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QUALITY MEASUREMENTS DEFINITION FOR ASAR LEVEL 1 PRODUCTS

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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 ($I_{c,int}$). IRF analysis is performed on this interpolated image as describe in section 3.
- integration of the interpolated and background corrected intensity over 20 x 20 resolution cells. The resulting background corrected integrated power I_p is used to derive the K measurements described in section 4.

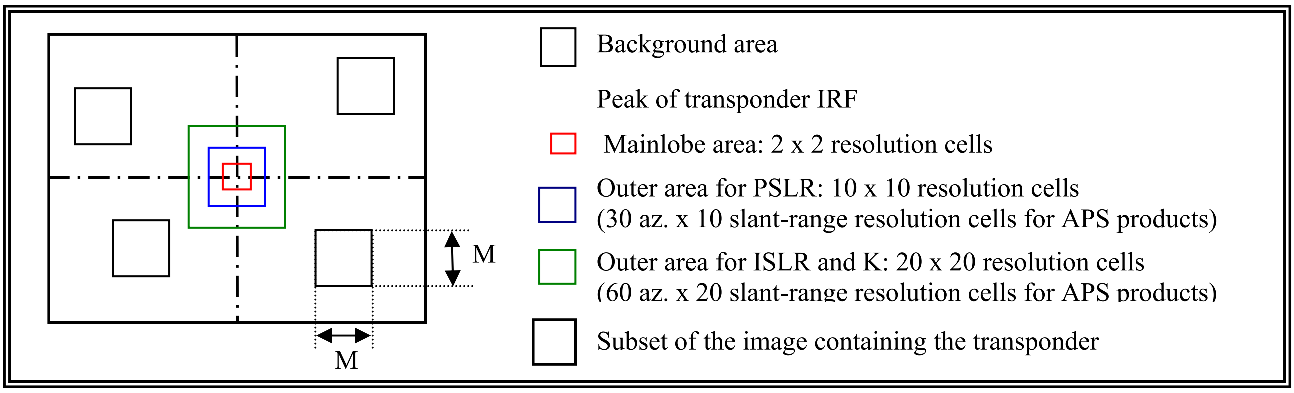


Fig.1. Definition of point target response area and background areas for IRF analysis and calibration.

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.
For APS products, the PSLR is defined as the ratio of the intensity of the most intense peak of the IRF outside a rectangle of 2x2 resolution lengths and within a rectangle of 30 resolution lengths in azimuth per 10 resolution lengths in slant range, to the peak intensity in the mainlobe (i.e. within a rectangle of 2x2 resolution lengths).

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).
For APS products, the SSLR is defined as the ratio of the intensity of the most intense value of the IRF outside a rectangle of 30x10 resolution lengths and within a rectangle of 60x20 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).
For APS products, the ISLR is obtained as the ratio of the energy in the sidelobes (outside a rectangle 2x2 resolution lengths and within a rectangle of 60 resolution lengths in azimuth x 20 resolution lengths in slant range) 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:

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

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
S_f: sampling factor for detection of complex data

Derivation of K for APS products

Due to the modulation of the APS IRF in azimuth, it is necessary to enlarge the integration area around the peak to ensure that all the target energy is gathered. Therefore, only for APS products, I_p should be obtained as the sum of the pixel intensities – after background intensity correction- over a rectangular area of 60 resolution cells in azimuth per 20 resolution cells in slant range, centred around the peak of the transponder IRF (see figure 1).

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

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

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:

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

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:

$$RadRes = 10\log_{10}(1+q_r) \qquad q_r = \frac{\sigma}{\mu}$$

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:

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

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:

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

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:

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

where:

$\sigma^0{}_{amb}$ = ambiguity background backscattering coefficient
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:

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

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:

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

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 DERIVATION OF ELEVATION ANGLE AND ANTENNA GAIN FOR ASAR PRODUCTS

Knowledge of the elevation angle associated to each image sample is required for some product quality analysis, such as the estimation of the elevation antenna pattern from a rainforest scene or the radiometric calibration of single look complex images (for which the elevation antenna pattern correction is not applied by the processor).

The elevation angle at each image sample can be derived from the SAR geometry in different ways. The methodology proposed here takes the maximum advantage of the information already available in the product. Since this information is different for products processed with and without antenna pattern correction (products without antenna pattern correction do not contain Antenna Pattern ADS), a different approach is proposed for each one of these cases.

NOTE: The information contained in this note does not apply to WSM and GM1 products and it is not precise for single swath products with large Doppler Centroid frequency. Furthermore, it is assumed that the analysis requiring use of elevation angles will be performed on products or parts of products (in case of stripline products) covering no more than 16 sec in azimuth.

1 PRODUCTS PROCESSED WITHOUT ANTENNA PATTERN CORRECTION

This method exploits information available for all product types, being therefore applicable to any product (except ScanSAR products). However, it is particularly suitable for Single Looks Complex products (IMS, APS), which are systematically processed without antenna pattern correction, and for precision images (IMP, APP) generated without antenna pattern correction for test purposes. For other products, an alternative method is proposed in Chapter 2.

1.1 REQUIRED INPUT INFORMATION

1.1.1 From Geolocation Grid LADS

NOTE: The Geolocation Grid ADS is available for all product types. The information available in this ADS is provided in the zero-Doppler geometry for 11 points across range. The information is updated several times in azimuth depending on the product type (based on defined granule size), typically every 10 Km for IM and AP.

- **Pixel number (field #6)**
  NOTE: Values are provided on a regularly spaced grid. The 1st and last pixel on the grid correspond to the 1st and last image sample in range or slant range depending on product type (including the SWST changes1). Provided pixel tie points are the same for all LADSRs and can therefore be read from any of them.

- **Slant range times (field #6).**
  NOTE: These are the slant range times for each sample number in the grid. The value of slant range times at mid-azimuth, i.e. for the LADS with time stamp closest to the image mid-azimuth time, shall be taken for the analysis and considered constant along azimuth.

- **Incidence angle (field #6)**
  NOTE: The incidence angles provided are those corresponding to the pixel numbers in the ADS. The analysis shall be performed using the incidence angles for the mid-azimuth image (same ADSR used to extract the slant range times) and considering them constant in azimuth.

[1] This means that pixel numbers in the LADSR reference the samples in the final product, including possible black pixels due to a SWST change.

1.1.2 From main Processing Parameters (MPP) ADS

- **State vectors (field #73, x,y,z position)**
  NOTE: The MPP ADSR provides 5 state vectors spanning the scene time. The position of the state vector with time stamp closest to the image mid-azimuth time shall be used for the analysis.

1.2 METHODOLOGY TO DERIVE THE ELEVATION ANGLE

1.2.1 Interpolate the inputs from the geolocation grid

The parameters read from the LADS -for the 11 range samples- shall be interpolated to obtain the corresponding values at each range (or slant range) sample in the product.
If N is total number of samples in the product a quadratic polynomial shall be fitted to the variation of slant range time and incidence angle versus sample numbers. The polynomial shall then be evaluated at every sample number from 1 to N.
Let's call 'slrt $_i$" and "α_i" the derived interpolated values of these parameters for a range sample "i", where "i" varies between 1 and N.

1.2.2 Derive the distance from the satellite to the Earth centre

The distance from satellite to the Earth centre is derived from the mid-azimuth satellite state vector positions. If "x, y, z" are the satellite positions on each axis, then the satellite distance Rsat is obtained as:

$$\mathrm{Rsat} = \sqrt{x^2 + y^2 + z^2}$$

1.2.3 Derive the slant range distance to each product sample

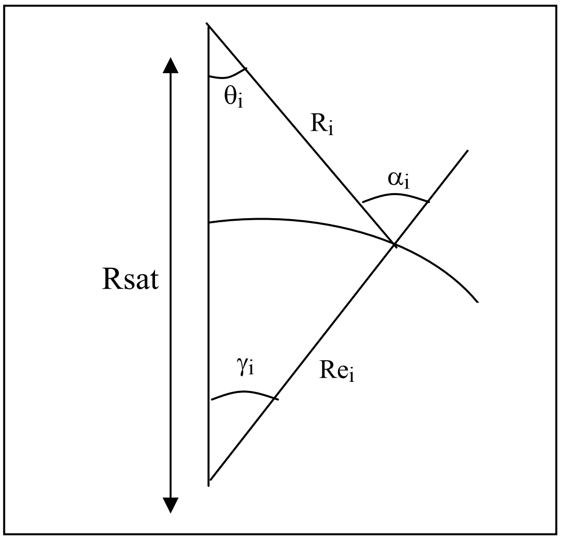
The slant range distance in zero-Doppler geometry can be obtained from the interpolated slant range time to each range sample ("slrt $_i$") as:

$$R_i = \frac{c.\mathrm{slrt}_i}{2}$$

where "c" is the speed of light and "i" increases from 1 to N.

1.2.4 Derive the elevation angle for each product sample

The figure below shows the relationship between incidence angle (α_i), Earth angle (γ_i), slant range distance (Ri), satellite to Earth centre distance (Rsat) and elevation angle (θ_i).



The Earth angle (γ_i) can be derived for each range sample as:

$$\gamma_i = a\sin\left(\frac{R_i}{\mathrm{Rsat}}\sin(\alpha_i)\right)$$

and the elevation angle (θ_i) as:

$$\theta_i = \alpha_i - \gamma_i$$

where "i" increases from 1 to N.

2 PRODUCTS PROCESSED WITH ANTENNA PATTERN CORRECTION

This method applies to all standard detected ground range products (except ScanSAR products), which are processed with antenna pattern correction.

In case of stripline IM and AP products covering more than 16 sec in azimuth, the analysis shall be done on a product subset of around 16 sec. The ADSRs with time stamps closest to the mid-azimuth time of the extracted subset shall be used.

2.1 REQUIRED INPUT INFORMATION

2.1.1 From Geolocation Grid LADS

NOTE: The Geolocation Grid ADS is available for all product types. The information available in this ADS is provided in the zero-Doppler geometry for 11 points across range. The information is updated several times in azimuth depending on the product type (based on defined granule size), typically every 10 Km for IM and AP.

- **Pixel number (field #6)**
  NOTE: Values are provided on a regularly spaced grid. The 1st and last pixel on the grid correspond to the 1st and last image sample in range or slant range depending on product type (including the SWST changes). Provided pixel tie points are the same for all LADSRs and can therefore be read from any of them.

- **Slant range times (field #6)**
  NOTE: These are the slant range times for each sample number in the grid. The value of slant range times at mid-azimuth, i.e. for the LADS with time stamp closest to the mid-azimuth time, shall be taken for the analysis and considered constant along azimuth.

2.1.2 From Antenna Pattern (AP) ADS

NOTE: The Antenna Pattern ADS is available only when the elevation antenna pattern correction has been applied to the product. The information in this ADS is provided in non-zero-Doppler geometry (original acquisition geometry) for 11 tie-points across range (different from those in the LADS) which may cover slightly more than the scene range at far range. The information is updated several times in azimuth.

- **2-Way Slant range times (field #4)**
  NOTE: These are the slant range times for 11 tie-points across range, equally spaced in slant range. These values vary slowly along azimuth. The information in the AP ADSR with time stamp closest to the image mid-azimuth time shall be taken for the analysis and considered constant along azimuth.

- **Elevation angle (field #4)**
  NOTE: The elevation angles are provided for the same 11 tie-points as above. The angles from the AP ADSR with time stamp closest to the image mid-azimuth time shall be taken for the analysis and considered constant along azimuth.

2.2 METHODOLOGY TO DERIVE THE ELEVATION ANGLE

2.2.1 Derive the relationship between sample number and slant range time from the Geolocation Grid ADS

The LADS provides the slant range time for 11 sample numbers across range. From this information, a quadratic polynomial shall be fitted to the variation of sample numbers versus slant range time:

$$sample = T0+T1 * slrt+ T2 * slrt^2$$

where "*slrt*" is the 11 elements vector of slant range times read from the LADS record , "*sample*" are the corresponding sample numbers read from the same record and T0, T1 and T2 are the polynomial coefficients.

2.2.2 Derive the sample numbers corresponding to the slant range times in the AP ADS

The AP ADS provides slant range times for 11 points in range but without the reference to the corresponding sample numbers. The sample numbers (*sampleAP*) associated to the AP ADS tie-points can be obtained evaluating the polynomial derived in 4.1. at the AP ADS slant range times (*slrtAP*):

$$sampleAP = T0+T1 * slrt+ T2 * slrt2$$

where "*sampleAP*" is the 11 element vector of sample numbers corresponding to the AP ADS tie-points.

For the same tie-points, the AP ADS provides also the elevation angles (θ_{AP}). The variation of elevation angle versus sample number can be fitted with a quadratic polynomial:

$$\theta_{AP} = P0 + P1 * sampleAP + P2 * sampleAP^2$$

where P0 , P1 and P2 are the constant, linear and quadratic terms of the fitted polynomial.

The polynomial shall then be evaluated at all product samples to obtain the elevation angle for each sample number (θ_i):

$$\theta_i = P0 + P1 * samples + P2 * samples^2$$

where '*samples'* is a vector of N elements ranging from 1 to N and "i' indicates the sample number.

3 USE OF THE ELEVATION ANGLE

3.1 CORRECTION OF THE ELEVATION ANTENNA PATTERN

In case the product shall be corrected for the elevation antenna gain, the reference antenna gains at the product elevation angles are required.

In order to derive the reference the 2-way elevation pattern gain at each product sample, the following steps shall be followed:

- Read the 2-way elevation antenna pattern gains corresponding to the product beam and polarisation from the XCA file used to generate the product. The XCA file name is annotated in the SPH data set descriptors.
- The corresponding elevation angle values are not provided in the XCA file. They range from –5 deg. to +5 deg. in steps of 0.05 deg., centred at the reference elevation angle (available in the XCA file for each swath number). Based on this, a vector of absolute reference elevation angles shall be created, centred at the swath reference elevation angle and ranging from "reference elevation angle-5deg." to "reference elevation angle+5deg." in steps of 0.05 deg.
- Interpolate the antenna gain at the product elevation angles θ_i, where "i" is the sample number ranging from 1 to N. A vector of N elements is obtained, corresponding to the reference elevations gains for each product sample.

3.2 ELEVATION ANTENNA PATTERN ESTIMATION

In case the product is used for antenna pattern estimation, a 2-way antenna gain will be estimated for each product sample.

The conversion from product sample number to elevation angle shall follow the steps defined in section 1.2. As a result the estimated antenna gain will be available versus the product elevation angles.

The product elevation angles shall then be converted to relative elevation angles by subtracting the swath reference elevation angle.

In order to provide the estimated pattern in the standard format (as used in the XCA file and as defined in the cal/val PATTEST template), the antenna gain versus relative product elevation angle shall be interpolated at the standard elevation angles, i.e. at elevation angles ranging from –5 to +5 degrees (maximum limits) around the reference elevation angle in steps of 0.05 degrees.

NOTE: The estimated pattern will not cover the maximum range of 10 degrees around the reference angle. Therefore, the interpolated pattern will be available only for a subset of the reference angles (from θ_{REF_MIN} to θ_{REF_MAX}, where θ_{REF_MIN} and θ_{REF_MAX} are the reference elevation angles closest to the minimum and maximum elevation angles derived from the product).

Table 1. List of symbols used

Parameter	Description	Units
c	Speed of light	m/s
Rsat	Distance from satellite to Earth Centre	m
Re	Local Earth radius	m
R_i	Distance from the satellite to the range (or slant range) sample "i'	m
x	State vector X position	m
y	State vector Y position	m
z	State vector Z position	m
i	Product range or slant range sample number	
N	Number of product samples	
sample	Sample numbers for the 11 tie-points in the LADSR	
sampleAP	Sample numbers for the 11 tie-points in the AP ADSR	
srt	2-way slant range times for the 11 tie-points in the LADSR	sec
srtAP	2-way slant range times for the 11 tie-points in the AP ADSR	sec
γ_i	Earth angle at the product sample "i"	degrees
α_i	Incidence angle at the product sample "i"	degrees
θ_i	Elevation angle at the product sample "i"	degrees
θ_{AP}	Elevation angle for the 11 tie-points in the AP ADSR	degrees

ANNEX B SYMBOL DEFINITION

A	Pixel digital number (amplitude value)
c	Speed of light
f_0	SAR frequency
$G^2(.)$	Two-way antenna 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 intensity image
$I_{c,int}$	Background corrected and interpolated intensity image
I_{int}	Intensity image
I_p	Background corrected integrated power of interpolated 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 (800km)
R_s	Satellite radius
R_T	Earth radius
S_f	Sampling factor for detection of complex data
V_S	Satellite velocity
α_i	Incidence angle at image pixel i
γ^0	Gamma nought
μ	Mean of signal power over an scene area
θ_i	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