

ASAR instrument performance and product quality evolution

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Abstract— ENVISAT ASAR is successfully operating since March 2002 and resulting ASAR products are operationally distributed to the user community since December 2002.

This paper provides an update of the ASAR performance, from the instrument status to the product quality assessment.

Keywords— *ASAR, Transmit/Receive antenna modules, calibration, ScanSAR, burst synchronisation.*

I. ASAR INSTRUMENT STATUS

Routine monitoring of the 320 antenna T/R modules is daily performed using Module Stepping Mode (MSM). In MSM, the instrument samples all 320 Transmit/Receive Modules (TRM) in less than one second for gain and phase.

Several failures in the antenna sub-assembly, due to different reasons but resulting in any case in a certain number of TRMs not operating, have been experienced since launch. The first failure in April 2002, was the loss of the power averaging module of Power Supply Unit (PSU)-1 in Tile C1. As a result, the four modules sharing the affected PSU are failed in transmit (both H & V) but still fully operational in receive. The second one in February 2003, with the complete loss of PSU-1 in Tile D2, resulting in the 4 T/R modules of this PSU being failed both in Tx and Rx, and in H & V polarisation. Later on, six individual T/R modules failures have been experienced (April 2004, May 2004, November 2004, January 2005, November 2005 and January 2007), three of them in H polarisation and three of them in V polarisation. Finally, the four modules sharing PSU-1 in Tile B3 have also been lost in February 2007. Fig. 1 shows the current status of the antenna, in H and V polarisation.

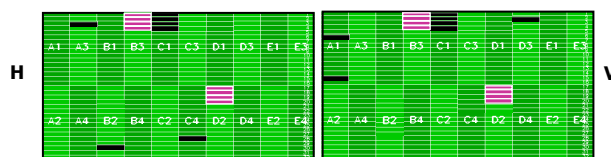


Figure 1. ASAR antenna modules failures in H (left) and V (right) polarisations. Modules highlighted in black have been lost in Tx only while modules in pink have been lost both in Tx and in Rx.

In total, there are 15 TRMs failed for Tx-H, 15 for Tx-V and 8 for Rx H and V. Up to 6% of failures (i.e. 19 modules) in a given mode (e.g. Tx H) are allowed by design before there is an impact on the instrument performance. Although the failures experienced up to now have not significantly degraded the instrument performance, changes in the antenna radiation have been experienced and corrected on ground, resulting in new auxiliary calibration files.

The antenna TRMs may not only fail but their gain and phase settings may also drift in time. A major gain & phase correction activity was performed in September 2005, as described in more detail in [1].

II. ASAR OPERATIONS

ASAR is providing nominally data quality in all modes after 5 years of operations.

Nevertheless, an increase of the number of particular ASAR instrument anomalies while operating in Alternating Polarisation (AP) Mode has been observed [1] and the reasons for this “AP related anomalies” are being deeply investigated. It is known however that the risk of having these anomalies is ANX dependent and also varies from beam to beam.

Two temporary measures to limit these anomalies have been implemented until the investigation is completed:

- 1) Reduce the overall AP mode usage, by reducing the AP background mission planning in AP mode and by changing some AP into IM after user consultation. This reduction has been progressively implemented since early 2007.
- 2) Suspend temporarily AP IS5 acquisitions (beam with highest probability of instrument anomalies). This has been implemented since end 2006

In addition, the preliminary results of the investigation point to an insufficient synchronization frequency in AP mode, which could be increased by modifying the mode timeline. A test campaign to acquire AP mode data with a reduced number of pulses per burst was performed at the end of February 2007. See [2] for details on the campaign dates and settings.

Additional tests with AP mode are envisaged in the future to confirm the hypothesis derived from the anomaly investigation. Any change in the nominal AP mode characteristics to support the investigation will be announced by EOHELP to AP mode users and it will also be published on line at the ESA EO news.

Operations in all other modes are fully nominal.

III. EXTERNAL CALIBRATION

Calibration of ASAR products and monitoring of ASAR product quality is performed based on data acquired over various calibration sites, namely:

- the four ASAR precision transponders
- the 4 RADARSAT transponders, deployed in Canada and used for ASAR performance monitoring under agreement with the Canadian Space Agency (CSA) and with the support from CCRS until 2006
- ASAR receiving ground stations
- the Amazon Rain Forest area
- corner reflectors deployed for specific calibration campaigns

Data acquired over the transponders is used for product quality monitoring and radiometric calibration. Data acquired over the ground stations is used primarily for monitoring the radiometric stability. Data acquired over the Amazon rain forest is used mostly for elevation antenna pattern monitoring and data acquired over the corner reflectors has been used till now for geometric product calibration. [3]

The 4 ASAR transponders where initially deployed in The Netherlands. Calibration acquisitions over the transponders shall be performed routinely and they shall cover all modes, beams and polarisations. Since the end of the Commissioning

Phase (Dec. 2002), the number of conflicts with user requests over the area was increasing and it was therefore decided to redeploy the ASAR transponders. In selecting the new sites, the following criteria were considered:

- more than one new location should be chosen and they should be at different latitudes to verify the instrument around orbit calibration;
- at least one location should be at very high (or low) latitude to ensure a very high revisit time;
- at least one transponder should be close to one of the RADARSAT transponders used for ASAR calibration;

As a result, 1 ASAR transponder has been left at the initial location in The Netherlands (Edam), 2 ASAR transponders have been redeployed in Canada (1 close to the RADARSAT transponder in Resolute Bay (very high latitude and very large number of potential passes per cycle) and one close to the RADARSAT transponder in Ottawa) and 1 ASAR transponder has been moved to Indonesia (Kalimantan), close to the Equator. Complete details about the redeployment activities and new locations are provided in [4].

A. Radiometric calibration

A significant recalibration activity has been possible after the redeployment of the ASAR transponders using the increasing number of calibration measured in all modes, beams and polarizations. Most recent results for the radiometric accuracy and the radiometric stability, based on measures over the ASAR transponders, are provided in Table 1 (all polarizations included).

TABLE I. RADIOMETRIC CALIBRATION ACCURACY & STABILITY

Product Type	Relative Radar Cross Section (RelRCS) [dB]						
	All swaths (bias±stdev)	IS1	IS2	IS3	IS4	IS5	IS6
IMP	-0.05±0.42	-0.01	-0.08	-0.02	-0.04	-0.01	-0.05
IMG	-0.01±0.43	-0.04	-0.11	-0.04	-0.05	0.24	0.04
IMS	0.00±0.42	-0.02	-0.02	-0.09	0	0.02	0.03
IMM	0.04±0.95						
APP	-0.06±0.39	-0.28	-0.22	-0.07	0.03	-0.01	0.01
APG	-0.04±0.47	-0.3	-0.31	-0.03	-0.06	-0.02	0.22
APS	-0.06±0.53	-0.1	-0.4	-0.01	-0.25	-0.06	0.17
APM	-0.06±0.98						
WSM	0.45±1.26						

Results for IMP and APP products for different polarisations (all swaths included) are provided in Table 2.

TABLE II. IMP & APP RADIOMETRIC CALIBRATION ACCURACY

Product Type	Mean Relative RCS [dB]			
	VV	HH	VH	HV
IMP	-0.03	-0.1		
APP	0.08	-0.04	-0.1	-0.07

B. Elevation antenna pattern monitoring

Evolution of the antenna radiation pattern shall be regularly monitored, particularly in the case of an active phase array antenna.

Accuracy of synthesized ASAR elevation antenna patterns (up to 0.5 dB) is lower than required (about 0.2 dB) due to the

limited accuracy of instrument characterization data. Azimuth pattern can be more accurately estimated using synthesis (also more stable in time).

Therefore, monitoring of the ASAR elevation antenna pattern is based on data routinely acquired over the Amazon Rain forest [1], using mostly Wide Swath, Image precision (IMP) and Alternating Polarisation precision (APP) products.

The use of Wide Swath mode products is particularly important since it offers the possibility to monitor 5 beams simultaneously (SS1, IS3-SS2, IS4-SS3, IS5-SS4, IS6-SS5). However, since no measurement is performed on the overlapping areas between neighboring beams, WSM products are combined together with Image and AP products in order to measure the pattern over the maximum possible range extend. See [2] for detailed information on the updates performed on each ASAR antenna beam and polarization.

Updated information is maintained on line at: http://earth.esa.int/pcs/envisat/asar/public_reports/. The elevation antenna patterns are provided in the ASAR External Calibration auxiliary file (ASA_XCA_AX), which is updated every time a new update is performed. These auxiliary files are provided on line at: http://earth.esa.int/services/auxiliary_data/asar/

IV. ASAR PRODUCTS QUALITY

Product quality analysis is mainly based on data acquired over the ASAR and RADARSAT transponders and it shows a nominal quality in all modes.

The measured Impulse Response Function (IRF) parameters (mean & standard deviation) are provided in Table 4.

TABLE III. MEASURED IRF PARAMETERS

Product type	Az. Resolution [m]	Range resolution [m]	ISLR [dB]	PSLR [dB]
IMP	22.13±0.49	rg-variant	-13.43±0.57	-16.67±0.98
IMG	22.35±0.45	21.8-35.4	-13.52±0.56	-16.83±1.00
IMS	4.76±0.04	9.44±0.05	-14.47±0.28	-19.19±0.52
IMM	146.87±3.34	rg-variant	-7.01±4.5	-15.52±3.42
APP	27.62±0.82	rg-variant	-12.85±0.47	-19.13±1.02
APG	27.72±0.86	23-35.4	-12.87±0.49	-19.20±1.00
APS	4.38±1.88	8.40±0.07	4.04±2.53	-1.87±1.41
APM	145.03±2.86	rg-variant	-8.29±5.13	-15.39±3.43
WSM	107.24±2.26	rg-variant	-9.06±3.92	-18.83±1.27

It should be noted that results for AP single look complex (APS) products are very different from the IM single look complex products (IMS), which is a consequence of the processing strategy adopted for APS products.

The range resolution for ground range product varies with the incidence angle. The measured ground range resolution for IM high resolution multi-look detected products (IMP), as

compared with the theoretical resolution is provided in Fig 3. An excellent agreement is observed, with results well below the requirement of 30 m at mid range.

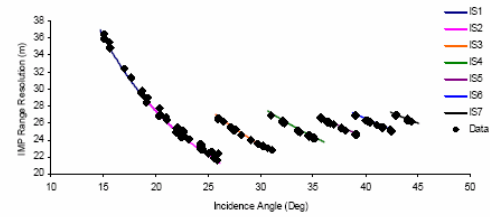


Figure 3. Measured (dots) ground range resolution for IMP (top) products and comparison with theoretical values (lines).

As part of the routine analysis of ASAR products, additional quality parameters are monitored, such as the radiometric resolution and noise equivalent sigma nought.

Table 7 shows the measured radiometric resolution and effective number of looks (ENL) for IMP, IMG, IMS and APS products, for which the radiometric resolution is basically constant for all beams. Table 8 shows the measured radiometric resolution and ENL for IMP, APM, APP and APG products, for which the radiometric quality varies slightly from beam to beam.

TABLE IV. MEASURED RADIOMETRIC RESOLUTION AND ENL FOR IMP, IMG, IMS AND APS PRODUCTS.

	ENL	Rad. Res [dB]
IMP/IMG Products	3.95	1.77
IMS Products	0.96	3.05
APS Products	0.93	3.09

TABLE V. MEASURED RADIOMETRIC RESOLUTION AND ENL FOR IMM, APM, APP, APG PRODUCTS.

	IS1	IS2	IS3	IS4	IS5	IS6	IS7
APM Products							
ENL	44.0	52.5	65.7	75.7	83.2	90.2	95.9
Rad. Res [dB]	0.6	0.6	0.5	0.5	0.5	0.4	0.4
IMM Products							
ENL	35.7	42.2	52.6	60.8	65.8	72.7	75.8
Rad. Res [dB]	0.7	0.6	0.6	0.5	0.5	0.5	0.5
APP/APG Products							
ENL	1.8	1.7	2.3	2.7	3.3	3.8	3.7
Rad. Res [dB]	2.4	2.5	2.2	2.1	1.9	1.8	1.8

The measures noise equivalent sigma nought (NES0) for APP products as a function of the incidence angle for HV and VH polarizations is provided in Fig. 5 as compared with the expected values.

VI. SCANSAR BURST SYNCHRONISATION

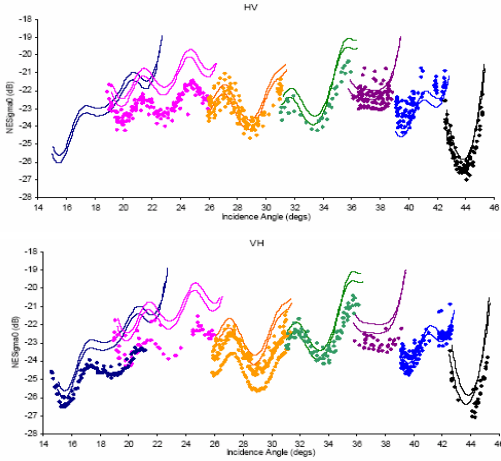


Figure 4. Measured NES0 for APP HV and VH products (dots) and expected values (solid lines).

V. RECENT PRODUCT QUALITY IMPROVEMENTS

A. Doppler Grid availability

The Doppler Grid ADS provides a grid of fine Doppler Centroid estimates within the product, tagged with the zero Doppler azimuth time and slant range time of the set of data used to perform each Doppler estimate [2].

The Doppler Grid ADS was originally introduced in the new ASAR WS Single Look Complex Products (ASA_WSS) to support the estimate of ocean surface currents.

However, WSS products are only available on request while support to ocean applications requires data is systematically generated and made systematically available.

Therefore, WSM products have been updated (no format changes) to include as well the Doppler Grid ADS. ASAR WSM products are systematically processed and made available on line in NRT. This allows the access to the Doppler Grid information systematically in NRT since 11 April 2007.

B. ASAR Wave Mode reprocessing

In order to have an homogeneous and quality optimised archive of ASAR WV mode L1/L2 products, the ASAR wave mode WVS and WVW products from December 2002 till early 2007 have been reprocessed with an optimised algorithm [2]. Details on the quality improvements of the reprocessed data can be found in [5].

Although ASAR Wide Swath mode was not designed to keep burst synchronisation between different acquisitions, the percentage of co-operative pairs was found to be higher than expected [6] (up to 80% compared with the expected 20%-30% in case of random synchronisation), which is a result of the planning strategy, the accurate ASAR timing and the precise orbit maintenance.

The analysis of the different factors contributing to the higher than expected burst synchronisation has indicated that this could be optimised with small changes in the planning strategy. Those changes are operational since 17 September 2007. Excellent results have been achieved with those changes. The probability of having 50% burst synchronisation between two interferometric images has increased from 50% to 90% and the probability of having 70% of burst synchronisation has increased from 40% to 75 %. More details can be found in [6].

VII. CONCLUSIONS

ASAR instrument stability continues after five years of operation. Few antenna TRMs experienced but performance remains still within the requirements.

Product quality and performance have been optimised and improved beyond the original requirements, with new information included to support new applications (e.g. Doppler grid) and optimised burst-synchronisation probability for ScanSAR interferometry.

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