Doc. No.:	PO-RS-ESA-GS-00245
Issue:	3.3
Date:	1 July 1997
Sheet:	1

ENVISAT GROUND SEGMENT

ASAR PROCESSING and PRODUCT QUALITY REQUIREMENTS

Prepared by:
Y-L DESNOS - NWP

Approved by:
G.LEVRINI - NWP
J.LOUET - NW

Authorised by:
JP.GUIGNARD - H/RS/P

Distribution list:

Envisat Project

DOCUMENT CHANGE RECORD

Issue/ Rev	Date	Page	Description of Changes	Approved by: (same signature as on the cover page)
1.0	27.2.95		new document	
2.0	3.10.95		Stripline processing definition updated Phase preserving processing Test definition update Phase error for point target test definition and specification Suppresssion of requirement to process auxiliary modes of ASAR (done in the ECC) Requirement of phase preserving processing for wave mode added Requirement of mosaiking GEC product added (previously in PO-RS-ESA-GS0162) Requirement of relative phase error suppressed(covered by Phase error for point target test definition and specification)	
2.1	24.10.95		Update Reference and applicable Documents Updated list of characterisation parameters/downlink processing parameters Definition of radiometric resolution/ENL added (previously in PO-RS-ESA-GS0162)	
3.0	10.11.95		Document revision following ESRIN comments (JP GUIGNARD & H.LAUR)	
3.1	15.11.95		Update following TH-CSF comments	
3.2	23 .04.96		Update according to red marked copy Reference PO-MN-MDA-GS2063 agreed by T4S/MDA. Additional modifications : BAQ option for energy conservation restricted to 8/2 and 8/3 compression ratios. Information on number of Bytes per pixels added as per PO-TN-ESA-GS-00231 issue 2.0 with exceptions of ASAR_APM ,ASAR_GM1 and ASAR_IMM which are coded on 2 bytes per pixel.	
3.3	01 .07.97		Update according to Action Item agreed by T4S/MDA at OSAT ; page 9 update of Applicable Reference documents ; page 12 update figure 1 ; p 29 TBC removed ; page 50 browse pixel spacing IM and AP ; page 45 ENL updated forAPP and APG (waiver PO-RW-CSF-GS-1584)	

Table of Contents

Table of Contents

Table of Contents

List of Tables

List of Figures

1 INTRODUCTION

1.1 BACKGROUND

The ASAR Generic Processor (ASAR-GP) is responsible for the processing of various type of High Rate ASAR signal data referred as Regional mission and Low rate ASAR signal data referred as Global mission to form various output products.

This consists primarily of processing image modes signal data (image mode alternating polarisation mode, wide swath mode, global monitoring mode, wave mode) to form different required scene products defined in Applicable document 3.

The ASAR GP is to be installed in PDHS (Kiruna and ESRIN) and to be procured by PACs and National Stations (NS-E) offering services to ESA standards.

1.2 SCOPE

This document states the detailed requirement specifications for the processing and the quality of the products to be generated by the ASAR GP. Applicable documents are listed in Section2.

1.3 ASAR instrument design implications

The starting point in deriving processing schemes for ASAR is to consider the ASAR instrument high level designs aspects and their implication for processing. In particular it is useful to identify the features of ASAR which are significantly different from the ERS-1 SAR.

- ASAR includes an active phased array antenna that provides distinct transmit and receive beams
- ASAR includes a complex calibration scheme with 4 calibration pulses embedded in the instrument mode timeline to provide instrument dependant correction factors
- ASAR includes digital waveform generation for pulse ("chirp") modulation with mode and swath dependant variable bandwidth
- ASAR includes a Block Adaptive Quantisation scheme
- ASAR includes SCANSAR modes
- ASAR includes an External Characterisation scheme with a Ground receiver to be used as part of the internal calibration corrections in the ground processor

1.4 ACRONYMS

ASAR GP = ASAR Generic Processor
AP = Alternating Polarisation
GM = Global Monitoring (Mode)
WS = Wide Swath
IM = Image Mode
PDS = Payload Data Segment
PAC = Processing and Archiving Centre
LRAC = Low Rate Archive Centre
PDHS = Payload Data Handling Centre

PDHS-E = Payload Data Handling Centre ESRIN
PDHS-K = Payload Data Handling Centre KIRUNA
FD = Fast Delivery
NRT = Near Real Time
DRS = Data Relay Satellite
ISP = Instrument Source Packets
PCD = Product Confidence Data
MPH = Main Product Header
SPH = Specific Product Header
OGRC= On Ground Range Compressed
RCMC=Range Cell Migration Correction
TBD = To Be Defined
TBC = To Be Confirmed

1.5 REFERENCE and APPLICABLE DOCUMENTS

1.5.1 Applicable documents

[A - 1] PO.WS.ESR.GS.0001Envisat-1 payload data segment Development S.O.W. (Appendix 1 -ITT-AO/2-1383/95/NL/CN)

[A - 2] PO-RS.ESA.GS.0239Envisat-1 payload data segment Technical Requirements.(Appendix 1- Annex D -ITT-AO/2-1383/95/NL/CN)

[A - 3] PO-RS-MDA-GS-2009 Issue 3 Envisat Product Specifications

[A - 4] PO-RS-ESA-GS-0242 Issue 5 Nov1996 Envisat Product Format Guidelines

1.5.2 Reference documents

[R - 1] PO-RS-DOR-SY-0029 Mission prime assumptions on ENVISAT-1 ground segment

[R - 2] PO-PL-MMS-SR-0004 Envisat-1 ASAR calibration and characterisation plan (issue H May 1996)

[R - 3] PO-ID-DOR-SY-0032 issue 3 January 97 Envisat 1 payload to ground segment interface control document Volume 5

[R - 4] PO-TN-MMS-SR-0248 Issue B Dec 96 Envisat ASAR Interpretation of Source Packet Data

[R - 5] PO-ID-DOR-SY-0037 (issue 1 June 96) Definition of instrument characterisation data base

[R - 6] PO-DW-MMS-SR-0018/19/20/21/22/23/24 issue H nov95 ASARModes Timelines

[R - 7] PO-IS-GMV-GS-0558 Envisat Orbit Propagator PPF_orbit version 4.2

[R - 8] DMA-TR-8350.2 World Geodetic System 1984 Its definition and relationships with local geodetic systems

[R - 9] FBAQ Extended Study Technical Report Volume 1 of 3 Image mode study Ref. MDA DC-TN-50-6904

2 DEFINITIONS

For the sake of clarity and preciseness in the requirements to follow a number of definitions are listed below.

2.1 ASAR modes of operation

A schematic illustrating ASAR different modes is given document figure 1.

2.1.1 Image Mode

In image mode the flexible swath position allows the choice between seven swaths covering a range of incidence angles from 17 to 45 degrees. The choice between HH or VV polarisation is possible.

2.1.2 Alternating Polarisation Mode

In alternating polarisation mode a scansar technique described in Reference Document 6 allows half the looks of an image to be acquired in horizontal polarisation HH and half the looks to be acquired in vertical polarisation VV so that in a single pass an image in HH polarisation and an image in VV polarisation will be acquired from the same scene. This mode is referred as co-polar mode.
Additionally two cross-polarisation sub-modes have been introduced:

- cross-H Mode where all Tx pulses are in H polarisation.The receiver alternates between H and V polarisations in blocks as in current Alternating Polarisation Mode.
- cross-V Mode where all Tx pulses are in V polarisation.The receiver alternates between H and V polarisations in blocks as in current Alternating Polarisation Mode.

In Alternating polarisation mode the flexible swath position allows the choice between seven swaths covering a range of incidence angles from 17 to 45 degrees.

2.1.3 Wide swath mode

In Wide Swath mode using the SCANSAR technique ASAR can switch very quickly between Subswaths. so that an overall swath of more than 400 km width can be imaged.
The choice between HH or VV polarisation is possible.

2.1.4 Global Monitoring Mode

This mode is a scansar mode operated in the same geometry as the wide swath mode but with a reduced spatial resolution (1000m approximately) to allow on board storage of the measurement data and possibly up to 100% orbit operation.
The choice between HH or VV polarisation is possible.

2.1.5 Wave Mode

The wave mode is a single mode operated up to 100% of the orbit with the following char-

acteristics: 100 km separation between vignettes, vignette positioned anywhere within an Image mode swath, two vignette positions may be defined for each mode (in one swath or in different swaths)
The choice between HH or VV polarisation is possible.

2.1.6 External characterisation mode

The external characterisation mode provides absolute calibration measurements by transmitting on each of the 32 elevation rows of the antenna according to a predefined sequence
Additionally some internal calibration measurements are made simultaneously in order to provide comparative values.

2.1.7 Module Stepping Mode (auxiliary mode)

Module stepping mode provides an internal health checking facility on an individual Transmit Receive module basis. The purpose of the mode is primarily to identify any malfunctioning modules to allow them to be switched-off if necessary, and to identify modules for which calibration offsets are to be applied.

figure 1 ASAR modes schematic

2.2 ASAR Generic Processor

The system which is responsible for the following:

From Level 0 data

- processing narrow swath mode signal data to image products
- processing alternating polarisation mode signal data to image products
- processing systematically all acquired data(IM,AP,WS,GM) to low resolution compressed image product for browse purpose only
- processing systematically all acquired data at PDHS from narrow swath mode, alternating polarisation mode and wide swath mode to medium resolution image product for NRT applications
- processing low Rate Signal data coming from Wave mode, Global monitoring mode

2.3 INPUT PROCESSING PARAMETERS

The input processing parameters are a base set of processing parameters from which all other control parameters necessary for proper ASAR GP operation can be derived.

These are further distinguished as:

- fixed parameters (ASAR sensor parameters described in Reference Document 5);
- downlink parameters (extracted from the downlink data and available in Level0 product);
- product generation parameters (updated for each product generated).
- external characterisation data (generated by ESA from the data received on a ground receiver built-in ASAR transponders when the instrument is in external characterisation mode)
- external calibration data (external calibration scaling factors mode and swath dependant provided by ESA)
- other parameters: orbit data, Earth model, Yaw Steering Law Identifier

A functional breakdown of the overall processing data flow is given document figure 2

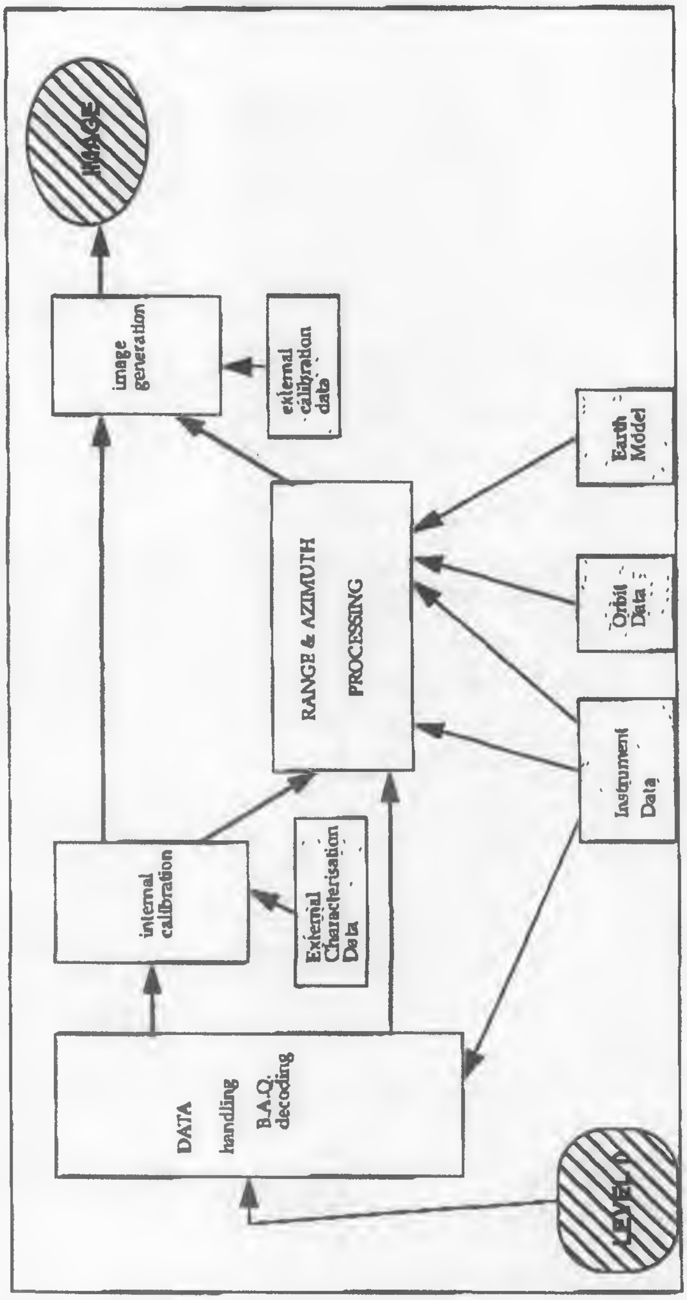

figure 2 ASAR Generic Processing Functional Block Diagram

2.3.1 FIXED PROCESSING PARAMETERS

The instrument data are measured on ground before launch and are provided via the characterisation data base Reference Document 5.

2.3.1.1 Parameters fixed for the lifetime of the instrument

PARAMETERS	VALUES	ACCURACY	UNITS	NOTE
Radar Frequency	5.331	=/-100Hz	GHz	1
Radar Sampling Rate	19.208	2ppm	MHz	2
Offset frequency for wave mode calibration pulses	document [R - 5]			3
Nominal values of amplitude and phase of calibration pulses 1,1A,2 and 3	document [R - 5]			4
Two way Antenna Azimuth Pattern	document [R - 5]			5
Range gate bias	document [R - 5]			6
ADC characterisation LUT	document [R - 4]			7
Antenna embedded row pattern	document [R - 4] document [R - 5]			8

table 1 : Fixed Processing Parameter

Notes:

1. The ASAR centre frequency is different from ERS1/ERS2 centre frequency

2. This is the complex sampling rate; each sample has a real part and an imaginary part.

3. Because of Data Rate limitation ASAR use a CW signal for calibration pulses in wave mode

4. To be used for ground processor internal calibration and performance monitoring appendix B

5. The antenna pattern is supplied (prior to launch) to ASAR GP in a form of a file or polynomial coefficient

6. Time delay of a pulse through the instrument.

7. ADC characterisation LUT consisting of measured voltage threshold values for both I and Q channels on the real non-ideal ADC. The LUT is used to estimate the output voltage level as per Reference Document 4.

8. This is the gain and phase of each antenna row when embedded in the array as a function of elevation angle . They are used in the internal calibration function described appendix B

2.3.1.2 Parameters fixed for the instrument baseline

Tables assumed to be fixed for the lifetime of the instrument. Nevertheless it is possible to modify the instrument settings by macro-command. so that these tables are no longer valid. In this case the tables have to be updated accordingly.

PARAMETERS	VALUES	ACCURACY	UNITS	NOTE
Default FBAQ reconstruction-LUT	document [R - 4]			1
Instrument mode data processing configuration Table	document [R - 4]			2
default swath identification table	document [R - 4]			3
calibration row sequence table	document [R - 4]			4
mode timelines	document [R - 5] document [R - 6]			

1. Default BAQ Reconstruction level associated with the default BAQ LUT stored on board the data Subsystem

2. Quantisation type for Echo, Calibration, Noise data and resampling subswath by subswath when applicable

3. The swaths, subswaths corresponding to Antenna beam Set parameters are programmable by macrocommand from the ground

4. During the initial calibration sequence the row number parameter is not updated in the source packet data field header. This is why a knowledge of the order in which the calibration rows are stepped is important.

2.3.1.3 Parameters defined for the reference orbit and the instrument baseline

The parameter values have to be modified when the satellite is in an orbit different from the reference orbit. They depend on the swath, subswath and mode.

PARAMETERS	VALUES	ACCURACY	UNITS	NOTE
Pulse window number	9 to 14			1
Reference elevation angles	parameter C26 of document [R - 5]	exact		2
Center of swath elevation angles	IS1 = 16.6 IS2=20.11 IS3/SS2=25.22 IS4/SS3=29.46 IS5/SS4=32.8 IS6/SS5=35.58 IS7=38.0 SS1=19.14		degree	3
Return time for the scansar modes	document [R - 1]			

08 AUG '97 12:03

1. This value is the number of pulse repetition intervals between transmission of pulse and receipt of the return from that pulse

2. Reference value used for internal calibration in the ground processor

3. Used for swath definitons, these values are taken from ASAR Instrument Requirement Specifications

2.3.1.4 ASAR antenna elevation pattern

The ASAR two way antenna patterns for SS1,IS1,IS2,IS3,IS4,IS5,IS6,IS7 will be characterised on ground before launch and will be provided as part of the instrument characterisation data base Reference Document 5. They will be updated as part of the External calibration activities described Section 2.3.5

2.3.1.5 Other parameters of the Instrument characterisation data base

For the seek of completeness the other parameters of the instrument characterisation data base are listed here under:

- Update Period for Complete Row Cycle Calibration
- Update Period for Noise Measurement
- Number of Samples per Pulse
- Duty Cycle in OGRC Modes
- Chirp Bandwidth (OGRC)
- Pulse Rise and Fall Time
- Reference Elevation Angle
- Calibration Loop Paths Characterisation Factor
- Peak Power - Two Way Gain Product of Instrument in Image Mode
- Peak Power - Two Way Gain Product of Instrument
- Auxiliary Transmit Power Monitor Nominal Level
- I & Q Channel DC Offset
- I/Q Ratio
- Non-orthogonality between I & Q
- Receiver Step Attenuator Characteristic
- Antenna pointing nominal wrt Nadir
- Second Local Oscillator frequency

2.3.2 DOWNLINK PROCESSING PARAMETERS

Parameters detailed definition and default values are given in Reference Document 4

PARAMETERS	VALUES	ACCURACY	UNITS	NOTE
mode ID				0
antenna beam set number	0 to 63			1
Pulse Repetition Interval(PRI)	PRF = 1/PRI = 1580-2150		Hz	2
On Board Time (epoch of received range pulse)		200	micros.	3
Sampling Window Start Time	Reference Document 4		sample	4
Tx pulse length	11.6 - 41.3		μs	5
Tx Pulse Bandwidth	0.4 to 16		MHz	6
Echo window length: echo data cal data noise data	parameters definition and range given in Reference Document 4	2ppm	 sample sample sample	7
Upconverter level				8
Downconverter Level (Receiver Attenuation)				9
Auxiliary transmit monitor level				
Beam Adjustment Delta				10
Calibration row number				11
source packet number				12
Echo, noise, or calibration data flag				13
Tx Polarisation (V/H flag) Rx Polarisation (V/H flag)				14
Mode packet count				15
Cycle packet count				16
Compression Ratio Calibration Type Global Monitoring Mode Resampling Factor				17 18 19

08 LUG '97 12:04

table 2 :Downlink Processing Parameters

Notes:

0.Defined Reference Document 4

1.This parameter is indicating the beam set to which the packet data applies. This parameter will be updated during an operating mode

2 PRF defined by the pulse repetition interval in sample clock interval

2. 5. and 6. For PRF, Tx pulse length and Tx Chirp, respectively will be updated simultaneously. An approach called "fixed PRF modes" is used:
- when any mode is entered the PRF for each individual swath or subswath will not be changed for the duration of the commanded mode (Requirement of PRF change for round orbit operation will be managed by the ground segment operations in the form of limited mode operation on certain part of the orbit)
- the transmit pulse length for each individual swath or subswath will always remain constant (the operational procedures to ensure that the pulse lengths are compatible with instrument operations will be implemented in the ground segment)
- there will be a single Chirp No parameter for each swath subswath

3. Absolute error in the epoch time will cause the processor to use the wrong orbit ephemeris data.

4. This value will be updated at nominally fifteen second intervals during an operation mode for each beam set . Samples at sample clock frequency given document table 1.

6.The chirp bandwidth will be in the range 0.4 Mhz to 16 Mhz,the precise value is given by the chirp pulse bandwidth codeword in the source packet Data Field Header described in Reference Document 4.

7. Different echo window length for Echo Noise or Calibration data. Samples at sample clock frequency given document table 1.

8. and 9. values supplied and not updated during a mode

10. Parameter describing the delta phase shift applied for beam adjustment. Will be updated during an operation mode

11.Defined Reference Document 4

12. Information used to check missing data

13. Indicates if the packet contains echo calibration or noise data respectively

14. transmit respectively receive polarisation of the source packet

13.Defined Reference Document 4

15. Mode packet count = counter reset to zero only on entry into an operation mode and wraps around when full

16. Cycle packet count = parameter updated during an operating mode

17. Compression ratio = compression ratio used in quanrtisation averaging mode (8/4,8/3,8/2)

18. Calibration Type = indicates Initial calibration or Periodic Calibration

2.3.3 PRODUCT GENERATION PARAMETERS

PARAMETERS	TYPICAL values	UNITS	NOTE
Processing Mode	processing for narrow swath image mode (PRI,SLC,GEC) processing alternating polarisation mode (PRI,SLC,GEC) Stripline processing to Medium resolution for wide swath mode, image mode, alternating polarisation mode Stripline processing to Browse for wide swath mode, image mode, alternating polarisation mode ,Global Monitoring stripline processing for global monitoring mode processing for wave mode		
Product type	see document [A - 3]		1
Raw Data Analysis Flag	Yes or No described appendix A		
Antenna elevation correction Flag	Yes or No		
Slant range to ground range projection flag	Yes or No		
Azimuth weighting factor	To Be Optimised to achieve required product Quality defined section 4		
Range weighting factor	To Be Optimised to achieve required product Quality defined section 4		
Range Look bandwidth	To Be Optimised to achieve required product Quality defined section 4.Nominal values are given section 4		
Replica pulse construction	from internal calibration appendix B		2
nominal output pixel spacing - slant range - ground range - azimuth	section 4		
Number of range looks	To Be Optimised to achieve required product Quality defined section 4		3
Number of azimuth looks	To Be Optimised to achieve required product Quality defined section 4		3
Azimuth Look Bandwidth	To Be Optimised to achieve required product Quality defined section 4. Nominal values are given section 4		

PARAMETERS	TYPICAL values	UNITS	NOTE
Default raw data correction parameters:			4
. I bias	0.0		
. Q bias	0.0		
. IQ gain imbalance	1.0		
. IQ quadrature departure	0.0		

table 3 Product Generation Parameters

Notes:

1. see product definitions and specifications
2. see document [R - 2]
3. Not applicable to Medium resolution and Browse products
4. Raw data correction are described appendix A

2.3.4 EXTERNAL CHARACTERISATION DATA

External Characterisation Data are determined at the beginning of ASAR operation and thereafter updated at regular intervals (typically 6 months).

External characterisationparameters shall be used by the Ground Processor as part of the internal calibration processing correction described appendix B.

External characterisation is a dedicated mode within ASAR performed overflying a receiver setup for H (or V) polarisation) located on the ground (built in the ASAR Transponder). During the mode ASAR transmits a sequence of pulses from each antenna row in turn. These pulses are received and digitized on the ground and the data recorded for off line analysis in the Engineering Calibration Computer. Simultaneously during the mode the calibration loop in the instrument is used to couple transmit pulses which are then sampled within a calibration window in order to provide comparative values.

PARAMETERS	DEFAULT VALUE	ACCURACY	UNITS	NOTE
Complex loop paths Characterisation Factors relative to free space g_{np} n is the index of the row n=32 p is the index of the polarisation (H or V)	$\|g_{np}\| = 1$			1
Antenna pointing error ΔP_1	0			2

table 4 External characterisation data

Notes:

1. g_{np} is a measure of the departure from the ideal responses for the calibration loop and the path from the calibration coupler to the antenna face for the different rows document [R - 2].

2. ΔP_1 elevation pointing error (instrument contribution)

2.3.5 EXTERNAL CALIBRATION DATA

External calibration is performed by ESA against three calibrated Transponders at the beginning of ASAR operation and thereafter at regular intervals specified as at least 6 months. The External Calibration Scaling Factor will be provided to the processor at the End of the ASAR Commissioning Phase and shall be annotated in the product.

In flight elevation antenna pattern estimate will be performed by ESA using natural targets with known properties like the rain forest.

The In Flight elevation Antenna pattern estimate will be provided to the processor in the form of a file or polynomial coefficients and will be used to perform antenna elevation radiometric corrections.

The antenna pattern used for antenna pattern radiometric correction shall be annotated in the product.

PARAMETERS	VALUE	ACCURACY	UNITS	NOTE
External Calibration Scaling Factor (mode /swath/polarisation dependant)	TBD		none	
In flight antenna patterns estimate	TBD			

table 5 : External calibration data

Notes:

1. The in flight antenna patterns are supplied to ASAR GP as a file or polynomial coefficient

2.3.6 OTHER PARAMETERS

- ORBIT DATA:The five considered orbit state vector sources are listed hereafter in order of time availability but also accuracy from the earliest predicted to the best restituted:

  the FOS predicted orbit state vectors (NRT processing)

  the DORIS level 0 navigator product acquired at PDHS (NRT processing)

  the FOS restituted orbit state vectors (off-line processing)

  the DORIS preliminary orbit (off-line processing)

  the DORIS level 2 Precise orbit (off-line processing)

The instrument ground processing software uses the orbit propagator software module and an orbit state vector as input to compute all along the orbit the satellite position with other geometrical parameters (i.e range), for a given UTC time, within an earth fixed reference frame .

The Orbit state vector is a data structure containing 8 elements described in [A - 4] and recalled hereafter:

table 6 Orbit state vector

Field	Bytes	Type	Description
UTC	25	char	UTC time of ascending node state vector
ΔUT1	6	char	ΔUT1 = UT1 - UTC. Format: ±..xxxx Example: -.9430
X	4	long	X position in Earth-fixed reference frame. Unit in 10^{-2} m
Y	4	long	Y position in Earth-fixed reference frame. Unit in 10^{-2} m
Z	4	long	Z position in Earth-fixed reference frame. Unit in 10^{-2} m

table 6 Orbit state vector

Field	Bytes	Type	Description
X velocity	4	long	X velocity in Earth-fixed reference frame. Unit in 10^{-5} m/s
Y velocity	4	long	Y velocity in Earth-fixed reference frame. Unit in 10^{-5} m/s
Z velocity	4	long	Z velocity in Earth-fixed reference frame. Unit in 10^{-5} m/s

ESA will provide as CFI software:

For NRT:

- GENOPS software & PPFORB (Reference Document 7)ingest DORIS NAVIGATOR
- PPFORB ingest FOS predicted State Vectors to produce State Vector at a user requested time

For Off Line:

- INTERPOL software & PPFORB ingest DORIS preliminary or precise orbit or ESOC restituted to produce State Vector at a user requested time

- EARTH MODEL WGS84 assumed ellipsoid defined by Length of semi major axis, flattening factor Reference Document 8.

table 7 Earth model parameters

Parameter	value
Semi major Axis	6378137 m
Flattening Factor	1/298.257223563

- Steering law identifier: if any change during lifetime of the instrument

3 ASAR PROCESSING REQUIREMENTS

3.1 DEFINITIONS of ASAR Processing Parameters

3.1.1 Level 0 product

As defined in applicable document [A - 2].

3.1.2 Stripline processing

Whenever systematic processing of a data segment is performed, the resulting product segment shall be processed and formatted such that it provides no discontinuity in geometry and radiometry along and across the processed data segment.

Geolocation information and auxiliary data shall be such that users can request extraction of any part of the product segment by multiple of the predefined scene size without any framing constraint on the along track position of the scene within the segment.

3.1.3 Doppler centroid estimate

This is an estimate of that frequency in the Doppler frequency spectrum which has maximum signal power. Due to the geometry and earth rotation this value varies with slant range. It can be estimated to within a PRF ambiguity by an examination of Doppler spectra data attitude information or a Doppler ambiguity estimator is normally used to solve the ambiguity issue.

3.1.4 Doppler ambiguity estimator

When the attitude information is not precise enough or not available to settle the ambiguity issue, a Doppler ambiguity estimator may be used. The estimator uses the offset of the correlation peak after correlating two looks in the range direction. This estimator's performance is terrain dependent and is known to be ineffective over water areas or areas of low contrast

3.1.5 Point target misregistration

3.1.5.1 Absolute Point Target Geometric Misregistration

This is the misregistration of a point target's energy from its assumed zero doppler location caused by approximations in the SAR processor. The zero doppler location of the point target is specified in term of its zero doppler range time and zero doppler azimuth time.

The absolute misregistration is the zero doppler range and azimuth time differences between the measured and expected location of the point target. Misregistration due to orbit data and terrain height error is not included.

3.1.5.2 Relative Point Target Geometric misregistration

This is the relative misregistration between two point targets. It is calculated by substracting the absolute misregistration of the two point targets.

3.1.6 Point target radiometric linearity

The point target linearity is measured by the coefficient of correlation of the regression of output point target peak power over input point target power. It is measured within the point target linear output dynamic range.

3.1.7 Point target linear output dynamic range

The point target linear output dynamic range is the range of the output powers over which processed point target peak power is linearly proportional to input point target power.

3.1.8 SAR processor gain

SAR processor gain is defined as the intercept of a linear regression of point target power (measured in dB) output over point target power (dB) input to the processor.

3.1.9 Range Cell Migration Correction Artifact

The RCMC artifact is the spurious compressed energy that appears on either side of a compressed target. It occurs as a result of amplitude modulation in the corrected target trajectory introduced by RCMC operation.

3.1.10 Missing Range Lines

A missing range line is detected when the line number increments by two or more. A missing range line may also be detected when an incorrect number of frames comprising a range line has been received.

3.1.11 Phase preservation Processing and testing

3.1.11.1 Definition of phase preserving processing;

The processing shall be phase preserving, which means that the following requirements shall be observed:

1) The azimuth reference function (when represented in the time domain) must have a phase equal to zero at its zero Doppler point (time origin) and must not be normalized to the phase at Doppler centroid.

2) The signal spectrum must not be shifted (i.e. no baseband conversion applied). For the azimuth spectrum, this means that it must be left at the Doppler centroid frequency.

3) The processing parameters varying along the scene must be sufficiently updated to avoid the introduction of focusing errors .All corrections and compensations must be performed with the necessary accuracy to avoid focusing errors (for the Range-Doppler algorithm, this implies a proper FM rate update and a perfect range migration compensation).

All data manipulations which lead to phase corruption have to be avoided. (e.g.data rescaling,data aliasing)

4) The Offset Processing Test must be performed with the following results:

- Mean of the interferometric phase ≤ 0.1 degrees

- Standard deviation of the interferometric phase ≤ 5 degrees (the minimum achievable phase noise depends on the inherent SNR of the ASAR system)

- No obvious phase noisy strips shall be observable in the interferogram (in particular, this implies that the structure of the processing blocks shall not be distinguished in the phase noise pattern).

5)The simulated point target test must be performed with the following results:

- The phase error at the correlation peak shall not exceed a systematic phase error of 0.1 degrees.

- The phase of the 2D Fourier transform contains no terms other than linear ones and a constant.

3.1.11.2 Offset processing test description:

Test Principle

Generate two complex products by processing independently twice the same raw data, but starting at different azimuth and range positions (i.e. the products will be shifted by y lines in azimuth and x samples in range).

Using the same raw data prevents from interferometric phase aberrations (phase bias and standard deviation) due to inherent SAR system effects. The obtained interferometric phase should ideally have a constant phase of zero. Thus, detected phase aberrations will reveal processor induced artifacts.

Practical considerations:

a. Both products must be processed using the same Doppler centroid frequency.

b. The number of offset lines and samples between both products should not be an integer multiple of the processing block dimension (nor in azimuth nor in range). Furthermore, if an "overlap & save" technique is used to process the data blocks, the offset value between products should not be either an integer multiple of the number of valid lines (samples in range) of each processed data block.

c. It is recommended that the scene shifts in both directions are chosen in such a way that the relative azimuth and range offset between the products are integer multiples of the azimuth and range sampling intervals respectively. This avoids the coregistration step before interferometry generation, which is critical for the test, since it tends to introduce additional phase noise.

d. The best available chirp should be used to perform the range compression

e. Data manipulations which lead to phase corruption (in particular data rescaling and data resampling by short interpolation kernels) should be avoided. In particular the interferogram should be generated using non rescaled complex products (i.e. with their floating point representation if available), in order to avoid the quantisation noise associated to the rescaling. (Guideline)

f. The interferometric phase analysed must include areas generated from the same processing block for each generated product as well as areas corresponding to consecutive processing blocks. The statistical values should be independently measured over both areas.

g. The test being carried out using real SAR data, those regions with very low backscatter intensity (either due to the local terrain properties or to the shadow effect) should be avoided (since the noise level inside them is already higher in each product of the interferometric pair).

3.1.11.3 Simulated point target test description:

Test principle:
Simulate a raw data scene with a number of point targets at varying range and azimuth positions including processing block boundaries. Process this simulated scene and analyse the peak phases as well as the 2D Fourier Transforms of the focused point targets

3.1.12 Slant to Ground Range Conversion

The image shall be projected on a WGS 84 earth ellipsoid .

3.1.13 Zero Doppler Coordinates

The zero-doppler image coordinate system is further specified by the property that the focused energy of any point target appears in the image at the pixel whose range and absolute time are exactly those of the target when the doppler frequency is 0.This corresponds to the closest point of approach between target and sensor.

Note: Assuming perfect yaw steering each image range-lines thus represent at fixed time the intersection of Earth Surface with that plane which contains both the satellite and the sub-satellite point and which is also orthogonal to the earth satellite relative velocity vector.

3.2 Operational Requirements

3.2.1 Modes of Operation

1. The ASAR Generic Processor(GP) shall have the following modes of operations:

- high resolution processing of ASAR image mode, alternating polarisation mode
- stripline processing of ASAR image mode, wide swath mode, alternating polarisation mode to medium resolution and browse
- stripline processing of ASAR GM mode
- wave mode processing of ASAR Wave mode

to produce from the level 0 data the different products as defined in document [A - 3].

3.3 Input Requirements

3.3.1 Processing parameters

1. The ASAR GP shall receive product generation parameters and the level 0 data. The users parameters (defined in document table 3) are specified by the user before the start of each processing. The processing parameters (defined in document table 2) are extracted and decoded from the Level 0 data.

08 LUG '97 12:12

2. PRF, sampling window start time, Tx pulse parameters shall be extracted from the data contained in the Source Packet Header.

3.3.2 Input Data Type

1. The input Level 0 data to the ASAR GP shall include the following instrument modes;

- Image mode data
- Wide swath mode data
- Alternating polarisation mode data
- Global Monitoring Mode data
- Wave Mode data

3.4 Processing Requirements

3.4.1 Data Decompression

1.The ASAR GP shall uncompress the (I,Q) data compressed on-board the instrument using a Bloc Adaptive Quantisation Scheme described in Reference Document 4

2. the ASAR GP shall perform an ADC nonlinearity correction based on the ADC characterisation LUT given as part of the instrument characterisation data base and described Reference Document 4.

3. The ASAR FBAQ decoding algorithm shall have the option of input /output gain equalisation described in appendix A

The following table summarizes the different compressions used on ASAR:

table 8 Data encoding on ASAR

OPERATIONAL MODE	ECHO	CAL	NOISE
IMAGE	3	5	4
WIDE SWATH	3	5	4
ALTERNATING POLARISATION	3	5	4
WAVE	6	2+5	4
GLOBAL MONITORING	1+2+3	1+2+5	1+2+4
External Characterisation		5	
Module Stepping		5	

1= Analog Filtering, 2 = resampling, 3=quantisation averaging (BAQ 8/4), 4= quantisation sign + magnitude mode, 5=full 8 bit quantisation, 6= quantisation averaging (BAQ 8/2)

3.4.2 Processing Algorithm

The ASAR GP algorithm(s) shall be selected to generate the products within specified product quality parameters described section 4.

3.4.3 SAR imagery Geometric representation

The geometric representation of the SAR imagery shall be the zero Doppler coordinate system.

3.4.4 Phase Preserving

The ASAR_IMS and ASAR_APS processing shall be phase preserving and the processing of ASAR wave mode imagette shall be phase preserving:

1. The CEOS offset processing test shall be passed with the following results:

- the mean of interferogram phase shall be $\leq 0.1 degrees$
- the standard deviation of interferogram phase shall be $\leq 5. degrees$
- there shall be no phase discontinuity (at the boundaries of processing blocks or within a processing block)

2. The simulated point target phase test shall be passed with the following result:

- The phase error at the correlation peak shall not exceed a systematic phase error of 0.1 degrees.
- The phase of the 2D Fourier transform shall contain no terms other than linear ones and a constant.

3.4.5 Interpixel spacing of products

The following requirements are applicable to all products except ASAR_IMS , ASAR_APS and ASAR wave mode imagette

1. Nominal interpixel spacing (defined in image quality requirements tables section 4.3) shall be specified at mid -swath (defined section 2.3.1.3)

2. The across track (slant range) interpixel spacing shall be projected on the WGS84 ellipsoid to the nominal pixel spacing .The error due to Slant Range to Ground Range conversion approximation shall be maintained to better than five meters.

3. Along Track interpixel spacing at Near and Far swath is governed by earth curvature impact relative to mid-swath.

4. For stripline processing the interpixel spacing along track(zero doppler time spacing) defined at mid-swath shall be a fixed time interval whatever the latitude of the acquired scene. The selected time interval shall be a fixed value calculated such that the interpixel spacing at mid-swath is fulfilled at a given latitude.

3.4.6 Stripline Processing

1.The ASAR GP shall be able to operate in stripline processing mode over a ten minutes (10') acquisition segment for the products generated systematically (except wave mode products).

2.The ASAR GP stripline processing shall be compliant with the processor radiometric error as defined Section 4.2.8

3. The ASAR GP stripline processing shall be compliant with the interpixel spacing of products requirements as defined section 3.4.5

3.4.7 Missing Range Lines

The ASAR GP shall insert a line of zeroes when it detects missing lines.

3.4.8 Level 0 Data Analysis

The ASAR GP shall perform Level0 data analysis (I/Q statistics) as described in appendix A after data decompression:

The I and Q data samples shall be analysed to determine the bias, imbalance and phase orthogonality.

3.4.9 Level 0 Data Corrections

The ASAR GP shall perform level 0 data corrections (I/Q corrections) as described in appendix A after data decompression:

Any I and Q echo data bias, imbalance, phase orthogonality shall be corrected using the calculated parameters.

3.4.10 Range spreading loss compensation

1. The ASAR GP shall be able to compensate the range compressed data for range spreading loss

3.4.11 Orbit propagator

1. The ASAR GP shall use the ESA CFI orbit propagator programs to compute the satellite state vectors (3 axis position and velocity) for each product

2. The ASAR GP shall be able to receive from the different sources identified Section 2.3.6 and use state vectors to initialize the propagator.

3.4.12 Range Antenna Patterns Correction

1. The ASAR GP shall be able to perform range antenna patterns correction.

2. The antenna patterns will be provided by ESA in a form of a file.

3. This file will have sufficient vectors such that accurate antenna patterns can be derived by linear interpolation between two vectors (error less than 0.05dB).

4.The ASAR GP shall be able to turn this function on/off on user request.

5. The antenna pattern file shall be annotated in the product.

3.4.13 Sampling Window Start Time Change

The ASAR GP shall be able to detect the sampling window start time change from the source packet header and shift the range line according to the start time change.

3.4.14 Doppler Frequency Modulation Rate Estimator

1. The ASAR GP shall estimate the Doppler (azimuth) FM rate using the satellite position and velocity vectors computed by the Orbit Propagator.

2.The estimate shall be updated in range often enough to give an accuracy of 1 Hz/s or better (SLC products) .The estimate shall be updated in range often enough to fullfill image quality requirements (other products).

3.4.15 Doppler Centroid Estimator

1. The ASAR GP shall employ a Doppler centroid estimator that estimates the centroid based on the azimuth Doppler spectra.

2. The estimator shall use all the data from near range to far range.

3. The estimate shall be updated in azimuth often enough to give an accuracy of 25 Hz (wide swath mode, Alternating Polarisation mode, Global Monitoring Mode and 50 Hz in other modes (Image mode Wave mode)

4. A confidence measure for this Doppler Centroid estimation shall be generated and available for a product confidence report

3.4.16 Doppler Ambiguity Estimator

1. The ASAR GP shall employ a Doppler ambiguity estimator to assess and correct the presence of PRF ambiguities on the Doppler centroid estimate.

2 A confidence measure for this Doppler Ambiguity estimation shall be generated and available for a product confidence report

3.4.17 Range Cell Migration Correction

The ASAR GP shall apply both integer and fractional RCMC to the image data.

3.4.18 Look Detection and Summation

1. the ASAR GP shall detect and sum looks in power.

2. the ASAR GP shall compute the magnitude (by taking the square root) of the look summed data.

3.4.19 Azimuth Interpolation

1. The ASAR GP shall be able to perform azimuth interpolation.(not applicable to ASAR_IMS and ASAR_APS and ASAR_WV1 (imagette) products)

3.4.20 Ground Range Conversion and Interpolation

1. The ASAR GP shall be able to perform ground range conversion to the required pixel spacing.

2. the ASAR GP shall be able to perform interpolation in slant range if ground range conversion is not required. The pixel spacing in slant range shall be such that the resulting image line has a number of pixel equivalent to the ground range image.

3. The slant-range to ground-range conversion table shall be calculated from near range to far range.

4. Interpolation shall be done on adequately sampled data.

5. The ASAR GP shall not perform ground range conversion nor range interpolation when generating ASAR_IMS and ASAR_APS and ASAR_WV1 (imagette) products.

3.4.21 Processing Gain

1. The ASAR GP shall not adjust the gains within a product generation

3.4.22 Analogue-to Digital Converter Non linearity Correction

1. the ASAR GP shall perform an ADC nonlinearity correction based on a non linearity correction table provided as part of the instrument characterisation data base Reference Document 5 and described Reference Document 4.

3.4.23 Internal Calibration processing

The ASAR GP shall perform instrument dependant correction appendix B:

- calibration pulse processing
- elevation gain function calculation
- noise estimation

The ASAR GP shall perform replica construction in view of range processing

3.4.24 Alternating Polarisation Image Co-registration

The ASAR GP shall insure a co-registration of the two images (HH/VV or HH/HV or VV/VH) better than 0.25 pixels

3.4.25 Geocoding processing (IM/AP modes)

1.The ASAR GP shall handle different map projections (UTM,UPS,National Map projections)
2.The absolute calibration of GEC products shall be the same as the corresponding PRI products (ASAR_IMP, ASAR_APP).

3.4.26 Point Target Linear Output Dynamic Range

The point target linear output dynamic range shall be equal to or greater than 48 dB.

3.4.27 Point target relative geometric misregistration

The point target relative geometric misregistration shall be equal to or less than half a pixel length in range or azimuth

3.4.28 Range Matched Filter Generation

1. The range matched filter shall be generated from the chirp replica reconstructed from the downlinked data as described in appendix B or from the nominal chirp coefficients specified as a command parameter.

2. When the range matched filter is to be obtained from the chirp replica reconstructed from the downlinked data, the range matched filter shall be updated as soon a new calibration cycle through the antenna 32 rows is completed.

3. When the range matched filter is to be obtained from the nominal chirp coefficient specified as a command parameter the range reference function shall be calculated from them and used for the entire image.

4. A window weighting function shall be applied to the matched filter .The weighting coefficient shall be selectable.

5.The measurements derived from the cross-correlation of the constructed chirp replicas with the default chirp replicas shall be annotated in the product.

3.5 Output product confidence measures

The following measures shall be included in the PCD attached to each product

3.5.1 Downlink Parameter Confidence

1. The number of changes in the following:

- sampling window start time code
- PRF code
- (TBD) codes

shall be reported for each product.

The code from the first and last processed line shall be reported also.

2. the number of missing lines shall be reported.

3.5.2 Chirp Replica quality

1. 3dB pulse width of the cross correlation result between the reconstructed chirp and the nominal chirp.

2. First Sidelobe of the cross correlation result between the reconstructed chirp and the nominal chirp.

3.Intergrated Sidelobe Ratio of the cross correlation result between the reconstructed chirp and the nominal chirp.

4. Peak location of the cross correlation result between the reconstructed chirp and the nominal chirp.

5. Replica Pulse Power of the reconstructed chirp .

3.5.3 Input data statistic

1. The mean and standard deviation of the I and Q input data shall be computed and reported

3.5.4 Doppler centroid estimator

1. The goodness of fit of the expected and actual beam profile shall be computed and reported

3.5.5 Doppler Ambiguity Estimator Measures

1. The confidence measure of the doppler ambiguity estimation shall be reported.

3.5.6 Output Data Statistic

1. the mean and standard deviation of output data shall be computed and reported.

4 IMAGE QUALITY REQUIREMENTS

4.1 Image Quality Definitions

4.1.1 Weighted theoretical range resolution

The weighted theoretical range resolution is the theoretical distance between the minus 3 dB points of the range IRF from a point target.

The maximum allowed range resolution for slant range image or ground range image is defined as,

$$\rho_r = 0.886(1 + W/100)(1 + x_r/100)(F_s/BW_r)\delta$$

Where

- ρ_r = maximum range resolutiom (meters)
- W = % broadening induced by the weighting used in range compression
- x_r = allowed processor induced percent broadening
- F_s = range sampling rate (Hz)
- BW_r = range look bandwith (Hz)
- δ = pixel spacing which is the slant range or ground range distance between input data sample

The formula for slant range pixel spacing is ,

$\delta_{sr} = c/(2Fs)$

where,

- δ_{sr} = pixel spacing in slant range
- c = speed of the light
- F_s = range sampling frequency

The formula for ground range pixel spacing is

$\delta_{gr} = \delta_{sr}/(\sin\theta)$

where

- δ_{gr} = pixel spacing in ground range (m)
- δ_{sg} = pixel spacing in slant range (m)
- θ = incidence angle in degrees

4.1.2 Weighted theoretical azimuth resolution

The weighted theoretical azimuth resolution is the theoretical distance between the minus 3dB points of the azimuth response from a point target.

The maximum allowed azimuth resolution (for slant range image or ground range image) is defined as,

$$\rho_A = 0.886(1 + W/100)(1 + x_A/100)(F_R/BW_A)\delta_A$$

Where

- ρ_A = maximum azimuth resolutiom (meters)
- W = % broadening induced by the weighting used
- x_A = allowed processor induced azimuth percent broadening
- F_R = pulse repetition frequency (Hz)
- BW_A = azimuth look bandwith (Hz)
- δ_A = azimuth pixel spacing

The formula for azimuth pixel spacing is ,

$$\delta_A = V_g/F_R$$

where,

- δ_A = pixel spacing in azimuth
- V_g = effective transport speed of antenna beam footprint over the Earth surface
- F_R = pulse repetition frequency

4.1.3 Point Target Peak Power

Point target peak power is the maximum power in the interpolated impulse response from a point target.

4.1.4 Maximum side lobe levels

The maximum sidelobe levels are the relative powers in decibels of the maxima in the interpolated impulse response on either side of the main peak, compared to the main peak power. The maximum sidelobe is searched within 15 pixels from the main peak.

4.1.5 Two-Dimensional Integrated Sidelobe Ratio

The two-dimensional Integrated Side Lobe Ratio (ISLR) is the ratio expressed in decibels between the sidelobe power and the main lobe power of the interpolated response from a point target.

The main lobe power is the total power inside an area centred about the main peak and extending two resolution lengths in the range and azimuth directions. The sidelobe power is the total power outside the main lobe but within an area bounded by ten resolution lengths in the range and azimuth directions.

4.1.6 Radiometric Error

The radiometric error is expressed as the maximum permitted deviation in the measured integrated energy between two areas of an image consisting of clusters of closely space point targets. These clusters are to consist of 100 point targets of uniform reflectivity, spaced at nominally 2 resolution cells apart in both range and azimuth direction and arranged in a grid form. The integrated energy for each cluster shall be measured over a region of fixed size chosen to fully and exclusively encompass the target of each cluster. As a minimum, the area chosen shall extend at least three resolution cells beyond the center of the last target of the cluster in that direction and no closer than three resolution cells to any other point target not in the cluster.

The radiometric error is calculated as follows:

$$\rho = |\mu_A - \mu_B|$$

where,

ρ = radiometric error (dB)

μ_A = integrated energy of area A

μ_B = integrated energy of area B

4.1.7 Absolute location accuracy

The absolute location error is specified as the distance along the ground between measured and predicted position of point targets within a processed image independent of orbit data .

The requirement is stated as a procedure for calculating the absolute location error of a point target and the maximum error permitted.

The predicted latitude and longitude of the point targets must be known.

The measured latitude and longitude is obtained from the processed image by measuring the range and azimuth pixel position .

4.1.8 Product ENL (Radiometric Resolution)

The radiometric resolution of the final processed image is a measure of the ability to distinguish between uniform distributed targets with different backscattering coefficients (sigma nought).

Its standard definition is the measure of the width of the probability distribution function of the signal power received from an uniform distributed target:

$$\Upsilon = 10\log(1 + q_r)$$

where the parameter q_r is the normalised standard deviation (or coefficient of variation) of the value of the signal power of a uniform distributed target.

$$q_r = \frac{\sigma}{\mu}$$

μ and σ are the sample mean and standard deviation of the signal power in the image of an homogeneous distributed target

The distributed target shall be uniform (without spatial variability of the sigma nought) and large enough to ensure statistical accuracy.

The normalised standard deviation q_r is related to the Equivalent Number of Looks *ENL* by the following equation:

$$ENL = \frac{1}{q_r^2}$$

4.1.9 Radiometric Accuracy

The radiometric accuracy is defined as the end to end error in the final image products. It includes the ASAR processor radiometric error ,all the ASAR instrument errors, propagation errors target fluctuations.

For an extended target the radiometric accuracy is defined as the worst case 3σ (three-standard deviation) uncertainty resulting from measurements of sigma nought of a uniform invariant extended target situated anywhere within the operating dynamic range of the system, anywhere in the swath and anywhere in the orbit.

For a point target the radiometric accuracy is defined as the worst case 3σ (three standard deviation)uncertainty resulting from measurements of radar cross section of invariant point target situated anywhere within the operating dynamic range of the system, anywhere in the swath and anywhere in the orbit.

The radiometric accuracy value is 1.75 dB .

4.2 Image Quality Requirements

4.2.1 Measurement

1. Image quality measures shall be done on simulated point targets.

2. Image quality parameters measurements is subject to uncertainty due to quantisation effect. The uncertainty shall be kept to:

- Impulse response ±4 %
- Maximum sidelobe level ±1 dB
- Integrated sidelobe ratio ±1 dB
- Peak power ±0.5 dB

by ensuring the specified processing parameters do not cause aliasing.

4.2.2 Range Impulse resolution

The range impulse resolution shall be less than or equal to 1.1 times the weighted theoretical range resolution (Image mode and Wave Mode)

The range impulse resolution shall be less than or equal to 1.1 times the weighted theoretical range resolution (Wide Swath mode,Alternating Polarisation Mode and Global Monitoring Mode)

4.2.3 Azimuth Impulse resolution

The azimuth impulse response resolution shall be less than or equal to 1.1 times the weighted theoretical azimuth resolution (Image mode and Wave Mode)

The azimuth impulse response resolution shall be less than or equal to 1.1 times the weighted theoretical azimuth resolution (Wide Swath mode,Alternating Polarisation Mode and Global Monitoring Mode)

4.2.4 Range/ Azimuth Maximum sidelobe levels

The range or azimuth maximum sidelobe levels shall not be higher than 2dB plus the theoretical side lobe level.

4.2.5 Two dimensional Integrated Sidelobe Ratio

The two dimensional ISLR shall be less than or equal to 2dB plus the theoretical two dimensional ISLR.

4.2.6 Point target linearity

The coefficient of correlation of the regression of output point target power over input point target power over the linear dynamic range shall be greater than 0.97

4.2.7 Absolute location accuracy (independent of orbit data)

The absolute location accuracy of a point target shall be equal to or less than two nominal pixel lengths.

4.2.8 Ground Processor Radiometric Error

The ground processor radiometric error shall be equal to or less than 0.1 dB in IM and wave mode and shall be equal to or less than 0.2 dB in WS, GM, and AP modes.

4.3 Image Quality Requirements Tables

The following tables are a summary of processing parameters, image quality requirements and nominal attributes for each of the required output products.

Image quality shall meet the requirements in these tables.

The processing parameters shall be configurable in the ASAR processor and the values quoted there are just initial values.

The processing parameters shall be optimised during the ASAR processing development.

4.3.1 ASAR_IMS Image Quality requirements

ASAR_IMS Image Quality requirements	
PROCESSING PARAMETERS	
pulse bandwith(IS1 to IS7(Mhz))	16/16/12.67/10.79/9.54/8.85/8.22
Number of range looks	1
Range weighting	To Be Optimised
Number of azimuth looks	1
Azimuth look Bandwith	1332 Hz (To Be Optimised)
Azimuth sampling frequency(IS1 to IS7 (Hz))	1677/1645/2096-2070/1680-1667/ 2082-2047/1698-1684/2070-2035
Azimuth weighting	To Be Optimised
Nominal Incidence angle	section 2.3.1.3
IMAGE QUALITY REQUIREMENTS	
Range IRF broadening	10%
Azimuth IRF broadening	10%
PSLR degradation	2dB
ISLR degradation	2dB
Radiometric error	0.1dB
Radiometric linearity	0.97
Absolute location Accuracy	10m
Point target phase error test	< 0.1 degrees
Offset processing test: mean & standard deviation interferogram phase	mean < 0.1 degrees standard deviation < 5 degrees
PRODUCT QUALITY REQUIREMENTS	
Range resolution	Section 4.1.1
Azimuth resolution	Section 4.1.2
Pixel Spacing	Natural sampling
Pixel Encoding	2 bytes I , 2 bytes Q

4.3.2 ASAR_APS Image Quality requirements

ASAR_APS Image Quality requirements	
PROCESSING PARAMETERS	
Pulse bandwith(IS1 to IS7(Mhz))	16/16/12.67/10.79/9.54/8.85/8.22
Number of range looks	1
Range weighting	To Be Optimised
Number of azimuth looks	2 scan looks per polarisation
Azimuth look Bandwith	254 Hz (approximate)
Azimuth sampling frequency (IS1 to IS7 (Hz))	1677/1645/2096-2070/1680-1667/ 2082-2047/1698-1684/2070-2035
Azimuth weighting	To Be Optimised
Nominal Incidence angle	section 2.3.1.3
IMAGE QUALITY REQUIREMENTS	
Range IRF broadening	10%
Azimuth IRF broadening	10%
PSLR degradation	2dB
ISLR degradation	2dB
Radiometric error	0.2dB
Radiometric linearity	0.97
Absolute location Accuracy	10m
Point target phase error test	< 0.1 degrees
Offset processing test: mean & standard deviation interferogram phase	mean < 0.1 degrees standard deviation < 5 degrees
PRODUCT QUALITY REQUIREMENTS	
Range resolution	Section 4.1.1
Azimuth resolution	Section 4.1.2
Pixel Spacing	multiple of natural sampling
Pixel Encoding	2 bytes I , 2 bytes Q

4.3.3 ASAR_WV1 Imagette Image Quality requirements

ASAR_WV1 Imagette Image Quality requirements	
PROCESSING PARAMETERS	
pulse bandwith(IS1 to IS7(Mhz))	16/16/12.67/10.79/9.54/8.85/8.22
Number of range looks	1
Range weighting	To Be Optimised
Number of azimuth looks	1
Azimuth look Bandwith	1332 Hz
Azimuth sampling frequency(IS1 to IS7 (Hz))	1677/1645/2096-2070/1680-1667/ 2082-2047/1698-1684/2070-2035
Azimuth weighting	To Be Optimised
Nominal Incidence angle	section 2.3.1.3
IMAGE QUALITY REQUIREMENTS	
Range IRF broadening	10%
Azimuth IRF broadening	10%
PSLR degradation	2dB
ISLR degradation	2dB
Radiometric error	0.1dB
Radiometric linearity	0.97
Absolute location Accuracy	10m
Point target phase error test	< 0.1 degrees
Offset processing test: mean & standard deviation interferogram phase	mean < 0.1 degrees standard deviation < 5 degrees
PRODUCT QUALITY REQUIREMENTS	
Range resolution	Section 4.1.1
Azimuth resolution	Section 4.1.2
Pixel Spacing	Natural sampling
Pixel Encoding	2 bytes I , 2 bytes Q

4.3.4 ASAR_IMP Image Quality requirements

ASAR_IMP Image Quality requirements	
PROCESSING PARAMETERS	
Pulse bandwith(IS1 to IS7(Mhz))	16/16/12.67/10.79/9.54/8.85/8.22
Number of Range looks	1
Range weighting	To Be Optimised
Azimuth look Bandwith Hz	320 null to null
Number of Azimuth looks	3 non overlapping looks
Azimuth sampling frequency (IS1 to IS7 (Hz))	1677/1645/2096-2070/1680-1667/ 2082-2047/1698-1684/2070-2035
Azimuth weighting	To Be Optimised
Nominal Incidence angle	section 2.3.1.3
IMAGE QUALITY REQUIREMENTS	
Range IRF broadening	10%
Azimuth IRF broadening	10%
PSLR degradation	2dB
ISLR degradation	2dB
Radiometric error	0.1dB
Radiometric linearity	0.97
Absolute location Accuracy	25 m
PRODUCT QUALITY REQUIREMENTS	
Range resolution	< 30m
Azimuth resolution	<30m
Pixel Spacing	12.5m*12.5m
PRODUCT ENL	>3
Pixel encoding	2 bytes

4.3.5 ASAR_APP Image Quality requirements

ASAR_APP Image Quality requirements	
PROCESSING PARAMETERS	
Pulse bandwith(IS1 to IS7(Mhz))	16/16/12.67/10.79/9.54/8.85/8.22
Number of Range looks	1
Range weighting	To Be Optimised
Azimuth look Bandwith (Hz)	254 Hz (To Be Optimised)
Number of Azimuth scan looks	2
Azimuth sampling frequency (IS1 to IS7 (Hz))	1677/1645/2096-2070/1680-1667/ 2082-2047/1698-1684/2070-2035
Azimuth weighting	To Be Optimised
Nominal Incidence angle	section 2.3.1.3
IMAGE QUALITY REQUIREMENTS	
Range IRF broadening	10%
Azimuth IRF broadening	10%
PSLR degradation	2dB
ISLR degradation	2dB
Radiometric error	0.2dB
Radiometric linearity	0.97
Absolute location Accuracy	25 m
PRODUCT QUALITY REQUIREMTS	
Range resolution	< 30m
Azimuth resolution	<30m
Pixel Spacing	12.5m*12.5m
PRODUCT ENL	>1.8
Pixel encoding	2 bytes

4.3.6 ASAR_IMG Image Quality requirements (Requirements identical to ASAR_IMP)

4.3.7 ASAR_APG Image Quality requirements (Requirements identical to ASAR_APP)

4.3.8 ASAR_WSM Image Quality requirements

ASAR_WSM Image Quality requirements	
PROCESSING PARAMETERS	
Pulse bandwith (SS1 to SS5(Mhz))	7.1/5.28/4.36/2.97/2.8 (TBC*) To Be Optimised
Number of Range looks	To Be Optimised
Range weighting	To Be Optimised
Azimuth look Bandwith (Hz)	50
Number of Azimuth Scan looks	3
Azimuth sampling frequency (SS1 to SS5 (Hz))	1662-1659/2096-2070/1680-1667/ 2082-2047/1698-1684
Azimuth weighting	To Be Optimised
Nominal Incidence angle	section 2.3.1.3
IMAGE QUALITY REQUIREMENTS	
Range IRF broadening	10%
Azimuth IRF broadening	10%
PSLR degradation	2dB
ISLR degradation	2dB
Radiometric error	0.2dB
Radiometric linearity	0.97
Absolute location Accuracy	150 m
PRODUCT QUALITY REQUIREMTS	
Range resolution	< 150m
Azimuth resolution	<150m
Pixel Spacing	75m*75m
PRODUCT ENL	>15 (TBC*)
Pixel Encoding	2 bytes

Note *: Pulse Bandwidth and Product ENL are linked together

08 LUG '97 13:31

4.3.9 ASAR_GM1 Image Quality requirements

ASAR_GM1 Image Quality requirements	
PROCESSING PARAMETERS	
Pulse bandwith (SS1 to SS5(Mhz))	0.941/0.627/0.565/0.502/0.439 (TBC*) To Be Optimised
Number of Range looks	To Be Optimised
Range weighting	To Be Optimised
Azimuth look Bandwith (Hz)	9Hz
Number of Azimuth Scan looks	4
Azimuth sampling frequency (SS1 to SS5 (Hz))	1662-1659/2096-2070/1680-1667/ 2082-2047/1698-1684
Azimuth weighting	To Be Optimised
Nominal Incidence angle	section 2.3.1.3
IMAGE QUALITY REQUIREMENTS	
Range IRF broadening	10%
Azimuth IRF broadening	10%
PSLR degradation	2dB
ISLR degradation	2dB
Radiometric error	0.2dB
Radiometric linearity	0.97
Absolute location Accuracy	1000 m
PRODUCT QUALITY REQUIREMTS	
Range resolution	< 1000m
Azimuth resolution	<1000m
Pixel Spacing	500m*500m
PRODUCT ENL	>15 (TBC*)
Pixel encoding	2 bytes

Note *: Pulse Bandwidth and Product ENL are linked together

4.3.10 ASAR_IMM Image Quality requirements

ASAR_IMM Image Quality requirements	
PROCESSING PARAMETERS	
pulse bandwith(IS1 to IS7(Mhz))	16/16/12.67/10.79/9.54/8.85/8.22
Number of Range looks	To Be Optimised
Range weighting	To Be Optimised
Azimuth look Bandwith Hz	To Be Optimised
Number of Azimuth looks	To Be Optimised
Azimuth sampling frequency (IS1 to IS7 (Hz))	1677/1645/2096-2070/1680-1667/ 2082-2047/1698-1684/2070-2035
Azimuth weighting	To Be Optimised
Nominal Incidence angle	section 2.3.1.3
IMAGE QUALITY REQUIREMENTS	
Range IRF broadening	10%
Azimuth IRF broadening	10%
PSLR degradation	2dB
ISLR degradation	2dB
Radiometric error	0.1dB
Radiometric linearity	0.97
Absolute location Accuracy	150 m
PRODUCT QUALITY REQUIREMTS	
Range resolution	< 150m
Azimuth resolution	<150m
Pixel Spacing	75m*75m
PRODUCT ENL	>30
Pixel encoding	2 bytes

4.3.11 ASAR_APM Image Quality requirements

ASAR_APM Image Quality requirements	
PROCESSING PARAMETERS	
pulse bandwith(IS1 to IS7(Mhz))	16/16/12.67/10.79/9.54/8.85/8.22
Number of Range looks	To Be Optimised
Range weighting	To Be Optimised
Azimuth look Bandwith Hz	To Be Optimised
Number of Azimuth looks	To Be Optimised
Azimuth sampling frequency (IS1 to IS7 (Hz))	1677/1645/2096-2070/1680-1667/ 2082-2047/1698-1684/2070-2035
Azimuth weighting	To Be Optimised
Nominal Incidence angle	section 2.3.1.3
IMAGE QUALITY REQUIREMENTS	
Range IRF broadening	10%
Azimuth IRF broadening	10%
PSLR degradation	2dB
ISLR degradation	2dB
Radiometric error	0.1dB
Radiometric linearity	0.97
Absolute location Accuracy	150 m
PRODUCT QUALITY REQUIREMTS	
Range resolution	< 150m
Azimuth resolution	<150m
Pixel Spacing	75m*75m
PRODUCT ENL	>30
Pixel encoding	2 bytes

4.3.12 ASAR Browse quality requirements

Table 9: Browse products quality requirements

ASAR mode	Global Monitoring	Wide Swath	Image Mode	Alternating Polarisation
Pixel Spacing (m)	1000	900*	225*	225*
Product ENL	> 15(TBC)	> 15	>15	>15

Note *Multiple of Medium Resolution Products pixel spacing

appendix AData Handling and Data Reformatting

A.1 Raw Data Correction

The ASAR GP is required to perform raw data analysis and use the result to perform raw data correction. The raw data correction is done as follows:

- Correct for bias:

$$I' = I_{in} - Bi$$

$$Q' = Q_{in} - Bq$$

where:

I_{in} , Q_{in} = complex input data after nominal bias is subtracted

Bi = I-channel bias

Bq = Q-channel bias

- Correct Q-channel for gain imbalance:

$$I'' = I'$$

$$Q'' = Q' G$$

where G is the IQ gain imbalance.

- Correct Q-channel for nonorthogonality:

$$Iout = I''$$

$$Qout = Q''/\cos(A) - I''\tan(A)$$

where A is the IQ quadrature departure.

08 AUG '97 13:32

The input parameters and flag for raw data analysis and correction are:

Parameters and Flag	Symbols
Raw data analysis flag	
I-channel bias preset value	bi
Q-channel bias preset value	bq
IQ gain imbalance preset value	g
IQ quadrature departure preset value	a
No of range lines to be used in raw data analysis	N
No of complex samples per line	M

The output parameters and flags from raw data analysis are:

Parameters and Flag	Symbols
I-channel bias	μi
Q-channel bias	μq
I-channel standard deviation	σi
Q-channel standard deviation	σq
IQ gain imbalance	τ
IQ gain lower bound	$\tau 1$
IQ gain upper bound	$\tau 2$
IQ quadrature departure	θ
IQ quadrature departure lower bound	$\theta 1$
IQ quadrature departure upper bound	$\theta 2$
I bias significant flag	I_BIAS_FLAG
Q bias significant flag	Q_BIAS_FLAG
IQ gain significant flag	IQ_GAIN_SIG_FLAG
IQ quadrature departure significant flag	IQ_QUAD_SIG_FLAG

The specifications for calculating the output parameters and flags are given below.

I-channel bias:

$$\mu i = \left[\frac{1}{NM}\sum_{k=1}^{N}\sum_{j=1}^{M} I_j\right] - b_{nom}$$

where:

N = number of lines used

M = number of pixels used per line

b_{nom} = nominal bias

Q-channel bias:

$$\mu q = \left[\frac{1}{NM}\sum_{k=1}^{N}\sum_{j=1}^{M} Q_j\right] - b_{nom}$$

I-channel standard deviation:

$$\sigma i = \sqrt{\frac{1}{NM}\sum_{k=1}^{N}\sum_{j=1}^{M} I_j^2 - (\mu i + b_{nom})^2}$$

Q-channel standard deviation:

$$\sigma q = \sqrt{\frac{1}{NM}\sum_{k=1}^{N}\sum_{j=1}^{M} Q_j^2 - (\mu q + b_{nom})^2}$$

IQ gain imbalance:

$$\tau = \frac{\sigma i}{\sigma q}$$

IQ gain lower bound:

$$\tau 1 = 1 - \frac{3}{\sqrt{NM}}$$

IQ gain upper bound:

$$\tau 2 = 1 + \frac{3}{\sqrt{NM}}$$

IQ quadrature departure, upper and lower bounds θ, θ1, θ2:

For each range line k, calculate the correlation coefficient between I and Q channels:

$$ck = \frac{Siq}{\sqrt{Sii \cdot Sqq}}$$

where:

$$Siq = \sum_{j=1}^{M} (I_j \cdot Q_j) - \left(\frac{1}{M}\sum_{j=1}^{M} I_j \sum_{j=1}^{M} Q_j\right)$$

$$Sii = \sum_{j=1}^{M} (I_j^2) - \left(\frac{1}{M}\sum_{j=1}^{M} I_j \sum_{j=1}^{M} I_j\right)$$

$$Sqq = \sum_{j=1}^{M} (Q_j \cdot Q_j) - \left(\frac{1}{M}\sum_{j=1}^{M} Q_j \sum_{j=1}^{M} Q_j\right)$$

From the correlation coefficient ck, calculate Zk as follows:

$$Zk = 0.5\ln\left(\frac{1+ck}{1-ck}\right)$$

From the N values of Zk (derived from N range lines) calculate

- the mean value of Z:

$$\mu z = \frac{1}{N}\sum_{k=1}^{N} Zk$$

- the standard deviation of Z:

$$\sigma z = \sqrt{\frac{1}{N}\sum_{k=1}^{N} Zk^2 - \mu z^2}$$

$C = \tanh \mu z$

$\sigma+ = \tanh(\mu z + \sigma z) - C$

$\sigma- = C - \tanh(\mu z - \sigma z)$

$\theta = \arcsin(C)$

$\theta 1 = \arcsin(C - \sigma-)$

$\theta 2 = \arcsin(C + \sigma+)$

I Bias Significant Flag:

$$IF \qquad \frac{-3\sigma i}{\sqrt{NM}} \le \mu i \le \frac{3\sigma i}{\sqrt{NM}} \qquad THEN$$

set flag = .FALSE. ELSE set flag = .TRUE.

Q Bias Significant Flag:

$$IF \quad \frac{-3\sigma q}{\sqrt{NM}} \leq \mu q \leq \frac{3\sigma q}{\sqrt{NM}} \quad THEN$$

set flag = .FALSE. ELSE set flag = .TRUE.

IQ Gain Significant Flag:

$$IF \quad \tau 1 \leq \tau \leq \tau 2 \quad THEN$$

set flag = .FALSE. ELSE set flag = .TRUE.

IQ Quadrature Departure Significant Flag:

$$IF \quad 3\sigma - \quad \leq C \leq 3\sigma + \quad THEN$$

set flag = .FALSE. ELSE set flag = .TRUE.

The parameters for raw data correction are set according to the raw data analysis flag as follows:

Raw Data Analysis Flag is FALSE	Raw Data Analysis Flag is TRUE
Bi = bi	Bi = μi
Bq = bq	Bq = μq
G = g	G = τ
A = a	A = θ

The output parameters and flags from raw data analysis are inserted in the product annotation. If the raw data analysis flag is FALSE, these parameters and flags are set as follows:

Parameters and Flag	Raw Data Analysis Flag is FALSE
I-channel bias	bi
Q-channel bias	bq
I-channel standard deviation	0.0
Q-channel standard deviation	0.0
IQ gain imbalance	g
IQ gain lower bound	0.0
IQ gain upper bound	0.0
IQ quadrature departure	a
IQ quadrature departure lower bound	0.0
IQ quadrature departure upper bound	0.0
I bias significant flag	.FALSE.
Q bias significant flag	.FALSE.
IQ gain significant flag	.FALSE.
IQ quadrature departure significant flag	.FALSE.

A.2 FBAQ DECODING

A.2.1 Standard Decoding

Described in document [R - 4]

A.2.2 Energy conservation Decoding

Described document [R - 9]

appendix B: Internal Calibration and Chirp Replica Processing

1 Objective

The objective of the internal calibration function is to process the calibration pulses,and to provide instrument dependent correction factors (i.e. elevation gain factor, noise estimation), which are used elsewhere in the ground processing to produce a calibrated image.

The elevation gain function calculation results in the determination of the elevation gain factor.

The phase and amplitude of the compressed calibration pulses from each row of modules is used to calculate the antenna gain as a function of elevation. This is then converted to a function of look angle by use of the elevation bias characterisation data. The orbit geometry and earth model shall be used to convert it to a function dependent on slant range.

The internal calibration scheme involves characterising the active part of the antenna on a row by row basis for both transmit and receive, using calibration pulses. As the replica must represent the response from the complete antenna, this part of the ground processing is assumed to generate the replica from the calibration pulses by coherent summations.

The I/Q corrected noise data is used to estimate the instrument noise power within the image. The noise data is scaled by a factor representing any normalisation that may have been used in the data processing.

2 Detail Structure

The detailed structure of the internal calibration function is shown in Figure 1. The rationale for the internal calibration function is given in Reference 2

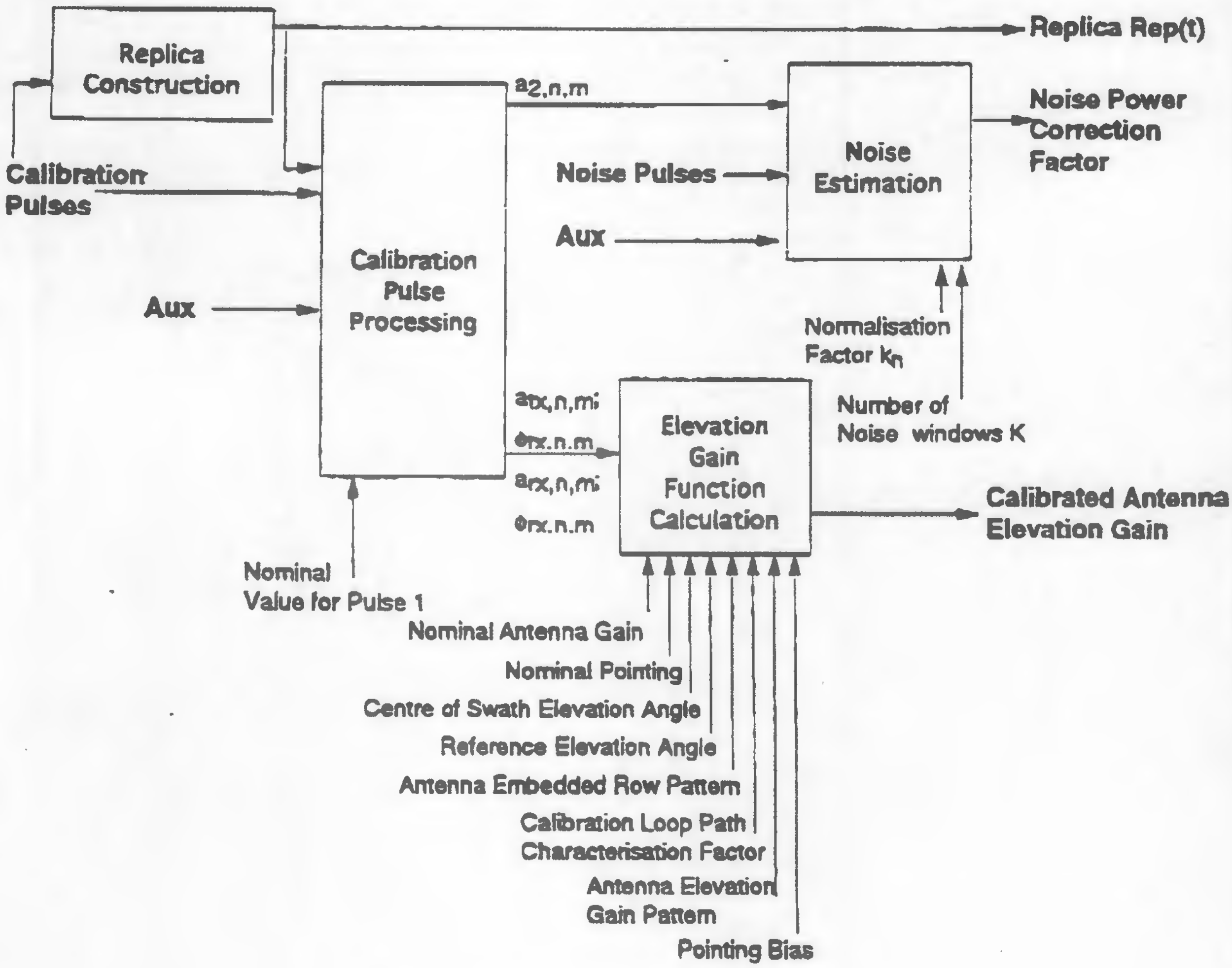

Figure 1 Internal Calibration

3 Definition of Variable(s)

The variables are defined in Table 1

VARIABLES	DESCRIPTIVE NAME	INPUT/OUTPUT	VALUE/UNITS/REFERENCE
$Z_{1,n,m}(t)$	Calibration pulse 1 complex sample	Input	From Data handling and reformatting
$Z_{1A,n,m}(t)$	Calibration pulse 1A complex sample	Input	From Data handling and reformatting
$Z_{2,n,m}(t)$	Calibration pulse 2 complex sample	Input	From Data handling and reformatting
$Z_{3,n,m}(t)$	Calibration pulse 3 complex sample	Input	From Data handling and reformatting
$Z_{w1,m}(t)$	Chirped calibration pulse 1 complex sample	Input	From Data handling and reformatting (only wave mode)
$Z_{w2,m}(t)$	Chirped calibration pulse 2 complex sample	Input	From Data handling and reformatting (only wave mode)
$Z_{w3,m}(t)$	Chirped calibration pulse 3 complex sample	Input	From Data handling and reformatting (only wave mode)
$Z_{N,k,m}(t)$	Noise complex sample	Input	From Data handling and reformatting
n	Antenna row number	Input	From Data handling and reformatting (Values 1-32)
m	Calibration cycle label	Input	From Data handling and reformatting
SWL(cal)	Sampling window length (of calibration pulses)	Input	From Data handling and reformatting [given in number of samples]
SWL(noise)	Sampling window length (of noise pulses)	Input	From Data handling and reformatting [given in number of samples]
t	Time variable within sampling window	Input	From Data handling and reformatting (Values $t=t_0,\ldots t_{SWL-1}$)
k	Noise sample window label	Input	From Data handling and reformatting
a_1(nom)	Nominal value of a_1	Input	From instrument data
f_o	Offset frequency for wave mode calibration data	Input	From instrument data
$G_e()$	Elevation gain pattern	Input	From instrument data
$G_2(_o)_{nom}$	Nominal value of $G_2(_o)$	Input	From instrument data

Table 1 Internal Calibration Variables

VARIABLES	DESCRIPTIVE NAME	INPUT/OUTPUT	VALUE/UNITS/REFERENCE
P	Nominal elevation pointing of antenna mechanical boresight	Constant	26.2°
P_1	Elevation pointing bias estimate		From External Characterisation
$P_{at}(m)$	Auxiliary transmit power measurement	Input	From data handling and reformatting
k_n	Normalisation factor to image pixel for instrument noise measurement	Input	Processor design dependent
K	Number of noise windows averaged	Constant	8
s	Centre of swath elevation angle	Input	From instrument data
o	Reference elevation angle	Input	From instrument data
$f_{n,p}()$	Complex factor characterising the path through the calibration loop and from the calibration coupler to the antenna face for row n, polarisation p	Input	From instrument data
$g_{n,p}$	Calibration loop paths characterisation factors relative to free space	Input	From External Characterisation
p_t	Label for Tx polarisation	Input	p_t=0:V from data Handling p_t=1:H and Formatting
p_r	Label for Rx polarisation	Input	p_r=0:V from data Handling p_r=1:H and Formatting
	Pulse length	Input	From data handling and reformatting
$a_{1,n,nom}$;$a_{2,n,nom}$; $a_{3,n,nom}$;$\varnothing_{1,n,nom}$; $\varnothing_{2,n,nom}$;$\varnothing_{3,n,nom}$;	Nominal values for amplitudes and phases of calibration pulses 1, 2 and 3	Input	From instrument data
Rep(t)	Replica	Output	
$G_{2,mT}(L)$	Calibrated antenna elevation gain as a function of the look elevation angle	Output	
N	Noise power correction factor	Output	

Table 1 Internal Calibration Variables (Continued)

4 Equation(s)

Note the following equations apply separately for each swath, sub-swath and polarisation.

4.1 Calibration Pulse Processing

The processor shall:
Calculate amplitude of each sample for each calibration pulse for the m^th^ cycle of calibration data:

$$a_{1,n,m}(t) = \left[Z^2_{I,1,n,m}(t) + Z^2_{Q,1,n,m}(t)\right]^{\frac{1}{2}}$$

$$a_{1A,n,m}(t) = \left[Z^2_{I,1A,n,m}(t) + Z^2_{Q,1A,n,m}(t)\right]^{\frac{1}{2}}$$

$$a_{2,n,m}(t) = \left[Z^2_{I,2,n,m}(t) + Z^2_{Q,2,n,m}(t)\right]^{\frac{1}{2}}$$

$$a_{3,n,m}(t) = \left[Z^2_{I,3,n,m}(t) + Z^2_{Q,3,n,m}(t)\right]^{\frac{1}{2}}$$

For wave mode:

$$Z_{I,3,n,m}(t) = Z_{I,3,1,m}(t), \text{ All n}$$

$$Z_{Q,3,n,m}(t) = Z_{Q,3,1,m}(t), \text{ All n}$$

In the above equations Z_I and Z_Q are the I, Q components of Z.
For pulses 1, 2 and 3, find the largest amplitude, ie

$$a_{1,n,m}(\max) = \text{greatest of } a_{1,n,m}(t)$$

$$a_{2,n,m}(\max) = \text{greatest of } a_{2,n,m}(t)$$

$$a_{3,n,m}(\max) = \text{greatest of } a_{3,n,m}(t)$$

For pulses 1, 2 and 3, average those amplitude samples which are greater than a given proportion k = 0.707 of the peak value (those which are within 3 dB of the peak), ie:

$$a_{1,n,m} = \frac{1}{N_1} \sum_{t=t_{I_1}}^{t_{I_1+N_1-1}} a_{1,n,m}(t)$$

where $a_{1,n,m}(t_{I_1-1}) \le k \cdot a_{1,n,m}(\max) < a_{1,n,m}(t_{I_1})$ and

$$a_{1,n,m}(t_{I_1+N_1}) \le k \cdot a_{1,n,m}(\max) < a_{1,n,m}(t_{I_1+N_1-1}).$$

$$a_{2,n,m} = \frac{1}{N_2} \sum_{t=t_{I_2}}^{t_{I_2+N_2-1}} a_{2,n,m}(t)$$

where $a_{2,n,m}(t_{I_2-1}) \leq k \cdot a_{2,n,m}(\max) < a_{2,n,m}(t_{I_2})$ and

$$a_{2,n,m}(t_{I_2+N_2}) \leq k \cdot a_{2,n,m}(\max) < a_{2,n,m}(t_{I_2+N_2-1}).$$

$$a_{3,n,m} = \frac{1}{N_3} \sum_{t=t_{I_3}}^{t_{I_3+N_3-1}} a_{3,n,m}(t)$$

where $a_{3,n,m}(t_{I_3-1}) \leq k \cdot a_{3,n,m}(\max) < a_{3,n,m}(t_{I_3})$ and

$$\hat{a}_{3,n,m}(t_{I_3+N_3}) \leq k \cdot a_{3,n,m}(\max) < a_{3,n,m}(t_{I_3+N_3-1}).$$

For pulse 1A, average amplitude samples over the sample window, ie:

$$a_{1A,n,m} = \frac{1}{SWL(cal)} \sum_{t=t_0}^{t_{SWL(cal)-1}} a_{1A,n,m}(t)$$

Except in wave mode, the processor shall compress calibration pulses prior to phase extraction:

$$Z'_{1,n,m}(t) = \int_{-\tau/2}^{+\tau/2} Rep^*(t') \cdot Z_{1,n,m}(t+t')\, dt$$

$$Z'_{1A,n,m}(t) = \int_{-\tau/2}^{+\tau/2} Rep^*(t') \cdot Z_{1A,n,m}(t+t')\, dt$$

$$Z'_{2,n,m}(t) = \int_{-\tau/2}^{+\tau/2} Rep^*(t') \cdot Z_{2,n,m}(t+t')\, dt$$

$$Z'_{3,n,m}(t) = \int_{-\tau/2}^{+\tau/2} Rep^*(t') \cdot Z_{3,n,m}(t+t')\, dt$$

Find the largest amplitude sample for each pulse, ie:

$$|Z'_{1,n,m}(\max)| = \text{greatest of } |Z'_{1,n,m}(t)|$$

$$|Z'_{1A,n,m}(\max)| = \text{greatest of } |Z'_{1A,n,m}(t)|$$

$$|Z'_{2,n,m}(\max)| = \text{greatest of } |Z'_{2,n,m}(t)|$$

$$|Z'_{3,n,m}(\max)| = \text{greatest of } |Z'_{3,n,m}(t)|$$

In wave mode, the processor shall correlate the pulses with a complex sinusoid at the offset frequency f_0 prior to phase extraction, i.e.:

$$Z'_{1,n,m}(\max) = \int_{-\tau/2}^{+\tau/2} \exp(-j2pf_0 t) \cdot Z_{1,n,m}(t)\, dt$$

$$Z'_{1A,n,m}(\max) = \int_{-\tau/2}^{+\tau/2} \exp(-j2pf_0 t) \cdot Z_{1A,n,m}(t)\, dt$$

$$Z'_{2,n,m}(\max) = \int_{-\tau/2}^{+\tau/2} \exp(-j2pf_0 t) \cdot Z_{2,n,m}(t)\, dt$$

$$Z'_{3,n,m}(\max) = \int_{-\tau/2}^{+\tau/2} \exp(-j2pf_0 t) \cdot Z_{3,n,m}(t)\, dt$$

Extract the phase for each pulse, ie:

$$\varnothing_{1,n,m} = \mathrm{ftan}\left[\frac{Z'_{Q,1,n,m}(\max)}{Z'_{I,1,n,m}(\max)}\right]$$

$$\varnothing_{1A,n,m} = \mathrm{ftan}\left[\frac{Z'_{Q,1A,n,m}(\max)}{Z'_{I,1A,n,m}(\max)}\right]$$

$$\varnothing_{2,n,m} = \mathrm{ftan}\left[\frac{Z'_{Q,2,n,m}(\max)}{Z'_{I,2,n,m}(\max)}\right]$$

$$\varnothing_{3,n,m} = \mathrm{ftan}\left[\frac{Z'_{Q,3,n,m}(\max)}{Z'_{I,3,n,m}(\max)}\right]$$

where

$$
\mathrm{ftan}\left[\frac{y}{x}\right]=\begin{cases}\arctan\left[\frac{y}{x}\right] & x>0\\ p+\arctan\left[\frac{y}{x}\right] & x<0,\ y\geq 0\\ \arctan\left[\frac{y}{x}\right]-p & x<0,\ y\leq 0\\ \frac{p}{2} & x=0,\ y>0\\ -\frac{p}{2} & x=0,\ y<0\\ 0 & x=0,\ y=0\end{cases}
$$

Adjust pulse 1 measurements for pulse 1A measurements, and normalise, ie:

$$
a_{tx,n,m}\exp(j\varnothing_{tx,n,m})=\left[a_{1,n,m}\exp(j\varnothing_{1,n,m})-a_{1A,n,m}\exp(j\varnothing_{1A,n,m})\right]/a_1(\mathrm{nom})
$$

Normalise pulse 2 measurements to pulse 3 measurements, ie:

$$
a_{rx,n,m}=a_{2,n,m}/a_{3,n,m}
$$

$$
\varnothing_{rx,n,m}=\varnothing_{2,n,m}-\varnothing_{3,n,m}
$$

4.2 Elevation Gain Function Calculation

Apart from the Elevation Gain Function calculation, the processor shall calculate the mth version of the reference gain function, ie:

$$
G_{t,m}(\theta_o)=\left|\sum_{n=1}^{32}a_{tx,n,m}\exp(j\varnothing_{tx,n,m})\cdot f_{n,p_t}(\theta_o).g_{n,p_t}\right|^2
$$

$$
G_{r,m}(\theta_o)=\left|\sum_{n=1}^{32}a_{rx,n,m}\exp(j\varnothing_{rx,n,m})\cdot f_{n,p_r}(\theta_o).g_{n,p_r}\right|^2
$$

$$
G_{2m}(\theta_o)=G_{t,m}(\theta_o).G_{r,m}(\theta_o)
$$

Scale two-way elevation gain pattern, ie:

$$
G'_{2m}(\theta)=G_{2,m}(\theta_o)G_e(\theta)/G_2(\theta_o)nom
$$

Where $G_2(_o)nom$ is calculated in an identical way to $G_{2,m}(_o)$ except that nominal values of calibration pulse amplitudes and phases are used; that is $a_{1,n,m}$, $a_{1A,n,m}$, $a_{2,n,m}$, $a_{3,n,m}$,

$\varnothing_{1,n,m}$, $\varnothing_{1A,n,m}$, $\varnothing_{2,n,m}$, $\varnothing_{3,n,m}$ are replaced by $a_{1,n,nom}$, 0, $a_{2,n,nom}$, $a_{3,n,nom}$, $\varnothing_{1,n,nom}$, 0, $\varnothing_{2,n,nom}$ and $\varnothing_{3,n,nom}$

Convert scaled antenna pattern to a function of look angle, i.e.:

$$G_{2,m,T}(L) = G'_{2,m}(\theta + P + \Delta P_1)$$

(The processor shall update the above function when a new set of calibration pulses for n = 1,32 is obtained. This takes typically 14-31 seconds).

4.3 Replica Construction

In all modes except wave mode, the ASARCP shall be able to use the calibration pulses for the replica construction. In wave mode, where CW pulses are used for the internal calibration, a separate chirped pulse measurement is made for each calibration pulse 1, 2 and 3 exciting the whole antenna. Therefore the processor shall be able to use the different algorithms as described below for the wave mode and the other modes.

FOR ALL MODES EXCEPT WAVE MODE

Calculate time varying phase through calibration pulses, ie

$$\varnothing_{1,n,m}(t) = \text{ftan}\left[\frac{Z_{Q,1,n,m}(t)}{Z_{I,1,n,m}(t)}\right]$$

$$\varnothing_{1A,n,m}(t) = \text{ftan}\left[\frac{Z_{Q,1A,n,m}(t)}{Z_{I,1A,n,m}(t)}\right]$$

$$\varnothing_{2,n,m}(t) = \text{ftan}\left[\frac{Z_{Q,2,n,m}(t)}{Z_{I,2,n,m}(t)}\right]$$

$$\varnothing_{3,n,m}(t) = \text{ftan}\left[\frac{Z_{Q,3,n,m}(t)}{Z_{I,3,n,m}(t)}\right]$$

where Z_I and Z_Q are the I,Q components of Z and f tan (y/x) is defined in Section 4.3.5.4.1.

Using within pulse amplitudes as determined in Section 4.3.5.4.1, calculate m^{th} replica.

$$\text{Rep}(t) = F^{1}\left[\frac{F[R_{1,m}(t)] \cdot F[r_{2,m}(t)]}{\left\langle F[a_{3,n,m}(t)\exp(j\varnothing_{3,n,m}(t))]\right\rangle_n}\right]$$

where F[ ] indicates Fourier Transform
F^{-1}[ ] indicates Inverse Fourier Transform
$< >_n$ indicates an average over n

$$R_{1,m}(t)=\sum_{n=1}^{32} a_{tx,n,m}(t)\exp(j\varnothing_{tx,n,m}(t))f_{n,p_t}(\theta_s)g_{n,p_t}$$

$$r_{2,m}(t)=\sum_{n=1}^{32} a_{2,n,m}(t)\exp(j\varnothing_{2,n,m}(t))f_{n,p_r}(\theta_s)g_{n,p_r}$$

$$a_{tx,n,m}\exp(j\varnothing_{tx,n,m}(t))=\left[a_{1,n,m}(t)\exp(j\varnothing_{1,n,m}(t))-a_{1A,n,m}(t)\exp(j\varnothing_{1A,n,m}(t))\right]$$

Rep (t) shall be updated when a new set of calibration pulses (for n = 1, 32) is obtained (This takes typically 14-31 seconds operating in the mode).

FOR WAVE MODE

In wave mode the processor shall be able to use the chirped calibration pulses 1. 2 and 3 for the construction of the replica.

$$\mathrm{Rep}(t)=F^{-1}\left[\frac{F[Z_{w1,m}(t)\cdot fg]\cdot F[Z_{w2,m}(t)\cdot fg]}{F[Z_{w3,m}(t)]}\right]$$

where

$$fg=\sum_{n=1}^{32} f_{n,p}(\theta_s)\cdot g_{n,p}$$

F[ ] indicates Fourier Transform
F-1[ ] indicates Inverse Fourier Transform

Rep (t) shall be updated when a new set of calibration pulses is obtained, i.e. for each vignette.

4.4 Noise Estimation

Average power over a noise window, ie:

$$P_{N,k}(m)=\frac{1}{SWL(noise)}\sum_{t=t_0}^{t_{SWL(noise)-1}}(Z^2_{I,N,k,m}(t)+Z^2_{Q,N,k,m}(t))$$

where Z_I and Z_Q are the I, Q components of Z. Average over noise windows, ie

$$P_N(m)=\frac{1}{K}\sum_{k=1}^{K}P_{N,k}(m)$$

In the Image and Alternating Polarisation Modes, only P_N (1) is calculated as above. Thereafter

$$P_N(m) = P_N(1) \cdot RG(m) / RG(1)$$

where

$$RG(m) = \left(\sum_{n=1}^{32} a_{2,n,m}^2\right) / P_{ar}(m)$$

$P_N(m)$ is then normalised to the image pixel to give the m^{th} value of the noise power estimate N specifically;

$$N = k_n P_N(m)$$

($P_N(m)$ is updated typically after 3-31 seconds)
A noise estimate shall be done by scheme 4.