/11/06	PLR	4.66	9.78	-5.7	-11.2	-17.4

V. GEOMETRIC QUALITY ASSESSMENT

The geometric quality of PALSAR products has been assessed by two approaches: image corner interpolation and orbit interpolation. For the image corner interpolation method the latitude and longitude of the four corners are used together with knowledge of the reference ellipsoid used in the processing to enable the conversion of pixel coordinates to lat/long and visa versa to be performed. For the orbit interpolation method, the range-Doppler equation is used to derive the time of closest approach between a point on the ground and the satellite (this requires interpolation of the orbit state vectors). Once the range and azimuth time of closest approach is determined, the conversion to pixel coordinate can be performed. The transformation from pixel coordinates to latitude and longitude can also be performed using this method.

Although the ALOS platform operates with yaw steering it does not acquire data with a zero Doppler. This is because the ALOS yaw axis is aligned with the centre of the earth rather than being aligned to maintain local orthogonality. A consequence of this type of yaw steering is that the Doppler frequency is not set to zero and changes as a function of latitude and beam number [1]. The ground range Level 1.5 products are processed to zero-Doppler but the slant range Level 1.1 products are not. Consequently the geometric measurements of Level 1.1 products need to account for the azimuth shift introduced by the data not being processed to zero Doppler.

The six DLR corner reflectors deployed at the DLR test site have been used to determine the absolute localisation error (ALE) of PALSAR products (the difference between the predicted and measured pixel position of an image feature). Table III gives the average ALE from the DLR corner reflectors for Level 1.5 products using the image corner interpolation method. The table shows that the range ALE differs between products and is up to 100m in one case. In azimuth there is less difference in the ALE at less than 20m.

The ALE for Level 1.1 products using the orbit interpolation method is shown in Table IV. Here the range

ALE is small at less than 6m while the azimuth ALE is still less than 20m in all but one of the products.

Note that in all cases the ALE is similar for each of the six corner reflectors. Also the terrain height of the corner reflectors has been taken into account for both image corner and orbit interpolation methods.

TABLE III. PALSAR LEVEL 1.5 ABSOLUTE LOCALISATION ERROR

Acq Date	Acq Time	Product Type	Range ALE (m)	Azimuth ALE (m)
06/08/06	21:40	FBS	30.08	-6.72
01/08/06	21:33	FBS	-0.87	-7.12
14/07/06	09:43	FBD	-103.79	6.32
23/05/06	21:41	FBD	48.57	-2.86
06/09/06	21:21	PLR	-6.38	-19.48
15/11/06	10:05	PLR	-26.78	1.02

TABLE IV. PALSAR LEVEL 1.1 ABSOLUTE LOCALISATION ERROR

Acq Date	Acq Time	Product Type	Range ALE (m)	Azimuth ALE (m)
06/08/06	21:40	FBS	-4.87	-18.37
01/08/06	21:33	FBS	-4.38	5.90
14/07/06	09:43	FBD	-5.16	46.25
23/05/06	21:41	FBD	-1.03	-16.90
06/09/06	21:21	PLR	-4.80	6.55
15/11/06	10:05	PLR	-1.91	4.84

VI. ANTENNA PATTERN ESTIMATION

In-flight elevation antenna patterns for spaceborne SAR's can be derived using large homogenous distributed targets such as the Amazon rainforest. Standard methods of measuring antenna patterns using homogeneous distributed scatterers are described in [2] and [3]. A tool for masking non-forested areas (rivers, clear-cuts, etc.) is available for use prior to pattern estimation and derivation of the gamma profile across the image. Measured patterns can be combined to enable an average pattern to be derived.

Two quad pol ALOS PALSAR level 1.5 products acquired over the Amazon rainforest (ALPSRP032537020 - 04.09.2006 and ALPSRP039463770 - 21.10.2006) have been used to measure and combine gamma profiles for beam number 3 in all available polarisations (i.e. HH, HV, VH and VV). At far range a strong decrease in the profile can be observed, which is due to defocusing at the swath edges and included in the product to maximize the swath extend. This part of the profile thus cannot be used for pattern estimation. Since L1.5 products are already corrected using a reference antenna pattern, the derived gamma profile is a measure of the deviation from this reference pattern, i.e. it can be seen as a delta gamma. By normalising the profile and adding the result to the reference pattern, an estimation of the antenna pattern can be derived and compared to the original reference pattern, which is done in Fig. 2. Note that only a part of the beam is used for the quad pol image, so that the angular range of the reference pattern is much larger. Hence the estimated pattern has to be extrapolated outside the image. In HH polarisation, a nearly perfect agreement is observed between the measured and the reference antenna patterns, with differences below 0.04

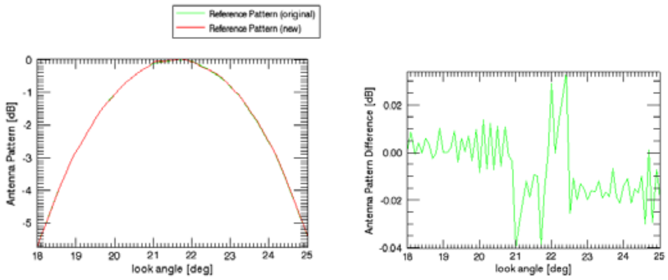

Figure 2. Left: derived (new) antenna pattern compared to original pattern for HH polarisation. Right: Difference of original and new reference pattern.

VII. POLARIMETRIC ASSESSMENT

In the experimental PLR (Quad-pol) Mode, ALOS PALSAR measures the full scattering matrix in a two-pulse mode by alternate transmitting H and V and receiving H and V, simultaneously. The underlying scattering matrix is however distorted primarily by the instrument itself (that introduces cross-talk and/or channel imbalance) and the propagation medium (at L-band it is the Ionosphere that causes Faraday rotation and phase delay distortions).

The calibration of polarimetric data delivered by JAXA has been evaluated on the basis of PLR Level 1.1 scenes (at 21.5° incidence) acquired during 4 consecutive ALOS cycles: ALPSRP022952640 / 029662640 / 036372640 / 030282640 (acquired on 30.6 / 15.8 / 30.9 and 15.11.2006 respectively). All scenes have been processed by JAXA's SAR processor and have been polarimetric calibrated using JAXA's distortion matrices [4]. Summarising the results obtained, the following points can be made with respect to the main polarimetric distortion parameters:

SNR Level: (of the cross polar channel estimated using the HV-VH correlation) is about 10 to 15dB over vegetated areas and about 0 to 5dB over bare fields. This is accordance confirming the nominal NESZ level of about -27dB.

Channel Imbalance: is in general well compensated by using JAXA's distortion matrices. The estimated amplitude imbalance is on the order of 0.2 dB while the phase imbalance is within 5°.

X-Talk level: Histograms of the estimated (over distributed scatterers) X-talks on transmit (top) and receive (middle) for the four data sets are shown in Fig. 4. For the first two data takes the X-talk level is about -25dB and increases in the last two acquisitions to -20 and -22 dB as consequence of an increased ionospheric distortion.

Faraday Rotation: The histograms of the (one way) estimated Faraday angles Ω estimated for the four data sets are shown at the bottom of Fig. 3. As expected, Ω is rather low and may vary from data set to data set. It is low in the first and almost negligible in the second data take. In the third and fourth data takes the estimated one way Faraday rotation increases up to 3.5 degrees, which explains the higher X-talk levels detected.

VIII. CONCLUSIONS

Analysis of the PALSAR product header has shown some issues relating to image corner lat/long values and incidence angles. Image quality assessment has been performed using the six DLR corner reflectors. This has shown that the spatial resolutions are comparable with the theoretical values and that the sidelobe ratios are lower for the complex Level 1.1 products. A relative radiometric quality assessment between Level 1.5 and 1.1 products has shown that they are consistent to less than 0.3dB. Geometric quality assessment has shown that the ALE for Level 1.1 product is less than 10m in range and generally less than 20m in azimuth.

The polarimetric quality of the data has been found within the JAXA specifications and suitable for a wide range of conventional applications. However, for applications that require a lower X-talk level, improvements in X-talk calibration can be achieved by using alternative calibration matrices.

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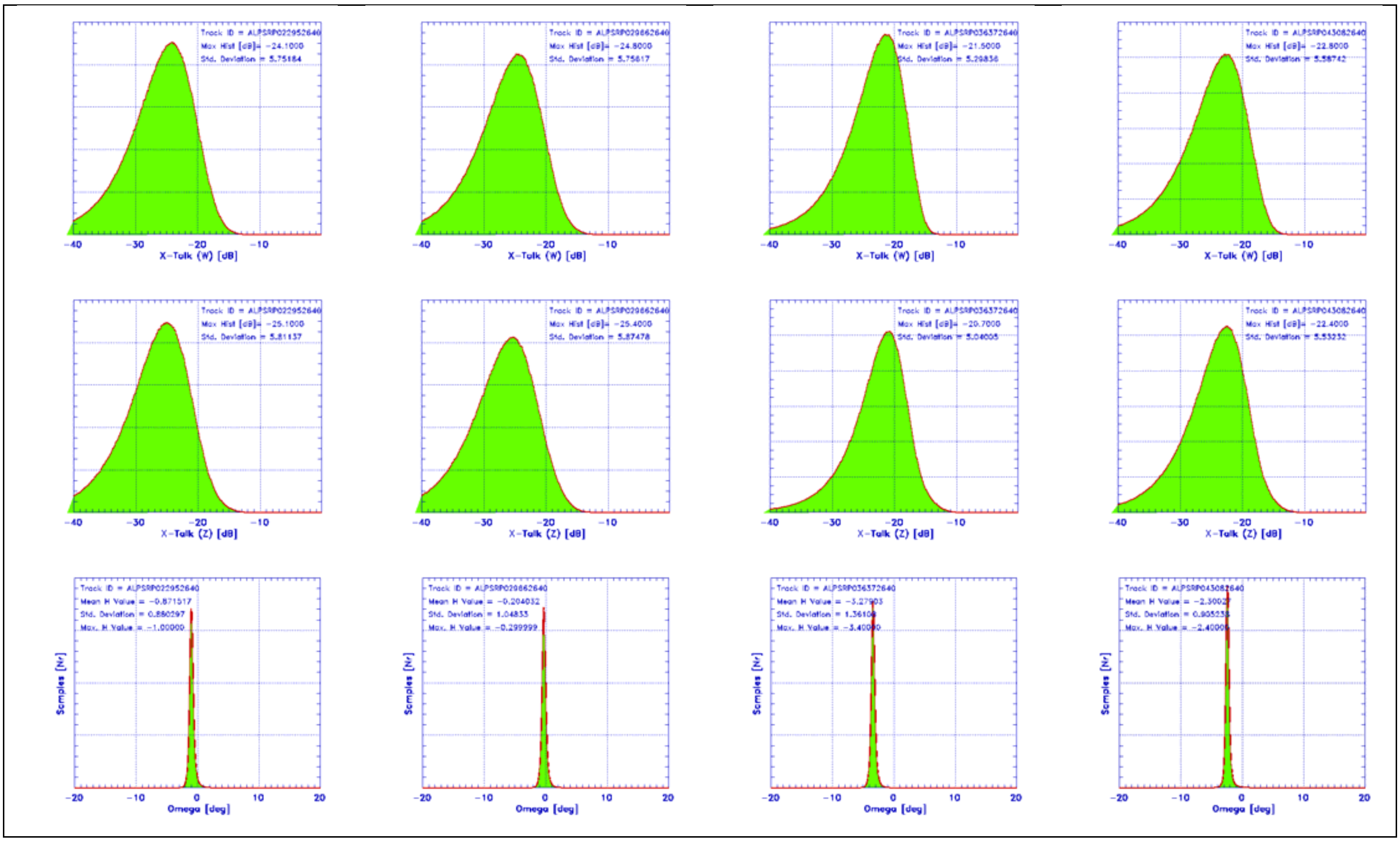

Figure 3. Estimated polarimetric distortion parameters: X-Talk levels on receive (top) and on transmit (middle). Faraday rotation (bottom).