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ABSOLUTE CALIBRATION OF ASAR LEVEL 1 PRODUCTS GENERATED WITH PF-ASAR

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CHANGE RECORD

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Absolute calibration for geocoded products included
Updated list of ASAR external calibration files and modified antenna patterns

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Added information on difference in radar cross-section expression between ASAR and ERS SAR

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Updated field number (available in the products specifications and EnviView display) information for some parameters required to calibrate the products. The change in field number for some parameters is the result of an update of product specifications (current version is now 4A). This updated do not change the location of any field in the ASAR products but field numbers might be modified since additional fields have been added using spares.

Updated elevation antenna pattern table and added additional information about ASA_XCA_AX updates.

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1. INTRODUCTION

The aim of this document is to describe the absolute calibration of high rate ASAR Level 1 products generated by ESA using the ASAR processing Facility (PF-ASAR).

ESA ASAR level 1 products are generated at the Processing and Archiving Centres (PACs) and at the acquisitions stations:

- D-PAC
- I-PAC
- UK-PAC
- PDHS-K (Kiruna)
- PDHS-E (Esrin)

Since the same processor is used in all facilities, a unique methodology is described here, which is applicable to any product regardless of where it has been generated.

The document is organised as follows:

Section 3 describes the derivation of sigma and gamma nought over distributed targets.
Section 4 presents the estimation of point targets Radar Cross Section.
Annex A provides a procedure to derive the elevation angle for each image pixel, which is a key parameter for the absolute product calibration.
Annex B describes how to perform the elevation antenna pattern correction, which is required for complex products calibration.
Annex C defines the parameters required for the above operations.
Annex D is provided for reference. It presents the evolution of the elevation antenna pattern since Aug. 2002.

2. ACRONYMS

ADSR	Annotated Data Set Record
AP	Alternating Polarisation
AP ADS	Antenna Pattern ADS
APM	Alternating Polarisation Mode
ASA_APP_1P	Alternating Polarisation Mode Precision Product
ASA_APS_1P	Alternating Polarisation Mode Single Look Complex Product
ASA_APM_1P	Alternating Polarisation Mode Medium Resolution Product
IM	Image Mode
ASA_IMM_1P	Image Mode Medium Resolution Product
ASA_IMP_1P	Image Mode Precision Products
ASA_IMS_1P	Image Mode Medium Resolution Product
IRF	Impulse Response Function
LADS	Geolocation Grid ADS
MPP	Main Processing Parameters
PF-ASAR	ASAR Processing Facility
RCS	Radar Cross Section
WS	Wide Swath Mode
ASA_WSM_1P	Wide Swath Mode Level 1 Product

3. DERIVATION OF SIGMA AND GAMMA NOUGHT OVER DISTRIBUTED TARGETS

3.1. General principles and assumptions

To perform a precise absolute image calibration and derive the radar backscattering coefficient σ^0 for detected ground range products, a detailed knowledge of the local slope (i.e. local incidence angle) is required. Since this information is usually not available at the processing time, a "flat terrain" is assumed during processing (based on the ellipsoid WSG84) and the final intensity image is therefore proportional to the radar brightness of the illuminated scene.

The relationship between the value of the image pixels ("DN"), the radar brightness (β^0) and the radar backscattering coefficient (σ^0) can be written as (α is the local incidence angle):

$$\boxed{DN^2 = \text{constant} \cdot \beta^0 = \text{constant} \cdot \frac{\sigma^0}{\sin(\alpha)} = \text{constant}(\alpha) \cdot \sigma^0}$$

The constant factor is hereafter referred as "absolute calibration constant" (K), which is derived -in the ASAR case- from measurements over precision transponders. This factor is processor and product type dependent, and might change between different beams for the same product type. The constant(α) term is equal to the absolute calibration constant divided by the sine of the local incidence angle α. Note that this is slightly different to the expression used for ERS SAR products [1] as the sine of the reference incidence angle has been incorporated into the ASAR product absolute calibration constant.

ASAR slant range products are also delivered as radar brightness but without any cross-track radiometric corrections, i.e. the elevation antenna pattern and range spreading loss are not corrected. For slant range products, the constant factor in the previous equation shall therefore include additional terms to correct for these effects.

3.2. Sigma and gamma nought for ground range detected products (ASA_IMP_1P, ASA_IMM_1P, ASA_APP_1P, ASA_APM_1P, ASA_WSM_1P, ASA_IMG_1P, ASA_APG_1P)

Calibrated sigma nought and gamma images for detected products can be derived as:

$$\sigma^0_{i,j} = \frac{DN^2_{i,j}}{K}\sin\left(\alpha_{i,j}\right) \qquad \gamma_{i,j} = \frac{\sigma^0_{i,j}}{\cos\left(\alpha_{i,j}\right)}$$

$$for\ i = 1 \ldots \text{L and } j = 1 \ldots \text{M}$$

where	K	=	absolute calibration constant
	$DN_{i,j}^2$	=	pixel intensity value at image line and column "i,j"
	$\sigma_{i,j}^0$	=	sigma nought at image line and column "i,j"
	$\alpha_{i,j}$	=	incidence angle at image line and column "i,j"
	$\gamma_{i,j}$	=	gamma at image line and column "i,j"
	L,M	=	number of image lines and columns

The average backscattering coefficient for an area of interest can be derived as an average of $\sigma_{i,j}^0$ for the N pixels within the distributed target as:

$$\sigma^0 = \frac{1}{N}\left(\sum_{i=1}^{i=L}\sum_{j=1}^{j=M}\sigma_{i,j}^0\right)$$

or, in case of small AOIs, an average incidence angle α_d for the area of interest can be considered:

$$\sigma^0 = \frac{1}{N}\sum_{i=1}^{i=L}\sum_{j=1}^{j=M}\frac{DN_{i,j}^2}{K}\sin\left(\alpha_d\right)$$

Finally, to convert sigma nought to dB:

$$\sigma^0[dB] = 10\cdot\log_{10}\left(\sigma^0\right)$$

3.3. Sigma nought and gamma for slant-range complex products

In order to estimate the backscattering coefficient for complex products, they shall be first detected applying:

$$\text{DN} = \sqrt{I^2 + Q^2}$$

where I and Q are the real and imaginary parts of the complex samples. Since ASAR complex products are sampled once per resolution cell, they shall be resampled by a factor of 2 before detection in order to obtain detected products adequately sampled (i.e. sampled twice per resolution cell). In addition, in case the power spectra is not completely within the sampling window, a spectrum shift is required to centre the spectrum before resampling. In the case where only the mean intensity of a distributed target is required (such as for the distributed target radar cross-section calculation) then it is possible to detect the complex data without resampling.

Derivation of backscattering coefficient for complex products is similar to the detected products but in this case it shall include the correction for the range spreading loss and antenna pattern gain, as ASAR complex products are provided without any cross-track radiometric corrections applied.

3.3.1. Sigma nought and gamma for Image Mode slant-range complex products (ASA_IMS_1P)

For image mode complex slant-range projected products, sigma and gamma nought images are derived as:

$$\sigma_{i,j}^0 = \frac{DN_{i,j}^2}{K}\frac{1}{G(\theta_{i,j})^2}\left(\frac{R_{i,j}}{R_{ref}}\right)^3\sin\left(\alpha_{i,j}\right) \qquad \gamma_{i,j} = \frac{\sigma_{i,j}^0}{\cos\left(\alpha_{i,j}\right)}$$

$$for\ i = 1 \ldots L \text{ and } j = 1 \ldots M$$

where	K	=	absolute calibration constant
	$DN_{i,j}^2$	=	pixel intensity at image line and column "i,j"
	$\sigma_{i,j}^0$	=	sigma nought at image line and column "i,j"
	$\gamma_{i,j}$	=	gamma nought at image line and column "i,j"
	$G(\theta_{i,j})^2$	=	two-way antenna gain at the look angle corresponding to pixel "i,j"
	$\theta_{i,j}$	=	look angle corresponding to pixel "i,j"
	$R_{i,j}$	=	slant range distance to pixel line and column "i,j"
	R_{ref}	=	reference slant range distance
	$\alpha_{i,j}$	=	incidence angle at pixel line and column "i,j"
	L,M	=	number of image lines and columns

The average backscattering coefficient for an area of interest can be derived as an average of $\sigma_{i,j}^0$ for the N pixels within the distributed target as:

$$\sigma^0 = \frac{1}{N}\left(\sum_{i=1}^{i=L}\sum_{j=1}^{j=M}\sigma_{i,j}^0\right)$$

or, in case of small AOIs:

$$\sigma^0 = \frac{1}{K}\sin(\alpha_d)\frac{1}{G(\theta_d)^2}\left(\frac{R_d}{R_{ref}}\right)^3 \frac{1}{N}\sum_{i=1}^{i=L}\sum_{j=1}^{j=M} DN_{i,j}^2$$

where in addition to the above:

$G(\theta_d)^2$	=	two-way antenna gain at the average elevation angle for the distributed target
R_d	=	distributed target slant range distance
α_d	=	distributed target average incidence angle

Finally, to convert sigma nought to dB:

$$\sigma^0[dB] = 10 \cdot \log_{10}\left(\sigma^0\right)$$

3.3.2. Sigma nought and gamma for Alternating Polarisation slant-range complex products (ASA_APS_1P)

Derivation of sigma and gamma nought for ASA_APS_1P products is the same as for complex image mode products but an additional factor ($R_{i,j}/R_{ref}$) shall be taken into account:

$$\sigma^0_{i,j} = \frac{DN^2_{i,j}}{K} \frac{1}{G(\theta_{i,j})^2} \left(\frac{R_{i,j}}{R_{ref}}\right)^4 \sin(\alpha_{i,j}) \qquad \gamma_{i,j} = \frac{\sigma^0_{i,j}}{\cos(\alpha_{i,j})}$$

$$for\ i = 1 \ldots \mathrm{L} \text{ and } j = 1 \ldots \mathrm{M}$$

The average backscattering coefficient is derived as for ASA_IMS_1P products while the average backscattering coefficient over a small area of interest can be approximated by:

$$\sigma^0 = \frac{1}{K} \sin(\alpha_d) \frac{1}{G(\theta_d)^2} \left(\frac{R_d}{R_{ref}}\right)^4 \frac{1}{N} \sum_{i=1}^{i=L} \sum_{j=1}^{j=M} DN^2_{i,j}$$

4. POINT TARGET CALIBRATION

4.1. Derivation of point target sigma for ground range detected products (ASA_IMP_1P, ASA_IMM_1P, ASA_APP_1P, ASA_APM_1P, ASA_WSM_1P, ASA_IMG_1P, ASA_APG_1P)

For ground range detected products, the radar cross section (RCS) of a point target visible in the image (target of opportunity, corner reflector or transponder) can be derived from its interpolated and background corrected impulse response as:

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

where:

σ: is the point target radar cross section to be measured

I_p: background corrected integrated power of the target IRF. It is obtained as the sum of the pixel intensities –after background intensity correction (see section 4.4)- 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 target position

P_{Agr}: ground range pixel area

K: absolute calibration factor for this product

4.2. Derivation of point target sigma for IM slant range complex products (ASA_IMS_1P)

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

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

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

K: absolute calibration factor for this product

4.3. Derivation of point target sigma for AP slant range complex products (ASA_APS_1P)

Due to the modulation of the ASA_APS_1P 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 ASA_APS_1P 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 ASA_APS_1P products, an additional factor (R_p/R_{ref}) shall be taken into account:

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

4.4. Methodology for intensity background removal and image interpolation

In order to measure the Radar Cross Section of a point target in the image, it is necessary to remove the background backscattering contribution from the image under analysis –around the target impulse response function (IRF)- and to convert the pixel values to intensity. The following pre-processing steps shall therefore be carried out:

- Extraction of a sub-image of 128 by 128 pixels around the point target IRF;
- 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.

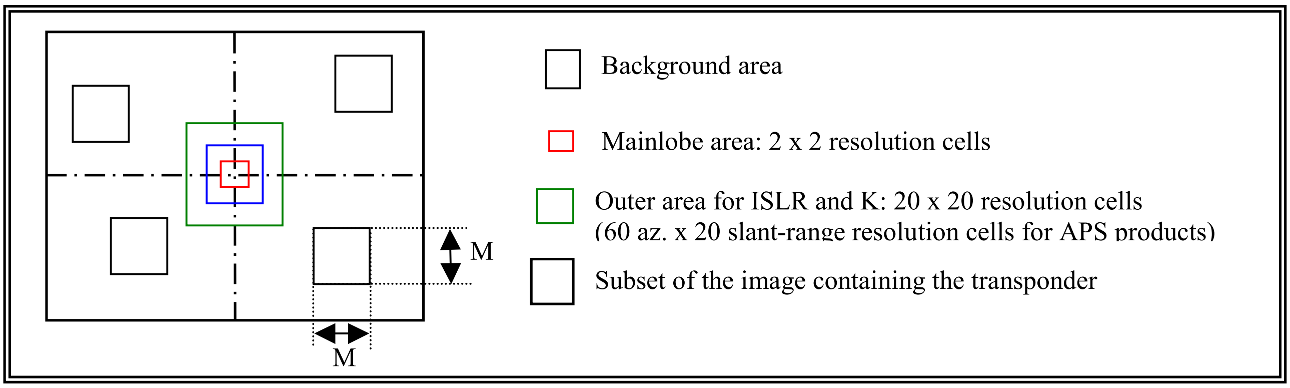


Fig.1. Definition of point target response area and background areas for IRF analysis and calibration.

5. REFERENCE

[1] Laur, H., Bally, P., Meadows, P., Sánchez, J., Schättler, B., Lopinto, E. & Esteban, D., *ERS SAR Calibration: Derivation of* σ^0 *in ESA ERS SAR PRI Product*, ESA/ESRIN, ES-TN-RS-PM-HL09, Issue 2, Rev. 5e, February 2003.

ANNEX A DERIVATION OF ELEVATION ANGLE

Knowledge of the elevation angle associated to each image sample is required for the radiometric calibration of single look complex images (for which the elevation antenna pattern correction is not applied by the processor). For completeness, derivation of elevation angle for detected products is also described.

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. Please note that although WSM products are processed with elevation antenna pattern correction, the same procedure as for the complex products is applied (this is due to the fact that the Antenna Pattern ADS for WSM products provides the information on a beam per beam basis rather than globally for the entire swath, which does not allow to follow the same procedure as for the other detected products).

NOTE: The information contained in this note is not precise for 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 60 sec (400km) in azimuth.

1 PRODUCTS PROCESSED WITHOUT ANTENNA PATTERN CORRECTION, WIDE SWATH MODE PRODUCTS AND GEOCODED PRODUCTS: ASA_IMS_1P , ASA_APS_1P AND ASA_WSM_1P, ASA_IMG_1P, ASA_APG_1P

This method exploits information available for all product types, being therefore applicable to any product. However, it is particularly suitable for Single Looks Complex products (ASA_IMS_1P, ASA_APS_1P), which are systematically processed without antenna pattern correction, for wide swath mode products (ASA_WSM_1P) and for geocoded products (ASA_IMG_1P, ASA_APG_1P). For other products, a simple alternative method is proposed in section 2 below.

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 changes[1]). 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, can be taken for the analysis and considered constant along azimuth (i.e. the dependency from line number "i" in sections 3.2 and 3.3 can be removed).

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

- **Incidence angle (field #6)**
  NOTE: The incidence angles provided are those corresponding to the pixel numbers in the ADS. The analysis can 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 (i.e. removing the dependency from line number "i" in sections 3.2 and 3.3).

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. The total number of samples in the product can be found in the product SPH (field 33 "line length").

Let's call '$slrt_j$" and "α_j" the derived interpolated slant range time and incidence angle for a range sample "j", where "j" 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 (Rsat) is derived from the mid-azimuth satellite state vector positions (i.e. the 3rd state vector from the 5 provided). 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 ("$slrt_j$) as:

$$R_j = \frac{c.slrt_j}{2}$$

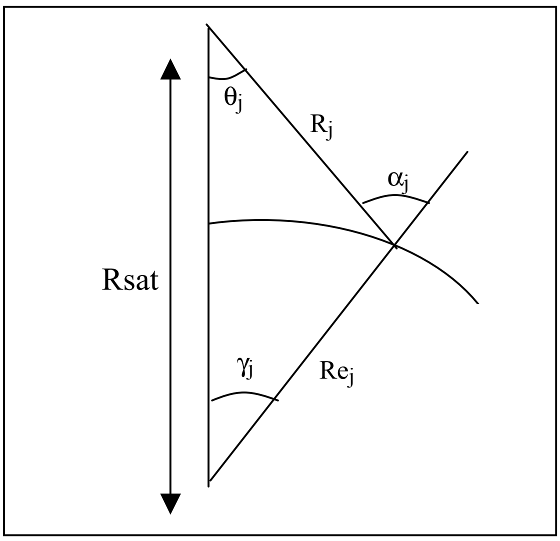
where "c" is the speed of light and "j" increases from 1 to N.

1.2.4 Derive the elevation angle for each product sample

The figure below shows the relationship between incidence angle (α_j), Earth angle (γ_j), slant range distance (R_j), satellite to Earth centre distance (Rsat) and elevation angle (θ_j).

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

$$\gamma_j = a\sin\left(\frac{R_j}{Rsat}\sin(\alpha_j)\right)$$



and the elevation angle (θ_j)s:

$$\theta_j = \alpha_j - \gamma_j$$

where “j increases from 1 to N.

2 PRODUCTS PROCESSED WITH ANTENNA PATTERN CORRECTION: ASA_IMP_1P, ASA_IMM_1P, ASA_APP_1P, ASA_APM_1P

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 60 sec (400km) 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 2.2.1 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_j):

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

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

Table 1. List of symbols used in Annex A

Parameter	Description	Units
c	Speed of light	m/s
Rsat	Distance from satellite to Earth Centre	m
Re	Local Earth radius	m
R_j	Distance from the satellite to the range (or slant range) sample "j'	m
x	State vector X position	m
y	State vector Y position	m
z	State vector Z position	m
j	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_j	Earth angle at the product sample "i"	degrees
α_j	Incidence angle at the product sample "i"	degrees
θ_j	Elevation angle at the product sample "i"	degrees
θ_{AP}	Elevation angle for the 11 tie-points in the AP ADSR	degrees

ANNEX B ELEVATION ANTENNA PATTERN GAIN

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 ASA_XCA_1P file used to generate the product. The ASA_XCA_1P file name is annotated in the SPH data set descriptors.
- The corresponding elevation angle values are not provided in the ASA_XCA_1P 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, see Annex C). 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_j, where “j” 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.

ANNEX C SYMBOL DEFINITION AND DERIVATION

C.1. Symbol definition

The table below defines the parameters used in the document and indicates where they can be read from when applicable.
Please note that when the ASA_XCA_1P file is taken as reference, the file used to generate the product shall be used. The name of the ASA_XCA_1P file used during processing is provided in the SPH data set descriptors.
The field number used to indicate the location of the parameters in the ASA_XCA_1P file or in the product ADSs is that used in EnviView.

c	Speed of light	
$DN_{i,j}$	Digital Number at image pixel line, sample “i,j”	See Annex C, section 2.
f_0	SAR frequency	= 5.331 GHz
$G^2(.)$	Two-way antenna gain	See Annex B
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 external calibration scaling factor	From product Main Processing Parameters ADS, filed 61: “*External calibration Scaling Factor*” (field 61[0].b[0] in EnviView v.2.2.8 or higher)
P_{Agr}	Ground range pixel area	- For ASA_IMP_1P and ASA_APP_1P products: P_{Agr} =156.25 m^2 - For ASA_IMM_1P and ASA_APM_1P products: P_{Agr} =5625 m^2
P_{Asr}	Slant range pixel area	P_{Asr} = azimuth pixel spacing * slant range pixel spacing - “Azimuth pixel spacing” and “range pixel spacing “ can be read from the product SPH fields 30 & 31.
PRF	ASAR Pulse Repetition Frequency	Product Main Processing Parameters ADS, filed 39 (39.d in EnviView v.2.2.8 or higher)
q_r	Normalised standard deviation of the intensity of a distributed target including instrument noise.	
$R_{i,j}$	Slant range distance to image sample line and column “i,j”	See Annex C, section 3.
R_{ref}	Reference slant-range distance	R_{ref} = 800000 m

R_s	Satellite radius	See Annex A
$slrt_{i,j}$	Slant range time to image sample line and column “i,j”	See Annex C, section 3.
S_f	Sampling factor for detection of complex data	$S_f = 2$
x,y,z	Satellite state vector position	From Product MPP, field 82 (3rd SV used)
$\alpha_{i,j}$	Incidence angle at image sample line and column “i,j”	See Annex C, section 3.
$\theta_{i,j}$	Elevation angle at image sample line and column “i,j”	See Annex A
γ	Gamma	
σ^0	Backscattering coefficient	
Reference Elevation Angle	Reference elevation angle	The reference elevation angle for each beam is provided in the ASA_XCA_1P file, fields 33 to 40.

C.2 Digital Number ($DN_{i,j}$) derivation

ASAR products are provided as radar brightness and pixel values correspond to amplitude information.
Therefore, for detected products:

$DN_{i,j}$ = pixel value at line and sample “i,j”

and for single look complex products:

$$DN_{i,j} = \sqrt{I_{i,i}^{\;2} + Q_{i,j}^{\;2}}$$

C.3 Slant range time ($slrt_{i,j}$), slant range distance ($R_{i,j}$) and incidence angle ($\alpha_{i,j}$) derivation

The Geolocation Grid LADS (available for all product types) provides the slant range time and incidence angle for a grid of 11 samples across range, which is updated several times in azimuth depending on the product type.

The 11 values read from the LADS –from the record corresponding to mid azimuth- 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 and $slrt_{i,j}$ and $\alpha_{i,j}$ are obtained for each sample. The total number of samples in the product can be found in the product SPH (field 33 “line length”).

The slant range distance to each sample can then be derived as:

$$R_{i,j} = \frac{c.slrt_{i,j}}{2}$$

ANNEX D HISTORY OF THE ELEVATION ANTENNA PATTERN UPDATES IN THE ASA_XCA_AX FILE

The table below summarises the evolution of the elevation antenna pattern used for processing since August 2002.

The files are available on line at: **http://earth.esa.int/services/auxiliary_data/asar/**

Updated information on antenna patterns modification and new ASA_XCA_AX files can be found on the ASAR performance reports available on line at: **http://earth.esa.int/pcs/envisat/asar/public_reports/**

The source information indicates whether the pattern has been derived from data acquired over the Rain Forest (“RF”) or whether it has been derived from antenna synthesis using results from Module Stepping acquisitions (“SYN”).

Please note that pre-launch antenna pattern where used before the first ASA_XCA_1P update.

Please note that the table indicates for each beam, in which file the update took place. Any file created after this date will include that updated unless a new file is specified for the beam. For instance, the pattern for IS3_SS2 VV was last updated on 27 August 2003. The file created on 9 December 2003 (when the IS1 VV pattern was updated) will include the same pattern for IS3_SS2 VV as in the file of 27 August 2003, since the table does no indicate any further update for the IS3_SS2 VV pattern.

ASAR ELEVATION ANTENNA PATTERNS UPDATES IN THE ASAR EXTERNAL CALIBRATION FILE					
Swath & polarisation	**Source**	**Update time** (file used in operations since 1 day after this date)	**File Name**	**Applicable to data acquired between:**	
				Start	**Stop**
IS1 VV	RF	20020813	ASA_XCA_AXVIEC20020813_080042_20020413_000000_20021231_000000	20020413	20021231
	NA[2]	20021107	ASA_XCA_AXVIEC20021107_144746_20020413_000000_20021231_000000	20020413	20021231
	RF	20021122	ASA_XCA_AXVIEC20021122_130838_20020413_000000_20021231_00000[3]	20020413	20021231
	RF	20031209	ASA_XCA_AXVIEC20031209_113559_20030211_000000_20041231_000000	20030211	20041231
	RF	20040406	ASA_XCA_AXVIEC20040406_160451_20030211_000000_20041231_000000	20030211	20041231
IS1 HH	RF	20021107	ASA_XCA_AXVIEC20021107_144746_20020413_000000_20021231_000000	20020413	20021231
	RF	20031209	ASA_XCA_AXVIEC20031209_113559_20030211_000000_20041231_000000	20030211	20041231
IS1 HV	RF	20021217	ASA_XCA_AXVIEC20021217_150852_20020413_000000_20031231_000000	20020413	20031231

[2] A corrupted IS1 VV pattern was included into the ASA_XCA_1P file updated of 11 Nov. 2002

[3] The corrupted IS1 VV pattern in the operational ASA_XCA_1P file was corrected on 22 Nov. 2002. Please note that the IS1 VV pattern in ASA_XCA_AXVIEC20021122_130838_20020413_000000_20021231_00000 is the same as in ASA_XCA_AXVIEC20020813_080042_20020413_000000_20021231_000000

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IS1 VH	RF	20021217	ASA_XCA_AXVIEC20021217_150852_20020413_000000_20031231_000000	20020413	20031231
	RF	20031209	ASA_XCA_AXVIEC20031209_113559_20030211_000000_20041231_000000	20030211	20041231
	RF	20040406	ASA_XCA_AXVIEC20040406_160451_20030211_000000_20041231_000000	20030211	20041231
IS2 VV	RF	20020813	ASA_XCA_AXVIEC20020813_080042_20020413_000000_20021231_000000	20020413	20021231
	RF	20031209	ASA_XCA_AXVIEC20031209_113559_20030211_000000_20041231_000000	20030211	20041231
	RF	20040406	ASA_XCA_AXVIEC20040406_160451_20030211_000000_20041231_000000	20030211	20041231
IS2 HH	RF	20021107	ASA_XCA_AXVIEC20021107_144746_20020413_000000_20021231_000000	20020413	20021231
	RF	20040406	ASA_XCA_AXVIEC20040406_160451_20030211_000000_20041231_000000	20030211	20041231
IS2 HV	RF	20021217	ASA_XCA_AXVIEC20021217_150852_20020413_000000_20031231_000000	20020413	20031231
	RF	20040406	ASA_XCA_AXVIEC20040406_160451_20030211_000000_20041231_000000	20030211	20041231
IS2 VH	RF	20021217	ASA_XCA_AXVIEC20021217_150852_20020413_000000_20031231_000000	20020413	20031231
	RF	20040406	ASA_XCA_AXVIEC20040406_160451_20030211_000000_20041231_000000	20030211	20041231
IS3_SS2 VV	RF	20020813	ASA_XCA_AXVIEC20020813_080042_20020413_000000_20021231_000000	20020413	20021231
	RF	20021018	ASA_XCA_AXVIEC20021018_121708_20020413_000000_20021231_000000	20020413	20021231
	RF	20030801	ASA_XCA_AXVIEC20030801_133024_20030428_000000_20031231_000000	20030428	20031231
	RF	20030801	ASA_XCA_AXVIEC20030801_134802_20020413_000000_20030211_000000	20020413	20030211
	RF	20030827	ASA_XCA_AXVIEC20030827_140210_20030211_000000_20031231_000000	20030211	20031231
	RF	20040812	ASA_XCA_AXVIEC20040812_170224_20040412_000000_20041231_000000	20040412	20041231

IS3_SS2 HH	RF	20021107	ASA_XCA_AXVIEC20021107_144746_20020413_000000_20021231_000000	20020413	20021231
	RF	20030801	ASA_XCA_AXVIEC20030801_133024_20030428_000000_20031231_000000	20030428	20031231
	RF	20030801	ASA_XCA_AXVIEC20030801_134802_20020413_000000_20030211_000000	20020413	20030211
	RF	20030827	ASA_XCA_AXVIEC20030827_140210_20030211_000000_20031231_000000	20030211	20031231
	RF	20031209	ASA_XCA_AXVIEC20031209_113559_20030211_000000_20041231_000000	20030211	20041231
	RF	20040812	ASA_XCA_AXVIEC20040812_170224_20040412_000000_20041231_000000	20040412	20041231
IS3 HV	SYN.	20021217	ASA_XCA_AXVIEC20021217_150852_20020413_000000_20031231_000000	20020413	20031231
IS3 VH	RF	20021217	ASA_XCA_AXVIEC20021217_150852_20020413_000000_20031231_000000	20020413	20031231
IS4_SS3 VV	RF	20020813	ASA_XCA_AXVIEC20020813_080042_20020413_000000_20021231_000000	20020413	20021231
	RF	20021018	ASA_XCA_AXVIEC20021018_121708_20020413_000000_20021231_000000	20020413	20021231
IS4_SS3 HH	RF	20021107	ASA_XCA_AXVIEC20021107_144746_20020413_000000_20021231_000000	20020413	20021231
	RF	20040812	ASA_XCA_AXVIEC20040812_170224_20040412_000000_20041231_000000	20040412	20041231
IS4 HV	RF	20021217	ASA_XCA_AXVIEC20021217_150852_20020413_000000_20031231_000000	20020413	20031231
	RF	20040406	ASA_XCA_AXVIEC20040406_160451_20030211_000000_20041231_000000	20030211	20041231
IS4 VH	RF	20021217	ASA_XCA_AXVIEC20021217_150852_20020413_000000_20031231_000000	20020413	20031231
	RF	20040406	ASA_XCA_AXVIEC20040406_160451_20030211_000000_20041231_000000	20030211	20041231
IS5_SS4 VV	RF	20020813	ASA_XCA_AXVIEC20020813_080042_20020413_000000_20021231_000000	20020413	20021231
	RF	20021018	ASA_XCA_AXVIEC20021018_121708_20020413_000000_20021231_000000	20020413	20021231

IS5_SS4 HH	RF	20021107	ASA_XCA_AXVIEC20021107_144746_20020413_000000_20021231_000000	20020413	20021231
	RF	20040406	ASA_XCA_AXVIEC20040406_160451_20030211_000000_20041231_000000	20030211	20041231
IS5 HV	RF	20021217	ASA_XCA_AXVIEC20021217_150852_20020413_000000_20031231_000000	20020413	20031231
	RF	20040406	ASA_XCA_AXVIEC20040406_160451_20030211_000000_20041231_000000	20030211	20041231
IS5 VH	RF	20021217	ASA_XCA_AXVIEC20021217_150852_20020413_000000_20031231_000000	20020413	20031231
	RF	20040406	ASA_XCA_AXVIEC20040406_160451_20030211_000000_20041231_000000	20030211	20041231
IS6_SS5 VV	RF	20020813	ASA_XCA_AXVIEC20020813_080042_20020413_000000_20021231_000000	20020413	20021231
	RF	20021018	ASA_XCA_AXVIEC20021018_121708_20020413_000000_20021231_000000	20020413	20021231
	RF	20030801	ASA_XCA_AXVIEC20030801_133024_20030428_000000_20031231_000000	20030428	20031231
	RF	20030801	ASA_XCA_AXVIEC20030801_134802_20020413_000000_20030211_000000	20020413	20030211
	RF	20030827	ASA_XCA_AXVIEC20030827_140210_20030211_000000_20031231_000000	20030211	20031231
IS6_SS5 HH	RF	20021107	ASA_XCA_AXVIEC20021107_144746_20020413_000000_20021231_000000	20020413	20021231
	RF	20030801	ASA_XCA_AXVIEC20030801_133024_20030428_000000_20031231_000000	20030428	20031231
	RF	20030801	ASA_XCA_AXVIEC20030801_134802_20020413_000000_20030211_000000	20020413	20030211
	RF	20030827	ASA_XCA_AXVIEC20030827_140210_20030211_000000_20031231_000000	20030211	20031231
IS6 HV	SYN.	20021217	ASA_XCA_AXVIEC20021217_150852_20020413_000000_20031231_000000	20020413	20031231
	RF	20040406	ASA_XCA_AXVIEC20040406_160451_20030211_000000_20041231_000000	20030211	20041231

IS6 VH	RF	20021217	ASA_XCA_AXVIEC20021217_150852_20020413_000000_20031231_000000	20020413	20031231
	RF	20040406	ASA_XCA_AXVIEC20040406_160451_20030211_000000_20041231_000000	20030211	20041231
IS7 VV	RF	20020813	ASA_XCA_AXVIEC20020813_080042_20020413_000000_20021231_000000	20020413	20021231
IS7 HH	RF	20021107	ASA_XCA_AXVIEC20021107_144746_20020413_000000_20021231_000000	20020413	20021231
IS7 HV	RF	20021217	ASA_XCA_AXVIEC20021217_150852_20020413_000000_20031231_000000	20020413	20031231
IS7 VH	RF	20021217	ASA_XCA_AXVIEC20021217_150852_20020413_000000_20031231_000000	20020413	20031231
SS1 VV	RF	20020813	ASA_XCA_AXVIEC20020813_080042_20020413_000000_20021231_000000	20020413	20021231
	RF	20021018	ASA_XCA_AXVIEC20021018_121708_20020413_000000_20021231_000000	20020413	20021231
	RF	20030801	ASA_XCA_AXVIEC20030801_133024_20030428_000000_20031231_000000	20030428	20031231
	RF	20030801	ASA_XCA_AXVIEC20030801_134802_20020413_000000_20030211_000000	20020413	20030211
	RF	20030827	ASA_XCA_AXVIEC20030827_140210_20030211_000000_20031231_000000	20030211	20031231
	RF	20040406	ASA_XCA_AXVIEC20040406_160451_20030211_000000_20041231_000000	20030211	20041231
SS1 HH	RF	20021107	ASA_XCA_AXVIEC20021107_144746_20020413_000000_20021231_000000	20020413	20021231
	RF	20030801	ASA_XCA_AXVIEC20030801_133024_20030428_000000_20031231_000000	20030428	20031231
	RF	20030801	ASA_XCA_AXVIEC20030801_134802_20020413_000000_20030211_000000	20020413	20030211
	RF	20030827	ASA_XCA_AXVIEC20030827_140210_20030211_000000_20031231_000000	20030211	20031231
	RF	20040406	ASA_XCA_AXVIEC20040406_160451_20030211_000000_20041231_000000	20030211	20041231
	RF	20040812	ASA_XCA_AXVIEC20040812_170224_20040412_000000_20041231_000000	20040412	20041231