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QUALITY MEASUREMENTS DEFINITION FOR ASAR LEVEL 1 PRODUCTS

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ESRIN
Via Galileo Galilei - Casella Postale 64 - 00044 Frascati (Rome)- Italy
Tel. (39) 06 941801 - Fax (39) 06 94180 280

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1. INTRODUCTION

The activities to verify and calibrate ASAR products during the ENVISAT Commissioning Phase (C.P.) will be carried out by the ASAR CAL/VAL team members at different centres and in some cases, using different product analysis tools. It is therefore important to establish the methodology for deriving all the quality parameters so that results from different team members are completely consistent.

This document describes the procedures to be followed during the C.P. for measuring the ASAR product quality parameters on Level 1 products.

2. BACKGROUND REMOVAL AND IMAGE INTERPOLATION

In order to perform IRF measurements and also calibration constant derivation, it is necessary to remove the background backscattering contribution from the image under analysis and to convert the pixel values to intensity. The following pre-processing steps shall therefore be carried out:

- extraction a sub-image of 128 by 128 pixels around the point target;
- conversion of pixel values to intensity (I_{int});
- derivation of the background intensity (I_{backg}) by summing the pixel intensities over four square areas of M=10 resolution cells, positioned around the target in such a way that they do not include samples on the range or azimuth IRF cuts or other PTs responses but mainly the clutter intensity (see fig. 1);
- subtraction of the mean background intensity (I_{backg}) from the intensity image (I_{int});

$$I_c = I_{int} - \frac{1}{4.M^2} I_{backg}$$

- interpolation of the intensity background corrected sub-image (I_c) by a factor of 8 (I_p).

The resulting interpolated and background corrected image I_p is used to derive the IRF and the K measurements described in sections 3 and 4.

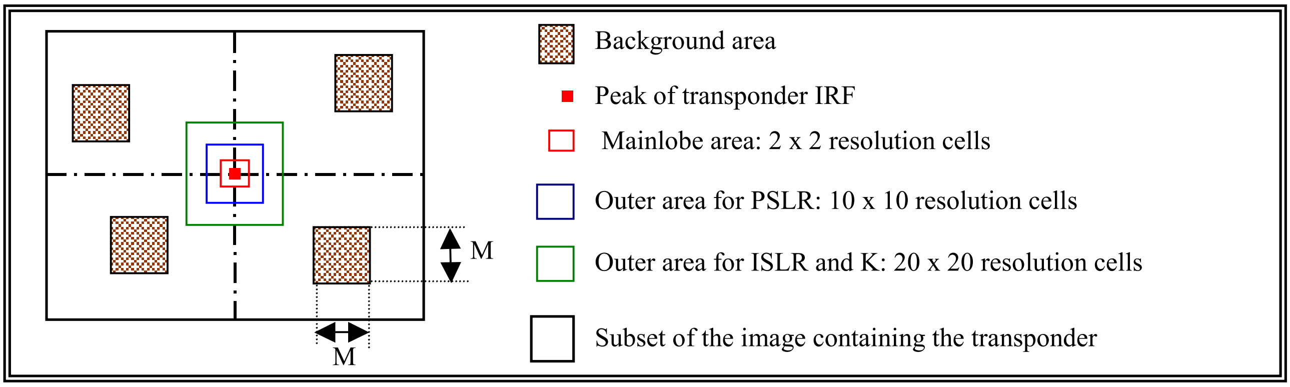

Fig.1. Derivation of the background power.

3. IMPULSE RESPONSE FUNCTION MEASUREMENTS

The following measurements are performed on the interpolated and background corrected image.

Spatial resolution in range and azimuth [m]
Distance in meters between the points to either side of the peak in a one-dimensional cross-section through the impulse response function which are 3dB below the interpolated peak power.

Peak Side Lobe ratio (PSLR) [dB]
Ratio of the intensity of the most intense peak of the IRF outside a rectangle of 2x2 resolution lengths and within a rectangle of 10x10 resolution lengths to the peak intensity in the mainlobe (i.e. within a rectangle of 2x2 resolution lengths). The PSLR in azimuth is defined as the minimum PSLR along the azimuth IRF cut and the PSLR in range as the minimum PSLR along the range IRF cut.

Spurious sidelobe ratio (SSLR) [dB]
Ratio of the intensity of the most intense value of the IRF outside a rectangle of 10x10 resolution lengths and within a rectangle of 20x20 resolution lengths, to the peak intensity in the mainlobe (2x2 resolution lengths).

Integrated Side Lobe Ratio (ISLR) [dB]
Ratio of the energy in the sidelobes (outside a rectangle 2x2 resolution lengths and within a rectangle of 20x 20 resolution lengths) to the energy in the mainlobe (2x2 resolution lengths).

Ratio of total power to peak height
This is the ratio of the energy within the IRF mainlobe (2x2 resolution lengths) to the IRF peak value.

4. CALIBRATION CONSTANT (K) DETERMINATION

The calibration constant will be derived using Level 1b products over the ASAR and RADARSAT transponders after a first verification of the accuracy of the pre-launch elevation antenna pattern.

Derivation of K for -ground range detected products
For ground range detected products, the calibration constant based on a transponder impulse response is derived on the interpolated and background corrected image as:

$$K = I_P . \frac{P_{Agr}}{\sigma_{nom}} . \sin(\alpha_i)$$

where:

I_p: background corrected integrated power of the transponder IRF. It is obtained as the sum of the pixel intensities –after background intensity correction- over a square area of 20 by 20 resolution cells centred around the peak of the transponder IRF (see figure 1).

α_i: incidence angle at transponder position

P_{Agr}: ground range pixel area

σ_{nom}: nominal transponder RCS

Derivation of K for slant-range complex products
For slant-range complex products, it is also necessary to correct for the range spreading loss and the elevation antenna pattern gain:

$$K = I_P . \frac{P_{Asr}}{\sigma_{nom}} . \frac{1}{S_f} . \left(\frac{R_p}{R_{ref}} \right)^3 . \left(\frac{1}{G^2(\theta_i)} \right)$$

where in addition to the parameters defined for ground-range products:

P_{Asr}: slant-range pixel area
R_{ref}: slant-range reference distance (unique value for all beams and modes)
R_p: slant range distance at the transponder location
θ_i: look angle at the transponder location
$G^2(.)$: two-way elevation antenna pattern
Sf: sampling factor for detection of complex data

For APS products, an additional factor (R_p/R_{ref}) shall be taken into account:

$$K = I_P . \frac{P_{Asr}}{\sigma_{nom}} . \frac{1}{S_f} . \left(\frac{R_p}{R_{ref}} \right)^4 . \left(\frac{1}{G^2(\theta_i)} \right)$$

Combination of multiple calibration constant measurements

The calibration constant factor will be derived over each visible transponder on each product acquired over the Canadian and The Netherlands calibration sites. After several independent measurements, a final value of K for each mode and polarisation shall be defined. If N_{obs} is the number of single measurements of K over each transponder and N_{trans} is the number of available transponders, then the final K value is derived as:

$$K = \frac{1}{Ntrans} . \sum_{i=1}^{Ntrans} \left(\frac{1}{N_{obs}} . \sum_{l=1}^{l=N_{obs}} K_{il} \right)$$

5. RADIOMETRIC ANALYSIS

Radiometric accuracy

It is the worst case uncertainty (3σ value) resulting from individual cross section measurements of a uniform invariant target situated anywhere within the operating dynamic range of the system or of a known point target, anywhere in the swath and anywhere in the orbit, assuming that the standard deviation of the multiple sigma nought estimates is zero.
Rain forest images of single calibrated beams and transponder measurements shall be used, acquired on the same orbit whenever possible.

Radiometric resolution and Equivalent Number of Looks (ENL)

The radiometric resolution of a Level 1 product is a measure of the ability to distinguish between uniform distributed targets with different backscattering coefficient. It is defined as the width of the probability distribution function of the signal power received from uniform distributed targets. It is measured on a uniform distributed target, large enough to ensure statistical accuracy, as:

$$Rad\,\mathrm{Re}\,s = 10 \log_{10}(1 + q_r) \qquad q_r = \frac{\sigma}{\mu}$$

Where μ , σ and q_r are respectively the mean, the standard deviation and the normalised standard deviation (or coefficient of variation) of signal power over the selected distributed target.

The equivalent number of looks over a uniform region of imagery is calculated as:

$$\mathrm{ENL} = \frac{\mu^2}{\sigma^2} = \frac{1}{{q_r}^2}$$

Radiometric stability

This is the standard deviation of the difference between predicted and measured point target radar cross-sections. A time sequence of RCS measurements over the transponders will be used to derive this parameter.

A related measurement is the Peak to Peak radar cross-section, which is the largest difference between predicted and measured point target radar cross-sections.

Noise equivalent sigma nought measured on level 1 images

It is computed as the sigma nought of mid-swath homogenous areas with very low backscattering response.

Note: The noise equivalent sigma nought will also be measured on Level 0 products using the noise samples provided at the beginning and at the end of each image sequence (for IM and AP modes) and at periodic intervals during the acquisition sequence for WSM, GMM and WV mode.

6. AMBIGUITY ANALYSIS

Azimuth ambiguity location offset [m]

It is measured on scenes with transponders or known point targets as:

$$\Delta \mathrm{AzAmb} = \frac{c R_p}{2 f_0 v_s} \mathrm{PRF}$$

Range ambiguity location offset [m]

For detected products (i.e. IMP, APP, IMM, APM, WSM and GMM) it is measured as:

$$\Delta \mathrm{RgAmb} = \mathrm{GR}\left(R_p + \frac{Mc}{2\mathrm{PRF}}\right) - \mathrm{GR}(R_p)$$

For complex products (i.e. IMS, APS), it is measured as:

$$\Delta \mathrm{RgAmb} = \left(R_p + \frac{Mc}{2\mathrm{PRF}}\right) - R_p$$

Where:

R_P = point target slant range distance

M = positive integer (1, 2…) for the far range ambiguities and negative integer (-1, 2, …) for the near range ambiguities.

c = speed of light

PRF = SAR pulse repetition frequency

GR(R)= ground range distance, computed as:

$$GR(R) = R_T.(\pi/180).\cos^{-1}\left(\frac{{R_S}^2 + {R_T}^2 - R^2}{2 R_S R_T}\right)$$

R_S = satellite radius

R_T =Earth radius

R = slant range distance

Note: The ambiguity slant range (R_P + Mc/2PRF) must be less than $\sqrt{(R_S^2 - R_T^2)}$ for the far range ambiguities and it must be greater than (R_S – R_T) for the near range ambiguities.

Ambiguity background backscattering coefficient [dB]

For detected products (i.e. IMP, APP, IMM, APM, WSM and GMM) it is defined as:

$$\sigma^o_{amb} = \frac{<A^2>}{K} \sin(\alpha_{amb})$$

where:

σ^0_{amb} = ambiguity background target radar cross-section
A = pixel digital number (amplitude)
$<A^2>$ = average pixel intensity of the ambiguity background
K = ASAR calibration constant (product type dependent)
α_{amb}= ambiguity background incidence angle

For complex slant-range projected products:

$$\sigma^o_{amb} = \frac{<A^2>}{K} \sin(\alpha_{amb}) \frac{1}{S_f^2} \frac{1}{G(\theta_{amb})^2} \frac{R^3_{amb}}{R^3_{ref}}$$

where in addition to the above:

S_f = sampling factor for detection of complex data
$G(\theta_{amb})^2$= 2-way elevation antenna pattern gain for the ambiguity background
θ_{amb} = ambiguity background target look angle
R_{amb} = ambiguity background target slant range
R_{ref} = ASAR reference slant range distance

For APS products, an additional factor (R_{amb}/R_{ref}) shall be taken into account:

$$\sigma^o_{amb} = \frac{<A^2>}{K} \sin(\alpha_{amb}) \frac{1}{S_f^2} \frac{1}{G(\theta_{amb})^2} \frac{R^4_{amb}}{R^4_{ref}}$$

Point target ambiguity ratio [dB]

It is defined as the ratio between the ambiguity total power and the point target total power.

7. GEOMETRIC ANALYSIS

Absolute location accuracy [m]

The absolute location error is specified as the distance along the ground between the measured and the predicted position of point targets within a Level 1 image. This measurement requires accurate knowledge of the 3-D location (latitude/longitude/height) of the transponder or corner reflector used for the measurement as well as precise knowledge of the internal electronic delay in the case of a transponder. Orbits with different accuracy may be used to quantify the impact of orbit accuracy on the final absolute location error.

SWST bias [sec]

The SWST is measured on Level 1b products processed using the default SWST bias and containing point targets for which the position is known very accurately. The location of the known targets on the image is determined and compared with their expected position. The mean of the systematic deviation between the measured and the expected slant range distance to the known target corresponds to the error in the SWST bias. The slant range distance error is converted into slant range time:

SWST bias error [sec] = (Slant-range distance error [m]*2)/c[m/s]

The most precise available orbit information shall be used for this measurement.

Swath width and position
The swath width shall be verified by measuring distances on the image between known ground features. The swath position is derived with the look angle at near, mid and far range and the swath width.

AP channel co-registration [pixels]
The miss-registration between the two channels of an AP product is computed as the difference in pixels of the precise location of a point target IRF peak in both image channels, both is azimuth and in range direction (or in slant range in case of APS products).

8. DERIVATION OF SIGMA AND GAMMA NOUGHT OVER DISTRIBUTED TARGETS

ASAR detected ground range projected products will be delivered as radar brightness (i.e. elevation antenna pattern and range spreading loss corrected but no incidence angle compensation) while complex slant-range products will delivered without any cross-track radiometric corrections. The derivation of sigma and gamma nought for the latest type of product shall therefore include the correction for the elevation antenna pattern and the range spreading loss.

Sigma and gamma nought for ground range projected products:

$$\sigma^0 = \frac{\langle A^2 \rangle}{K} \sin(\alpha_d) \qquad \gamma^0 = \frac{\sigma^0}{\cos(\alpha_d)}$$

where	K	=	absolute calibration constant
	$\langle A^2 \rangle$	=	average pixel intensity
	σ^0	=	distributed target sigma nought
	α_d	=	distributed target incidence angle

Sigma and gamma nought for complex slant-range projected products
For all complex slant-range projected products except for APS products, the sigma and gamma nought are computed as:

$$\sigma^0 = \frac{\langle A^2 \rangle}{K} \frac{1}{G(\theta_d)^2} \left(\frac{R_d}{R_{ref}} \right)^3 \sin(\alpha_d) \qquad \gamma^0 = \frac{\sigma^0}{\cos(\alpha_d)}$$

where	K	=	absolute calibration constant
	$\langle A^2 \rangle$	=	average pixel intensity
	σ^0	=	distributed target sigma nought
	$G(\theta_d)$	=	two-way antenna gain at the distributed target look angle
	R_d	=	distributed target slant range distance
	R_{ref}	=	reference slant range distance
	α_d	=	distributed target incidence angle

For APS products, an additional factor (R_d/R_{ref}) shall be taken into account:

$$\sigma^0 = \frac{\langle A^2 \rangle}{K} \frac{1}{G(\theta_d)^2} \left(\frac{R_d}{R_{ref}} \right)^4 \sin(\alpha_d) \qquad \gamma^0 = \frac{\sigma^0}{\cos(\alpha_d)}$$

ANNEX A SYMBOL DEFINITION

A	Pixel digital number (amplitude value)
C	Speed of light
f_0	SAR frequency
$G^2(.)$	Two-way antenna pattern gain
GR(.)	Ground range distance
I_{backg}	Mean background intensity obtained by summing the pixel intensities over four areas of 10 per 10 resolution cells, positioned around the peak of the transponder IRF.
I_c	Background corrected integrated power, obtained as the sum of the pixel intensities over an area of 20 by 20 resolution cells centred around the peak of the transponder IRF.
I_{int}	Intensity image.
I_p	Interpolated background corrected intensity image.
K	Calibration constant or absolute calibration factor
M	Positive integer (1, 2…) for the far range ambiguities and negative integer (-1, 2, …) for the near range ambiguities.
P_{Agr}	Ground range pixel area
P_{Asr}	Slant range pixel area
PRF	ASAR Pulse Repetition Frequency
q_r	Normalised standard deviation of the intensity of a distributed target including instrument noise.
R_P	Slant range to point target
R_{ref}	Reference slant-range distance
R_s	Satellite radius
R_T	Earth radius
S_f	Sampling factor for detection of complex data
V_S	Satellite velocity
αI	Incidence angle at image pixel i
γ^0	Gamma nought
μ	Mean of signal power over an scene area
θI	Look angle at image pixel i
σ	Standard deviation of signal power over an scene area
σ_{nom}	Nominal transponder radar cross-section
σ^0	Backscattering coefficient