ASCAT Level 1: Product Generation Specification

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Document Change Record

Issue / Revision	*Date*	*DCN. No*	*Changed Pages / Paragraphs*
1 Draft F	31/8/99		Full doc. Addressed CGSRR RIDs.
1 Draft G	20/4/00		Full doc. Addressed CGS RIDs
2 Draft A	30/6/00		Full doc. Addressed CGS RIDs
3 Draft A	15/11/00 14/05/01		Full doc. Re-structuring of the document. Full doc. Update for First review cycle before CGS PDR
4.0	31/05/01		Sec. 1.1. Addition to clarify the expected future evolution of this document Sec. 4.2. Added System Concept Sec. 3, 4 and 7. Addition of a new type of instrument measurement mode, after the results of the instrument CDR: Gain Compression Monitoring (GCM). As a consequence, addition of a function in the A0 functional decomposition (B3). As a consequence, addition of another internal file for accessing GCM data and results from cal/val (7.4.8). Sec. 4 and 5. Restructuring of the functional decomposition of A0 (sections 4 and 5), in order to reflect more clearly the roles of routine and occasional functionality. For that, the different data flows are identified, clearly distinguishing between the measurement and the external calibration data flow: Occasional functionality de-scoped from A2 and A3, into occasional functions in their own right B1 and B2. The rest of the PGS has been made consistent with the new sections 4 and 5. Sec. 4, 5 and 7. General change in telemetry data flow: it will go directly to Level 1A, and not to Level 0. Sec. 4 and 5. Figures 2 and 3 from previous version become 3 and 5. The actual figure 5 has been refined as part of the restructuring of sections 4 and 5. Sec. 1. Addition of RD9 and RD10 Sec. 3: ALG.A0.5: Addition of figure 2, in order to reflect, for clarifying purposes, the distinction between routine and occasional functionality. Addition of an explanatory paragraph under the figure. ALG.A0.8: Addition of Deblooming Kernels and GCM related information to the list of items to make accessible to the ASCAT cal/val facility. ALG.A0.9: Addition of a new functionality: support of GCM-related data handling. Another bullet was added, making explicit the functionality related to the generation of Normalisation Factors and Deblooming Kernels. This is not an addition in practice, since those were considered within the general calibration functionality in the previous version of the document. ALG.A0.15: Clarified

Issue / Revision	***Date***	***DCN. No***	***Changed Pages / Paragraphs***
			ALG.A0.18: added GCM instrument measurement mode ALG.A0.19: Clarified and added Secondary mode: GCM ALG.A0.25: Occasional functionality de-scoped from A2 and A3, into occasional functions in their own right B1 and B2. Addition of B3 (GCM) functionality within the occasional part. ALG.A0.26: Updated to reflect change in ALG.A0.25 Sec. 4.1. Addition of Calibration and GCM-related data as outputs from ASCAT PGF Sec. 7: Added general comment about internal product/files at the beginning. Level 0: telemetry removed. Level 0: Block II: Appended data list reduced. Level 1A: Appended transponder data (in 7.2, Block II) has been removed: as calibration data flow now becomes different from the measurement data flow, all transponder-related data are stored in the two calibration internal files (to 7.4.1 and 7.4.2). Deleted references to calibration data. Level 1A: Commissioning / Operations phase flag moved to Block I. Level 1A: Appended quality flags and qualifiers section re-written. Level 1B: Structure reorganised, data content not changed, except for the quality flags and qualifiers, which have been re-written. This applies to all 50 km, 25 km and full-resolution products. Internal products / files: Added comment on accessibility (7.4) and static/dynamic character. Internal products / files: 7.4.1: change of file name and adding of transponder characterisation parameters and corrected source packets and their r applied reference functions. Internal products / files: 7.4.2: change of file name. Internal products / files: 7.4.3: contents re-written. Internal products / files: Spatial Filtering internal file and its contents added. Internal products / files: File for Instrument settings and parameters file(s) added. Contents TBD. Internal products / files: Transponder characterisation data file and contents added. Internal products / files: GCM data product and contents added. Sec. 6: Algorithm overview and philosophy added at the beginning of section 6. Equation numbers have changed through the whole section. When an equation has been added or changed, the number in this version of the document will be given. When it has been deleted, the number in the previous version of the document will be given

Issue / Revision	***Date***	***DCN. No***	***Changed Pages / Paragraphs***
			Added paragraph 6.2.9 Added equations: 7, 11, 12. Added equation 14 (in 6.2.6) Variables are expressed depending on discriminator frequency sample (i) and not on discriminator frequency value (f(i)). Kp algorithm added (section 6.1.4) Calibration frequency values added (eq. 10) Section 6.2.2 added Eq 54 from previous version deleted Eq 56, 57, 58, 59 modified significantly Eq 13 added Eq 63, 64, 65, 67, 68, 69, 70, 73, 74, 75, 76, 77, 82, 83, 84, 85, and 86 changed. Eq 114, 116, 122 changed Eq 124, 125, 126, 127 from previous version deleted. Eq 15 and 16 in 6.3.3 added Eq. 145, 146 changed
6.0 For Internal Review (FIR)	08/02/02		Full doc. One issue number skipped Sec. 3: ALG.A0.6: Deleted ALG.A0.30, 31, 32, 33, 34, 25: Added ALG.A0.7, 11, 15, 16, 19, 22, 28: Clarified Fig. 2 detailed Sec. 4. Fig. 5 detailed Sec. 7: Fig. 6 added Fig. 7 added Fig. 8 added Sec. 6. Eq. Numbers rearranged Sec. 3, 4 and 5. Different data flows renamed for consistency Sec. 3, 4. Instrument Test mode added Sec. 5. Function sequence simplified Sec. 4. Definition of G/S Auxiliary data, Processing Configuration Databases, Reporting, Instrument/Processor status monitoring information refined. Sec. 4. Backlog processing and reprocessing defined. Sec. 5. GCM function updated Sec. 6. GCM algorithm updated Sec. 6. Flag strategy added (sec. 6.1.5) Sec. 7. Instrument and processing configuration parameters added Sec. 7. All product content files refined Sec. 8. TBCs and TBDs section removed Sec. 8. Algorithm variable/setting tables added Full doc. All chapters of document have been updated for the third evolution.
6.1	28/02/02		Full doc. Internal review comments implemented Sec. 9. Acronyms section added
6.1	12/03/02		Sec. 6. Equation 6.2.10.-2 modified
6.1	12/03/02	EPS System	Full doc. Additional revision to remove the end of dump degraded product generation concept (in

Issue / Revision	***Date***	***DCN. No***	***Changed Pages / Paragraphs***
		Forum, issue 1859	particular, ALG.A0.15, 16, 22 and Chapter 7 significantly modified)
6.2	18/04/02	EUM.EPS.SYS.DCR.02.102	Sec. 5. Function B3.2 refers now to algorithm in 6.2.7 Sec. 6. Algorithm to calculate F_{ORBIT} and $F_{ATTITUDE}$ added (Equation 220 and .-11) Sec. 7.4.6. X_{ORBIT} and $X_{ATTITUDE}$ added as processing configuration parameters Sec. 6.1.5.2 and 7.4.1. F_{ORBIT} and $F_{ATTITUDE}$ removed as calibration data flags Sec. 6. Corrected indexes in Eq. 6.2.1.-4 and .-7 Sec. 6. Modification of pulse distortion model: Eq. 6.2.4.-13, 6.2.5.-13, 6.2.7.-10. Sec. 7.4.5. Modification of pulse distortion model instrument parameters Sec. 7.4.1. Removal of explicit $F_{COM/OP}$ as a bullet
6.3	06/06/02	EUM.EPS.SYS.DCR.02.124	Sec. 3.5.2. Header modified Sec 5. B1.3.5: bullet numbering corrected Overall doc. MetOp to METOP Sec 5. C1: Corrected MCF meaning Sec 5. A5.1: Last paragraph deleted Sec 1.3. AD4 name and reference corrected Sec 7.4.6. Name of parameter modified Sec 7.4.6. Parameter added: θ_{LOOK} Sec 8. Algorithm variable table 11 synchronised with above Sec 3. ALG.A0.22, last bullet clarified Sec B2. Necessary modifications consistent with previous change above Sec 6.4.6. Added last paragraph to clarify building of GAP estimates data set for AGPO Sec 7.4.6. Necessary modifications consistent with previous change above Sec B2.1. Necessary modifications consistent with previous change above Sec 3. ALG.A0.19, Note added to clarify the triggering of processing modes Sec 6.2.10. Eq. 6.2.10.-2, Log_10 added Sec 3. Qualification of ALG.A0.35 for the testing of the node generation algorithm implementation Sec 7.4.6. Added processing configuration parameter consistent with ALG.A0.35 qualification Sec 5. Clarification of the meaning of reporting and monitoring in A5, A5.1 and A5.2 Sec 1.4. Reference Documents numbering reversed to previous issue of document (4:0) Sec 7.4.5. Added G4 Guard time at the end of measurements timeline, for Measurement and Calibration modes Sec 6.2.1. Typo in equation 6.2.1.-2 Sec 6.2.1. Additional normalisation introduced in the filter shape estimation: Eq. 6.2.1.-7 modified and Eq. 6.2.1.-11 and 6.2.1.-12 added Sec 8. Variable table 5 updated accordingly Sec 6.2. p^{C-E}, c^{C-E} , p^{M-E} , c^{M-E} values removed from

Issue / Revision	***Date***	***DCN. No***	***Changed Pages / Paragraphs***
			Eq. 6.2.4.-11, 6.2.5.-11, 6.2.7.-8 , as they are processing configuration parameters Sec 7.1, 7.2, 7.3. Level 0, 1A, 1B product header contents synchronised with GPFS generic L0 and MPH record formats. In particular, 'absolute dump number' concept eliminated. DATA TIMING ISSUES Sec 6.1.1. and 6.3.3 modified to clarify echo and noise measurements timing and echo localisation.. In particular, - SBT at Time Tag field used - Equations introduced to calculate time offsets Sec 7.4.5. Time offsets deleted as instrument parameters, Nominal Slant Range to mid swath for beam b added ($s_{MID-NOM}$) as instrument parameter Sec 8. Variable tables 1 and 10 updated accordingly Sec 5. Functions A2.1 and A2.2.2 clarified and updated accordingly Sec 7. L1A, L1B data timing clarified, as well as Internal files data timing
6.4	10/12/02	EUM.EPS. SYS.DCR. 02.238	Sec 1.3, 1.4 and general: RD9 becomes AD10, and specific references to AD10 added across the document RD10 replaced by the latest relevant report from SEA study and becomes AD11 Sec 6.2.6. Automatic search technique for AGPO specified Sec 6.2.10. GCM Exceptional Method simplified Sec 7.4.8. GCM product contents simplified consistently with above modification Sec 7.4.2. AGPO product contents refined after prototyping results in AD11 Sec 7.4.6. AGPO-related processing configuration parameters refined after prototyping results in AD11 Sec 8 Table 10. Meaning and relationship between Δ_{PRI} and Δ clarified
6.4	16/12/02	EUM.EPS. SYS.DCR. 02.245	Sec 6.2.4. Eq. 6.2.4.-34 Added for clarification (consistent with CC test data delivery) Sec 6.2.5. Eq. 6.2.4.-32 Added for clarification (consistent with CC test data delivery) Sec 7.4.5. Chirp parameters modified, made specific for every single of the 6 antennae, and different for Measurement and Calibration Modes
6.5	15/03/04	EUM.EPS. SYS.DCR. 03.170	Sec 6.1.2. Eq. 6.1.2.-4 modified Sec. 6.2.5. GAP algorithm: - Eq. 6.2.5.-3, 6.2.5.-10, 6.2.5.-20 modified - typos in text corrected Sec. 6.3.4.3. Section added - ground range algorithm Sec. 6.1.4. Kp algorithm modified Sec. 7.4.5. Pulse timing info for instrument calibration mode modified and clarified Sec. 6.3.4.2. Equation numbering corrected (editorial) Sec. 6.1.5.4. Section added - Solar array interference algorithm

Issue / Revision	*Date*	*DCN. No*	*Changed Pages / Paragraphs*
			Sec 1.4. Added RD13 for information complementary to new section 6.1.5.4 (Technical note on Solar Array Interference) Sec. 7.2.8. Last empty bullet deleted (editorial) Sec. 6.2.4 and sec. 6.2.7. Typo correction in Eq. 6.2.4.-11 and 6.2.7.-8 Sec. 6.2.5. Eq. 6.2.5.-11: Shift of origin of window function
6.6	11/04/05	EUM.EPS. SYS.DCR. 05.197	Sec. 2.2. Carrier frequency corrected for typo Sec. 6.2.6. Domain control function updated Sec. 7.4.2. Parameters for domain control function updated in ‘Antenna gain and orientation’ internal product Sec. 7.4.6. Parameters for domain control function updated in ‘Processing parameters’ internal file
v7A	13/06/08		Import into Hummingbird. Body contents copied into standard template. Editorial updates only: - Signature table updated. - References to sections, figures etc. automated. - Headings in Section 5 converted to standard numbering; previous numbers (A1, A1.1 etc.) appended to heading titles. - Several typos corrected.
v7B	29/08/14	OPS_ECPD_304	Changed document to current EUMETSAT technical document template. References to sections, figures etc. automated. Lookup Tables for all Variables and Settings Tables at the end of the document in Section 8. Document parts transcribed from Framemaker format.
v7c	11/09/14	OPS_ECPD_304	Updated document signature table.
V7D	13/09/16		Created tables for ASCAT PGF Variables and Settings Tables 1-23. Created links to all equations used in the document from settings tables.

Table of Contents

1 INTRODUCTION

1.1 Purpose and Scope of the Specification

The purpose of this specification is to present requirements specific to the METOP ASCAT Product Generation Function (PGF) that are not already covered in the Core Ground Segment Requirements Document (CGSRD) and the other applicable documents. The ASCAT PGF leads to the generation of ASCAT Level 0, 1A and 1B products. This specification encompasses not only the required algorithm functions but also certain supporting functions pertaining to the ASCAT PGF.

The document covers the functions encompassed by the ASCAT PGF, the interrelations between these functions and the relation to the other functions of the EPS Core Ground Segment (CGS).

This document is the third evolution of the PGS as planned in the EPS Programme Core Ground Segment Statement of Work (EUM.EPS.GSE.SOW.99.0004) and identified as V2 therein.

As used in this document, both terms “routine” and “occasional” apply to inherent functionality of the PGF.

1.2 Relation to EPS Core Ground Segment

The Product Generation Specification (PGS) documents address all the requirements pertaining to the corresponding instrument PGF of the EPS Core Ground Segment. The PGF encompasses all the functions (algorithms & scientific functions, supporting functions) required for the generation of the products, including but not limited to the instrument-specific usage of the Product Generation Environment (PGE) services. The ASCAT PGF is a constituent of CGS, and unless otherwise specified, all the requirements of the CGSRD (AD 1) apply to this PGF.

1.3 Structure of the Document

The document starts with an overview of the processing to be performed and provides background on the related scientific aspects. This is followed by the structured decomposition of the Product Generation Function functions and by the requirements corresponding to these functions.

The document is organised in the following sections:

Section 1	of this document is this Introduction.
Section 2	Presents the overview of the instrument and the technical and scientific background of the processing.
Section 3	Presents the high-level requirements.
Section 4	Details the system context of the ASCAT PGF, the operations concept, and the logical model of the functionality decomposition (Flow Diagrams).
Section 5	Contains the detailed requirements for the ASCAT PGF, following the structure of the functionality decomposition presented in Section 4.
Section 6	Contains a detailed description of the algorithms.
Section 7	Presents the contents of the Level 0, 1A and 1B products and other internal data

	files.

1.4 Applicable Documents

Following documents are applicable to this ASCAT Product Generation Specification:

	Document Name	*Reference*
AD 1	EPS Core Ground Segment Requirements Document	EPS/GGS/REQ/95327
AD 2	EPS Generic Product Format Specification	EPS/CGS/SPE/96167
AD 3	ASCAT Level 1 Product Format Specification	EPS/MIS/SPE/97233
AD 4	ASCAT TM/TC Interface Control Document	MO-IC-DOR-SC-0031
AD 5	METOP Space to Ground Interface Specification	MO-IF-MMT-SY-0001
AD 6	EPS Mission Conventions Document	EPS/GGS/SPE/990002
AD 7	EPS Product Conventions Document	EPS/SYS/TEN/990007
AD 8	ASCAT Measurement Data Interface Specification	MO-TN-DOR-SC-0015
AD 9	METOP Satellite System Requirements	MO-RS-ESA-SY-0023
AD 10	ASCAT DPU Requirements Specification	MO-RS-DOR-SC-0006
AD 11	Final Report from ASCAT External Calibration Algorithm Study	SEA-02-TR-3859

1.5 Reference Documents

Not all the algorithms and procedures indicated in the reference documents will be part of the PGF. The reference documents are provided for information only.

	Document Name	*Reference*
RD 1	ASCAT GPP Level 1B Processor Algorithms	MO-RS-DOR-SC-0027
RD 2	ASCAT GPP External Calibration Processor Algorithms	MO-RS-DOR-SC-0028
RD 3	ASCAT GPP Point Target Simulator Algorithms	MO-RS-DOR-SC-0029
RD 4	ASCAT GPP Normalisation Table Generator	MO-RS-DOR-SC-0030
RD 5	ASCAT Calibration and Characterisation Plan	MO-PL-DOR-SC-0010
RD 6	ASCAT Instrument Technical Description	MO-RP-DOR-SC-0001
RD 7	METOP-ASCAT GPP Interfaces	MO-RS-DOR-SC-0026
RD 8	ASCAT GPP ICD	MO-IC-DOR-SC-0029
RD 9	Transponder Separation Analysis	MO-TN-ESA-SC-0319
RD 10	ASCAT On-Board Parameter Tables	MO-LI-DOR-SC-0198
RD 11	Technical note on ASCAT Solar Array Interference	MO-TN-DOR-SC-0111

1.6 Requirements Hierarchy and Precedence

The requirements presented herein are organised according to the hierarchical functionality decomposition. In case of conflict between higher level and lower level requirements, the higher level ones shall take precedence.

Similarly, in case of conflict between these PGF requirements and those contained in CGSRD, the latter shall take precedence.

Please note that Section 5 is, in effect, a list of requirements, regardless of the fact that they have not been labelled as such. They shall be traced down as requirements by using the corresponding section and subsection numbering (i.e., An.x.x.x or Bn.x.x.x).

1.7 Acronyms Used in this Document

Acronym	*Meaning*
A/D	Analogue-to-Digital
AD	Applicable Document
ADC	Analogue Digital Converter
AGPO	Antenna Gain Pattern and Orientation
ANTLA	ANTenna Left Aft
ANTLF	ANTenna Left Fore
ANTLM	ANTenna Left Mid
ANTRA	ANTenna Right Aft
ANTRF	ANTenna Right Fore
ANTRM	ANTenna Right Mid
ASCAT	Advanced SCATterometer
CAL/VAL	Calibration/Validation
CDA	Command and Data Acquisition
CDR	Critical Design Review
CGS	Core Ground Segment
CGSRD	Core Ground Segment Requirements Document
CGSRR	Core Ground Segment Requirements Review
CMSP	Calibration Mode Source Packets
CVCDU	Coded Virtual Channel Data Unit
DC	Direct Current
DF	Data Flow
DK	Deblooming Kernels
DPU	Digital Processing Unit
DSP	Digital Signal Processor
EPS	EUMETSAT Polar System
FDF	Flight Dynamics Function
FIR	Finite Impulse Response
G/S	Ground Segment

Acronym	Meaning
GAP	Gain at Angular Positions
GCM	Gain Compression Monitoring
GPP	Ground Processing Prototype
HPA	High Power Amplifier
ICD	Interface Control Document
IERS	International Earth Rotation System
IP	Instrument Parameters
LNA	Low Noise Amplifier
LUT	Look-Up Table
M&C	Monitoring and Control
MCF	Mission Control Function
METOP	METeorological OPerational Satellite
MMI	Man-Machine Interface
N/A	Not Applicable
OCM	Orbit Control Mode
OFP	Out of Plane
OPM	Operational Mode
PCP	Processing Configuration Parameters
PDR	Preliminary Design Review
PG	Power Gain
PGE	Product Generation element
PLM	PayLoad Module
PRI	Pulse Repetition Interval
RC	Redundancy Configuration
RD	Reference Document
RF	Radio Frequency
RFU	Radio Frequency Unit
RID	Review Item Discrepancy
SBT	Satellite Binary Time
SFE	Scatterometer Front End
SMMSP	Special Measurement Mode Source Packets
SP	Switch Path
SSPA	Solid State Power Amplifier
TM	TeleMetry
TMSP	Test Mode Source Packets
TRF	Terrestrial Reference Frame
Tx	Transmit
UTC	Universal Time Clock
WGS84	World Geodetic System 84

2 INSTRUMENT CONCEPT

2.1 Definitions

The basic definitions used in this document are specified in the EPS Mission Conventions Document [AD 6], and the EPS Product Conventions Document [AD 7].

2.2 Instrument Description

The Advanced SCATterometer ASCAT is a real aperture, vertically polarised C-band radar with high radiometric stability. The primary scientific objective of ASCAT is to measure near-surface ocean winds. A detailed technical description of the instrument can be found in [RD 6].

2.2.1 Instrument design principle

ASCAT transmits long pulses with Linear Frequency Modulation ('chirps') at a carrier frequency of 5.255 GHz. The received echoes are “dechirped” and Fourier-transformed on board, resulting in a signal where the frequency components map to slant range. The on-board processing is basically a power spectrum estimation, followed by a (spatial) low pass filtering, with the effect of substantially reducing the data rate required to record the science data. The averaged raw echoes together with averaged noise measurements are sent to the ground in source packets.

2.2.2 Measurement principle and geometry

The six antennas of the instrument sequentially illuminate the sea surface. The backscattered signal is measured to determine the specific sea surface backscattering. From this the wind speed and direction are determined by using a model that relates those quantities to normalised radar backscattering cross-section (σ_0).

To determine the wind direction, σ_0 measurements are required from at least three different directions. This is achieved by collecting data from three different azimuth angles (45°, 90° and 135°) across both of the 550 km wide swaths on either side of the nadir track as shown in Figure 1). The swaths correspond to incidence angles ranging from approximately 25° to 53.4 ° for the mid beam and 33.7° to 64.3° for the side beams).

ASCAT is designed to provide surface winds at a 50 km horizontal resolution over a 25 × 25 km grid along and across both swaths. A high-resolution wind product is also generated at 25 km horizontal resolution over a 12.5 × 12.5 km grid. During the ground processing, the ASCAT source packets are processed to obtain normalised backscatter measurements at those spatial resolutions, which result in 21 nodes per swath, for a total of 42, for the 50 km resolution winds, and 41 nodes per swath, for a total of 82, for the 25 km resolution winds.

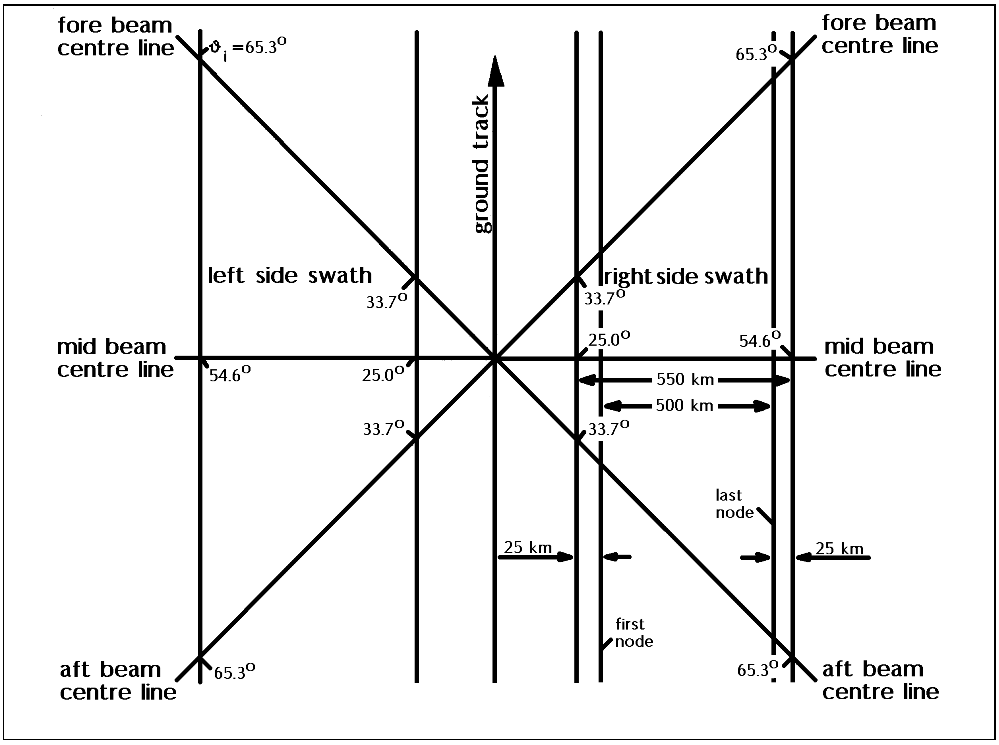


Figure 1: ASCAT Swath Geometry

2.3 Reference Frames Definition and Use

The usage of reference frames must comply with the definitions expressed in [AD 6]. Additional reference frames needed by the ASCAT PGF and their corresponding transformations are included in Section 6.3.

3 HIGH LEVEL REQUIREMENTS

The level of the requirements in this section corresponds to the Context Diagram shown in Figure 3 and to the A0 Decomposition in Figure 5. They apply to the entirety of the ASCAT PGF and derive directly from the basic requirements on the mission that this PGF is supporting. As the PGF is the sum of all components hardware, software and data, these requirements are fulfilled by the operation of the entire processing chain.

The section is organised as follows:

- General ASCAT PGF functional requirements
- Supported platforms, instruments and instrument modes
- Supported modes of operation of the ASCAT PGF
- Nominal product and performance requirements
- Specific requirements on the processing chain

All requirements in the list of Applicable Documents in Section 1.4 of this document shall apply, except for [AD 9], where only chapter 6 (corresponding to ASCAT) shall apply where stated below. The reference documents provide further details in relation to implementation.

3.1 General ASCAT PGF functional requirements

3.1.1 Context

Number	*Configuration Item*
ALG.A0.1	The ASCAT PGF shall contain the processing chain for the ASCAT instrument. The scope of the PGF is the context diagram in Section 4.1.
ALG.A0.2	The contents of the external data flows to/from the ASCAT PGF shall be as described in Section 4.1.
ALG.A0.3	Interfaces regulating the input data shall, where applicable, be as described in [AD 4], [AD 5], and [AD 8].
ALG.A0.4	Requirements regulating the CGS input/output interface in [AD 1] apply, including general PGE services.

3.1.2 General functionality (A0)

This instrument-specific functionality is in addition to the generic functions identified in [AD 1].

ALG.A0.5
The nature of the ASCAT processing requires that some reference functions be re-generated and updated during the instrument lifetime. The ASCAT PGF shall therefore have some routine functionality (central processing chain) and some (in the sense described in section 4 of this document) occasionally-executing functionality. Figure 2 illustrates the relationship between routine and occasional functionality within the ASCAT PGF. It is purely a functional decomposition and shall not prejudge the actual implementation.

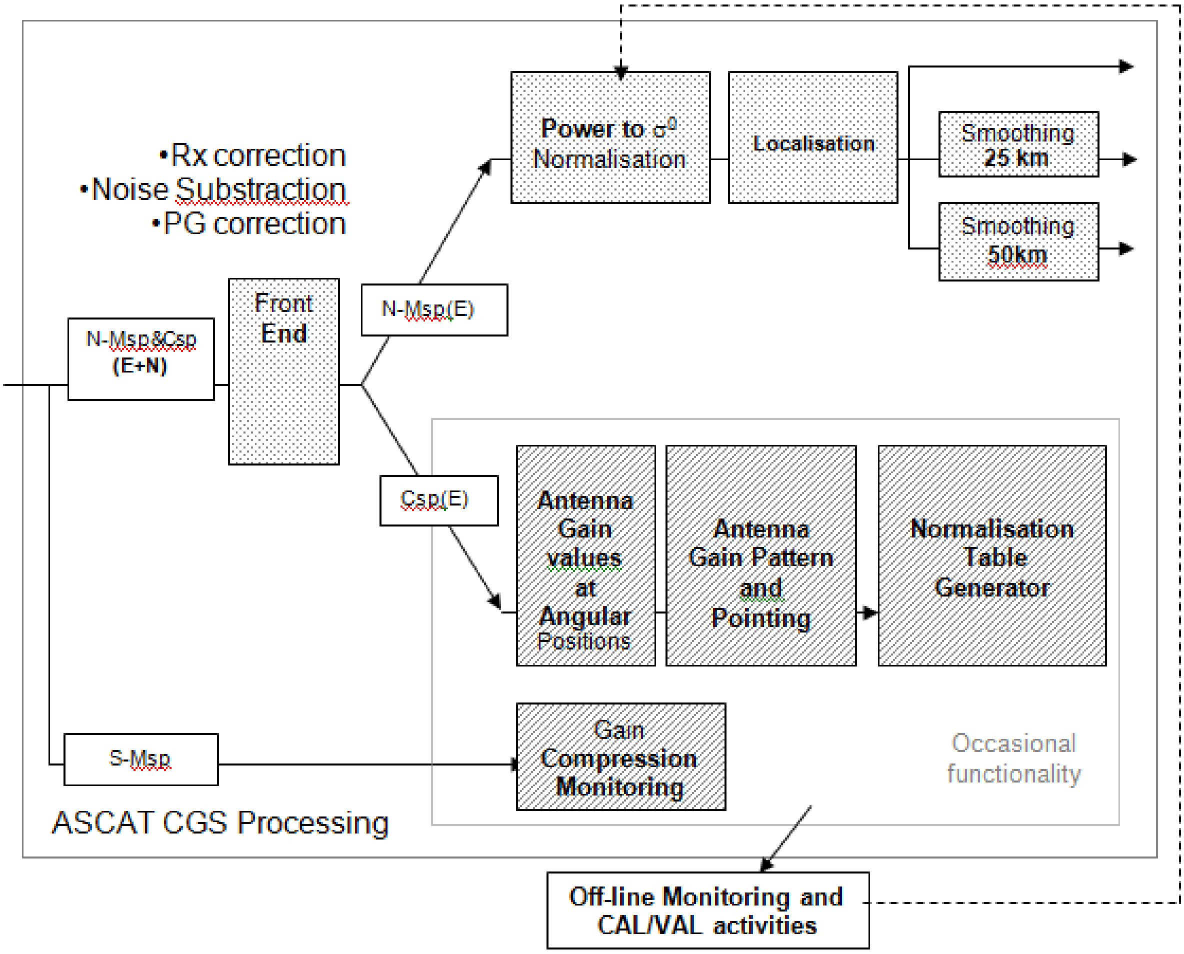


Figure 2: Routine and Occasional Functionality of the PGF N-Msp and S-Msp stand for Normal Measurement Mode source packets and Special Measurement Mode source packets respectively. CSP(Calibration Mode source packet)s. E and N refer to Echo and Noise respectively.

The dotted boxes generate routine ASCAT Level 1 products. The striped boxes consist of occasional functionality and perform External In-flight Calibration and Gain Compression Monitoring (GCM). GCM will explained in more detail in the following sections.

The resulting reference functions generated from the calibration-related occasional functionality shall be uploaded to the central processing chain after approval, following tests performed in a facility external to the ASCAT PGF (ASCAT cal/val facility). The GCM monitors the HPA Gain Compression at the HPA operating point.

The detailed description of both the routine and the occasional functionality is given later on in this document, in Section 4, Section 5 and Section 6.

ALG.A0.31
The configuration of the ASCAT PGF at any given time shall always be determinable and reproducible. ***Note***: the configuration of the ASCAT PGF is determined by at least the labels and contents of any configuration data sets: the names and contents of internal files.

ALG.A0.7
It shall be possible to update all look-up tables used by the routinely-executing part of the ASCAT PGF originating either from the occasionally-executing (in the sense described in section 4 of this document) part of the ASCAT PGF (default) or from an external source (the ASCAT CAL/VAL facility).

ALG.A0.8

The occasionally-executing (as described in Section 4 of this document) part of the ASCAT PGF shall allow but not be limited to transfer the following items to the ASCAT CAL/VAL and other facilities:

- Calibration source packets and appropriate correction reference functions (Rx filter shape, noise power and Power Gain (PG-product) and the required derived parameters, including:
    - ➢ Antenna gain at angular position measurements;
    - ➢ Antenna gain patterns and pointings/orientations;
    - ➢ Power to σ_0 normalisation tables;
    - ➢ Deblooming Kernels.
- CGM source packets and the required derived parameters extracted from them.

ALG.A0.9

The ASCAT PGF shall provide all the functionality required to support the following:

- Level 0 processing;
- Level 1A processing;
- Level 1B processing;
- Data formatting;
- On-line quality control, monitoring, reporting and informing of the processing status;
- All required calibration processing and calibration data handling;
- Generation of in-flight Normalisation Factors and Deblooming Kernels;
- All required GCM data handling;
- All required interface functions—including those using the generic PGE services and the interface to the CAL/VAL facility;
- All required command and control functions;
- Storage of all required permanent and temporary internal data files.

ALG.A0.10

Each function of the ASCAT PGF shall monitor its performance and raise events of user-configurable severity on the occurrence of:

- Any abnormal instrument or satellite behaviour being detected;
- Any occurrence and transition to/from a degraded mode of product generation;
- Any non-nominal operation of the function;
- Any occurrence likely to affect the product quality, based on the flags generated during the processing.

3.1.3 Calibration functionality

ALG.A0.11

The ASCAT PGF shall be able to support periodic ASCAT external calibration campaigns, including the automatic determination and the updating of the necessary reference functions.

3.1.4 Gain Compression Monitoring Functionality

ALG.A0.30

The ASCAT PGF shall support the processing of Gain Compression Monitoring data, as described in Section 6.2.10.

3.1.5 PGF operations

ALG.A0.12

The ASCAT PGF shall be as automatic and autonomous as possible and require the absolute minimum operator intervention to achieve the functionality described.

ALG.A0.13

Where operator intervention is required, for example to update necessary reference functions in connection with an ASCAT external calibration campaign, the enabling of the configuration modification shall use an approval mechanism to prevent unauthorised modification.

3.1.6 Continuity of the processing

ALG.A0.14

The ASCAT PGF shall be able to process nominally and continuously across dump boundaries.

ALG.A0.15

The ASCAT PGF shall be a pipeline processor, driven by input data. For Level 0 to Level 1B processing, it shall have a latency time, which is configurable, as specified in more detail in Section 5 and Section 6. The σ_0 processing functionality shall halt and wait until the correct data are available at its input and then resume σ_0 processing. If the σ_0 processing stops and resets, the σ_0 processing shall resume as soon as the first good new measurement mode source packet arrives.

ALG.A0.16

For certain processing operations like Rx filter shape computation, smoothing power gain values along track, smoothing raw σ_0 values to obtain node σ_0 triplets at 25 km and 50 km resolution and deblooming data from both sides of a dump, boundary will be required. The ASCAT PGF shall allow this wherever it is required by the algorithm.

ALG.A0.34

Level 1A and 1B full resolution products shall not be generated until enough data are available to generate the first good filter shape.

ALG.A0.35

Level 1B product shall not be generated until enough data are available to generate the first good filter shape and, from at least one beam, to completely fill the Hamming window used to generate the first node that it is possible to create; σ_0 node values shall be generated whenever the Hamming window is completely filled.

For testing purposes, it shall be possible to generate the first line of nodes at a user configurable time ΔT_{FLN} after the time of the first source packet given to the processor, as defined in section 6.1.1 ($T_{UTC\text{-}FIRST\text{-}IN\text{-}SP/E}$).

3.2 Supported platforms, instruments and instrument modes

3.2.1 Supported platforms/instruments

ALG.A0.17
The ASCAT PGF shall produce Level 0, 1A and 1B products in the context defined in Section 4.1, for input data acquired by the following Instrument and Platform configurations: • METOP-1/Instrument ASCAT • METOP-2/Instrument ASCAT • METOP-3/Instrument ASCAT

3.2.2 Supported instrument modes

ALG.A0.18
The ASCAT PGF shall support the following instrument modes: • Measurement (normal source packets and special GCM source packets). • Calibration • Test Mode Data shall be recognised and archived by the Level 0 processing, but it is ignored by Level 1A and 1B processing.

3.3 Supported modes of operation of the ASCAT PGF

ALG.A0.19
The ASCAT PGF shall be able to support the following modes: • Off • Processing Normal Measurement Mode Source Packets (NMMSP) • Processing Calibration Mode Source Packets (CMSP) • Processing Special Measurement Mode Source Packets (SMMSP) (for Gain Compression Monitoring) • Handling Test Mode Source Packets (TMSP) • Processing NMMSP simultaneously with Antenna Gain Pattern and Orientation (AGPO) Estimation • Processing NMMSP simultaneously with Normalisation Table and Deblooming Kernel (NT and DK) Generation • AGPO Estimation • NT and DK Generation ***Note***: It is envisaged that some modes will be triggered by the arrival of data and others by commanding. The selection between ON and OFF is controlled by operator intervention (i.e. commanded). The decision to run both AGPO and NT and DK is controlled by operator intervention as is the data set / configuration to be used as input to the algorithms. However NMMSP processing, CMSP processing, SMMSP processing, TMSP handling are data driven and simply depend on the type of data arriving at the processor

ALG.A0.32

It shall only be possible to change the instrument parameters between two instrument operations.

Note: The correct instrument parameters are indicated by the on-board software configuration, the on-board parameter configuration and the instrument configuration given in each source packet.

ALG.A0.33

It shall only be possible to change the processing parameters and the transponder information between different ASCAT PGF operations.

Note: A new instrument operation always results in the ASCAT PGF being restarted.

ALG.A0.20

The contractor shall indicate any ASCAT PGF required modes that have not been indicated above.

3.4 Nominal product and performance requirements

ALG.A0.21

In generating Level 0, 1A and 1B data, and all other internal data, including that required for calibration, for all nominal modes and states of the instrument, the ASCAT PGF design and its implementation shall not degrade the data quality by introducing errors via processing operations (word lengths, interpolations, numerical integrations, numerical differentiations, etc).

Note: This shall be taken to mean, inter alia, that the ASCAT PGF shall not degrade the data delivered to it.

ALG.A0.22

The ASCAT PGF shall also be able to produce Level 0, 1A and 1B data in a degraded manner in at least the following cases. In all these cases, the PGF shall generate and append to the product the necessary flags unambiguously indicating the nature of the degradation.

- Non-nominal platform orientation;
- Non nominal orbit;
- Missing, invalid or corrupted data from one or more of the antennas.
- Start and End of instrument operation
- Start and Stop of data flow availability to PGF.

Note: This refers to the situation when the processing is started or stopped. It does not apply to the gap between dump boundaries where the processing is simply paused until the next required data item arrives.

3.5 Specific requirements on the processing chain

3.5.1 A0 Functionality Decomposition

ALG.A0.23
The functionality of A0 shall be as indicated in section 4.5.

ALG.A0.24
The ASCAT PGF shall accept as primary input either the input indicated in Figure 3 (section 4) or alternatively the Level 0 data product plus appropriate telemetry, in case of reprocessing.

ALG.A0.25
The functionality of A0 shall be decomposed into A1, A2, A3, A4, A5, B1, B2, B3 and C1, as indicated in section 4.5.

3.5.2 A1, A2, A3, A4, A5, B1, B2 B3 and C1 Functional Detailed Specification

ALG.A0.26
The functionality of A1, A2, A3, A4, A5, B1, B2, B3 and C1 shall be as specified in the relevant paragraphs in Section 5.

ALG.A0.27
The ASCAT PGF internal input/output data flows that are not specified in section 4.1 shall be as specified in the relevant paragraphs in Section 5.

ALG.A0.28
The processing shall be as described in Section 5 and Section 6.

ALG.A0.29
Any product and internal file data content description contained in Section 7 shall be part of the specification.

4 SYSTEM AND OPERATIONS CONCEPT, PGF FUNCTIONALITY DECOMPOSITION

4.1 System Context and Major Interfaces

The context diagram of the ASCAT PGF is presented below. This is purely a functionality decomposition and shall not prejudge the actual implementation.

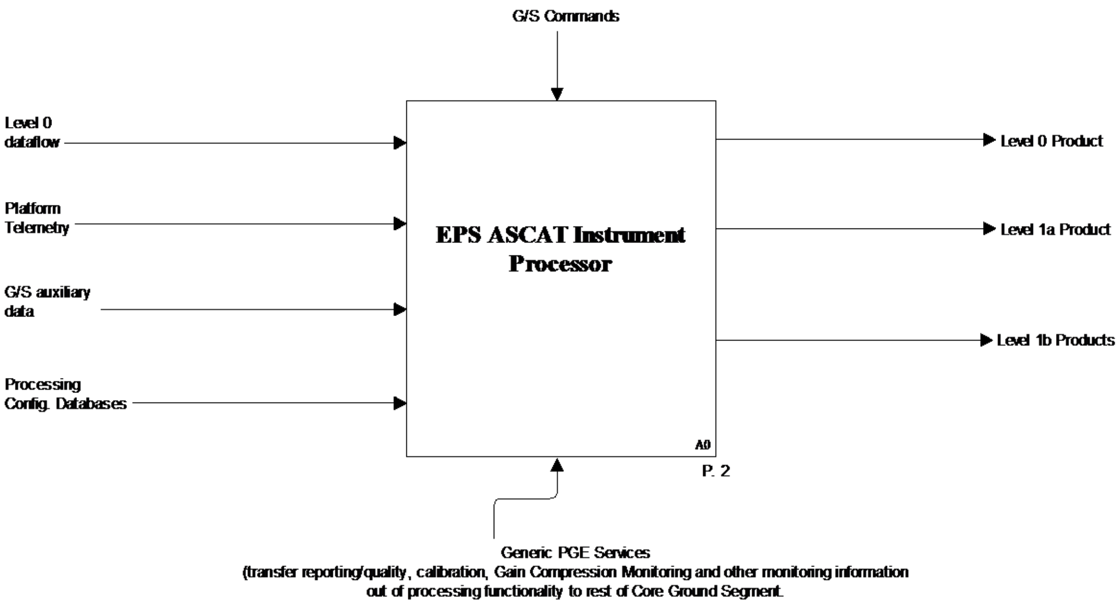


Figure 3: ASCAT PGF Context Diagram

The external data flows are defined in the tables that follow:

Inputs:

Level 0 dataflow	Corresponds to the ASCAT Level 0 data flow received from the CGS (instrument source packets). The data origin can be any of the supported satellites via the CDA or via the NOAA exchange link. ***Note***: In case that the ASCAT PGF operates in reprocessing mode, the information is received via the CGS function providing the reprocessing support. The data might also originate from one of the test tools if the ASCAT PGF is being tested standalone.
Platform Telemetry:	Is similar to the Level 0 data except that it corresponds to the platform telemetry that is required in addition to the Level 0 data flow indicated above. These data typically contain various spacecraft/platform/instrument parameters required by the ASCAT PGF. The source of these data is the satellite and administration packets.
G/S Auxiliary data:	Corresponds to all data that are required from the Ground Segment and that are not present in the Platform Telemetry or the Level 0 data flow. These data include, but are not limited to, orbit data, attitude data, instrument parameters, instrument characterisation data and all relevant ground transponder parameters.
Processing Configuration Databases:	They indicate to the ASCAT PGF the database version of the static parameters (i.e., user-configurable processing parameters) that are to be used for the processing. They define, together with the version of the installed processing software, the configuration of the processing that is used to derive the products.

Outputs:

Level 0 Product:	It contains the information needed to feed the ASCAT PGF, except TM data. The Level 0 product is defined in the EPS Generic Format Specification [AD 2] and the contents of these products are also specified in Section 7.
Level 1A/1B Product:	The Level 1A and 1B products are defined in the Level 1 Product Format Specification [AD 3] and the contents of these products are also specified in Section 7.
Reporting and Quality Control Information	Corresponds to the compiled reporting information produced by the ASCAT PGF (on the received data, on the quality of the processing and on the performance of the mission) that are transferred to the reporting function of the CGS.

	Note: the information includes also all quality information required by the offline Quality Control function of the CGS. In addition, the information contains also all events and command acknowledgements raised by the ASCAT PGF.
Monitoring Information:	Contains all regular monitoring information on the Product Generation Function, providing the G/S maintenance and control function with the information on the status of the instrument, data, processing functions, processing platforms, links.
Calibration information:	Contains calibration source packets and their associated correction reference functions (Rx filter shape, noise power and PowerGain product); antenna gain at angular position measurements; antenna gain patterns and pointings; power to σ^0 normalisation tables, deblooming kernels.
GCM information:	Contains the Special Measurement Mode Source Packets, for GCM, together with extracted relevant parameters.

Controls:

G/S Commands	This data stream corresponds to the transfer of commands generated by the G/S and controlling the operation of the ASCAT PGF. Note that these are only influencing the way the processing is done and are not related to any instrument/platform commands.

Mechanism:

Generic PGE Services	The ASCAT PGF makes use of the generic PGE services for (amongst others) the communication, the reporting, the monitoring, informing of the processing status, orbit and attitude as a function of time, etc.

4.2 System concept

4.2.1 ASCAT PGF states

The following figure sets out the states of the ASCAT PGF and the situations and signals that lead to transitions between those states.

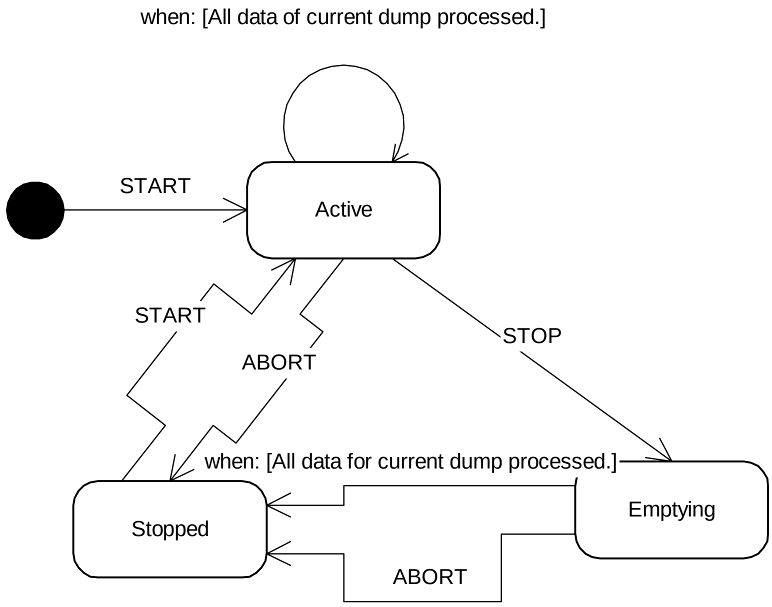


Figure 4: ASCAT PGF State Transition Diagram

The ASCAT PGF supports the following PGF states:

Initial
The PGF does not process data. It accepts a START command. On receipt of the START command it enters the Active state.

Active
The PGF processes data. If the PGF completes the processing of data for an entire dump, it remains in the active state, and processes the data for the next dump if appropriate. ***Note***: During backlog processing or reprocessing, it is foreseen that the PGF will eventually process the last in the series of dumps that it is to process. The PGF accepts STOP and ABORT commands. On receipt of the STOP command it enters the Emptying state. On receipt of the ABORT command the current processing shall terminate with no further delay and shall produce no further outputs apart from a user-configurable event notifying the system that it is stopping, and the PGF then enters the Stopped state.

Emptying
The PGF continues to process the data for the entire dump which it was processing when it received the STOP command. If it had completed the processing of all data for an entire dump when it received the STOP command, and had not begun processing the next dump, then it sends a user-configurable event notifying the system that it is stopping to the system via the PGE interface and enters the Stopped state. It does not accept any data pertaining to the next dump. When it has processed all the data pertaining to the current dump, it sends a user-configurable event notifying the system that it is stopping to the system via the PGE interface and enters the Stopped state. If it receives the ABORT command the current processing shall terminate with no further delay and shall produce no outputs apart from signalling that it has aborted with an event of user configurable severity.

Stopped
The PGF does not process data. Once in the Stopped state, it only accepts a START command.

4.3 Product Generation Function Capability

The processing to Level 1A/1B is specified for 24 hours/day fully automated operation during the full mission time of the EPS programme. The Table 1 presents the behaviour of the Product Generation Function in some specific operational situations.

Operational Situation	*Handling / Behaviour of the algorithms*	*Impact on Product*
Nominal processing	Fully nominal product generation	Nominal quality products
Backlog processing	Fully nominal product generation	Nominal quality products
Reprocessing	Fully nominal product generation, but based on archived Level 0 product “re-injected” via PGE services. Possibility of modified algorithm version (for product improvement) and/or processing parameters.	Nominal quality products

Table 1: Scenario table

4.4 Product Generation Function and High Level Operations Concept: Supported Modes of Operation

4.4.1 ASCAT Instrument Measurement Modes

The ASCAT instrument may operate in flight in one of three primary modes: MEASUREMENT, CALIBRATION and TEST mode. Additionally, in measurement mode, the instrument occasionally generates special source packets for GAIN COMPRESION MONITORING.

The instrument will normally operate in normal MEASUREMENT mode.

During the commissioning phase and, thereafter, approximately once a year for a 30 day-period, the instrument will be operated in CALIBRATION mode only when it passes over the ground transponders. Additionally, the instrument will be operated periodically (once per month) in CALIBRATION mode for one ascending and one descending pass over the ground transponders.

In addition, the instrument Gain Compression needs to be monitored periodically. This is a special variant of measurement mode, called GAIN COMPRESSION MONITORING (GCM), and monitors the relationship between the transmitted power and the RFU drive level setting. These measurements are not used to retrieve science data.

TEST Mode will only be used in flight if the instrument is malfunctioning.

4.4.2 Product Generation Function Operation Modes

The Product Generation Function supports all the modes of operations identified in the CGSRD [AD 1].

The following sections describe NRT, Backlog, and Reprocessing.

4.4.2.1 Near-Real-Time Processing

When the instrument operates in MEASUREMENT mode generating NMMSP, the ASCAT PGF shall automatically produce the standard instrument products: the Level 0 Product, the Level 1A Product and the Level 1B Products.

When the instrument operates in MEASUREMENT mode generating SMMSP, the ASCAT PGF shall generate Gain Compression Monitoring Internal Product.

When the instrument operates in CALIBRATION mode generating CMSP, the ground ASCAT PGF shall generate calibration-related internal products, namely the ASCAT Gain at Angular Position Internal Product.

When the instrument operates in TEST mode generating TMSP, the ASCAT PGF shall handle but not process TEST Mode data (i.e., it will just be archived in the Level 0 product).

Independently of processing NMMSP, the ASCAT PGF shall be able to perform AGPO Estimation or NT and DK Generation. The AGPO Estimation generates the ASCAT Antenna Gain Patterns and Orientations Internal Product and the NT and DK Generation generates the Normalisation Tables and Deblooming Kernels Internal Products.

4.4.2.2 Backlog Processing

Backlog processing is processing of old data with nominal processing parameters.

During Backlog processing, the same ASCAT PGF modes will be allowed.

4.4.2.3 Reprocessing

Reprocessing is processing of old data with new processing parameters and/or algorithms.

Reprocessing might take place if algorithms are changed and/or modified in the future. In that case, reprocessing will take as input the Level 0 product and other necessary relevant information coming from the G/S auxiliary data, contemporary telemetry, instrument and processing configuration parameters.

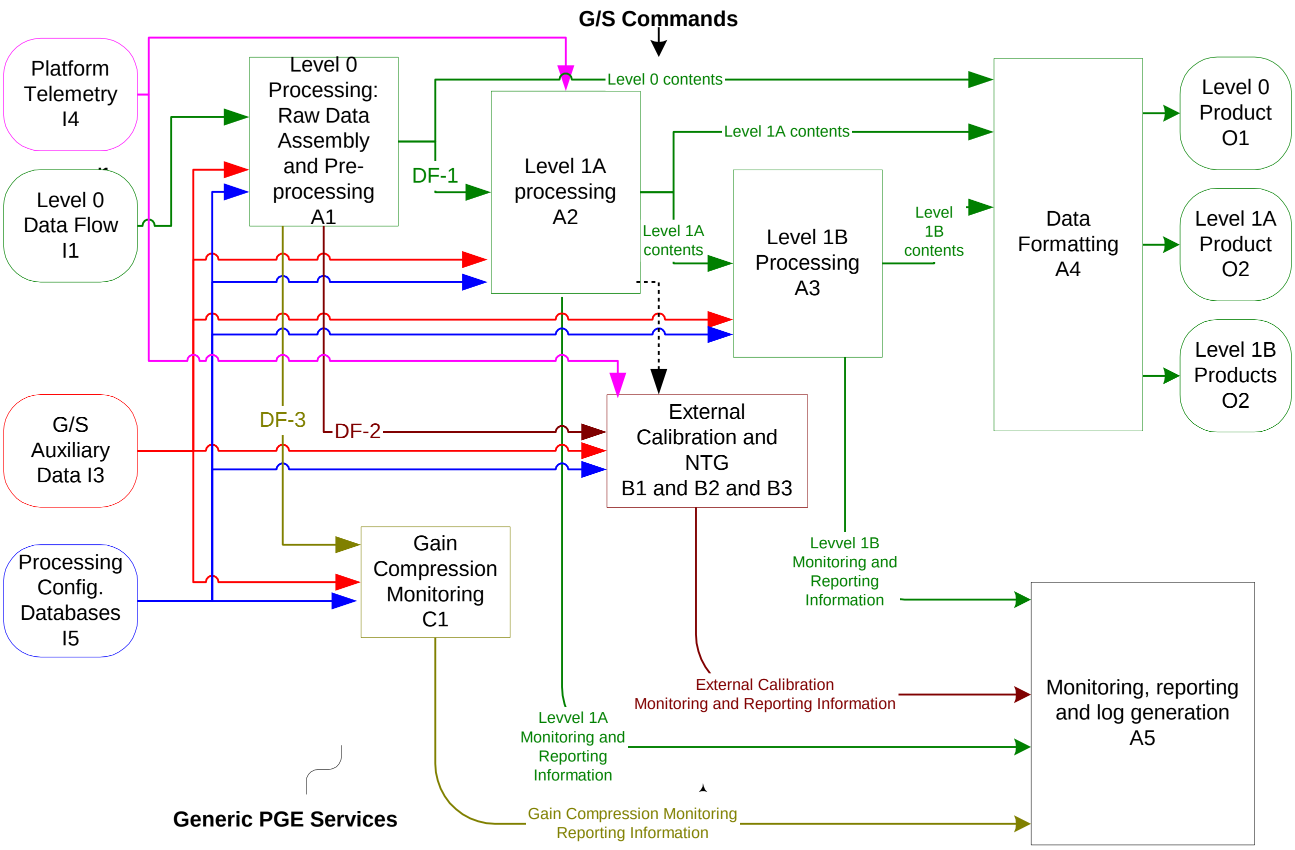
4.5 Overview of the processing chain

The processing chain can be decomposed into different functional levels. For the routine functionality, Level 0 processing accepts and collates the input data, Level 1A processing generates all required reference functions and appends localisation data, Level 1B processing generates full resolution and smoothed $\sigma 0$ values and finally, all data products are formatted as specified in [AD 3]. For the occasional functionality, the External Calibration processing chain estimates the in-flight antenna gain patterns and pointings, as well as generating the necessary in-flight reference function data. The GCM processing chain extracts relevant parameters necessary for monitoring the gain compression at the HPA operating point. In addition, quality control, monitoring, reporting and informing of the processing status will be performed.

4.5.1 Level A0 Decomposition

The first level functionality decomposition of the product generation function is presented below. This is purely a functionality decomposition and shall not prejudge the actual implementation. The colours indicate the different input sources, as well as the main data flows. Green lines are the main processing chain, dark brown lines for the external calibration data flow and ochre lines for the GCM.

Figure 5: ASCAT PGF Level A0 Decomposition



4.5.2 Level 0 Processing (A1)

Level 0 processing consists of accepting and collating all ASCAT PGF input data.

4.5.3 Level 1A Processing (A2)

The objective of Level 1A processing is to calculate the basic reference functions needed in the central chain processing (Level 1B processing). The following operations are carried out:

- Smoothing and interpolation of telemetry;
- Rx filter shape computation;
- Noise power computation;
- Power/internal gain product computation;
- Interpolation of Normalisation Table;
- Localisation;
- Flagging.

4.5.4 Level 1B Processing (A3)

Level 1B processing applies the reference functions calculated in Level 1A processing and then produces the desired Level 1B products:

- On-board Rx filter shape correction;
- Noise subtraction;
- Power/internal gain product correction;
- Power to σ_0 conversion;
- Deblooming subtraction (optional/ Default=OFF);
- Node position generation/data selection;
- Spatial averaging;
- Kp estimation;
- Flagging.

4.5.5 In-flight External calibration, Generation of Normalisation factors and Deblooming Kernels (B1, B2 and B3)

The In-flight External Calibration processing chain estimates the in-flight antenna gain patterns and pointings, as well as generating the necessary in-flight reference function data. Over Calibration source packets, the following functionality is achieved:

- Rx filter shape computation;
- Noise power computation;
- Power/internal gain product computation;
- Localisation.
- On-board Rx filter shape correction;
- Noise subtraction;
- Power/internal gain product correction;
- Calculation of antenna gain at angular positions and generation of relevant calibration internal product;
- Estimation of in-flight antenna gain patterns and pointings and generation of relevant calibration internal product data;
- Generation of in-flight Normalisation Factors and generation of relevant normalisation table internal product data;
- Generations of in-flight Deblooming Kernels and generation of relevant deblooming internal product data.

4.5.6 Gain Compression Monitoring (C1)

The GCM processing chain extracts relevant parameters necessary for monitoring the gain compression at the HPA operating point. Over Measurement source packets of the special GCM type, the following functionality is achieved:

- Extraction of transmitted power values
- Extraction of instrument RFU gain settings
- Generation of relevant GCM internal product

4.5.7 Data Formatting (A4)

The purpose of this function is to format all output data products in accordance with the Product Generation Specifications [AD 3].

4.5.8 Quality control, monitoring, reporting and informing of the processing status (A5)

The following supporting functions are included in the ASCAT PGF functionality.

- Reporting and informing of the processing status
- Usage of M and C services
- On-line quality control functions
- On-line MMI functionality

5 PRODUCT GENERATION FUNCTION: DETAILED DECOMPOSITION

5.1 Raw data assembly and pre-processing (A1)

A1 assembles the instrument raw data and other auxiliary data that will constitute the contents of Level 0 product. Additionally, it separates the input instrument source packets into the three different data flows within the ASCAT PGF (Note that test mode data is not processed).

5.1.1 Inputs and Outputs

The input to, and configuration parameters for, the A1 processing shall consist of the Level 0 data flow, the ground segment Auxiliary Data and the Processing Configuration Databases.

Output from A1 processing shall be as follows:

- Level 0 Product contents (refer to Section 7.1), which shall be supplied to A4 processing (for data formatting of Level 0 product).
- The following data flows:
  - DF-1 or main processing chain input data flow, which shall be supplied to A2 and follow the processing specified in A2, A3 and A4 to routinely generate Level 1A and 1B products,
  - DF-2 or external calibration chain data flow, which shall be supplied to B1 and follow the processing specified in B1, B2 and B3 to occasionally process the data from an external calibration campaign and generation of normalisation factors
  - DF-3 or GCM chain data flow, which shall be supplied to C1 and follow the processing specified in C1 to occasionally monitor the gain compression at the operating point of the HPA.

5.1.2 Accept and Validate Level 0 and Auxiliary Data (A1.1)

5.1.2.1 Check Data Source (A1.1.1)

The origin of source packet data shall be checked (especially at dump boundaries) to ensure that it is from the correct satellite (from the correct ASCAT instrument). Source Packets from different ASCAT instruments shall be processed separately. The METOP satellite can be identified by the parameters in the CVCDU transfer frame header.

5.1.2.2 Assemble and Supply Level 0 Product Contents (A1.1.2)

The following data shall be assembled as described in the definition of Level 0 Product Contents in Section 7.1.

1. The orbit and attitude information applicable for the time interval corresponding to the data dump, supplied to the ASCAT PGF by the Core Ground Segment (PGE Services), together with the METOP satellite identification, the Acquisition Ground Station, the UTC time of the start of downlinking and the dump number.
2. The instrument source packets.

5.1.3 Raw data pre-processing (A1.2)

Three data flows shall be identified according to the Application Process Identification field and Parameter Configuration field in the source packet:

- DF-1: ASCAT Normal Measurement Source packets (excluding the Gain Compression Monitoring special type) and the corresponding noise packets.
- DF-2: ASCAT Calibration Source packets, if there are any present within the input data, and their corresponding noise packets.
- DF-3: ASCAT GCM Measurement Source Packets, if there are any present within the input data, and their corresponding noise packets.

5.2 Main Processing Chain

The objective of the Main Processing Chain is to routinely generate Level 1A and Level 1B ASCAT products.

The main input to the Main Processing Chain is DF-1: ASCAT Measurement Source packets — excluding the Gain Compression Monitoring special type—and their corresponding noise packets.

5.2.1 Level 1A Processing (A2)

5.2.1.1 Inputs and Outputs

The input to the A2 processing shall consist of Level 0 data flow DF-1 (refer to section 7.1), satellite telemetry, processing configuration parameters (for Level 1A processing), as well as G/S auxiliary data.

Output from the A2 processing shall be as follows:

- Level 1A Product contents (refer to section 0), which shall be supplied to both the A3 processing (for Level 1B Processing) and to the A4 processing (for Data Formatting of Level 1A Product).
- Filter shape values on either side of an external calibration sequence. These filter shape values shall be supplied to B1 to be used in the filter shape correction of external calibration echoes.
- Level 1A monitoring, reporting and processing status data (see section 7), which shall be supplied to A5.

5.2.1.2 Source Packet UTC Time Generation (A2.1)

UTC Time Generation is performed using the following information: SBT at Time Tag (for real data), on-board UTC at Time Tag (for test data), PRI Count at Time Tag and PRI Count. Note that for time generation it is necessary to unwrap counter values, which wrap around.

5.2.1.3 Pre-processing of Echo & Noise Data (A2.2)

5.2.1.3.1 Check Source Packet Data and Generate Synthetic Source Packets if Required (A2.2.1)

Source packets shall be checked, in order to ensure that there are no missing, corrupted, invalid or duplicated source packets. In order to allow the ASCAT PGF to work continuously, missing, corrupted and invalid source packets shall be replaced by synthetic source packets and flagged accordingly, as indicated in the following paragraphs. Duplicated source packets shall be discarded.

Missing and *duplicated* source packets are detected by examination of the following items within each source packet to ensure that the sequence is as expected:

- the Source Sequence Count,
- the PRI Count,
- the Tag Field,
- the Application Process Identification and
- the Ground Processor Flags.

Corrupted source packets are detected by examination of the following items:

(1) the Packet Error Control Field of the source packet and

Invalid source packets are detected by inspecting the following items:

(1) Ground Processor Flags,

(2) the Out-Of-Range Count and

(3) any static or variable non-data field which does not contain permitted values.

For the case of the Out-Of-Range Count, if it exceeds a threshold value (T_{OORC}) the echo or noise data are deemed to be invalid due to A/D Converter Overflows.

Source Packets that are not found to be missing, corrupted or invalid, are deemed to be good source packets.

Missing, Corrupted or Invalid source packets shall be replaced with synthetic source packets generated by averaging the echo/noise lines of two good source packets of the same Application Process Identification, 1 on either side of the missing, corrupted and/or invalid source packet or packets.

Synthetic source packets shall be flagged according to Section 6.1.5.

5.2.1.3.2 Check, Smooth and Interpolate Telemetry to UTC time associated to Source Packets & Append Resulting Data (A2.2.2)

It shall be checked if platform and instrument telemetry applicable to the UTC time T_0 associated to the echo is available, and in that case the available telemetry shall be interpolated to that UTC time T_0 See relevant parameters needed in Block II in Section 0.

The range of the available relevant telemetry parameters shall be checked with respect to a reference range for each parameter and a Telemetry out-of-range flag per parameter shall be generated accordingly.

A Telemetry missing or out of range flag shall be generated according to Section 6.1.5.

Note: The telemetry data are available within the Admin Packets (and Satellite Packets) provided in the X-band downlink data stream [AD 4], [AD 5].

5.2.1.3.3 Separate Echo and Noise Source Packets (A2.2.3)

The echo and noise source packets shall be identified and separated. The noise source packets are used to compute reference functions and reference parameter values needed for echo processing.

Those values are later appended to the echo source packets in Level 1A product. The noise packets are not appended to the Level 1A product.

5.2.1.4 Noise Data Processing (A2.3)

The noise processing requires approximately five minutes worth of noise data on each side of the time associated with reference function or parameter value. Therefore, noise processing for a particular time needs to be completed before echo processing for that time is started.

5.2.1.4.1 Compute Rx Filter Shapes (A2.3.1)

The Rx filter shape computation shall be performed as described in Section 6.2.1.

The shape of the on-board radar receive chain spectral characteristic is estimated using the reception windows of noise samples. Approximately 10 minutes of continuous data in time are required to estimate each noise power spectrum.

5.2.1.4.2 Compute Noise Power Values (A2.3.2)

The noise power value associated with each echo shall be estimated for noise subtraction as described in sections 6.1.1 and 6.2.2.

5.2.1.4.3 Discard Noise data and associated telemetry (A2.3.3)

The noise source packets shall now be discarded leaving:

(1) the Rx Filter shape estimation-related quality flags; generated according to Section 6.1.5,

(2) the Noise power estimation-related quality flags; generated according to Section 6.1.5)

5.2.1.5 Echo Data Processing (A2.4)

5.2.1.5.1 Generate the Power/Internal Gain Product (A2.4.1)

The Power/Internal Gain Product value for each echo source packet shall be generated as described in section 0.

5.2.1.5.2 Interpolate Power to σ_0 normalisation function and its roll, pitch and yaw derivatives to the time of the echo source packet (A2.4.2)

The power to σ_0 normalisation values and the roll/pitch/yaw derivatives to be applied to a given echo shall be interpolated to the echo time using the values provided in the Normalisation Table Internal Product.

5.2.1.5.3 Localisation of individual power echoes (A2.4.3)

The necessary geometry transformations to localise individual power echoes in the Terrestrial Reference Frame shall be performed, according to the algorithms described in Section 6.3.1, Section 6.3.2 and Section 6.3.3. The individual power echoes, so far characterised by (discriminator frequency/time) coordinates, shall be localised by (x,y,z) coordinates in the Terrestrial Reference Frame and by latitude and longitude.

5.2.1.5.4 Generate other necessary localisation information and geometry (A2.4.4)

Other necessary localisation information and geometry shall be generated according to algorithms described in Sections 6.3.1, 6.3.2 and 6.3.3.

5.2.1.5.5 Generate Quality Flags & Qualifiers (A2.4.5)

Quality Flags and qualifiers shall be generated according to Section 6.1.5.1.

5.2.1.6 Assemble Level 1A Product Contents (A2.5)

The output of A2 processing shall be assembled as described in the definition of Level 1A Product contents, auxiliary data and Processing in Section 0.

5.2.1.7 Generate Monitoring and Reporting Information (A2.6)

Monitoring, reporting and processing status data, as detailed in Section 7 shall be generated.

5.2.2 Level 1B Processing (A3)

5.2.2.1 Inputs and Outputs

The input to the A3 processing shall consist of Level 1A Product contents (refer to Section 0), processing configuration parameters (for Level 1B processing) and Ground Segment auxiliary data.
Output from the A3 processing shall be:

- Level 1B Product contents (refer to Section 7.3), which shall be supplied to A4 processing.
- Level 1B monitoring, reporting and processing status data (see Section 7), which shall be supplied to A5.

5.2.2.2Processing into normalised σ0 (A3.1)

5.2.2.1.1 Apply Reference Functions to Source Packet Measurement Mode Echo Powers (A3.1.1)

Reference functions shall be applied to Measurement echo powers as the next paragraphs indicate. The resulting σ_0 value shall be flagged according to Section 6.1.5.1.

5.2.2.1.1.1 **Rx Filter Shape Correction (A3.1.1.1)**

The Rx filter shape correction shall be applied to the source packet echo data in accordance with the algorithm given in Section 6.1.1.

5.2.2.1.1.2 **Noise Power Value Subtraction (A3.1.1.2)**

The Noise Power Value shall be subtracted in accordance with the algorithm description given in Section 6.1.1.

5.2.2.1.1.3 **Power-Internal Gain Product Correction (A3.1.1.3)**

The Power Internal Gain Product Correction shall be applied in accordance with the algorithm description given in Section 6.1.1.

5.2.2.1.1.4 **Power To σ_0 Normalisation (A3.1.1.4)**

The corrected measurement echo power values shall be converted to σ_0 values in accordance with the algorithm described in Section 6.1.2.

5.2.2.1.1.5 **Perform Deblooming on Full Resolution σ_0 (A3.1.1.5)**

This is an optional functionality (the default is Off). If deblooming is selected, it shall be performed in accordance with the algorithm described in Section 6.1.2.

5.2.2.2 Full Resolution σ_0 Product (A3.2)

5.2.2.2.1 Generate Land flags and Quality flags and qualifiers (A3.2.1)

Land/quality flags and qualifiers for the full resolution σ_0 product, as specified in Section 7.3.3, shall be generated.

The resolution of the land/sea mask used shall be better than the best resolution of the full resolution data.

5.2.2.2.2 Assemble Full Resolution σ_0 Data Product Contents (A3.2.2)

The Full Resolution σ_0 Data Product contents shall be assembled as described in the definition of Level 1B Product contents in Section 7.3.3.

5.2.2.2.3 Generate Monitoring and Reporting Information (A3.2.3)

Monitoring, reporting and processing status data (see Section 7) shall be generated.

5.2.2.3 Level 1B 50km Spatial Resolution Product (A3.3)

5.2.2.3.1 Generate σ0 Triplets and Kp Estimates at 50km Spatial Resolution (A3.3.1)

5.2.2.3.1.1 Generate and land-flag Node Positions (A3.3.1.1)

Node positions for (the first or) the next line of 50 km resolution nodes shall be generated in accordance with the algorithm specified in Section 6.3.4. Note that the full-resolution σ_0 data need to be buffered until the necessary data for spatial averaging are available for each antenna beam.

5.2.2.3.1.2 Transform Relevant Full Resolution σ_0 Values To Node Frame (A3.3.1.2)

For each node in the line of nodes and for each antenna beam, the relevant full resolution σ_0 data shall be transformed to the 50 km node reference frame for that node, in accordance with the algorithms specified in Section 6.3.2 and Section 6.1.2.

5.2.2.3.1.3 Perform Spatial Averaging for 50 km Spatial Resolution (A3.3.1.3)

For each node on the line of nodes and for each antenna beam, spatial averaging shall be performed over full-resolution σ_0 values, to generate the smoothed σ_0 estimate at 50 km spatial resolution, in accordance with the algorithm specified in Section 6.1.3.

The ensemble of the spatially averaged σ_0 estimates from the three beams (Fore, Mid and Aft) is called 50 km resolution σ_0 triplet. Every Node of the spatial resolution product contains therefore up to three averaged values of σ_0, one per beam. For a given node, and due to the geometry of the measuring system (see Section 2) the σ_0 values from the three different beams correspond to measurements taken at different times. The fore beam measurements lead in time, followed by the mid beam and later by the aft beam. The distance between the measurement time of the σ_0 values corresponding to different beams within a node depends on the node position within the swath, ranging from approximately one minute in the near swath, to up to three minutes in the far swath.

5.2.2.3.1.4 Estimate Kp Value (A3.3.1.4)

For each node on the line of nodes and for each antenna beam, the Kp value (standard error) of the 50 km resolution smoothed σ_0 estimate shall be computed in accordance with the algorithm specified in Section 6.1.4.

5.2.2.3.1.5 **Generate Flags and qualifiers (A3.3.1.5)**

For each node on the line of nodes and for each antenna beam, the flags and qualifiers of the 50 km resolution smoothed σ_0 product, as specified in Section 7.3.2, shall be generated, according to Section 6.1.5.1.

5.2.2.3.1.6 **Generate Node Geometry (A3.3.1.6)**

For each node on the line of nodes and for each antenna beam, the 50 km resolution node geometry information indicated in Section 7.3.1 shall be generated.

5.2.2.3.2 Assemble σ_0 Triplet Data Product Contents for 50 km Spatial Resolution (A3.3.2)

The 50 km Resolution σ_0 Data Product contents shall be assembled as described in the definition of Level 1B contents in Section 7.3.1.

5.2.2.3.3 Generate Monitoring and Reporting Information (A3.3.3)

Monitoring, reporting and processing status data shall be generated. Details are in Section 7.

5.2.2.4 Level 1B 25 km Spatial Resolution Product (A3.4)

5.2.2.4.1 Generate σ_0 Triplets & Kp Estimates at 25 km Spatial Resolution (A3.4.1)

5.2.2.4.1.1 **Generate and land-flag Node Positions (A3.4.1.1)**

Node positions for (the first or) the next line of 25 km resolution nodes shall be generated in accordance with the algorithm specified in Section 6.3.4. Note that the full resolution σ_0 data needs to be buffered until the necessary data for spatial averaging are available for each antenna beam.

5.2.2.4.1.2 **Transform Relevant Full Resolution σ_0 Values To Node Frame (A3.4.1.2)**

For each node in the line of nodes and for each antenna beam, the relevant full resolution σ_0 data shall be transformed to the 25 km node reference frame for that node, in accordance with the algorithms specified in Section 6.3.2 and Section 6.1.2.

5.2.2.4.1.3 **Perform Spatial Averaging for 25 km Spatial Resolution (A3.4.1.3)**

For each node on the line of nodes and for each antenna beam, spatial averaging shall be performed over full-resolution σ_0 values, to generate the smoothed σ_0 estimate at 25 km spatial resolution, in accordance with the algorithm specified in Section 6.1.3.

The ensemble of the spatially averaged σ_0 estimates from the three beams (fore, mid and aft) is also called 25 km resolution σ_0 triplet.

Every Node of the spatial resolution product contains therefore up to three averaged values of σ_0, one per beam. For a given node, and due to the geometry of the measuring system (see Section 2) the σ_0 values from the three different beams correspond to measurements taken at different times. See Section 2. The fore beam measurements lead in time, followed by the mid beam and later by the aft beam. The distance between the measurement time of the σ_0 values corresponding to different beams within a node depends on the node position within the swath, ranging from approximately one minute in the near swath, to up to three minutes in the far swath.

5.2.2.4.1.4 **Estimate Kp Value (A3.4.1.4)**

For each node on the line of nodes and for each antenna beam, the Kp value (standard error) of the 25 km resolution smoothed σ_0 estimate shall be computed in accordance with the algorithm specified in Section 6.1.4.

5.2.2.4.1.5 **Generate Flags and qualifiers (A3.4.1.5)**

For each node on the line of nodes and for each antenna beam, the flags and qualifiers of the 25 km resolution smoothed σ_0 product, as specified in Section 7.3.2, shall be generated, according to Section 6.1.5.

5.2.2.4.1.6 **Generate Node Geometry (A3.4.1.6)**

For each node on the line of nodes and for each antenna beam, the 25 km resolution node geometry information indicated in Section 7.3.2 shall be generated.

5.2.2.4.2 Assemble σ_0 Triplet Data Product Contents for 25 km Spatial Resolution (A3.4.2)

The 25 km Resolution σ_0 Triplet Data Product contents shall be assembled as described in the definition of Level 1B contents in Section 7.3.1.

5.2.2.4.3 Generate Monitoring and Reporting Information (A3.4.3)

Monitoring, reporting and processing status data shall be generated. See Section 7.

5.2.3 Data formatting (A4)

Level 0, 1A and 1B product contents supplied from A1, A2 and A3 processing respectively shall be formatted in accordance with the specifications contained in [AD 2] and [AD 3].

5.2.4 Monitoring, reporting and informing of the processing status (A5)

Monitoring and Reporting Information supplied by A1, A2 and A3 shall be compiled/processed for Quality control, monitoring, reporting and informing of the processing status. See Section 7.

It shall be possible to read, display and print all Monitoring and Reporting Information for a period of at least two weeks after their generation.

Note: This may, for example, be implemented via the generation of a human-readable report, i.e., a file of ASCII encoded data and figures.

Note: To keep the Monitoring and Reporting Information for at least two weeks from their generation may involve exporting it to a facility external to the ASCAT PGF via, for example, the PGE services.

To display a value or set of values shall consist of showing on a monitor as the most recent of a time series of the n previous values or sets of values, where the value of n is user selectable. Note: thus, the display of a power gain product could result in a plot of the last n power gain product values, and the display of the Rx filter shape could result in a sequence of n plots of the Rx filter shape.

5.2.4.1 Instrument / Processing Status Monitoring (A5.1)

The ASCAT PGF shall report on all instrument/processing mode transitions, both to and from the following modes, together with their times of occurrence at the processor and, where applicable, at the instrument.

- Off
- Processing Normal Measurement Mode Source Packets (NMMSP)
- Processing Calibration Mode Source Packets (CMSP)
- Processing Special Measurement Mode Source Packets (SMMSP) (for Gain Compression Monitoring)

- Handling Test Mode Source Packets (TMSP)
- Processing NMMSP simultaneously with Antenna Gain Pattern and Orientation (AGPO) Estimation
- Processing NMMSP simultaneously with Normalisation Table and Deblooming Kernel (NT and DK) Generation
- AGPO Estimation
- NT and DK Generation

The ASCAT PGF shall also report on all changes of processing configuration, together with their times of occurrence.

5.2.4.2 On-line Quality Control (A5.2)

While the PGF is processing NMMSP, the data items and time averaged data items given in Section 7.4.9 shall be reported and displayed at user selectable intervals, normally 6000 seconds. While the PGF is processing NMMSP, user selectable flag transitions (of flags indicated in Section 7.4.9) shall be reported and displayed, together with the time of occurrence of these transitions.

While the PGF is processing CMSP, the data items and time averaged data items given in Section 7.4.9 shall be reported and displayed, for each CMSP. While the PGF is processing CMSP, user selectable flag transitions (of flags indicated in Section 7.4.9) shall be reported and displayed, together with the time of occurrence of these transitions.

While the PGF is processing SMMSP for GCM, the UTC time of each SMMSP, the drive level and the transmit power shall be reported and displayed. At the end of a sequence of SMMSP, the derived GCM parameters shall be computed, reported and displayed. At the end of each sequence of SMMSP, the ASCAT GCM information (see Section 7.4.8) shall be reported to the Measurement and Calibration facility without delay.

It shall be possible to display and report on, at user selectable time intervals, any subset to up to 25 data items contained in products or time averages of these data items over user selectable intervals of time. Note: this capability is envisaged for diagnostic purposes.

5.2.4.3 Usage of M&C services (A5.3)

It shall be allowed that the PGF make use of the generic M&C service of the PGE to receive commands from the CGS, to transfer the processing status and monitoring information to the CGS and to receive flight dynamics information and the land mask.

5.2.4.4 Online MMI functionality (A5.4)

The PGF shall also provide the following online MMI functionality: real-time quick look display capability of data flow and parameter values, as well as online analysis display capability of all received data, generated products, internal files, data sets and quality information. See also Section 7.

5.3 External Calibration and NTG Processing Chain

The Calibration Processing Chain processes the transponder calibration data to determine the in-flight antenna gain patterns and their boresight pointings and orientations. The estimated parameters are then used to generate in-flight Power-to-σ_0 normalisation functions and Deblooming Kernels, given an orbit and a spacecraft attitude law.

Part of this functionality (B1) shall be performed every time a Calibration Source Packet arrives to the PGF. Other parts (B2 and B3) shall be performed in response to a command to the PGF.

The main input to the Calibration Processing Chain is DF-2: ASCAT Calibration Source packets, if there are any present within the input data, and their corresponding noise packets.

5.3.1 Estimation of antenna gain at different angular positions (B1)

The Calibration Source Packets are first subjected to a front-end correction that is very similar to the one applied to Measurement Source packets. Therefore, several references to functions within A2 and A3 will be made in the following sections. The main differences between the correction of Measurement and Calibration source packets is in the estimation of the applicable reference functions. Corrected Calibration Source Packets are then used to estimate the values of the antenna gain at different angular positions in the antenna coordinates frame.

5.3.1.1 Inputs and Outputs

The input to the B1 processing shall consist of the DF-2 contents, satellite telemetry corresponding to the product time, processing parameters (for Level 1A calibration data processing) and filter shape values calculated using the Normal Measurement Mode noise packets on either side of the external calibration sequence as calculated in A2. DR-2 contents are described in Section 7.1.

Output from the B1 processing shall be as follows:

- Calibration source packets, raw with corrections for variations of the Rx filter shape, noise power and Power-Gain product and other parameters.
- Corresponding antenna gain values at angular positions, which shall be supplied to B2.
- Monitoring, reporting and processing status data (see Section 7) shall be generated, which shall be supplied to A5.

The output from the B1 processing shall be written to an internal file (Calibration Data Internal Product, see section 7.4.1 for contents), which shall be accessible from both the ASCAT PGF and a facility external to the ASCAT PGF (ASCAT cal/val facility).

5.3.1.2 Source Packet UTC Time Generation (B1.1)

This function shall be performed as explained in Section 6.

5.3.1.3 Pre-processing of Echo and Noise Data (B1.2)

5.3.1.3.1 Check Source Packet Data (B1.2.1)

Source packets shall be checked, in order to ensure that there are no missing, corrupted, invalid or duplicated source packets.

Missing and duplicated source packets
Missing and duplicated source packets are detected by examination of the following items within each source packet to ensure that the sequence is as expected: 1. the Source Sequence Count, 2. the PRI Count, 3. the Tag Field, 4. the Application Process Identification and 5. the Ground Processor Flags.

Corrupted source packets
Corrupted source packets are detected by examination of the following items: 1.the Packet Error Control Field of the source packet

Invalid source packets
Invalid source packets are detected by inspecting the following items: 1. Ground Processor Flags, 2. the Out-Of-Range Count and 3. any static or variable non-data field which does not contain permitted values.

For the case of the Out-Of-Range Count, if it exceeds a threshold value (T_{OORC}) the echo or noise data are deemed to be invalid due to A/D Converter Overflows.

Missing, Corrupted or Invalid measurement source packets shall be replaced with synthetic source packets generated by filling the data fields of the source packet with zeros or a default value. They shall be flagged according to Section 6.1.5.1.

5.3.1.3.2 Check, Smooth and Interpolate Telemetry to UTC time associated to Source Packets and Append Resulting Data (B1.2.2)

This function shall be identical to A2.2.2.

5.3.1.3.3 Separate Echo and Noise Source Packets (B1.2.3)

The echo and noise source packets shall be identified and separated. The noise source packets are used to compute reference parameter values needed for echo processing. Those values are later appended to the echo source packets in the Calibration Data Internal Product (see Section 7.4.1). The noise source packets are not appended in that product.

5.3.1.4 Noise Data Processing (B1.3)

5.3.1.4.1 Compute Rx Filter Shapes (B1.3.2)

The Rx filter shape computation shall be performed as described in Section 6.2.1 for calibration source packets.

The shape of the on-board radar receive chain spectral characteristic is estimated using the reception windows of noise samples. In order to obtain an Rx Filter Shape estimate to be used to correct the calibration mode data, the last and first good Rx Filter Shape estimates from the measurement mode operations, on either side of the calibration mode operation sequence, shall be averaged.

5.3.1.4.2 Compute Noise Power Values (B1.3.3)

The noise power value associated with each echo shall be estimated for noise subtraction as described in Section 6.2.2 for calibration source packets.

5.3.1.4.3 Discard noise data and associated telemetry (B1.3.5)

The noise data can now be discarded from the noise source packets leaving only:

(1) the Rx Filter shape estimation related quality flags (generated according to Section 6.1.5.2),

(2) the Noise power estimation related quality flags (generated according to Section 6.1.5.2).

5.3.1.5 Echo Data Processing (B1.4)

5.3.1.5.1 Generate the Power/Internal Gain Product (B1.4.1)

The Power/Internal Gain Product value for each echo source packet shall be generated as described in Section 0 for calibration source packets.

5.3.1.5.2 Localisation of individual power echoes (B1.4.2)

The necessary geometry transformations to localise individual power echoes in the Terrestrial Reference Frame shall be generated, according to the algorithms described in Section 6.3.1, Section 6.3.2 and Section 6.3.3. The individual power echoes, so far characterised by (discriminator frequency/time) coordinates, shall be localised by (x,y,z) coordinates in the Terrestrial Reference Frame and by latitude and longitude.

5.3.1.5.3 Generate other necessary localisation information and geometry (B1.4.3)

Other necessary localisation information and geometry shall be generated according to algorithms described in Sections 6.3.1, 6.3.2 and 6.3.3.

5.3.1.5.4 Generate Quality Flags & Qualifiers (B1.4.4)

Quality Flags and qualifiers shall be generated according to Section 6.1.5.2.

5.3.1.6 Calibration source packets front-end correction (B1.5)

Reference functions shall be applied as the next paragraphs indicate to Calibration echo powers. The resulting σ_0 value shall be flagged according to Section 6.1.5.2.

5.3.1.6.1 Rx Filter Shape Correction (B1.5.1)

The Rx filter shape correction shall be applied to the source packet echo data in accordance with the algorithm given in Section 6.1.1.

5.3.1.6.2 Noise Power Value Subtraction (B1.5.2)

The Noise Power Value shall be subtracted in accordance with the algorithm description given in Section 6.1.1.

5.3.1.6.3 Power-Internal Gain Product Correction (B1.5.3)

The Power Internal Gain Product Correction shall be applied in accordance with the algorithm description given in Section 6.1.1.

5.3.1.7 Calculating Gain at angular positions values (B1.6)

For every transponder measurement, the gain at angular positions shall be calculated as described in Section 6.2.5.

5.3.1.8 Assemble Calibration Data Internal product Contents (B1.7)

For every calibration source packet which arrives at the ASCAT PGF, the raw Calibration Source Packet, the reference functions used to correct it and the derived gain at angular position measurements shall be written to a file (ASCAT Gain at Angular Position Internal Product), which shall be accessible from both the ASCAT PGF and a facility external to the ASCAT PGF, which is the ASCAT calibration/validation facility). This information constitutes the output of B1 processing, and shall be assembled as described in the definition of the ASCAT Gain at Angular Position Internal Product contents in Section 7.

5.3.1.9 Generate Monitoring and Reporting Information (B1.8)

Monitoring, reporting and processing status data (see Section 7) shall be generated.

5.3.2 Antenna Gain Pattern and Orientation Estimation (B2)

The External calibration shall be an occasionally executing functionality, which shall be performed in response to a command given to the PGF.

The External calibration consists on estimating the in-flight antenna gain patterns and three depointing angles for each antenna.

5.3.2.1 Inputs and Outputs

The input to B2 processing shall be the Antenna Gain at Angular Position Internal Product.

Output from the B2 processing shall be:

- In-flight antenna gain patterns and three de-pointing angles.
- Monitoring, reporting and processing status data (see Section 7) shall be generated which shall be supplied to A5.

The output from the B2 processing shall be written to an internal file (ASCAT Antenna Gain Patterns and Orientations Internal Product, see Section 7 for contents), which shall be accessible from both the ASCAT PGF and a facility external to the ASCAT PGF, the ASCAT calibration/validation facility).

5.3.2.2 Estimation of in-flight antenna gain patterns and de-pointing angles (B2.1)

This shall be done by processing a user selectable set of gain at angular position estimates, according to the algorithms expressed in Section 6.2.6.

A number of GAP estimates shall be selectable on the basis of time interval or time intervals, by transponder number or numbers, by ascending or descending pass, by gain drop (with respect to the expected peak gain of a given antenna) and / or by combinations of these. It shall also be possible to manually edit all GAP estimates or selections of GAP estimates (made as described in the previous sentence) to obtain a final set for use in the Antenna Gain Pattern and Orientation Determination Algorithm.

The in-flight external calibration shall be carried out separately for these three passes:

- ascending passes
- descending passes
- all passes

5.3.2.3 *Assemble Calibration Results product contents (B2.2)*

The output of B2 processing shall be assembled as described in the definition of the ASCAT Antenna Gain Patterns and Orientations Internal Product contents in Section 7.

5.3.2.4 *Generate Monitoring and Reporting Information (B2.3)*

Monitoring, reporting and processing status data shall be generated. See Section 7.

5.3.3 Generation of in-flight σ_0 Normalisation Factors and Deblooming Kernels (B3)

The Generation of σ_0 Normalisation Factors and Deblooming Kernels is an occasional functionality, which shall be performed in response to a command given to the PGF.

5.3.3.1 *Inputs and Outputs*

The input to B3 processing shall be the ASCAT Antenna Gain Patterns and Orientations Internal Product.

Output from B3 processing shall consist of the following:

- a set of Normalisation factors in a LUT (NT), with other information. See Section 7.
- a set of Deblooming Kernels in a LUT (DK), with other information See Section 7.
- Monitoring, reporting and processing status data shall be generated, which shall be supplied to [A5]. See Section 7.

The output from B3 processing shall be written to internal files, which shall be accessible from both the ASCAT PGF and a facility external to the ASCAT PGF. The contents of the files are as defined in Section 7.4.3 and Section 7.4.4 respectively.

5.3.3.2 *Generation of in-flight Normalisation Factors (B3.1)*

An in-flight Normalisation factors Table (NT) shall be generated, according to the algorithm expressed in Section 6.2.4.

5.3.3.3 *Generation of in-flight Deblooming kernels (B3.2)*

An in-flight Deblooming Kernels Table (DK) shall be generated, according to the algorithm expressed in Section 6.2.7.

5.3.3.4 *Generate Monitoring and Reporting Information (B3.3)*

Monitoring, reporting and processing status data as described in Section 7 shall be generated.

5.4 Gain Compression Monitoring processing chain

The objective of the Gain Compression Monitoring Processing Chain is to monitor the gain compression at the operating point of the HPA.

5.5 Gain Compression Monitoring (C1)

This functionality shall be occasional and performed every time a sequence of Special Measurement Mode Source Packet for Gain Compression Monitoring arrives to the ASCAT PGF, according to the algorithm described in Section 6.2.10.

The sequences of special measurement mode source packets for gain compression monitoring, as well as the resulting derived parameters and flags shall be immediately reported to the Mission Control Function (MCF).

5.5.1 Inputs and Outputs

The input to the C1 processing shall be the DF-3 data flow: ASCAT Measurement Mode Source Packet of the Gain Compression Monitoring special type, if there are any present within the input data.

Output from the B3 processing shall consist of the following:

- extracted relevant parameters from the input source packets.
- flags derived by testing the values of these parameters
- Monitoring, reporting and processing status data as detailed in Section 7, which shall be supplied to A5.

The results of GCM shall be reported to Monitoring and Calibration immediately.

The inputs and outputs from the C1 processing shall be jointly written to a file (Gain Compression Monitoring Information Internal Product, see Section 7), which shall be accessible from both the ASCAT PGF and a facility external to the ASCAT PGF (ASCAT cal/val facility).

5.5.2 Computation of the Average Effective Transmitted Power values (C1.1)

For every Drive Level Setting, an Average Effective Transmitted Power value shall be generated.

5.5.3 Computation of CGM parameters (C1.2)

For a nominal Gain Compression Monitoring Sequence, the values of $P_{TEST\text{-}GCM}$ and $Z_{GAIN\ COMPRESSION}$ and the relevant flags (see Section 7) shall be computed.

For an exceptional Gain Compression Monitoring Sequence, the required parameters shall be computed as described in Section 7.

5.5.4 Assembly of Gain Compression Monitoring data (C1.3)

Gain Compression Monitoring, reporting and processing status data shall be generated as described in Section 7.

6 ALGORITHMS FOR THE ASCAT PGF

The following is a description of the algorithms used in the ASCAT PGF. The algorithms are organised in the following paragraphs as follows. First, the central processing chain algorithms (which are used in Level 1B processing) are given together with algorithms for the correction of calibration source packets. Level 1B processing consists basically of applying a set of reference functions to the raw data, generating normalised backscatter σ_0 values and smoothing them into the 25 km and 50 km spatial resolution σ_0 triplets. Second, the algorithms to be used for the determination of the above mentioned reference functions are given. Some of these algorithms are used in the Level 1A processing. Finally, a set of auxiliary algorithms related to the system geometry is described.

Nominally, the ASCAT generates only three classes of source packet in orbit: Normal Measurement Mode source packets, Special Measurement Mode source packets (for GCM) and Calibration Mode source packets.

The Normal Measurement Mode source packets are either echo source packets or noise source packets. The Normal Measurement Mode echo source packets are processed to create the Level 1B σ_0 products using the central chain algorithms. The Normal Measurement Mode noise source packets are used to generate reference functions required for processing the Normal Measurement Mode echo source packets. Normally the ASCAT operates in Measurement Mode.

The Special Measurement Mode source packets are not used for generation of σ_0 products but are instead used for monitoring the gain compression at the operating point of the HPA. These source packets are identified by inspection of the parameter configuration field of the source packet. They are stored permanently in a file within the ASCAT PGF, which can be read by the cal/val facility as well as the ASCAT PGF itself. It is expected that GCM is carried out once a month using a GCM sequence lasting approximately five minutes.

The Calibration Mode source packets are not used for generation of σ_0 products but are instead used to determine the in-flight antenna gain patterns and their boresight pointings and orientations. The Calibration Mode echo source packets are first subjected to corrections for receive chain spectral transfer characteristic, noise removal and variations in transmitted power and receiver gain. Each packet is then used to determine the antenna gain at one or more angular positions; this data is stored permanently in a file within the ASCAT PGF (which can be read by the cal/val facility as well as the ASCAT PGF itself). A set of 24×56 antenna gain at an angular position measurements for each antenna is acquired during each external calibration campaign, which lasts approximately one month and usually performed once per year. A further set of 24×2 antenna gain at an angular position measurements for each antenna is acquired approximately every month for monitoring purposes. A user-selectable subset of the data stored within the file can be used to generate an antenna gain pattern and boresight pointing estimate. The estimated antenna gain patterns and boresight pointing estimates can be used to generate new power to σ_0 normalisation functions given an orbit, instrument parameters and a spacecraft attitude steering law.

6.1 Central Chain Algorithms

6.1.1 Correction for Receive Chain Spectral Transfer Characteristic, Noise Subtraction and Transmit Power / Internal Gain Product Correction

For further information, see also [RD 1]. The detected echo samples within each source packet are corrected for, firstly, variation of the shape of the receiver filter characteristic, secondly, the relevant noise power is subtracted and, thirdly, the resulting signal is corrected for transmitted power and internal instrument gain variations. These corrections are defined by the following equation.

$$S(i, j, b) = \frac{1}{\lambda(j, b, SP)} \left[\frac{E(i, j, b)}{h_{RX}(i, k(j))\, \chi(i, b)} - c(b)\, n(k(j), b) \right] \qquad \textit{Equation 1}$$

$E(i, j, b)$ is the set of source packet echo samples associated with along track time $T_E(j, b)$ for beam b. The index i runs from 1 to N_{ECHO} and labels the source packet detected echo sample associated with discriminator frequencies f(i). The index j starts at 1 and increases in steps of unity to $N_{ECHO\text{-}PACKETS}$; it labels sequentially the echo source packets from a particular beam b associated with the along track time T_E (j, b). The index j associated with the first line of source packet echo from each beam when a ground processing run is started is unity. The first line of echo will be the first line received after a noise packet for each beam.

$T_E(j, b)$ is given by the following equation for real measurement mode and calibration mode echo data:

$$\begin{aligned} T_E(j, b) &= T_{UTC\text{-}FIRST\text{-}IN\text{-}SP/E} \\ &= UTC\left(T_{SBT-AT-TT} \right. \\ &\quad + N_{PRI}\, \Delta_{PRI}\, \mathrm{Floor}\left[\frac{\mathrm{Unwrap}(C_{PRI-COUNT}) - C_{PRI-AT-TT}}{N_{PRI}} \right] \\ &\quad \left. + \Delta_{PRI}\, \mathrm{mod}\left[\left(\mathrm{Unwrap}(C_{PRI-COUNT}) - C_{PRI-AT-TT}\right), N_{PRI} \right] \right) \end{aligned} \qquad \textit{Equation 2}$$

For test measurement mode, echo data UTC ($T_{SBT\text{-}AT\text{-}TT}$) is replaced by $T_{UTC\text{-}AT\text{-}TT}$ in the above equation.

where:

$T_{UTC\text{-}FIRST\text{-}IN\text{-}SP/E}$	is the UTC Time associated with the first PRI contribution to that echo source packet.
$T_{SBT\text{-}AT\text{-}TT}$	is the satellite binary time at Time Tag given in the source packet.
$T_{UTC\text{-}AT\text{-}TT}$	is the on-board UTC at Time Tag given in the source packet.
$C_{PRI\text{-}COUNT}$	is the PRI count given in the source packet.
N_{PRI}	is the number of beams firing in the beam cycle: six for Measurement Mode and two for Calibration Mode.
Δ_{PRI}	is the pulse repetition interval for a beam. This is calculated from the instrument timeline parameters given in Section 7.4.

The index b labels the beams: it takes values from 1 to B = 6.

$h_{RX}(i,k(j))$	is the receive chain filter shape function associated with along-track time $T_N(k(j), b)$); it is not beam dependant.
n(k(j),b))	is the noise power applicable for beam b associated with along-track $T_N(k(j), b)$.

Let the noise packets be labelled by the integer index *k* which runs from 1 to $N_{NOISE\text{-}PACKETS}$.

$T_N(k(j), b)$ is given by the following equation for real measurement mode and calibration mode noise data:

$$\begin{aligned} T_N(j,b) &= T_{UTC\text{-}FIRST\text{-}IN\text{-}SP/N} \\ &= UTC\left(T_{SBT-AT-TT}\right) \\ &\quad + N_{PRI}\,\Delta_{PRI}\,\mathrm{Floor}\left[\frac{\mathrm{Unwrap}(C_{PRI-COUNT}) - C_{PRI-AT-TT}}{N_{PRI}}\right] \\ &\quad + \Delta_{PRI}\,\mathrm{mod}\left[\left(\mathrm{Unwrap}(C_{PRI-COUNT}) - C_{PRI-AT-TT}\right), N_{PRI}\right] \end{aligned} \qquad \textit{Equation 3}$$

For test measurement mode, echo data UTC ($T_{SBT\text{-}AT\text{-}TT}$) is replaced by $T_{UTC\text{-}AT\text{-}TT}$ in the above equation. Where $T_{UTC\text{-}FIRST\text{-}IN\text{-}SP/N}$ is the UTC Time associated with the first PRI contribution to that noise source packet. A noise packet index k(j) may be associated to an echo packet index j using the following equation:

$$k(j) = \text{Floor}\left(\frac{j-\frac{1}{2}}{L_N}\right)+1$$ *Equation 4*

where L_N is given by the following equation where N_{NOISE} and N_{FIR} will be chosen in such a fashion as to make L_N an integer:

$$L_N = \frac{2\,N_{NOISE}}{N_{FIR}}$$ *Equation 5*

N_{NOISE} is the number of windows of noise averaged on board along track from a given beam to create a noise packet and N_{FIR} is the length of the on board along track averaging finite impulse response filter.

The samples in reception windows of echo and noise are subjected to different processing on board the spacecraft. One range look is used for noise processing on board whereas several overlapping range looks are used for echo processing on board. In addition, for certain echo range looks, only a subset of the available discriminator signal frequency spectrum is used on board. Furthermore the lines of radar echo are subjected to different along-track averaging with a different weighting function than the lines of radar noise. For these reasons the functions c(b) and χ(i,b) are required to make the on-board noise processing equivalent to the on-board echo processing and to ensure that echo is correctly normalised at all discriminator signal frequencies (which is not done during on-board processing).

λ(j,b,SP) is the power-gain product correction factor applicable for beam b associated with along-track time T_E(j, b). The power-gain product correction removes any variations in the source packet echo lines associated with variations in the transmitted RF power and internal instrument receiver chain gain as a function of along-track time.

6.1.2 Power To σ_0 Conversion, Deblooming Subtraction and Coordinate Transformation

See also [RD 1]. The power to σ_0 normalisation is performed in accordance with the following equation:

$$\sigma_0(\mathrm{i}, \mathrm{T_E}(\mathrm{j}, \mathrm{b}), \mathrm{b}) = \frac{\mathrm{S}(\mathrm{i}, \mathrm{T_E}(\mathrm{j}, \mathrm{b}), \mathrm{b})}{\Omega(\mathrm{f}(\mathrm{i}), \mathrm{T_E}(\mathrm{j}, \mathrm{b}), \mathrm{b}, \mathrm{SP}, \mathbf{P}_{\mathrm{SAT-ACT}}(\mathrm{T_E}(\mathrm{j}, \mathrm{b})), \mathbf{P}_{\mathrm{ANT\text{-}ACT}}(\mathrm{T_E}(\mathrm{j}, \mathrm{b}), \mathrm{b}))}$$ *Equation 6*

where this equation applies:

$$
\begin{aligned}
&\Omega(f(i), T_E(j,b), b, SP, \mathbf{P}_{SAT\text{-}ACT}(T_E(j,b)), \mathbf{P}_{ANT\text{-}ACT}(T_E(j,b),b)) \\
&= \\
&\Omega(f(i), T_E(j,b), b, SP, \mathbf{P}_{SAT\text{-}NOM}(T_E(j,b)), \mathbf{P}_{ANT\text{-}ACT}(T_E(j,b),b)) \\
&+ S_{ROLL}(f(i), T_E(j,b), b, SP, \mathbf{P}_{SAT\text{-}NOM}(T_E(j,b)), \mathbf{P}_{ANT\text{-}ACT}(T_E(j,b),b)) \\
&.\Delta\alpha_{ROLL}(T_E(j,b)) \\
&+ S_{PITCH}(f(i), T_E(j,b), b, SP, \mathbf{P}_{SAT\text{-}NOM}(T_E(j,b)), \mathbf{P}_{ANT\text{-}ACT}(T_E(j,b),b)) \\
&.\Delta\beta_{PITCH}(T_E(j,b)) \\
&+ S_{YAW}(f(i), T_E(j,b), b, SP, \mathbf{P}_{SAT\text{-}NOM}(T_E(j,b)), \mathbf{P}_{ANT\text{-}ACT}(T_E(j,b),b)) \\
&.\Delta\gamma_{YAW}(T_E(j,b))
\end{aligned}
$$

Equation 7

The normalisation values above are determined by sampling the normalisation functions at the required discriminator frequencies f(i) and at the required orbit position times $T_E(j, b)$. The normalisation functions are stored as look-up tables and interpolated to the required orbit time positions. The normalisation look-up tables contain the following information:

$$
\begin{aligned}
&\Omega(f(i), T_0, b, SP),\ \Omega(f(i), T_{1A}, b, SP),\ .....,\ \Omega(f(i), T_{NA}, b, SP) \\
&S_{ROLL}(f(i), T_0, b, SP),\ S_{ROLL}(f(i), T_{1B}, b, SP),\ .....,\ S_{ROLL}(f(i), T_{NB}, b, SP) \\
&S_{PITCH}(f(i), T_0, b, SP),\ S_{PITCH}(f(i), T_{1C}, b, SP),\ .....,\ S_{PITCH}(f(i), T_{NC}, b, SP) \\
&S_{YAW}(f(i), T_0, b, SP),\ S_{YAW}(f(i), T_{1D}, b, SP),\ .....,\ S_{YAW}(f(i), T_{ND}, b, SP)
\end{aligned}
$$

Equation 8

The normalisation table for each antenna beam consists of 256 values at each orbit position corresponding to a specific orbit time. The number of orbit times around the orbit is selectable. The time sampling of the normalisation functions is, in general, non-linear in orbit time. Linear interpolation is used between these samples to interpolate to each orbit time $T_E(j,b)$ at which normalisation functions are required. The look-up tables cover the entire orbit; T_0 is the ascending node time and T_{NA} ,T_{NB} ,T_{NC} and T_{ND} are the times of the last rows of normalisation function samples before the next ascending node. Whatever strategy is used for the generation and utilisation of normalisation values negligible numerical errors will be introduced by this strategy so that no performance degradation occurs. The normalisation functions must be updated if any parameters or functions on which they depend are changed.

Deblooming subtraction can be selected optionally for data reprocessing. It is performed according to the following equation where Π is the desired estimation region determined by the deblooming radius:

$$\sigma_0^{\mathrm{DEBLOOM}}(\mathrm{i}, \mathrm{T_E}(\mathrm{j}, \mathrm{b}), \mathrm{b}) = \frac{\int_{\mathrm{ALL}}\int \mathrm{K}_{\mathrm{DEBLOOM}}(\nu_0, \mathrm{T}_0, \nu, \mathrm{T}; \mathrm{b}, \mathbf{P}_{\mathrm{SAT}}, \mathbf{P}_{\mathrm{ANT}}(\mathrm{b}))\, \sigma_0(\mathrm{i}, \mathrm{T_E}(\mathrm{j}, \mathrm{b}), \mathrm{b})\, \mathrm{d}\nu\, \mathrm{dT}}{\int_{\mathrm{INSIDE}\ \Pi}\int \mathrm{K}_{\mathrm{DEBLOOM}}(\nu_0, \mathrm{T}_0, \nu, \mathrm{T}; \mathrm{b}, \mathbf{P}_{\mathrm{SAT}}, \mathbf{P}_{\mathrm{ANT}}(\mathrm{b}))\, \mathrm{d}\nu\, \mathrm{dT}} - \frac{\int_{\mathrm{OUTSIDE}\ \Pi}\int \mathrm{K}_{\mathrm{DEBLOOM}}(\nu_0, \mathrm{T}_0, \nu, \mathrm{T}; \mathrm{b}, \mathbf{P}_{\mathrm{SAT}}, \mathbf{P}_{\mathrm{ANT}}(\mathrm{b}))\, \sigma_0(\mathrm{i}, \mathrm{T_E}(\mathrm{j}, \mathrm{b}), \mathrm{b})\, \mathrm{d}\nu\, \mathrm{dT}}{\int_{\mathrm{INSIDE}\ \Pi}\int \mathrm{K}_{\mathrm{DEBLOOM}}(\nu_0, \mathrm{T}_0, \nu, \mathrm{T}; \mathrm{b}, \mathbf{P}_{\mathrm{SAT}}, \mathbf{P}_{\mathrm{ANT}}(\mathrm{b}))\, \mathrm{d}\nu\, \mathrm{dT}}$$

Equation 9

where $\mathrm{K}_{\mathrm{DEBLOOM}}$ is defined in section 6.2.7. The localisation algorithm allows coordinates in the Terrestrial Reference Frame to be associated to the σ_0 values in discriminator frequency / orbit time space. This is essentially the full resolution σ_0 product. To generate smoothed σ_0 data at 25 km and 50 km spatial resolutions, the Terrestrial Reference Frame coordinates of the relevant full resolution data are then transformed to the Node Reference Frame coordinates for a specific node N centred at position $\mathbf{K}_\mathrm{T}(\mathrm{N})$ in the Terrestrial Reference Frame. The two mentioned geolocation steps are applied to the normalised σ_0 as follows:

$$\begin{gathered} \sigma_0(\mathrm{i}, \mathrm{T_E}(\mathrm{j}, \mathrm{b}), \mathrm{b}) \\ \updownarrow \\ \sigma_0(\mathrm{x_T}(\mathrm{i}, \mathrm{j}), \mathrm{y_T}(\mathrm{i}, \mathrm{j}), \mathrm{z_T}(\mathrm{i}, \mathrm{j}), \mathrm{T_E}(\mathrm{j}, \mathrm{b}), \mathrm{b}) \\ \updownarrow \\ \sigma_0(\mathrm{x}_{\mathbf{K}_\mathrm{T}(\mathrm{N})}(\mathrm{i}, \mathrm{j}), \mathrm{y}_{\mathbf{K}_\mathrm{T}(\mathrm{N})}(\mathrm{i}, \mathrm{j}), \mathrm{z}_{\mathbf{K}_\mathrm{T}(\mathrm{N})}(\mathrm{i}, \mathrm{j}), \mathrm{T_E}(\mathrm{j}, \mathrm{b}), \mathrm{b}) \end{gathered}$$

Equation 10

If the actual satellite orbit or actual satellite attitude become too different from those used to generate the Normalisation Tables and Deblooming Kernels the σ_0 data are flagged and the Normalisation Tables and Deblooming Kernels must be regenerated using accurate and up-to-date satellite orbit and satellite attitude data.

6.1.3 Spatial Averaging (See RD 1)

See [RD 1] for further specifications. A smoothed σ_0 estimate at node N centred at position $\mathbf{K}_T(N)$ in the Terrestrial Reference Frame is generated in accordance with the following equation.

$$\sigma_{0\,NODE}(\mathbf{K}_T(N), b, T_{ORBIT}) = \frac{\left(\sum_i \sum_j W_0(x_{\mathbf{K}_T(N)}(i,j), y_{\mathbf{K}_T(N)}(i,j), \mathbf{K}_T(N), b)\; \sigma_0(x_{\mathbf{K}_T(N)}(i,j), y_{\mathbf{K}_T(N)}(i,j), z_{\mathbf{K}_T(N)}(i,j), T_E(j,b), b)\right)}{\left(\sum_i \sum_j W_0(x_{\mathbf{K}_T(N)}(i,j), y_{\mathbf{K}_T(N)}(i,j), \mathbf{K}_T(N), b)\right)}$$

Equation 11

Where T_{ORBIT} is the orbit time associated with the centre of node N and W is the weighting function used for the spatial averaging of the σ_0 values. The weighting function is given by the following equations:

$$W_0(x, y, \mathbf{K}_T(N), b) = F_{0X}(x, \mathbf{K}_T(N), b) F_{0Y}(y, \mathbf{K}_T(N), b)$$

Equation 12

$$F_{0X}(x, \mathbf{K}_T(N), b) = \left(\alpha_{HX}(\mathbf{K}_T(N), b) + (1-\alpha_{HX}(\mathbf{K}_T(N), b))\cos\left(\frac{\pi x}{L_{HX}(\mathbf{K}_T(N), b)}\right)\right) H\left(L_{HX}(\mathbf{K}_T(N), b) - |x|\right)$$

Equation 13

$$F_{0Y}(y, \mathbf{K}_T(N), b) = \left(\alpha_{HY}(\mathbf{K}_T(N), b) + (1-\alpha_{HY}(\mathbf{K}_T(N), b))\cos\left(\frac{\pi y}{L_{HY}(\mathbf{K}_T(N), b)}\right)\right) H\left(L_{HY}(\mathbf{K}_T(N), b) - |y|\right)$$

Equation 14

The Hamming parameters, a_{HX} and a_{HY}, and the Hamming window dimensions L_{HX} and L_{HY} vary as a function of both across-track position (node number) and beam number. H is Heaviside's step function.

6.1.4 Kp computation

The node Kp value is computed from the data using the following equation:

$$Kp = \frac{\sqrt{\mathrm{var}(\sigma_{0\,NODE})}}{\sigma_{0\,NODE}}$$ *Equation 15*

where:

$$\sigma_{0\,NODE} = \frac{1}{N} \sum_i \sum_j W_0(i,j)\,\sigma_0(i,j)$$ *Equation 16*

where $W_0(i,j)$ is the two-dimensional Hamming window function value applied to the σ_0 value labelled by (i,j) within the Hamming window and the normalisation factor is given by the following equation:

$$N = \sum_i \sum_j W_0(i,j)$$ *Equation 17*

The variance is given by the following equation:

$$\mathrm{var}(\sigma_{0\,NODE}) = \sum_i \sum_j \sum_k \sum_l \frac{W_0(i,j)\,W_0(k,l)}{N^2} C(i,j;k,l;b) \left| \sigma_0(i,j) - \sigma_{0\,NODE} \right| \left| \sigma_0(k,l) - \sigma_{0\,NODE} \right|$$ *Equation 18*

Where:

$$C(i,j;k,l;b) = \rho^{INTRA}(i,j;k,l;b)\,\rho^{FIR}(i,j;k,l;b)$$ *Equation 19*

Where the correlation functions are given by the following equations:

$$\rho^{INTRA}(i,j;k,l;b) = \left| \frac{\int_{-z/2}^{+z/2} \omega_{RAN}(t) \exp[-2\pi i \Delta_f(i,j;k,l;b)t] dt}{\int_{-z/2}^{+z/2} \omega_{RAN}(t)\, dt} \right|^2$$

Equation 20

where:

$\omega_{RAN}(t)$	is the range look window function
z	is the duration of the range look (equal to T_{RL})
Δ_f (i,j ; k,l ; b)	is absolute value of the difference of discriminator frequencies between sample (i,j) and sample (k,l) (in the two dimensional Hamming window) for beam b.

$$\rho^{FIR}(i,j;k,l;b) = \frac{\int_{-z/2+z(1-\Delta_t(i,j;k,l;b))}^{+z/2} \omega_{FIR}(t)\omega_{FIR}(t - z(1-\Delta_t(i,j;k,l;b)))dt}{\int_{-z/2}^{+z/2} \omega_{FIR}{}^2(t)\, dt}$$

Equation 21

where:

$\omega_{FIR}(t)$	is the FIR along-track weighting function
z	is the FIR along-track weighting function duration
z (1- Δ_t (i,j ; k,l ; b))	is the absolute value of the along-track time separation between sample (i,j) and sample (k,l) in the two-dimensional Hamming window for beam b.

Note: If z (1- Δ_t (i,j ; k,l ; b)) is greater than or equal to z, the correlation, ρ^{FIR}(i,j ; k,l ; b) , is zero.

6.1.5 Error Handling And Flagging Algorithms

The meaning of certain terms used in this section is as set out in Section 6.2.

6.1.5.1 Normal Measurement Mode Source Packets

If one or more echo source packets are missing, corrupted or invalid then the average of the first good preceding E(i,P_E ,b) and first good following E(i,F_E ,b) echoes are used to replace the missing E(i,j,b) values.

$$E(i, j, b) = \frac{E(i, P_E, b) + E(i, F_E, b)}{2} \quad \forall \quad \text{missing } j$$

Equation 22

If this is done, the corresponding corrected echo or echos S(i,j,b) will be labelled as synthetic echo by setting the flags F_{ECHO}(i,j,b) and qualifiers M_{ECHO}(i,j,b), C_{ECHO}(i,j,b) and I_{ECHO}(i,j,b) appropriately. Thus each echo sample is classified with a flag F_{ECHO} and Qualifiers M_{ECHO}, C_{ECHO} and I_{ECHO}. F_{ECHO} is zero if the sample is not synthetic and unity if the sample is synthetic. M_{ECHO} is unity if the sample is synthetic due to missing data and zero otherwise. C_{ECHO} is unity if the sample is synthetic due to corrupted data and zero otherwise. I_{ECHO} is unity if the sample is synthetic due to invalid data and zero otherwise.

If one or more echo source packets are Missing, Corrupted or Invalid such that one or more values of the power gain product (before along track averaging), λ^*(j,b,SP) are not available then the average of the first good preceding $\lambda^*(P_{PG}$,b,SP) and first good following $\lambda^*(F_{PG}$,b,SP) values are used to replace the missing value or values.

$$\lambda^*(j, b, SP) = \frac{\lambda^*(P_{PG}, b, SP) + \lambda^*(F_{PG}, b, SP)}{2} \quad \forall \quad \text{missing } j$$

Equation 23

If the power gain product value λ(j,b,SP) is computed using any synthetic power gain products before along-track averaging then the F_{PG}(i,j,b) flags are set equal to unity (for all i). If the power gain product value λ(j,b,SP) is computed using more than a user selectable percentage, T_{PG} of synthetic power gain products before along-track averaging then the V_{PG}(i,j,b) flags are set equal to unity (for all i). The flags $F_{EXT\text{-}PG}$(i,j,b) will be set equal to unity (at the start and end of an ASCAT instrument operation) where extrapolated pg-values have to be used. The corrected echo S(i,j,b) will be labelled with the flags of power-gain product used to generate it, V_{PG}(i,j,b), F_{PG}(i,j,b) and $F_{EXT\text{-}PG}$(i,j,b).

If one or more noise source packets are Missing, Corrupted or Invalid then the average of the first good preceding N(i,P_N,b) and first good following N(i,F_N,b) noise source packets is used to replace the N(i,k,b) values. Thus, the following applies:

$$N(i, k, b) = \frac{N(i, P_N, b) + N(i, F_N, b)}{2} \quad \forall \quad \text{missing } k$$

Equation 24

If this is done, the samples of noise N(i,k,b) will be labelled as synthetic noise by setting the flags F_{NOISE}(i,k,b) and qualifiers M_{NOISE}(i,k,b) C_{NOISE}(i,k,b) and I_{NOISE}(i,k,b). Thus each noise sample is classified with a flag F_{NOISE} and qualifiers M_{NOISE}, C_{NOISE} and I_{NOISE}. F_{NOISE} is zero if the sample is not synthetic and unity if the sample is synthetic. M_{NOISE} is unity if the sample is synthetic due to missing data and zero otherwise. C_{NOISE} is unity if the sample is synthetic due to corrupted data and zero otherwise. I_{NOISE} is unity if the sample is synthetic due to invalid data and zero otherwise.

If the corrected echo S(i,j,b) is computed using synthetic noise to perform the noise subtraction it will be flagged by F_{NOISE}(i,j,b), M_{NOISE}(i,j,b), C_{NOISE}(i,j,b) and I_{NOISE}(i,j,b) (if n(k(j),b) was calculated from synthetic noise).

If the Rx path filter shape used to calculate S(i,j,b) is computed using any synthetic noise F_{FILTER}(i,j,b) is set equal to unity. If the Rx path filter shape is computed using more than a user selectable percentage, T_{FILTER} of synthetic noise V_{FILTER}(i,j,b) is set equal to unity. If any of the telemetry data associated with the noise packets used to compute a Rx path filter shape were missing or out of EUMETSAT specified ranges then the flag $F_{TEL\text{-}FILTER}$(i,j,b), associated with that filter shape, is set equal to 1. It is zero otherwise. The corrected echo S(i,j,b) will be labelled with the filter flags used to generate it, V_{FILTER}(i,j,b), F_{FILTER}(i,j,b) and $F_{TEL\text{-}FILTER}$(i,j,b). Wherever two filters are averaged the flag set with the highest degree of corruption will be taken for this labelling.

If the corrected echo S(i,j,b) is computed using an extrapolated Rx filter shape (at the beginning or end of an ASCAT operation) then a flag $F_{EXT\text{-}FIL}$(i,j,b) is set equal to unity. If the Rx filter shape used is not extrapolated the flag is set to zero.

In addition to the flags mentioned above which characterise the generation of the corrected echo, the following additional flags are also established for Level 1A data and for full resolution σ_0 values, σ_0(i, T_E(j,b), b):

F_{ORBIT} – 0

If orbit within nominal range and 1 otherwise. Let **R** be the position vector of the satellite at a particular position in the orbit corresponding to time T after the ascending node and $\mathbf{R}_\Omega$ be the position vector of the satellite at time T after the ascending node that was used to generate the normalisation table. Then:

$$\left| \textit{Radial Component}\left[\mathbf{R}(T) - \mathbf{R}_\Omega(T)\right] \right| \leq X_{ORBIT} \qquad \textit{Equation 25}$$

the normalisation table is valid and the flag F_{ORBIT} is set equal to zero. The threshold X_{ORBIT} is a (user-configurable) processing parameter.

$F_{ATTITUDE}$ **– 0**

if attitude within nominal range and 1 otherwise. Let **A** be the satellite attitude vector at time T after the ascending node and $\mathbf{A}_\Omega$ is the satellite attitude vector at time T after the ascending node that was used to generate the normalisation table. Then, if

$$\frac{\mathbf{A}\,.\,\mathbf{A}_\Omega}{|\,\mathbf{A}\,|\;|\,\mathbf{A}_\Omega\,|} \geq X_{ATTITUDE} \qquad \textit{Equation 26}$$

the normalisation table is valid and the flag $F_{ATTITUDE}$ is set equal to zero. The threshold $X_{ATTITUDE}$ is a (user-configurable) processing parameter.

F_{OMEGA}(i,j,b) – 0

if normalisation function valid for echo line and 1 otherwise ***Note***: the main purpose of this flag is to check the instrument parameters.

F_{MAN}(i,j,b) – 1

from just before a spacecraft manoeuvre until the spacecraft has stabilised after the manoeuvre and 0 otherwise.

F_{DSL}(i,j,b) – 1
if the SVM or PLM depointing signal lines are high and 0 otherwise.

$F_{S/A}$(i,j,b) – 1
if the echo data is potentially corrupted by solar array reflections and 0 otherwise.

$F_{E\text{-}TEL\text{-}PRES}$(i,j,b) – 0
if telemetry data associated with the line of echo is present and 1 otherwise.

$F_{E\text{-}TEL\text{-}IR}$(i,j,b) – 0
if telemetry data associated with the line of echo is all in-range with respect to EUMETSAT specified limits and 1 otherwise.

F_{LAND}(i,j,b) – 1
if echo sample position corresponds to Land and 0 otherwise.

$F_{DEBLOOM}$ – 1
if deblooming has been performed and 0 otherwise.

$F_{COM/OP}$ – 1
if Commissioning Phase data and 0 if Operational Phase data.

F_{CAL} – 0
if calibration is deemed to be good and 1 otherwise.

The corrected echo lines, S(i,T_E(j,b), b) and the full resolution σ_0 values (prior to smoothing), σ_0(i, T_E(j,b), b) are labelled by the following flags and qualifiers:

- F_{ECHO}(i,j,b),
- M_{ECHO}(i,j,b),
- C_{ECHO}(i,j,b),
- I_{ECHO}(i,j,b),
- F_{NOISE}(i,j,b),
- M_{NOISE}(i,j,b),
- C_{NOISE}(i,j,b),
- I_{NOISE}(i,j,b),
- F_{PG}(i,j,b),
- V_{PG}(i,j,b),
- $F_{EXT\text{-}PG}$(i,j,b),
- F_{FILTER}(i,j,b),
- V_{FILTER}(i,j,b),

- $F_{TEL\text{-}FILTER}(i,j,b)$,
- $F_{EXT\text{-}FIL}(i,j,b)$,
- $F_{ORBIT}(i,j,b)$,
- $F_{ATTITUDE}(i,j,b)$,
- $F_{OMEGA}(i,j,b)$,
- $F_{MAN}(i,j,b)$,
- $F_{DSL}(i,j,b)$,
- $F_{S/A}(i,j,b)$,
- $F_{E\text{-}TEL\text{-}PRES}(i,j,b)$,
- $F_{E\text{-}TEL\text{-}IR}(i,j,b)$,
- $F_{LAND}(i,j,b)$,
- $F_{DEBLOOM}$,
- $F_{COM/OP}$,
- F_{CAL}.

The following derived flags are established via logical operations on the above flags according to the following equations:

$$F_{CE} = F_{ECHO}\ .OR.\ F_{NOISE}\ .OR.\ F_{FILTER}\ .OR.\ F_{PG}\ .OR.\ F_{EXT-PG}$$ *Equation 27*

$$V_{CE} = F_{ECHO}\ .OR.\ F_{NOISE}\ .OR.\ V_{FILTER}\ .OR.\ V_{PG}\ .OR.\ F_{EXT-PG}$$ *Equation 28*

$$F_{OA} = F_{ORBIT}\ .OR.\ F_{ATTITUDE}\ .OR.\ F_{OMEGA}\ .OR.\ F_{MAN}\ .OR.\ F_{DSL}$$ *Equation 29*

$$F_{TEL} = F_{TEL\text{-}IR}\ .OR.\ F_{TEL\text{-}PRES}\ .OR.\ F_{TEL\text{-}FILTER}$$ *Equation 30*

Let the smoothing of a flag F(i,j) by the two dimensional Hamming Window be defined by the following equation:

$$\Gamma[\,F\,] = \frac{1}{N}\sum_{i}\sum_{j} W_0(i,j)\,F(i,j) \qquad \textit{Equation 31}$$

where the normalisation is given by the following:

$$N = \sum_{i}\sum_{j} W_0(i,j) \qquad \textit{Equation 32}$$

The following flag parameters are associated with each node σ_0 value generated:

f_F – equal to $\Gamma[\,F_{CE}\,]$
This parameter indicates if any synthetic data has been used or if the data comes from the beginning or end of an ASCAT instrument operation where an extrapolated power-gain value is used. A value of 0 indicates effectively that no synthetic data were used to generate a σ_0 node value.

f_V – equal to $\Gamma[\,V_{CE}\,]$
This parameter controls the quantity of synthetic data used or if the data comes from the beginning or end of an ASCAT instrument operation where an extrapolated power-gain value is used. A value of below approximately 0.05 indicates that the σ_0 node value is usable.

f_{OA} – equal to $\Gamma[\,F_{OA}\,]$
This parameter indicates if the satellite orbit and attitude allow valid data to be generated. The data is only usable if this parameter is zero.

$f_{S/A}$ – equal to $\Gamma[\,F_{S/A}\,]$
This parameter indicates if the data maybe corrupted by solar array reflections. If the value is zero the data is completely uncorrupted by solar array reflections.

f_{TEL} – equal to $\Gamma[\,F_{TEL}\,]$
This parameter indicates if all telemetry is present and within certain limits. A zero value indicates that all telemetry is present and within these limits. The data may be valid if this parameter takes any value however a value of zero gives extra confidence that the data is very good.

$f_{EXT\text{-}FIL}$ – equal to $\Gamma[\,F_{EXT\text{-}FIL}\,]$
This parameter indicates if an extrapolated Rx filter shape has been used to correct the data. The data may be valid if this parameter takes any value however a value of zero gives extra confidence that the data is very good.

f_{LAND} – equal to $\Gamma[\, F_{LAND} \,]$
The parameter indicates the fraction of land contributing to a σ_0 node value. Unity indicates all land and zero indicates entirely ocean.

$F_{COM/OP}$ – 1
if Commissioning Phase data and 0 if Operational Phase data.

F_{CAL} – 0
if calibration is deemed to be good and 1 otherwise.

$F_{DEBLOOM}$ – 1
if deblooming has been performed and 0 otherwise.

$F_{Kp\,-}$ 0
if f_F is zero and 1 otherwise. Zero indicates the Kp estimate is good. Unity indicates the Kp estimate is approximate or invalid.

The following general quality flag is also assigned to each σ_0 node value: F_{QUAL}. It can have the following values:

GOOD
A σ_0 node value is deemed to be good if f_F, f_{OA}, f_{SA}, f_{TEL}, $f_{EXT\text{-}FIL}$, $F_{COM/OP}$, F_{CAL}, F_{Kp} are all zero.

USABLE
A σ_0 node value is deemed to be usable if f_V is less than T_{USABLE} and f_{OA} , f_{SA}, f_{CAL} are zero.

BAD
A σ_0 node value is deemed to be bad if it is not good or usable.

6.1.5.2 Calibration Mode Source Packets

If a calibration echo source packet is Missing, it is replaced by a blank packet, with the correct counter indices, filled with zeros, which is flagged as missing with a flag M_{ECHO}(j,b) set to unity. If a packet is not missing this flag is set to zero. Missing calibration echo source packets are not used for gain at angular position estimation but are stored together with the other calibration source packets.

If a calibration echo source packet is *Corrupted* or *Invalid*, then it is stored together with the other calibration source packets but not used for gain at angular position estimation. It is labelled with the qualifiers C_{ECHO}(j,b) and I_{ECHO}(j,b). C_{ECHO} is unity if the packet is corrupted and zero otherwise. I_{ECHO} is unity if the packet is invalid and zero otherwise.

If one or more calibration echo source packets are Missing, Corrupted or Invalid such that one or more values of the power gain product (before along track averaging), λ^*(j,b,SP) are not available then the average of the first good preceding $\lambda^*(P_{PG},b,SP)$ and first good following $\lambda^*(F_{PG},b,SP)$ values are used to replace the missing value or values.

$$\lambda^*(j,b,SP) = \frac{\lambda^*(P_{PG},b,SP) + \lambda^*(F_{PG},b,SP)}{2} \quad \forall \quad \text{missing } j$$

Equation 33

If the power gain product value $\lambda(j,b,SP)$ is computed using any synthetic power gain products before along-track averaging then the $F_{PG}(j,b)$ flag is set equal to unity. If the power gain product value $\lambda(j,b,SP)$ is computed using more than a selectable percentage, $T_{PG\text{-}CAL}$ of synthetic power gain products before along-track averaging then the $V_{PG}(j,b)$ flag is set equal to unity. The flags $F_{EXT\text{-}PG\text{-}CAL}(j,b)$ will be set equal to unity (at the start and end of an ASCAT instrument beam calibration operation) where extrapolated pg-values have to be used. The corrected echo S(i,j,b) will be labelled with the flags of power-gain product used to generate it, $V_{PG}(j,b)$, $F_{PG}(j,b)$ and $F_{EXT\text{-}PG\text{-}CAL}(j,b)$.

If one or more calibration noise source packets is Missing, Corrupted or Invalid then the average of the first good preceding $N(i,P_N,b)$ and first good following $N(i,F_N,b)$ noise source packets is used to replace the N(i,k,b) values. Thus, the following:

$$N(i,k,b) = \frac{N(i,P_N,b) + N(i,F_N,b)}{2} \quad \forall \quad \text{missing } k$$

Equation 34

If this is done the samples of noise N(i,k,b) will be labelled as synthetic noise by setting the flags $F_{NOISE}(k,b)$ and qualifiers $M_{NOISE}(k,b)$, $C_{NOISE}(k,b)$ and $I_{NOISE}(k,b)$. Thus each noise line is classified with a flag F_{NOISE} and qualifiers M_{NOISE}, C_{NOISE} and I_{NOISE}. F_{NOISE} is zero if the line is not synthetic and unity if the line is synthetic. M_{NOISE} is unity if the line is synthetic due to missing data and zero otherwise. C_{NOISE} is unity if the line is synthetic due to corrupted data and zero otherwise. I_{NOISE} is unity if the line is synthetic due to invalid data and zero otherwise.

If the corrected echo S(i,j,b) is computed using synthetic noise to perform the noise subtraction it will be flagged by $F_{NOISE}(j,b)$, $M_{NOISE}(j,b)$, $C_{NOISE}(j,b)$ and $I_{NOISE}(j,b)$ (i.e. if n(k(j),b) was calculated from synthetic noise).

The Rx path filter shape used to calculate S(i,j,b) is computed using the average of the last filter shape from the measurement mode operation immediately preceding the calibration sequence and the first filter shape from the measurement mode operation immediately following the calibration sequence. The resulting filter shape will be labelled with the flag set $F_{FILTER}(j,b)$, $V_{FILTER}(j,b)$ $F_{TEL\text{-}FILTER}(j,b)$ with the highest degree of corruption, together with a flag $F_{TIME}(j,b)$, which is set equal to unity if the two filter shapes averaged are separated in time by an interval larger than T_{TIME} and set to zero otherwise.

In addition to the flags mentioned above which characterise the generation of the corrected calibration echo, the following additional flags are also established for each calibration echo line, $S(i, T_E(j,b), b)$:

F_{MAN}(i,j,b) – 1
from just before a spacecraft manoeuvre until the spacecraft has stabilised after the manoeuvre and 0 otherwise.

F_{DSL}(i,j,b) – 1
if the SVM or PLM depointing signal lines are high and 0 otherwise.

$F_{S/A}$(i,j,b) – 1
if the echo data is potentially corrupted by solar array reflections and 0 otherwise.

$F_{E\text{-}TEL\text{-}PRES}$(i,j,b) – 0
if telemetry data associated with the line of echo is present and 1 otherwise.

$F_{E\text{-}TEL\text{-}IR}$(i,j,b) – 0
if telemetry data associated with the line of echo is all in-range with respect to EUMETSAT specified limits and 1 otherwise.

F_{LAND}(i,j,b) – 1
if echo sample position corresponds to Land and 0 otherwise.

$F_{COM/OP}$ - 1
if echo sample position corresponds to Land and 0 otherwise.

The calibration echo lines (prior to gain at angular position estimation), S(i, T_E(j,b), b) are labelled by the following flags and qualifiers:

- M_{ECHO}(j,b),
- C_{ECHO}(j,b),
- I_{ECHO}(j,b),
- F_{NOISE}(j,b),
- M_{NOISE}(j,b),
- C_{NOISE}(j,b),
- I_{NOISE}(j,b),
- F_{PG}(j,b),
- V_{PG}(j,b),
- $F_{EXT\text{-}PG\text{-}CAL}$(j,b),
- F_{FILTER}(j,b),
- V_{FILTER}(j,b),
- $F_{TEL\text{-}FILTER}$(j,b),
- F_{TIME}(j,b),
- F_{MAN}(j,b),
- F_{DSL}(j,b),
- $F_{S/A}$(j,b),
- $F_{E\text{-}TEL\text{-}PRES}$(j,b),

- $F_{E\text{-}TEL\text{-}IR}(j,b)$,
- $F_{LAND}(i,j,b)$,
- $F_{COM/OP}$.

The following derived flags are established via logical operations on the above flag according to the following equations:

$$V_{CE\text{-}CAL} = M_{ECHO} \;.OR.\; C_{ECHO} \;.OR.\; I_{ECHO} \;.OR.\; V_{FILTER} \;.OR.\; V_{PG} \;.OR.\; F_{EXT-PG\text{-}CAL} \;.OR.\; F_{TIME}$$

Equation 35

$$F_{OAS\text{-}CAL} = F_{MAN} \;.OR.\; F_{DSL} \;.OR.\; F_{S/A}$$

Equation 36

If $V_{CE\text{-}CAL}$ and $F_{OAS\text{-}CAL}$ are both zero the corrected calibration echo line is used for gain at angular position estimation.

6.1.5.3 Special Measurement Mode Source Packets

If a special echo source packet is Missing it is replaced by a blank packet, with the correct counter indices, filled with zeros which is flagged as missing with a flag $M_{ECHO}(j,b)$ set to unity. If a packet is not missing this flag is set to zero. Missing special echo source packets are not used for gain compression monitoring but are stored together with the other special measurement mode source packets. Duplicated special echo source packets are discarded.

If a special echo source packet is corrupted or invalid then it is stored together with the other special source packets but not used for gain compression monitoring. It is labelled with the qualifiers $C_{ECHO}(j,b)$ and $I_{ECHO}(j,b)$. C_{ECHO} is unity if the packet is corrupted and zero otherwise. I_{ECHO} is unity if the packet is invalid and zero otherwise.

The occurrence and number of missing, duplicated, corrupted or invalid source packets in a Gain Compression Monitoring Sequence has to be reported together with the estimated Gain Compression at the HPA operating point.

6.1.5.4 Solar Array Flag Algorithm

The following source packet echo samples from the ASCAT ANTLF are to be flagged ($F_{S/A}(i, j, b) = 1$ for $b = 1$) to indicate they are potentially corrupted due to RF solar array reflections:

Solar Array Angle Band	*Sample Index i of First Sample to be Flagged*	*Sample Index i of Last Sample to be Flagged*
- 13° to -12°	242	256
- 12° to -11°	227	256
- 11° to -10°	211	256
- 10° to -09°	197	256
- 09° to -08°	183	256
- 08° to -07°	170	256
- 07° to -06°	156	256
- 06° to -05°	143	256
- 05° to -04°	130	256
- 04° to -03°	117	256
- 03° to -02°	104	256
- 02° to -01°	92	256
- 01° to 00°	79	254
00° to +01°	69	236
+ 01° to +02°	58	223
+ 02° to +03°	49	209
+ 03° to +04°	39	197
+ 04° to +05°	28	185
+ 05° to +06°	16	173
+ 06° to +07°	5	161
+ 07° to +08°	1	150
+ 08° to +09°	1	138
+ 09° to +10°	1	128
+ 10° to +11°	1	118
+ 11° to +12°	1	108
+ 12° to +13°	1	98
+ 13° to +14°	1	89
+ 14° to +15°	1	79
+ 15° to +16°	1	69
+ 16° to +17°	1	58
+ 17° to +18°	1	50
+ 18° to +19°	1	41
+ 19° to +20°	1	33
+ 20° to +21°	1	24
+ 21° to +22°	1	15
+ 22° to +23°	1	6

Table 2: Source packet echo samples from the ASCAT ANTLF to be flagged.

Sample 1 is the sample closest to the source packet header and sample 256 is the sample furthest from the source packet header. The solar array angle, θ_{SA}, is given by the following function:

$$\theta_{SA}\left(t_{ASC},d\right)=90+\frac{180}{\pi}\Lambda\left(d\right)-360\frac{\left(t_{ASC} \bmod T_{ORBIT}\right)}{T_{ORBIT}} \quad \textit{Equation 37}$$

Where t_{ASC} is the time since the last ascending node crossing, T_{ORBIT} is the period of the orbit and $\Lambda(d)$ is given by:

$$\Lambda\left(d\right)=\mathrm{ArcTan}\left[\begin{array}{l}\left\{\begin{array}{l}\mathrm{Sin}\left(\delta_{MAX}\,\mathrm{Sin}\left(2\pi\frac{\left(d-d_0\right)}{d_{YEAR}}\right)\right)\mathrm{Sin}\left(i_{INC}\right)\\+\mathrm{Cos}\left(\delta_{MAX}\,\mathrm{Sin}\left(2\pi\frac{\left(d-d_0\right)}{d_{YEAR}}\right)\right)\mathrm{Cos}\left(i_{INC}\right)\mathrm{Sin}\left(\lambda\left(d\right)\right)\end{array}\right\}\\,\\-\mathrm{Cos}\left(\delta_{MAX}\,\mathrm{Sin}\left(2\pi\frac{\left(d-d_0\right)}{d_{YEAR}}\right)\right)\mathit{Cos}\left(\lambda\left(d\right)\right)\end{array}\right] \quad \textit{Equation 38}$$

Where δ_{MAX} is the maximum solar inclination, d is the day of year, d_0 is the reference value of the day of year, d_{YEAR} is the number of days in a year, i_{INC} is the orbit inclination, ArcTan[x,y] is the arctangent of y/x taking into account which quadrant the point (x, y) is in and $\lambda(d)$ is given by:

$$\lambda\left(d\right)=\pi+2\pi\frac{\left(24-h\left(d\right)\right)}{24} \quad \textit{Equation 39}$$

Where h (d) is given by:

$$\begin{aligned}h\left(d\right)=h_{ACS}&+0.0072\mathrm{Cos}\left(\frac{2\pi d}{d_{YEAR}}\right)-0.1229\mathrm{Sin}\left(\frac{2\pi d}{d_{YEAR}}\right)\\&-0.0528\mathrm{Cos}\left(\frac{4\pi d}{d_{YEAR}}\right)-0.1565\mathrm{Sin}\left(\frac{4\pi d}{d_{YEAR}}\right)\\&-0.0012\mathrm{Cos}\left(\frac{6\pi d}{d_{YEAR}}\right)-0.0041\mathrm{Sin}\left(\frac{6\pi d}{d_{YEAR}}\right)\end{aligned} \quad \textit{Equation 40}$$

Where h_{ASC} is the hour at the ascending node crossing.

t_{ASC} is obtained from the Metop CFI Software in the PGE services (using "UTC Of Next Ascending Node", "Nodal Period" and the t_0 time of the source packet). d is obtained from the t_0 time of the source packet. d is such that it takes values between 0 and d_{YEAR}. d is initialised such that $d = d_0$ at the first vernal equinox after the launch of the given Metop Satellite.

d_0 is set to 81.25 days corresponding to the vernal equinox. δ_{MAX} is set to 23.5 degrees. h_{ASC} is obtained from the Metop CFI Software in the PGE services (using "Mean Local Solar Time Of Ascending Node"). i_{INC} is obtained from the Metop CFI Software in the PGE services (using "Inclination Of Orbit"). T_{ORBIT} is obtained from the Metop CFI Software in the PGE services (using "Nodal Period").

The nominal values of these parameters for the Metop Orbit are the following:

$$\begin{aligned}
h_{ASC} &= 21.5 \quad \text{hours} \\
\delta_{MAX} &= 23.5 \text{ x} \left(\pi / 180 \right) \quad \text{radians} \\
d_0 &= 81.25 \quad \text{days} \\
i_{INC} &= 98.7022 \text{ x} \left(\pi / 180 \right) \quad \text{radians} \\
T_{ORBIT} &= 29 \text{ x } 24 \text{ x } 60 \text{ x } 60 / 412 \quad \text{seconds} \\
d_{YEAR} &= 365.242198781 \quad \text{days}
\end{aligned}$$

Equation 41

6.2 Reference Function Algorithms

6.2.1 Rx Filter Shape Computation

This function is detailed in [RD 1]. Let N(i, k, b) be the set of source packet noise samples from beam b associated with along-track time $T_N(k, b)$. The index k starts at 1 and increases in steps of unity; it labels the along track time associated with the noise source packets from a particular beam b. The index k associated with the first line of source packet noise from each beam is unity.

The corresponding noise samples from the same beam, at the same discriminator frequency, from consecutive sets of M_{SEG} noise source packets are averaged without weighting, to form a noise segment q(i, m, b). The noise segments are labelled by the index m, which starts at unity and increases in steps of unity to $N_{SEG\text{-}TOTAL}$. The noise segments are constructed such that they do not overlap. The noise segments are constructed according to the following equation:

$$q(i, m, b) = \sum_{n=1}^{n = M_{SEG}} N(i, n + (m-1) M_{SEG}, b)$$

Equation 42

The noise power in each noise segment at the calibration frequency, q(f(cal),k,b) is next determined by linear interpolation between the two noise segment samples closest to the calibration frequency. q(f(icalp),k,b) is the noise power sample at frequency f(icalp) above the calibration frequency and q(f(icalm),k,b) is the noise power sample at frequency f(icalm) below the calibration frequency. The calibration frequency is f(cal).

$$q(f(cal),k,b) = \frac{(f(cal) - f(icalm))}{(f(icalp) - f(icalm))} q(icalp,k,b) + \frac{(f(icalp) - f(cal))}{(f(icalp) - f(icalm))} q(icalm,k,b)$$

Equation 43

Note: The user-configurable values of f(cal), f(icalp), f(icalm), icalp, icalm which are expected to be used in the above equation are the following:

$$\begin{aligned} f(cal) &= 103052\,Hz \\ f(icalp) &= 103125\,Hz \\ f(icalm) &= 102319.3359\,Hz \\ icalp &= 129 \\ icalm &= 128 \end{aligned}$$

Equation 44

The noise segment power is first normalised to unity at the calibration frequency. The noise segments for the different beams are then averaged. Finally the resulting samples, at the same discriminator frequency, from M_{BLOCK} noise segments centred on each noise segment are subjected to weighted averaging to provide a smoothed estimate of the filter shape at the position / along-time corresponding to index m.

$$h^*(i,m) = \frac{1}{M_{BLOCK}} \sum_{n=1}^{n=M_{BLOCK}} \left[\frac{1}{B} \sum_{b=1}^{b=B} \frac{q(i, m+n-(M_{BLOCK}+1)/2, b)}{q(f(cal), m+n-(M_{BLOCK}+1)/2, b)} \right]$$

Equation 45

Where M_{BLOCK} is required to be an odd integer greater than or equal to one and the index m is required to take values in the range defined by the following equation.

$$\frac{M_{BLOCK}+1}{2} \le m \le N_{SEG-TOTAL} - \frac{(M_{BLOCK}-1)}{2}$$

Equation 46

$$\text{For } m < \frac{M_{BLOCK}+1}{2},$$
$$h^*(i,m) = h^*\left(i, \frac{M_{BLOCK}+1}{2}\right)$$

$$\text{For } m > N_{SEG-TOTAL} - \frac{(M_{BLOCK}-1)}{2},$$
$$h^*(i,m) = h^*\left(i, N_{SEG-TOTAL} - \frac{(M_{BLOCK}-1)}{2}\right)$$

Equation 47

The final filter shape is obtained by limited averaging of h*(i, m) over local discriminator signal frequencies, thus the final Rx Filter Shape estimates are given by the following equations where $\alpha_{h\text{-}FIL}(n)$ is a weighting function:

$$h_{RX}(i,\ m) = \frac{h'_{RX}(i,\ m)}{h'_{RX}(f(cal),\ m)}$$	*Equation 48*

where

$$h'_{RX}(i,\ m) = \frac{1}{\sum_{n=1}^{n=N_{h\text{-}FIL}} \alpha_{h\text{-}FIL}(n)} \sum_{n=1}^{n=N_{h\text{-}FIL}} \alpha_{h\text{-}FIL}(n)\, h^*(\,i + n - (N_{h\text{-}FIL} + 1)/2\,, m)$$	*Equation 49*

and

$$h'_{RX}(f(cal),\ m) = \frac{(f(cal) - f(icalm))}{(f(icalp) - f(icalm))} h'_{RX}(icalp,\ m) + \frac{(f(icalp) - f(cal))}{(f(icalp) - f(icalm))} h'_{RX}(icalm,\ m)$$	*Equation 50*

Where $N_{h\text{-}FIL}$ is required to be an odd integer greater than or equal to one and the index i is required to take values in the range defined by the following equation.

$$\frac{N_{h-FIL} + 1}{2} \le i \le N_{ECHO} - \frac{(N_{h-FIL} - 1)}{2}$$	*Equation 51*

$$\text{For } i < \frac{N_{h-FIL}+1}{2}, \quad h_{RX}(i, m) = h_{RX}\left(\frac{N_{h-FIL}+1}{2}, m\right)$$ $$\text{For } i > N_{ECHO} - \frac{(N_{h\text{-}FIL} - 1)}{2}, \quad h_{RX}(i, m) = h_{RX}\left(N_{ECHO} - \frac{(N_{h\text{-}FIL} - 1)}{2}, m\right)$$	*Equation 52*

An alternative approach to filter shape finalisation which will be implemented as a selectable option is the following. First remove the DC spike in h*(i, m). Then continue the filter shape via reflection in the y-axis. Then transform to the frequency domain (via 512 point FFT). Then remove the samples 1 to X and 512 – X to 512 corresponding to the highest frequencies: where X is selectable but nominally 50. Then transform back to the time domain and select the positive x-axis portion as the proto filter shape. The final filter shape, $h_{RX}(i, m)$ is obtained by normalising the proto filter shape to have the same power at the calibration frequency as h*(i, m).

The following equation allows values of index k to be associated to each value of index m and thus allows Rx filter shapes to be associated to noise packets.

$$m(k) = \mathrm{Floor}\left(\frac{k-\frac{1}{2}}{M_{SEG}}\right)+1$$

$$h_{RX}(i,k) = h_{RX}(i,m(k))$$

Equation 53

For clarification, it should be noted that the algorithm is a trade-off between two conflicting desires. Firstly, the desire to use long noise segments in order to average as much as possible before normalising at the calibration frequency so as to reduce statistical noise. Secondly, the desire to use short segments to avoid the temporal position of the filter shape estimate becoming biased to earlier or later times because, for example, the filter shape changes along-track and/or the measured noise power either decreases or increases in some manner over the estimation interval (because the noise power really changes or because the Rx chain gain changes). The final limited averaging over local discriminator frequencies is necessary to reduce the statistical noise to the required level.

The first good Rx Filter Shape estimate shall be used for processing the data close to the start of an instrument operation (where no good local Rx Filter Shape estimate exists) and the data shall be flagged accordingly. The last good Rx Filter Shape estimate shall be used for processing the data close to the end of an instrument operation (where no good local Rx Filter Shape estimate exists) and the data shall be flagged accordingly.

For calibration mode operation sequences, the last and first good Rx Filter Shape estimates from the measurement mode operations on either side of the calibration mode operation sequence shall be averaged to obtain an Rx Filter Shape estimate to be used to correct the calibration mode data.

6.2.2 Noise Power Computation

See complete specification in [RD 1]. The lines of source packet noise are first subjected to filter shape correction and then samples from a selected range of discriminator signal frequencies are averaged without weighting.

$$n(k,b) = \frac{1}{(E-S+1)}\sum_{i=S}^{i=E}\left[\frac{N(i,k,b)}{h_{RX}(i,k)}\right]$$

Equation 54

For calibration mode operation sequences, the noise estimates from the calibration mode data shall be used to remove the noise power from the calibration mode data.

6.2.3 Power Gain Product Computation

See complete specifications in [RD 1]. The internal calibration approach may be summarised briefly in the following manner.

During RF pulse transmission, the transmitted power is measured on the way to the antenna by a diode detector connected to the Tx path calibration coupler. The detected signal is sampled by an ADC and the output from that ADC is time-averaged within the DSP. The resulting detector power measurement is called the “transmitted power, PT”. Also during RF pulse transmission, the power reflected back from the antenna is measured by another diode detector connected to the Rx path calibration coupler. The detected signal is sampled by an ADC and the output from that ADC is time-averaged within the DSP. The resulting power measurement is called the “reflected power, PR”. The ratio of the transmitted power to a reference value (of this quantity) effectively monitors the SSPA power and the measurements of transmitted power and reflected power together allow the power lost due to mismatch at the antenna port to be determined thereby allowing the actual power transmitted from the antenna to be monitored.

During the calibration interval associated with each RF pulse transmission cycle (for each beam), a calibration sine wave signal from the RFU is injected into the Rx chain from the Tx path calibration coupler (with the switch matrix directly coupling the Tx and Rx chains). At the same time, the power of this injected signal is measured by the diode detector associated with the Tx path calibration coupler; this power is called the “injected power, PI”. The injected signal is processed in the normal (one look) way by the receive chain but without spectral deramping (i.e. the down converter mixer reference signal is a single frequency sine wave). The peak of the detected signal output from the receiver after processing the calibration signal is called the “calibration power, PCAL”. The ratio formed by dividing the calibration power by the injected power monitors the entire Rx chain gain (including the LNA and other front-end equipment). Furthermore the radar adjusts the injected signal in such a way as to attempt to keep the injected power equal to the transmitted power so that the Tx chain diode detector experiences the same power levels during both measurements; this serves to eliminate any effects associated with diode detector non-linearity.

The power gain product applicable for the source packet echo line associated with time $T_E(j, b)$ is given by the following equation:

$$\lambda(j, b, SP) = \frac{1}{N_{PG}} \sum_{k=1}^{k=N_{PG}} \lambda^*\left(j + k - \frac{(N_{PG}+1)}{2}, b, SP\right)$$ *Equation 55*

Where N_{PG} must be an odd integer greater than or equal to unity and index j must lie in the range defined by the following:

$$\frac{(N_{PG}+1)}{2} \leq j \leq N_{ECHO-PACKETS} - \frac{(N_{PG}-1)}{2}$$ *Equation 56*

$$\text{For } j < \frac{(N_{PG}+1)}{2},$$
$$\lambda(j,b,SP) = \lambda\left(\frac{(N_{PG}+1)}{2}, b, SP\right)$$
$$\text{For } j > N_{ECHO-PACKETS} - \frac{(N_{PG}-1)}{2},$$
$$\lambda(j,b,SP) = \lambda\left(N_{ECHO-PACKETS} - \frac{(N_{PG}-1)}{2}, b, SP\right)$$

Equation 57

The power-gain product before along-track averaging, λ*, is given by the following equation:

$$\lambda^*(j,b,SP) = \frac{C_{CAL}(b)}{8} \sum_{\ell=1}^{\ell=2} \sum_{i=1}^{i=4} \left[\begin{array}{l} \left(\dfrac{P_{CAL}(j+\ell-1,i,b)}{P_I(j+\ell-1,i,b)}\right) \\ \cdot P_T(j+\ell-1,i,b) \\ .\,\Gamma(j+\ell-1,i,b,SP) \end{array} \right]$$

Equation 58

Where:

$$\Gamma(j,i,b,SP) = \left(1 - \frac{P_R(j,i,b)}{L_{CC}(b,SP)\,P_T(j,i,b)}\right)^2$$
$$\text{or} \quad = 1 \quad \text{(user selectable)}$$

Equation 59

The six constants C_{CAL}(b) are determined at locking when the internal calibration reference values are set. These factors are chosen such that λ is unity for all beams at locking. Locking will be performed at the beginning of the Commissioning Phase The loss factors LCC(b, SP) are the path losses between the Tx and Rx calibration couplers via antenna port b; the loss factors LCC(b, SP) are less than unity (and greater than zero) and are dependent on the switch path (SP) taken to and from the antenna port (either the nominal or the long "emergency" path). The values of the actual transmitted power, the actual reflected power and the actual injected power have to be determined via a look-up table from, respectively, the measured transmitted power, the measured reflected power and the measured injected power and relevant front-end equipment temperatures taking into account the redundancy configuration, RC. The index j labels the source packet and the index i labels the powers within it.

$$P_T(j,i,b) = F_T\left[\, P_{TM}(j,i,b,RC)\,,\, \theta_{SFE4}(j,i,b,RC)\,,\, RC \,\right]$$

Equation 60

$$P_I(j,i,b) = F_I\left\lfloor P_{I\,M}(j,i,b,RC)\,;\,\theta_{SFE4}(j,i,b,RC)\,,\,RC\right\rfloor$$ *Equation 61*

$$P_R(j,i,b) = F_R\left\lfloor P_{R\,M}(j,i,b,RC)\,;\,\theta_{SFE5}(j,i,b,RC)\,,\,RC\right\rfloor$$ *Equation 62*

The temperatures θ_{SFE4} and θ_{SFE5} are the temperatures of the calibration coupler associated with the Tx path and the calibration coupler associated with the Rx path respectively (These are measured by thermistors in the SFE.) The calibration power is determined from the real and imaginary parts of the three calibration pulse complex samples (taken about the expected peak position corresponding to the actual calibration frequency after on-board calibration processing) which are provided in every source packet for the calibration cycles associated with the first four of the eight radar echo lines averaged to construct the source packet echo line. The calibration power is determined from the three complex samples (six real numbers) according to the following equation:

$$P_{CAL}(j,i,b) = X(X-1)a + (X+1)(X-1)b + (X+1)Xc$$ *Equation 63*

Where:

$$X = \frac{a-c}{2(a+b+c)}$$ *Equation 64*

$$a = +\left[(\mathrm{Re}\{A_{CAL\,1}(j,i,b)\})^2 + (\mathrm{Im}\{A_{CAL\,1}(j,i,b)\})^2\right]/2$$ *Equation 65*

$$b = -\left[(\mathrm{Re}\{A_{CAL\,2}(j,i,b)\})^2 + (\mathrm{Im}\{A_{CAL\,2}(j,i,b)\})^2\right]$$ *Equation 66*

$$c = +\left[(\mathrm{Re}\{A_{CAL\,3}(j,i,b)\})^2 + (\mathrm{Im}\{A_{CAL\,3}(j,i,b)\})^2\right]/2$$ *Equation 67*

For calibration mode operation sequences, the power gain product estimates from the calibration mode shall be used to perform the power gain product correction on the calibration mode data For calibration mode, the power-gain product before along-track averaging, λ^*, is given by the following equation:

$$\lambda^*(j,b,SP) = C_{CAL}(b)\left[\begin{array}{l}\left(\dfrac{P_{CAL}(j,2,b)}{P_I(j,2,b)}\right)\\ \cdot\, P_T(j,2,b)\\ .\,\Gamma(j,2,b,SP)\end{array}\right]$$ *Equation 68*

The other equations are the same as those for measurement mode source packets.

6.2.4 Power to σ_0 Normalisation Function

Complete specifications are in [RD 4]. The power to σ_0 normalisation function is given by the following equation:

$$\begin{aligned}&\Omega(\nu_0, T_0, b, SP, \mathbf{P}_{\text{SAT-ACT}}(T_0), \mathbf{P}_{\text{ANT-ACT}}(T_0, b))\\ = \quad &\Omega(\nu_0, T_0, b, SP, \mathbf{P}_{\text{SAT-NOM}}(T_0), \mathbf{P}_{\text{ANT-ACT}}(T_0, b))\\ &+ S_{\text{ROLL}}(\nu_0, T_0, b, SP, \mathbf{P}_{\text{SAT-NOM}}(T_0), \mathbf{P}_{\text{ANT-ACT}}(T_0, b))\, \Delta\alpha_{\text{ROLL}}(T_0)\\ &+ S_{\text{PITCH}}(\nu_0, T_0, b, SP, \mathbf{P}_{\text{SAT-NOM}}(T_0), \mathbf{P}_{\text{ANT-ACT}}(T_0, b))\, \Delta\beta_{\text{PITCH}}(T_0)\\ &+ S_{\text{YAW}}(\nu_0, T_0, b, SP, \mathbf{P}_{\text{SAT-NOM}}(T_0), \mathbf{P}_{\text{ANT-ACT}}(T_0, b))\, \Delta\gamma_{\text{YAW}}(T_0)\end{aligned} \qquad \textit{Equation 69}$$

Where

$$\begin{aligned}&S_{\text{ROLL}}(\nu_0, T_0, b, SP, \mathbf{P}_{\text{SAT-NOM}}(T_0), \mathbf{P}_{\text{ANT-ACT}}(T_0, b))\\ = \quad &\left.\frac{d\Omega(\nu_0, T_0, b, SP, \mathbf{P}_{\text{SAT}}(T_0), \mathbf{P}_{\text{ANT-ACT}}(T_0, b))}{d\alpha_{\text{ROLL}}}\right|_{\mathbf{P}_{\text{SAT}}(T_0) = \mathbf{P}_{\text{SAT-NOM}}(T_0)}\end{aligned} \qquad \textit{Equation 70}$$

$$\begin{aligned}&S_{\text{PITCH}}(\nu_0, T_0, b, SP, \mathbf{P}_{\text{SAT-NOM}}(T_0), \mathbf{P}_{\text{ANT-ACT}}(T_0, b))\\ = \quad &\left.\frac{d\Omega(\nu_0, T_0, b, SP, \mathbf{P}_{\text{SAT}}(T_0), \mathbf{P}_{\text{ANT-ACT}}(T_0, b))}{d\beta_{\text{PITCH}}}\right|_{\mathbf{P}_{\text{SAT}}(T_0) = \mathbf{P}_{\text{SAT-NOM}}(T_0)}\end{aligned} \qquad \textit{Equation 71}$$

$$\begin{aligned}&S_{\text{YAW}}(\nu_0, T_0, b, SP, \mathbf{P}_{\text{SAT-NOM}}(T_0), \mathbf{P}_{\text{ANT-ACT}}(T_0, b))\\ = \quad &\left.\frac{d\Omega(\nu_0, T_0, b, SP, \mathbf{P}_{\text{SAT}}(T_0), \mathbf{P}_{\text{ANT-ACT}}(T_0, b))}{d\gamma_{\text{YAW}}}\right|_{\mathbf{P}_{\text{SAT}}(T_0) = \mathbf{P}_{\text{SAT-NOM}}(T_0)}\end{aligned} \qquad \textit{Equation 72}$$

The derivatives of the normalisation function with respect to the roll, pitch and yaw angles are computed via numerical methods. The nominal attitude of the spacecraft is specified by $P_{\text{SAT-NOM}}(T0)$; this is the attitude which the spacecraft is programmed to maintain and the attitude used to generate the Normalisation Table. The actual attitude of the spacecraft is specified by $P_{\text{SAT-ACT}}(T0)$; it deviates from the desired pointing predominately because of small bias and quasi-static errors. If these errors can be adequately modelled by a spacecraft attitude distortion model specifying the depointing angles as a function of orbit time, $\Delta\alpha(T0)$, $\Delta\beta(T0)$ and $\Delta\gamma(T0)$ then the errors introduced in this manner can be corrected. Note that suitable depointing models for METOP employ a superposition of harmonic functions with different amplitudes and with periods equal to the orbital period and fractions thereof.

The nominal pointing of the electrical boresight of antenna beam b is specified by $P_{\text{ANT-NOM}}(T_0,b)$; this is the theoretical pointing (or on-ground characterised pointing) relative to the reference frame fixed to the satellite. The actual in-flight pointing of the electrical boresight of antenna beam b is specified by $P_{\text{ANT-ACT}}(T_0,b)$; it deviates from the nominal pointing predominately because of bias and very slow quasistatic errors (fixed mechanical bias, for example, due to de-weighting, and quasistatic mechanical bias due to, for example, ageing of thermal surfaces). The actual antenna gain pattern and the actual electrical boresight pointing is established in flight for each beam via transponder calibration. Note that the actual antenna gain patterns and actual electrical boresight pointings may only be established after a complete sequence of transponder measurements; however this is expected to be satisfactory as it is believed that they will retain the same values for relatively long periods of time.

The normalisation function is a function of both discriminator frequency (ν0) and orbit time (T_0), for each antenna beam b and for satellite pointing, described by $\mathbf{P}_{SAT}$ and for antenna beam electrical boresight pointing, described by $\mathbf{P}_{ANT}(b)$. Both of these pointings are functions of time; however; the dependence is assumed and suppressed below to simplify the notation. For the computation of the normalisation function the same implementation of the on-board processing algorithm will be used on ground as that used on board; refer to [AD 10]. The normalisation function is given by the following equation:

$$\begin{aligned}&\Omega(\nu_0, \mathrm{T}_0, \mathrm{b}, \mathrm{SP}, \mathbf{P}_{\mathrm{SAT}}, \mathbf{P}_{\mathrm{ANT}}(\mathrm{b}))\\ &= \sum_{k=0}^{k=1}\sum_{j=1}^{j=4} \mathrm{g}(\mathrm{k}, \mathrm{j})\mathrm{Q}(\nu_0, \mathrm{T}(\mathrm{k}, \mathrm{j}), \mathrm{b}, \mathrm{SP}, \mathbf{P}_{\mathrm{SAT}}, \mathbf{P}_{\mathrm{ANT}}(\mathrm{b}))\end{aligned}$$

Equation 73

Where g is the eight-point finite impulse response filter function employed on board for along-track echo averaging (the azimuth look weighting) and where T(k,j) is given by:

$$\mathrm{T}(\mathrm{k}, \mathrm{j}) = \mathrm{T}_0 + \Delta\left(\mathrm{jk} + (4 - \mathrm{j})(\mathrm{k} - 1) - 1/2\right)$$

Equation 74

Where Δ is the (measurement mode) pulse repetition interval for beam b and Q is given by:

$$\begin{aligned}&\mathrm{Q}(\mathrm{v}_0, \mathrm{T}(\mathrm{k}, \mathrm{j}), \mathrm{b}, \mathrm{SP}, \mathrm{P}_{\mathrm{SAT}}, \mathrm{P}_{\mathrm{ANT}}(\mathrm{b}))\\ &= \frac{\sum_{m=1}^{m=M(b)} \rho(\mathrm{v}_0, \mathrm{m}, \mathrm{b})\mathrm{J}(\mathrm{v}_0, \mathrm{T}(\mathrm{k}, \mathrm{j}), \mathrm{m}, \mathrm{b}, \mathrm{SP}, \mathrm{P}_{\mathrm{SAT}}, \mathrm{P}_{\mathrm{ANT}}(\mathrm{b}))}{\sum_{m=1}^{m=M(b)} \rho(\mathrm{v}_0, \mathrm{m}, \mathrm{b})}\end{aligned}$$

Equation 75

Where ρ is the range look summation weighting used for the summation of the M range looks in the on-board processing. The function takes the value unity or zero in each range look depending on the value of the discriminator signal frequency. J is given by the following expression:

$$\begin{aligned}&\mathrm{J}(\nu_0, \mathrm{T}(\mathrm{k}, \mathrm{j}), \mathrm{m}, \mathrm{b}, \mathrm{SP}, \mathbf{P}_{\mathrm{SAT}}, \mathbf{P}_{\mathrm{ANT}}(\mathrm{b}))\\ &= \iint \left| f(\nu_0, \mathrm{T}(\mathrm{k}, \mathrm{j}), \mathrm{m}, \mathrm{b}, \mathrm{SP}, \mathbf{P}_{\mathrm{SAT}}, \mathbf{P}_{\mathrm{ANT}}(\mathrm{b}); \mathrm{x}, \mathrm{y}) \right|^2 \mathrm{dxdy}\end{aligned}$$

Equation 76

The squared modulus of function, f is the expected power contribution of an elemental area at (x,y) on the surface of the Earth to the power observed in the m^{th} range look at discriminator signal frequency ν_0 when the orbit time position of the satellite is T(k,j). J is the sum of all such contributions from the surface of the Earth and is thus the total power expected in the m^{th} range look at discriminator signal frequency ν_0 when the orbit time position of the satellite is T(k,j). The function f is given by the following equation:

$$f(\nu_0, \mathrm{T(k,j), m, b, SP}, \mathbf{P}_{\mathrm{SAT}}, \mathbf{P}_{\mathrm{ANT}}(\mathrm{b}); \mathrm{x, y})$$
$$= \int_{-\infty}^{+\infty} \omega(\mathrm{t,m,b})\, \mathrm{s}_{\mathrm{RX}}^{\mathrm{DR}}(\mathrm{t,T(k,j),b,SP}, \mathbf{P}_{\mathrm{SAT}}, \mathbf{P}_{\mathrm{ANT}}(\mathrm{b}); \mathrm{x, y}) \exp(-2\pi i \nu_0 \mathrm{t})\, \mathrm{dt}$$

Equation 77

The function ω(t,m,b) is the look extraction function for the m^th range look which is given by the following expression:

$$\omega(\mathrm{t,m,b}) = \left\{ \omega_{\mathrm{M-E}}\left(\left[\mathrm{t} - \mathrm{T_{DR}} + \mathrm{T_{DRW}}/2 - (\mathrm{m}-1)(1-\sigma)\mathrm{T_{RL}} - \mathrm{T_{RL}}/2\right], \mathrm{b}, \mathrm{T_{RL}} \right) \right\} \begin{bmatrix} \mathrm{H}\left[\mathrm{t} - \mathrm{T_{DR}} + \mathrm{T_{DRW}}/2 - (\mathrm{m}-1)(1-\sigma)\mathrm{T_{RL}}\right] \\ - \mathrm{H}\left[\mathrm{t} - \mathrm{T_{DR}} + \mathrm{T_{DRW}}/2 - \mathrm{T_{RL}} - (\mathrm{m}-1)(1-\sigma)\mathrm{T_{RL}}\right] \end{bmatrix}$$

Equation 78

The window function ω_{M-E} is given by:

$$\omega_{\mathrm{M-E}}(\mathrm{x, b, T_{RL}}) = \mathrm{c^{M-E}(b)}$$
$$\forall \quad \mathrm{x} \;\; \mathrm{s.t.} \;\; 0 \le \mathrm{Abs(x)} \le \mathrm{p^{M-E}(b)T_{RL}}/2$$

$$\omega_{\mathrm{M-E}}(\mathrm{x, b, T_{RL}}) = \frac{\mathrm{c^{M-E}(b)}}{2}\left[1 + \cos\left(\frac{2\pi(\mathrm{Abs(x)} - \mathrm{p^{M-E}(b)T_{RL}}/2)}{\mathrm{T_{RL}}(1-\mathrm{p^{M-E}(b)})} \right) \right]$$
$$\forall \quad \mathrm{x} \;\; \mathrm{s.t.} \;\; \mathrm{p^{M-E}(b)T_{RL}}/2 < \mathrm{Abs(x)} \le \mathrm{T_{RL}}/2$$

Equation 79

where:

T_{DR}	is the centre time of the spectral deramping window for beam b
T_{DRW}	is the deramping window duration for beam b
T_{RL}	is the range look duration for beam b
σ	is the fractional overlap between adjacent range looks for beam b
sDR-RX	is the spectrally de-ramped baseband receive signal from the distributed target scattering element located at position (x, y) on the surface of the Earth.

Note: The dependence on b is not shown explicitly in Equation 79 to simplify the notation.

To determine the form of sDR-RX, it is now necessary to consider the pulse transmitted from the radar, its backscattering by the distributed target scattering element and its subsequent reception by the radar. Note that any dependence on redundancy configuration is suppressed since such effects are removed by the power gain product correction and therefore do not have to be considered in the context of the power to σ_0 normalisation function. The power-gain product correction compensates for any variation in the monitored portions of the transmit and receive paths including switches between redundant equipment in the monitored path. Any residual bias errors or drifts are removed by external calibration and are assumed to be changes in the antenna gain, whether or not they actually are so.

The pure baseband transmit signal is given by the following equation:

$$s_{TX}^{BB}(p) = a_{TX}(p)\left[H\left[p+\frac{T_{TX}(b)}{2}\right]-H\left[p-\frac{T_{TX}(b)}{2}\right]\right]\exp\left(2\pi i\alpha(b)p^2\right)$$

Equation 80

Where $a_{TX}(p)$ is the amplitude function of the pure baseband transmit pulse, $T_{TX}(b)$ is duration of the transmit pulse for beam b, $\alpha(b)$ is such that $2\alpha(b)$ is the linear frequency modulation rate for beam b which may be positive or negative. The amplitude function, $a_{TX}(p)$ is described by a third order polynomial:

$$a_{TX}(p) = A_{TX0} + A_{TX1}\,p + A_{TX2}\,p^2 + A_{TX3}\,p^3$$

Equation 81

The baseband transmit signal, after corruption by the transmit chain spectral transfer characteristic, is given by:

$$s_{TX}^{CBB}(q) = \int_{-\infty}^{+\infty} h_{TX}(q-p)s_{TX}^{BB}(p)dp$$

Equation 82

Where h_{TX} is the time domain transmit path filter function. The RF transmit signal is given by:

$$s_{TX}^{RF}(q) = s_{TX}^{CBB}(q)\exp\left(+2\pi i f_{UC}q\right)$$

Equation 83

Where f_{UC} is the up conversion frequency, which is also the radar carrier frequency. The RF receive signal is given by:

$$\begin{aligned}&s_{RX}^{RF}(q, T(k,j), b, SP, \mathbf{P}_{SAT}, \mathbf{P}_{ANT}(b); x, y)\\&= K(T(k,j), b, SP, \mathbf{P}_{SAT}, \mathbf{P}_{ANT}(b); x, y)s_{TX}^{RF}(q - T_{RDT}(q; T(k,j), x, y))\end{aligned}$$

Equation 84

The function K determines the amplitude of the signal from the distributed target scattering element (and here, also, all constant transmit path and receive path amplitude changing effects) and T_{RDT} is the radar delay time function. Both functions are discussed explicitly below. The baseband receive signal is given by:

$$\begin{aligned}&s_{RX}^{BB}(q, T(k,j), b, SP, \mathbf{P}_{SAT}, \mathbf{P}_{ANT}(b); x, y)\\&= s_{RX}^{RF}(q, T(k,j), b, SP, \mathbf{P}_{SAT}, \mathbf{P}_{ANT}(b); x, y)\exp\left(-2\pi i f_{DC}q\right)\end{aligned}$$

Equation 85

Where f_{DC} is the down conversion frequency. The baseband receive signal, after corruption by the receive chain spectral transfer characteristic, is given by:

$$s_{RX}^{CBB}(t, T(k,j), b, SP, \mathbf{P}_{SAT}, \mathbf{P}_{ANT}(b); x, y) = \int_{-\infty}^{+\infty} h_{RX}(t-q) s_{RX}^{BB}(q, T(k,j), b, SP, \mathbf{P}_{SAT}, \mathbf{P}_{ANT}(b); x, y) dq$$

Equation 86

Where h_{RX} is the time domain receive path filter function. The spectrally-deramped baseband receive signal is given by:

$$s_{RX}^{DR}(t, T(k,j), b, SP, \mathbf{P}_{SAT}, \mathbf{P}_{ANT}(b); x, y) = s_{RX}^{CBB}(t, T(k,j), b, SP, \mathbf{P}_{SAT}, \mathbf{P}_{ANT}(b); x, y) \Xi_{DR}(t; b)$$

Equation 87

Where the spectral deramping function is given by the following expression:

$$\Xi_{DR}(t;b) = \left[H\left(t - T_{DR}(b) + \frac{T_{DRW}(b)}{2} \right) - H\left(t - T_{DR}(b) - \frac{T_{DRW}(b)}{2} \right) \right] \exp\left(-2\pi i \alpha(b)(t - T_{DR}(b))^2 \right)$$

Equation 88

The impact on power of receive path filter shape has already been compensated for in the front end algorithms, thus assuming no phase distortion, the time domain receive path filter function may be taken to be a Dirac delta function. The transmit chain filter shape function is assumed to be unity, thus the time domain transmit path filter function may be taken to be a Dirac delta function. Thus the transmit and receive path filter shape functions are as follows:

$$h_{TX}(t) = \delta_{DIRAC}(t)$$

Equation 89

$$h_{RX}(t) = \delta_{DIRAC}(t)$$

Equation 90

The amplitude function K is given by the following equation with σ_0 function set equal to unity:

$$K(T(k,j), b, SP, \mathbf{P}_{SAT}, \mathbf{P}_{ANT}(b); x, y) = \sqrt{\frac{\lambda^2 P_{TX-P} g_{RX}}{(4\pi)^3 L_{TX}(b, SP) L_{RX}(b, SP)}} \sqrt{\frac{G^2{}_{ACT}(x, y; T(k,j), b, \mathbf{P}_{SAT}, \mathbf{P}_{ANT}(b)) \sigma_0(x, y)}{s(x, y; T(k,j))^4 \exp\left(+2\ell_{ATM}(x, y) h_{ATM}(x, y) \sec(i(x, y; T(k,j)))\right)}}$$

Equation 91

where:

λ	is the radar carrier wavelength.
P_{TX-P}	is the nominal peak RF power at the SSPA output (any amplitude characteristic is accounted for by $a_{TX}(p)$ which is less than or equal to unity for all values of p), g_{RX} is the nominal setting of the receive chain gain.
$L_{TX}(b,SP)$	is the transmit path losses for beam b, which are functions of switch path and must be changed if the switch path is changed.
$L_{RX}(b,SP)$	is the receive path losses for beam b, which are functions of switch path and must be changed if the switch path is changed.
G	is the antenna one-way power gain at (x,y) at time T(k,j).
s	is the slant range to (x,y) from the radar at time T(k,j).
l_{ATM}	is the nominal dry air atmospheric loss (which may be varied as a function of latitude and longitude).
h_{ATM}	is the height of the atmosphere (which may be varied as a function of latitude and longitude).
i	is the incidence angle at (x,y) at time T(k,j)

Note: If the switch path is changed, then $L_{TX}(b,SP)$ and $L_{RX}(b,SP)$ must be changed to allow use of the antenna pattern currently in the normalisation table generator. (Preferable this should be implemented in a way which avoids the need to re-evaluate all of the integrals.) Doing this should maintain an approximate instrument calibration however the flag F_{CAL} should be set to 1. If the switch path is changed a new in-flight calibration campaign must be performed as soon as possible. When the new normalisation table resulting from this has been loaded the flag F_{CAL} may be reset to 0.

The function $T_{RDT}(q)$ is the radar-delay-time function which is given by the following expression —assuming all higher order terms can be neglected: powers of time and radar-target accelerations):

$$T_{RDT}(q) = \Delta_{RADAR} + \frac{2s(x,y)}{c} + \frac{2v_R(x,y)q}{c} \qquad \textit{Equation 92}$$

Where Δ_{RADAR} is the delay within the radar, s(x,y) is the slant range from the radar to the distributed target scattering element located at position (x,y) on the surface of the Earth and $v_R(x,y)$ is the relative speed between the radar and the distributed target scattering element; the relative speed is negative when the radar is closing in on the target.

Note: For the case of no Tx and Rx filter effects, the exponential term (multiplying the Heaviside step functions) in the equation for the spectrally de-ramped baseband received signal is given by this:

$$2\pi i\Big((f_{UC} - f_{DC})\, t - f_{UC}\, T_{RDT}[t] + \alpha\,(t - T_{RDT}[t])^2 - \alpha\,(t - T_{DR})^2 \Big) \qquad \textit{Equation 93}$$

Thus the exponential term (multiplying the Heaviside step functions and the range look extraction function) in the integral for f is given by:

$$2\pi i\left(\left(f_{UC} - f_{DC} - \nu_0 \right) t - f_{UC}\, T_{RDT}[t] + \alpha \left(t - T_{RDT}[t] \right)^2 - \alpha \left(t - T_{DR} \right)^2 \right)$$

Equation 94

Substituting the expression for the radar delay time function and expanding in power of t results in the following expression:

$$\begin{aligned}
&2\pi i\left(\left(\frac{2s}{c} + \Delta_{RADAR} \right)\left(\alpha\left(\frac{2s}{c} + \Delta_{RADAR} \right) - f_{UC} \right) - \alpha T_{DR}^2 \right) \\
&+ 2\pi i\left(\begin{matrix} \left(f_{UC} - f_{DC} \right) + 2\alpha\left(T_{DR} - \Delta_{RADAR} \right) - \dfrac{4\alpha s}{c} - \nu_0 \\ - \dfrac{2v_R}{\lambda_{UC}}\left(1 - \dfrac{2\alpha T_{TX}}{f_{UC}} \dfrac{\left(\frac{2s}{c} + \Delta_{RADAR} \right)}{T_{TX}} \right) \end{matrix} \right) t \\
&+ 2\pi i\left(-\frac{2}{\lambda_{UC}} \frac{\left(2\alpha T_{TX} \right)}{f_{UC}} \frac{v_R}{T_{TX}}\left(1 - \frac{v_R}{c} \right) \right) t^2
\end{aligned}$$

Equation 95

When the integral is performed and the resulting function is subjected to squared modulus detection the peak will occur, for a given slant range, where the following condition is satisfied:

$$\begin{aligned}
&\left(f_{UC} - f_{DC} \right) + 2\alpha\left(T_{DR} - \Delta_{RADAR} \right) - \frac{4\alpha s}{c} \\
&- \frac{2v_R}{\lambda_{UC}}\left(1 - \frac{2\alpha T_{TX}}{f_{UC}} \frac{\left(\frac{2s}{c} + \Delta_{RADAR} \right)}{T_{TX}} \right) - \nu_0 \quad = \quad 0
\end{aligned}$$

Equation 96

In Equation 96, the first and second terms are constant frequency offset terms, the third term is the slant range dependent term, the fourth term is the Doppler frequency dependent term and the fifth term is the discriminator signal frequency at which the peak of the response from a given slant range occurs. The part of the fourth term in brackets is to a very good approximation equal to unity, thus the above equation may be rewritten as follows:

$$f_{OFFSET}(b) - \frac{4\alpha(b)s}{c} - \frac{2v_R}{\lambda_{UC}} - \nu_0 = 0$$

Equation 97

Where $f_{OFFSET}(b)$ is the beam-dependent offset frequency which is given by the following equation:

$$f_{OFFSET}(b) = -f_{LO4} + 2(f_{CH-START}(b) - f_{DR-START}(b)) + 2\alpha(b)(T_{DR\text{-}TRIGGER}(b) - \Delta_{RADAR})$$

Equation 98

Where f_{LO4} is the LO4 mixer frequency equal to 900000 Hz, $f_{CH\text{-}START}$ is the chirp start frequency, $f_{DR\text{-}START}$ is the spectral deramping start frequency and $T_{DR\text{-}TRIGGER}$ is the spectral deramping window trigger time (i.e. the time interval between the leading edge of the transmitted pulse and the start of the deramping window). The chirp start frequency and the spectral deramping frequency are given, in terms of the parameter table code words, by the following equations:

$$f_{CH-START}(b) = \frac{1}{2}(79200000/262144)\ (ch\_start\_freq[tx, b])$$

Equation 99

$$f_{DR-START}(b) = \frac{1}{2}(79200000/262144)\ (ch\_start\_freq[rx, b])$$

Equation 100

For this measurement mode:

$$T_{DR\text{-}TRIGGER}(b) = T_{TX}(b) + g_1$$

Equation 101

The relationship between sample index, i and discriminator signal frequency υ_0 is given by the following equation where ν_{ADC} is the discriminator signal sampling frequency and N_{FFT} is the number of samples in the range look Fast Fourier Transformation.

$$\nu_0 = \delta_f\ (i - 1)$$

$$\delta_f = \frac{\nu_{ADC}}{N_{FFT}}$$

Equation 102

When the integral for f is evaluated and the squared modulus is taken, the terms which are not functions of pulse time t will drop out and those terms that are functions of higher time terms (t^2) will cause defocusing effects. For a rectangular pulse in the absence of transmit and receive path filter functions, the range look extraction weighting function and the Heaviside step function products may be subjected to decomposition and the integral may then be evaluated analytically.)

For testing the normalisation table generator it shall be possible to load an analytic function antenna gain pattern with a specific selectable antenna depointing / orientation.

6.2.5 Determination of Antenna Gain at an Angular Position from a Transponder Measurement

The purpose of calibration is to establish the absolute in-flight antenna one-way power gain pattern and its electrical boresight pointing and orientation. The absolute in-flight one-way power gain pattern is needed for accurate power to σ_0 conversion and the in-flight actual antenna electrical boresight pointing and orientation is needed for localisation. The in-flight antenna one-way power gain patterns and their electrical boresight pointings and orientations are established by many transponder measurements.

The actual one-way antenna power gain pattern in the Actual Antenna Coordinate System for beam b is the same as the actual one-way antenna power gain pattern in the Nominal Antenna Coordinate System, thus:

$$\begin{aligned} & G_{ACT}(\theta_{A(b)}, \phi_{A(b)}; b, \mathbf{P}_{SAT}, \mathbf{P}_{ANT\text{-}ACT}(b)) \\ & = G_{ACT}(\theta_{N(b)}, \phi_{N(b)}; b, \mathbf{P}_{SAT}, \mathbf{P}_{ANT\text{-}NOM}(b)) \\ & = G_{ACT}(\theta_{N(b)}, \phi_{N(b)}; b, \mathbf{P}_{SAT}) \end{aligned} \qquad \textit{Equation 103}$$

On the last line in Equation 103, the nominal antenna pointing is suppressed since it is fixed for all time relative to the satellite pointing. Consideration is now given to the determination of the actual antenna one-way power gain pattern at the specific position where a transponder is located.

$$\begin{aligned} & G_{ACT}(\theta_{A(b)}(\mathrm{TRANS}), \phi_{A(b)}(\mathrm{TRANS}); b, \mathbf{P}_{SAT}, \mathbf{P}_{ANT\text{-}ACT}(b)) \\ & = G(x_{TRANS}, y_{TRANS}; T(0,2), b, \mathbf{P}_{SAT}, \mathbf{P}_{ANT}(b)) \end{aligned} \qquad \textit{Equation 104}$$

The satellite position is determined by the time T(0,2) and the actual antenna electrical boresight pointing and orientation are determined by $\mathbf{P}_{SAT}$ and $\mathbf{P}_{ANT}(b)$ and the transponder position is (x_{TRANS}, y_{TRANS}, z_{TRANS}). The one-way power gain antenna pattern at a transponder is determined by the following equation where S_{TRANS} is the actual echo from the real transponder or transponders.

$$\begin{aligned} & G(x_{TRANS}, y_{TRANS}; T(0,2), b, \mathbf{P}_{SAT}, \mathbf{P}_{ANT}(b)) = \\ & G_{REF} \sqrt{\frac{\sigma_{P-REF} \displaystyle\int_{\nu_{TRANS}(n)-\delta_{TRANS}/2}^{\nu_{TRANS}(n)+\delta_{TRANS}/2} S_{TRANS}(\nu_0, T_0, b, SP, \mathbf{P}_{SAT}, \mathbf{P}_{ANT}(b); x_{TRANS}, y_{TRANS})\, d\nu_0}{\sigma_{P-TRANS}(n)\, N_{REF}(\nu_{TRANS}, T_0, b, SP; x_{TRANS}, y_{TRANS})}} \end{aligned} \qquad \textit{Equation 105}$$

The echo S_{TRANS} may contain zero, one, two or three peaks (of different and variable strengths) associated with transponder echoes. These peaks are first identified, if above a selectable threshold, by searching the echo to identify them and their positions. These peaks occur at frequencies $\nu_{TRANS}(n)$ at T_0. The integrals over S_{TRANS} are performed over an interval centred on each peak. The appropriate transponder cross-section, $\sigma_{TRANS}(n)$, and the corresponding transponder number, n, are determined from the position of the transponder which is determined by the location of a given peak. The transponder calibration factor function N_{REF} is given by the following equation with G_{REF} and $\sigma_{P\text{-}REF}$ both set equal to unity. This function can be determined numerically (or analytically if the amplitude of the transmitted pulse may be assumed to be constant: $a_{TX}(p) = 1$). The function must be re-calculated if any of the parameters on which it depends are changed.

$$N_{REF}(\nu_{TRANS}, T_0, b, SP; x_{TRANS}, y_{TRANS}) =$$
$$\left(\frac{\lambda^2 P_{TX-P} g_{RX} G^2_{REF} \sigma_{P\text{-}REF}}{(4\pi)^3 L_{TX}(b,SP) L_{RX}(b,SP) s(x_{TRANS}, y_{TRANS}; T(0,2))^4} \right)$$
$$\exp\left(-\frac{2\ell_{ATM}(x_{TRANS}, y_{TRANS}) h_{ATM}(x_{TRANS}, y_{TRANS})}{\cos(i(x_{TRANS}, y_{TRANS}; T(0,2)))} \right)$$
$$\int_{\nu_{TRANS}-\delta_{TRANS}/2}^{\nu_{TRANS}+\delta_{TRANS}/2} \Omega_{REF}(\nu_0, T_0, b; x_{TRANS}, y_{TRANS})\, d\nu_0$$

Equation 106

In Equation 106, where:

λ	is the radar carrier wavelength.
PTX-P	is the nominal peak RF power at the SSPA output —any amplitude characteristic is accounted for by $a_{TX}(p)$ which is less than or equal to unity for all values of p.
g_{RX}	is the nominal setting of the receive chain gain.
$L_{TX}(b,SP)$	is the transmit path loss for beam b which are functions of the switch paths used and must be changed if the switch path is changed.
$L_{RX}(b,SP)$	is the receive path loss for beam b which are functions of the switch paths used and must be changed if the switch path is changed.
G	is the antenna one-way power gain at (x,y) at time T(k,j).
s	is the slant range to (x,y) from the radar at time T(k,j).
l_{ATM}	is the nominal dry air atmospheric loss, which may be varied as a function of latitude and longitude.
h_{ATM}	is the height of the atmosphere, which may be varied as a function of latitude and longitude.
i	is the incidence angle at (x,y) at time T(k,j).

For the computation of the transponder calibration factor function N_{REF} the same implementation of the on-board processing algorithm will be used on ground as that used on board; refer to [AD 10].

In instrument calibration mode (where on-board along-track averaging is prevented) the return from a transponder at position (x_{TRANS}, y_{TRANS}, z_{TRANS}) is given by the following expression in the echo reception window of the pulse repetition interval following that associated with the pulse transmission.

$$\Omega_{REF}(\nu_0, T_0, b; x_{TRANS}, y_{TRANS}) = g_{CAL}(0,2) Q_{REF}(\nu_0, T(0,2), b; x_{TRANS}, y_{TRANS})$$

Equation 107

Where g_{CAL} is the eight-point finite impulse response filter function employed on board for along-track echo averaging in calibration mode which is set to (0, 1, 0, 0, 0, 0, 0, 0) so that $g_{CAL}(0,2)$ is unity and all other elements are zero and where T(0,2) is given by:

$$T(0,2) = T_0 - 5\Delta_{CAL}/2$$

Equation 108

Where Δ_{CAL} is the (calibration mode) pulse repetition interval and Q is given by:

$$Q_{REF}(\nu_0, T(0,2), b; x_{TRANS}, y_{TRANS}) = \frac{\sum_{m=1}^{m=M(b)} \rho(\nu_0, m, b) J_{REF}(\nu_0, T(0,2), m, b; x_{TRANS}, y_{TRANS})}{\sum_{m=1}^{m=M(b)} \rho(\nu_0, m, b)}$$

Equation 109

Where ρ is the range look summation weighting used for the summation of the M range looks in the on-board processing and J is given by the following expression:

$$J_{REF}(\nu_0, T(0,2), m, b; x_{TRANS}, y_{TRANS}) = \left| f_{REF}(\nu_0, T(0,2), m, b; x_{TRANS}, y_{TRANS}) \right|^2$$

Equation 110

The squared modulus of function, f_{REF} is the expected power contribution from the transponder at (x_{TRANS},y_{TRANS}) on the surface of the Earth to the power observed in the m^{th} range look at discriminator signal frequency ν_0 when the orbit time position of the satellite is T(k,j). The function f_{REF} is given by the following equation:

$$f_{REF}(\nu_0, T(0,2), m, b; x, y) = \int_{-\infty}^{+\infty} \omega(t, m, b) s^{DR}_{RX\text{-}REF}(t, T(0,2); x, y) \exp(-2\pi i \nu_0 t) dt$$

Equation 111

The function ω(t,m,b) is the look extraction function for the m^{th} range look which is given by the following expression:

$$\omega(t,m,b) = \left\{ \omega_{C-E}\left(\left[t - T_{DR\text{-}CAL} + T_{DRW\text{-}CAL}/2 - (m-1)(1-\sigma)T_{RL} - T_{RL}/2\right], b, T_{RL} \right) \right\} \begin{bmatrix} H\left[t - T_{DR\text{-}CAL} + T_{DRW\text{-}CAL}/2 - (m-1)(1-\sigma)T_{RL}\right] \\ -H\left[t - T_{DR\text{-}CAL} + T_{DRW\text{-}CAL}/2 - T_{RL} - (m-1)(1-\sigma)T_{RL}\right] \end{bmatrix}$$

Equation 112

The window function $\omega_{C\text{-}E}$ is given by:

$$\omega_{C\text{-}E}(x, b, T_{RL}) = \frac{c^{C-E}(b)\,(-1)^{p^{C\text{-}E}(b)/2}\,(x + T_{RL}/2)^{p^{C\text{-}E}(b)/2}\,(x - T_{RL}/2)^{p^{C\text{-}E}(b)/2}}{(T_{RL}/2)^{p^{C\text{-}E}(b)}}$$

Equation 113

Where T_{DR} is the centre time of the spectral deramping window for beam b, T_{DRW} is the deramping window duration for beam b, T_{RL} is the range look duration for beam b, σ is the fractional overlap between adjacent range looks for beam b. (The dependence on b is not shown explicitly in Equation 113 to simplify the notation.)

And sDR-RX is the spectrally-deramped baseband receive signal from the transponder located at position (x_{TRANS},y_{TRANS}) on the surface of the Earth. In order to determine the form of sDR-RX it is now necessary to consider the pulse transmitted from the radar, its backscattering by the transponder and its subsequent reception by the radar.

The pure baseband transmit signal is given by the following:

$$s_{TX}^{BB}(p) = a_{TX}(p)\left[H\left[p + \frac{T_{TX}(b)}{2}\right] - H\left[p - \frac{T_{TX}(b)}{2}\right]\right]\exp\left(2\pi i\alpha(b)p^2\right)$$

Equation 114

Where $a_{TX}(p)$ is the amplitude function of the pure baseband transmit pulse, T_TX(b) is duration of the transmit pulse for beam b, α(b) is such that 2α(b) is the linear frequency modulation rate for beam b which may be positive or negative. The amplitude function, $a_{TX}(p)$ is described by a third order polynomial:

$$a_{TX}(p) = A_{TX0} + A_{TX1}\,p + A_{TX2}\,p^2 + A_{TX3}\,p^3$$

Equation 115

The baseband transmit signal, after corruption by the transmit chain spectral transfer characteristic, is given by this:

$$s_{TX}^{CBB}(q) = \int_{-\infty}^{+\infty} h_{TX}(q-p)\,s_{TX}^{BB}(p)\,dp$$

Equation 116

Where h_{TX} is the time domain transmit path filter function. The RF transmit signal is given by:

$$s_{TX}^{RF}(q) = s_{TX}^{CBB}(q)\exp\left(+2\pi i f_{UC} q\right)$$

Equation 117

Where f_{UC} is up conversion frequency which is also the radar carrier frequency. The RF receive signal is given by the following:

$$s^{RF}_{RX\text{-}REF}(q,T(0,2);x,y) = s^{RF}_{TX}(q - T_{RDT\text{-}CAL}(q;T(0,2),x,y)) \quad \text{Equation 118}$$

The function $T_{RDT\text{-}CAL}$ is the radar delay time function. The baseband receive signal is given by:

$$s^{BB}_{RX\text{-}REF}(q,T(0,2);x,y) = s^{RF}_{RX\text{-}REF}(q,T(0,2);x,y)\exp\left(-2\pi i f_{DC} q\right) \quad \text{Equation 119}$$

Where f_{DC} is the down-conversion frequency. The baseband receive signal, after corruption by the receive chain spectral transfer characteristic, is given by:

$$s^{CBB}_{RX\text{-}REF}(t,T(0,2);x,y) = \int_{-\infty}^{+\infty} h_{RX}(t-q)\, s^{BB}_{RX\text{-}REF}(q,T(0,2);x,y)\,dq \quad \text{Equation 120}$$

Where h_{RX} is the time domain receive path filter function. The spectrally-deramped baseband receive signal is given by:

$$s^{DR}_{RX\text{-}REF}(t,T(0,2);x,y) = s^{CBB}_{RX\text{-}REF}(t,T(0,2);x,y)\,\Xi_{DR\text{-}CAL}(t;b) \quad \text{Equation 121}$$

Where the calibration spectral deramping function is given by the following expression:

$$\Xi_{DR\text{-}CAL}(t;b) = \left[H\left(t - T_{DR\text{-}CAL}(b) + \frac{T_{DRW\text{-}CAL}(b)}{2}\right) - H\left(t - T_{DR\text{-}CAL}(b) - \frac{T_{DRW\text{-}CAL}(b)}{2}\right)\right] \exp\left(-2\pi i \alpha(b)(t - T_{DR\text{-}CAL}(b))^2\right) \quad \text{Equation 122}$$

Since the transponder returns have been subjected to the front end corrections the spectral transfer characteristic of the Rx chain has been removed. The spectral transfer characteristic of the Tx chain is assumed to be unity. Thus,

$$h_{TX}(t) = \delta_{DIRAC}(t) \quad \text{Equation 123}$$

And,

$$h_{RX}(t) = \delta_{DIRAC}(t) \quad \text{Equation 124}$$

The function $T_{RDT\text{-}CAL}(q)$ is the radar delay time function which is given by the following expression (assuming that all higher order terms can be neglected—powers of time and radar-target accelerations):

$$T_{RDT\text{-}CAL}(q) = \Delta_{RADAR} + \Delta_{TRANS} + \frac{2s(x,y)}{c} + \frac{2v_R(x,y)q}{c}$$ *Equation 125*

Where Δ_{RADAR} is the delay within the radar, Δ_{TRANS} is the delay within the transponder, s(x,y) is the slant range from the radar to the transponder located at position (x_{TRANS},y_{TRANS}) on the surface of the Earth and $v_R(x,y)$ is the relative speed between the radar and the transponder; the relative speed is negative when the radar is closing in on the target.

Note: For the case of no Tx and Rx filter effects, the exponential term (multiplying the Heaviside step functions) in the equation for the spectrally-deramped baseband received signal is given by:

$$2\pi i\Big((f_{UC} - f_{DC})\, t - f_{UC}\, T_{RDT\text{-}CAL}[t] + \alpha\,(t - T_{RDT\text{-}CAL}[t])^2 - \alpha\,(t - T_{DR\text{-}CAL})^2 \Big)$$ *Equation 126*

Thus the exponential term (multiplying the Heaviside step functions and the range look extraction function) in the integral for f_{REF} is given by:

$$2\pi i\Big((f_{UC} - f_{DC} - \nu_0)\, t - f_{UC}\, T_{RDT\text{-}CAL}[t] + \alpha\,(t - T_{RDT\text{-}CAL}[t])^2 - \alpha\,(t - T_{DR\text{-}CAL})^2 \Big)$$ *Equation 127*

Substituting the expression for the radar delay time function and expanding in power of t results in the following expression:

$$\begin{aligned}
&2\pi i\left(\begin{array}{l} \left(\frac{2s}{c} + \Delta_{RADAR} + \Delta_{TRANS}\right)\left(\alpha\left(\frac{2s}{c} + \Delta_{RADAR} + \Delta_{TRANS}\right) - f_{UC} \right) \\ \\ -\alpha T^2_{DR\text{-}CAL} \end{array} \right) \\
&+ 2\pi i\left(\begin{array}{l} (f_{UC} - f_{DC}) + 2\alpha(T_{DR\text{-}CAL} - \Delta_{RADAR} - \Delta_{TRANS}) - \frac{4\alpha s}{c} - \nu_0 \\ -\frac{2v_R}{\lambda_{UC}}\left(1 - \frac{2\alpha T_{TX}}{f_{UC}} \frac{\left(\frac{2s}{c} + \Delta_{RADAR} + \Delta_{TRANS}\right)}{T_{TX}} \right) \end{array} \right) t \\
&+ 2\pi i\left(-\frac{2}{\lambda_{UC}} \frac{(2\alpha T_{TX})}{f_{UC}} \frac{v_R}{T_{TX}} \left(1 - \frac{v_R}{c} \right) \right) t^2
\end{aligned}$$ *Equation 128*

When the integral is performed and the resulting function is subjected to squared modulus detection the peak will occur where the following condition is satisfied:

$$
\begin{aligned}
&(f_{UC} - f_{DC}) + 2\alpha(T_{DR\text{-}CAL} - \Delta_{RADAR} - \Delta_{TRANS}) - \frac{4\alpha s}{c} \\
&- \frac{2v_R}{\lambda_{UC}}\left(1 - \frac{2\alpha T_{TX}}{f_{UC}}\,\frac{(\frac{2s}{c} + \Delta_{RADAR} + \Delta_{TRANS})}{T_{TX}}\right) - \nu_0 \quad = \quad 0
\end{aligned}
$$

Equation 129

In Equation 129, the first and second terms are constant frequency offset terms, the third term is dependent on the slant range to the transponder, the fourth term is dependent on the Doppler frequency from the transponder and the fifth term is the discriminator signal frequency at which the peak of the response from the transponder occurs. The part of the fourth term in brackets is to a very good approximation equal to unity, thus the above equation may be rewritten as follows:

$$
f_{OFFSET\text{-}CAL}(b) - \frac{4\alpha(b)s}{c} - \frac{2v_R}{\lambda_{UC}} - \nu_0 = 0
$$

Equation 130

Where $f_{OFFSET\text{-}CAL}(b)$ is the beam -dependent calibration offset frequency which is given by the following equation:

$$
\begin{aligned}
f_{OFFSET\text{-}CAL}(b) = -f_{LO4} + 2(f_{CH-START}(b) - f_{DR-START}(b)) \\
+ 2\alpha(b)(T_{DR\text{-}TRIGGER\text{-}CAL}(b) - \Delta_{RADAR} - \Delta_{TRANS})
\end{aligned}
$$

Equation 131

Note: In Calibration Mode the transponder echo is received in the pulse repetition interval immediately following the pulse repetition window associated with the transmitted pulse.

Where f_{LO4} is the LO4 mixer frequency equal to 900000 Hz, $f_{CH\text{-}START}$ is the chirp start frequency, $f_{DR\text{-}START}$ is the spectral deramping start frequency and $T_{DR\text{-}TRIGGER\text{-}CAL}$ is the calibration spectral deramping window trigger time (i.e. the time interval between the leading edge of the transmitted pulse and the start of the calibration deramping window). The chirp start frequency and the spectral deramping frequency are given, in terms of the parameter table code words, by the following equations:

$$
f_{CH-START}(b) = \frac{1}{2}(79200000/262144)\ (\text{ch\_start\_freq}[tx, b])
$$

Equation 132

$$
f_{DR-START}(b) = \frac{1}{2}(79200000/262144)\ (\text{ch\_start\_freq}[rx, b])
$$

Equation 133

For Calibration Mode:

$$
T_{DR\text{-}TRIGGER\text{-}CAL}(b) = \Delta_{PRI} + T_{TX}(b, DIS) + g_1(b, DIS)
$$

Equation 134

Note: In Calibration Mode, the transponder echo is received in the pulse repetition interval immediately following the pulse repetition window associated with the transmitted pulse.

Note: When the integral for f_{REF} is evaluated and the squared modulus is taken the terms which are not functions of pulse time t will drop out and those terms that are functions of higher time terms (t-squared etc.) will cause defocusing effects. For a rectangular pulse in the absence of transmit and receive path filter functions, the range look extraction weighting function and the Heaviside step function products may be subjected to decomposition and the integral may then be evaluated analytically.

The Gain at Angular Position estimation algorithm essentially processes all corrected calibration echo source packets to build a file of antenna gain at angular position estimates. The processing of each corrected calibration echo source packet contributes between three and zero new measurements to this file. The gain at an angular position estimates are stored with the calibration echo used to generate them together with other data including time, transponder number, ascending/descending pass indicator, flags, etc.

6.2.6 Determination of Antenna Gain Pattern and Orientation from a Set of Antenna Gain at Angular Position Measurements

The in-flight antenna one way power gain pattern and its electrical boresight pointing and orientation are determined by performing a least squares fit to a set of transponder measurements. A more explicit description of this algorithm is given in [AD 11]. The actual antenna one-way power gain pattern is given by the following equation where D_{EST} is the estimated antenna one-way power gain pattern distortion function and G_{EST} is the theoretical (or on-ground characterised) antenna gain pattern.

$$
\begin{aligned}
&G_{ACT}(\theta_{A(b)}, \phi_{A(b)}; b, \mathbf{P}_{SAT}, \mathbf{P}_{ANT\text{-}ACT}(b)) \\
&= G_{ACT}(\theta_{A(b)}, \phi_{A(b)}; b, \mathbf{P}_{SAT}(T), \mathbf{P}_{ANT\text{-}ACT}(b,T)) \\
&= G_{ACT}(\theta_{N(b)}, \phi_{N(b)}; b, \mathbf{P}_{SAT}(T)) \\
&= D_{EST}(\theta_{N(b)}, \phi_{N(b)}; b, \{c_{nm}(b,T)\}, \Delta\psi_{SKEW}(b,T), \Delta\theta_{ELE}(b,T), \Delta\varphi_{AZI}(b,T)) \\
&\quad G_{EST}(\theta_{N(b)}, \phi_{N(b)}; b, \Delta\psi_{SKEW}(b,T), \Delta\theta_{ELE}(b,T), \Delta\varphi_{AZI}(b,T), \mathbf{P}_{SAT}(T))
\end{aligned}
\quad \textit{Equation 135}
$$

G_{EST} is the theoretical or on-ground characterised antenna pattern pointed and orientated in the actual in-flight pointing and orientation, thus:

$$
\begin{aligned}
&G_{EST}(\theta_{N(b)}, \phi_{N(b)}; b, \Delta\psi_{SKEW}(b,T), \Delta\theta_{ELE}(b,T), \Delta\varphi_{AZI}(b,T), \mathbf{P}_{SAT}(T)) \\
&= G_{EST}(\theta_{A(b)}, \phi_{A(b)}; b, \mathbf{P}_{SAT}(T))
\end{aligned}
\quad \textit{Equation 136}
$$

The estimated distortion function is given by the following two dimensional polynomial function:

$$
\begin{aligned}
& D_{EST}(\theta_{N(b)},\phi_{N(b)};b,\{c_{nm}(b,T)\},\Delta\psi_{SKEW}(b,T),\Delta\theta_{ELE}(b,T),\Delta\varphi_{AZI}(b,T)) \\
& = \left(1+c_{00}(b,T)\right) \quad + \\
& F_{DOMAIN}(\theta_{N(b)},\phi_{N(b)};b,\{c_{nm}(b,T)\},\Delta\psi_{SKEW}(b,T),\Delta\theta_{ELE}(b,T),\Delta\varphi_{AZI}(b,T)) \\
& \cdot \left(\begin{array}{l} \sum_n \sum_m c_{nm}(b,T)\left(\cos(\phi_{A(b)})\sin(\theta_{A(b)})\right)^n \left(\sin(\phi_{A(b)})\sin(\theta_{A(b)})\right)^m \\ -\, c_{00}(b,T) \end{array} \right)
\end{aligned}
$$

Equation 137

The domain function is given by the following equation:

$$
\begin{aligned}
& F_{DOMAIN}(\theta_N,\phi_N,\Delta\psi_{SKEW},\Delta\theta_{ELE},\Delta\phi_{AZI}) \\
& = \{\, H\left[10\log_{10}\left(\frac{G_{EST}(\theta_A,\phi_A)}{Max[G_{EST}(\theta_A,\phi_A)]}\right) - T_{HIGH}\right] \quad + \\
& \frac{1}{2}\left(1+\mathrm{Sin}\left(\pi\left(\left(\frac{10\log_{10}\left(\frac{G_{EST}(\theta_A,\phi_A)}{Max[G_{EST}(\theta_A,\phi_A)]}\right)-T_{LOW}}{T_{HIGH}-T_{LOW}}\right)-\frac{1}{2}\right)\right)\right) \\
& \cdot \left(\begin{array}{l} H\left[10\log_{10}\left(\frac{G_{EST}(\theta_A,\phi_A)}{Max[G_{EST}(\theta_A,\phi_A)]}\right) - T_{LOW}\right] \\ -\, H\left[10\log_{10}\left(\frac{G_{EST}(\theta_A,\phi_A)}{Max[G_{EST}(\theta_A,\phi_A)]}\right) - T_{HIGH}\right] \end{array} \right) \} \\
& \cdot \; \{ \left(\begin{array}{l} H[\alpha_A(\theta_A,\phi_A)+\beta_A(\theta_A,\phi_A)\mathrm{Tan}(\Delta_A)-\alpha_{AL}] \\ -H[\alpha_A(\theta_A,\phi_A)+\beta_A(\theta_A,\phi_A)\mathrm{Tan}(\Delta_A)-\alpha_{AH}] \end{array} \right) \\
& + (1/2)\left(1+\mathrm{Sin}[\pi\left(\left(\frac{\alpha_A(\theta_A,\phi_A)+\beta_A(\theta_A,\phi_A)\mathrm{Tan}(\Delta_A)-\alpha_{ALL}}{\alpha_{AL}-\alpha_{ALL}}\right)-1/2\right)]\right) \\
& \cdot \left(\begin{array}{l} H[\alpha_A(\theta_A,\phi_A)+\beta_A(\theta_A,\phi_A)\mathrm{Tan}(\Delta_A)-\alpha_{ALL}] \\ -H[\alpha_A(\theta_A,\phi_A)+\beta_A(\theta_A,\phi_A)\mathrm{Tan}(\Delta_A)-\alpha_{AL}] \end{array} \right) \\
& + (1/2)\left(1+\mathrm{Sin}[\pi\left(\left(\frac{\alpha_A(\theta_A,\phi_A)+\beta_A(\theta_A,\phi_A)\mathrm{Tan}(\Delta_A)-\alpha_{AHH}}{\alpha_{AH}-\alpha_{AHH}}\right)-1/2\right)]\right) \\
& \cdot \left(\begin{array}{l} H[\alpha_A(\theta_A,\phi_A)+\beta_A(\theta_A,\phi_A)\mathrm{Tan}(\Delta_A)-\alpha_{AH}] \\ -H[\alpha_A(\theta_A,\phi_A)+\beta_A(\theta_A,\phi_A)\mathrm{Tan}(\Delta_A)-\alpha_{AHH}] \end{array} \right) \}
\end{aligned}
$$

Equation 138

Where the thresholds T_{HIGH} and T_{LOW} are chosen to select a suitable portion of the main lobe of the antenna gain pattern and the parameters α_{ALL}, α_{AL}, α_{AH}, α_{AHH} and Δ_A are chosen for each beam to select the swath. H is the Heaviside step function (H[x] = 0 for all x < 0, H[x] = 1/2 for x = 0 and H[x] = 1 for all x > 0). The angles α and β are related to the angles θ and Φ by the following equations for an orthogonal left-handed Cartesian coordinate system (x, y, z):

$$\begin{aligned} \mathrm{Tan}(\alpha) &= x / z \\ \mathrm{Tan}(\beta) &= y / z \\ \\ \mathrm{Tan}(\theta) &= \sqrt{x^2 + y^2} / z \\ \mathrm{Tan}(\phi) &= y / x \end{aligned}$$

Equation 139

In Equation 139, θ_A and ϕ_A are given by:

$$\theta_{A(b)} = \theta_{A(b)}(\theta_{N(b)}, \phi_{N(b)}, b, \Delta\psi_{SKEW}(b,T), \Delta\theta_{ELE}(b,T), \Delta\varphi_{AZI}(b,T))$$

$$\phi_{A(b)} = \phi_{A(b)}(\theta_{N(b)}, \phi_{N(b)}, b, \Delta\psi_{SKEW}(b,T), \Delta\theta_{ELE}(b,T), \Delta\varphi_{AZI}(b,T))$$

Equation 140

$$\hat{x}_{N(b)} = \begin{bmatrix} \sin(\theta_{N(b)})\cos(\phi_{N(b)}) \\ \sin(\theta_{N(b)})\sin(\phi_{N(b)}) \\ \cos(\theta_{N(b)}) \end{bmatrix}$$

Equation 141

$$\hat{x}_{A(b)} = [T_{A(b)->N(b)}]^T \hat{x}_{N(b)}$$

Equation 142

$$\hat{x}_{A(b)} = \begin{bmatrix} \sin(\theta_{A(b)})\cos(\phi_{A(b)}) \\ \sin(\theta_{A(b)})\sin(\phi_{A(b)}) \\ \cos(\theta_{A(b)}) \end{bmatrix}$$

Equation 143

The polynomial coefficients, $c_{nm}(b,T)$ and the depointing angles, $\Delta\psi_{SKEW}(b,T)$, $\Delta\theta_{ELE}(b,T)$ and $\Delta\phi_{AZI}(b,T)$ are estimated by solving the simultaneous equations resulting from minimisation of the objective function.

$$\frac{\partial \rho_{OBJ}}{\partial c_{nm}} = 0 \;\forall c_{nm}$$

Equation 144

$$\frac{\partial \rho_{\mathrm{OBJ}}}{\partial \Delta \psi_{\mathrm{SKEW}}} = 0$$

Equation 145

$$\frac{\partial \rho_{\mathrm{OBJ}}}{\partial \Delta \theta_{\mathrm{ELE}}} = 0$$

Equation 146

$$\frac{\partial \rho_{\mathrm{OBJ}}}{\partial \Delta \varphi_{\mathrm{AZI}}} = 0$$

Equation 147

The objective function, ρ_{OBJ} is given by the following equation:

$$\begin{aligned}\rho_{\mathrm{OBJ}} \quad = \\ \sum_{\mathrm{TRANS(T)}} \\ \left(\begin{aligned} & G_{\mathrm{ACT}}(\theta_{N(b)}(\mathrm{TRANS}(T)), \phi_{N(b)}(\mathrm{TRANS}(T)); b, \mathbf{P}_{\mathrm{SAT}}) \\ & - \\ & \;D_{\mathrm{FIT}}(\theta_{N(b)}(\mathrm{TRANS}(T)), \phi_{N(b)}(\mathrm{TRANS}(T)); \\ & \qquad b, \{c_{nm}(b,T)\}, \Delta\psi_{\mathrm{SKEW}}(b,T), \Delta\theta_{\mathrm{ELE}}(b,T), \Delta\varphi_{\mathrm{AZI}}(b,T)) \\ & . \;\; G_{\mathrm{EST}}(\theta_{N(b)}(\mathrm{TRANS}(T)), \phi_{N(b)}(\mathrm{TRANS}(T)); \\ & \qquad b, \Delta\psi_{\mathrm{SKEW}}(b,T), \Delta\theta_{\mathrm{ELE}}(b,T), \Delta\varphi_{\mathrm{AZI}}(b,T), \mathbf{P}_{\mathrm{SAT}}) \end{aligned} \right)^2\end{aligned}$$

Equation 148

where

$$\begin{aligned} & D_{\mathrm{FIT}}(\theta_{N(b)}, \phi_{N(b)}; b, \{c_{nm}(b,T)\}, \Delta\psi_{\mathrm{SKEW}}(b,T), \Delta\theta_{\mathrm{ELE}}(b,T), \Delta\varphi_{\mathrm{AZI}}(b,T)) \\ & = 1 \;+\; \sum_n \sum_m c_{n\,m}(b,T)\left(\cos(\phi_{A(b)})\sin(\theta_{A(b)})\right)^n \left(\sin(\phi_{A(b)})\sin(\theta_{A(b)})\right)^m \end{aligned}$$

Equation 149

It shall be possible to detect and discard spurious transponder data which do not satisfy the threshold condition—after the polynomial coefficients and the depointing angles have been determined:

$$\left| G_{\mathrm{ACT}}(\mathrm{TRANS}(T)) - D_{\mathrm{EST}}\; G_{\mathrm{EST}} \right|^2 \le \eta_{\mathrm{THRESHOLD}}$$

Equation 150

By using transponder data spanning different periods of time in the objective function the in-flight antenna one-way power gain pattern and its boresight pointing and orientation may be established and monitored. These quantities are established and monitored using transponder data from a single calibration campaign (lasting perhaps for approximately 30 days) over which the parameters for each antenna beam c_{nm} and , $\Delta\psi_{SKEW}$, $\Delta\theta_{ELE}$ and $\Delta\phi_{AZI}$ are assumed to constants. If the gain pattern and its boresight pointing and orientation are found to be stable over longer periods of time transponder data from several consecutive calibration campaigns may be combined to give refined estimates of the polynomial coefficients and the depointing angles. It is envisaged to have one transponder calibration campaign per year to monitor the in-flight antenna patterns and their electrical boresight pointings and orientations.

The search technique (simulated annealing) given in [AD 11] shall be implemented in order to find the global minimum and thus render the algorithm fully automatic.

The set of Gain at Angular Position Estimates to be used as input to the Antenna Gain Pattern and Orientation Determination Algorithm may be selected by time interval or time intervals, by transponder number or numbers, by ascending or descending pass, by gain drop (with respect to the expected peak gain of a given antenna) and / or by combinations of these. It shall also be possible to manually edit all GAP estimates or selections of GAP estimates (made as described in the previous sentence) to obtain a final set for use in the Antenna Gain Pattern and Orientation Determination Algorithm. The set of GAP estimates from which selections can be made comprises all GAP estimates available at the time that the selection.

6.2.7 Inverse Impulse Response Function / Deblooming Kernels

The deblooming kernels are given by the following equation:

$$K_{DEBLOOM}(\nu_0, T_0, \nu, T, b, \mathbf{P}_{SAT}, \mathbf{P}_{ANT}(b)) = \frac{\Lambda_{IIRF}(\nu_0, T_0, \nu, T, b, \mathbf{P}_{SAT}, \mathbf{P}_{ANT}(b))}{\Lambda_{IIRF}(\nu_0, T_0, \nu_0, T_0, b, \mathbf{P}_{SAT}, \mathbf{P}_{ANT}(b))}$$

Equation 151

For the computation of the deblooming kernels the same implementation of the on-board processing algorithm will be used on ground as that used on board; refer to [AD 10]. The deblooming kernels must be re-calculated if any of the parameters or functions on which they depend are changed.

The inverse impulse response function in discriminator signal frequency/orbit time space is given by the following equation:

$$\Lambda_{IIRF}(\nu_0, T_0, \nu, T, b, \mathbf{P}_{SAT}, \mathbf{P}_{ANT}(b)) = \sum_{k=0}^{k=1}\sum_{j=1}^{j=4} g(k,j) Q_{IIRF}(\nu_0, T(k,j), \nu, T, b, \mathbf{P}_{SAT}, \mathbf{P}_{ANT}(b))$$

Equation 152

Where g is the eight-point finite impulse response filter function employed on board for along-track echo averaging the azimuth look weighting) and where T(k,j) is given by:

$$T(k,j) = T_0 + \Delta\left(jk + (4-j)(k-1) - 1/2\right)$$

Equation 153

Where Δ is the (measurement mode) pulse repetition interval for beam b and Q is given by:

$$Q_{IIRF}(\nu_0, T(k,j)\,\nu, T, b, \mathbf{P}_{SAT}, \mathbf{P}_{ANT}(b)) = \frac{\sum_{m=1}^{m=M(b)} \rho(\nu_0, m, b) J_{IIRF}(\nu_0, T(k,j), \nu, T, m, b, \mathbf{P}_{SAT}, \mathbf{P}_{ANT}(b))}{\sum_{m=1}^{m=M(b)} \rho(\nu_0, m, b)}$$

Equation 154

Where ρ is the range-look summation weighting used for the summation of the M range looks in the on-board processing and J is given by the following expression:

$$J_{IIRF}(\nu_0, T(k,j), \nu, T, m, b, \mathbf{P}_{SAT}, \mathbf{P}_{ANT}(b)) = \left| f_{IIRF}(\nu_0, T(k,j), m, b, \mathbf{P}_{SAT}, \mathbf{P}_{ANT}(b); x(\nu,T), y(\nu,T)) \right|^2$$

Equation 155

The squared modulus of function, f_{IIRF} is the expected power contribution of an elemental area at (x,y) on the surface of the Earth to the power observed in the m^{th} range look at discriminator signal frequency ν_0 when the orbit time position of the satellite is T(k,j). The function f_{IIRF} is given by the following equation:

$$f_{IIRF}(\nu_0, T(k,j), m, b, \mathbf{P}_{SAT}, \mathbf{P}_{ANT}(b); x(\nu,T), y(\nu,T)) = \int_{-\infty}^{+\infty} \omega(t,m,b)\, s_{RX}^{DR}(t, T(k,j), b, \mathbf{P}_{SAT}, \mathbf{P}_{ANT}(b); x(\nu,T), y(\nu,T)) \exp(-2\pi i \nu_0 t)\,dt$$

Equation 156

The function ω(t,m,b) is the look extraction function for the m^{th} range look which is given by the following expression:

$$\omega(t,m,b) = \left\{ \omega_{M-E}\left(\left[t - T_{DR} + T_{DRW}/2 - (m-1)(1-\sigma)T_{RL} - T_{RL}/2 \right], b, T_{RL} \right) \right\} \begin{bmatrix} H\left[t - T_{DR} + T_{DRW}/2 - (m-1)(1-\sigma)T_{RL} \right] \\ - H\left[t - T_{DR} + T_{DRW}/2 - T_{RL} - (m-1)(1-\sigma)T_{RL} \right] \end{bmatrix}$$

Equation 157

The window function $\omega_{M\text{-}E}$ is given by:

$$\omega_{M\text{-}E}(x, b, T_{RL}) = c^{M-E}(b)$$
$$\forall \quad x \ \text{ s.t. } \ 0 \le \mathrm{Abs}(x) \le p^{M\text{-}E}(b)T_{RL}/2$$

$$\omega_{M\text{-}E}(x, b, T_{RL}) = \frac{c^{M-E}(b)}{2}\left[1 + \cos\left(\frac{2\pi(\mathrm{Abs}(x) - p^{M\text{-}E}(b)T_{RL}/2)}{T_{RL}(1 - p^{M-E}(b))}\right)\right]$$
$$\forall \quad x \ \text{ s.t. } \ p^{M\text{-}E}(b)T_{RL}/2 < \mathrm{Abs}(x) \le \ T_{RL}/2$$

Equation 158

Where:

T_{DR}	is the centre time of the spectral deramping window for beam b
T_{DRW}	is the deramping window duration for beam b
T_{RL}	is the range look duration for beam b
σ	is the fractional overlap between adjacent range looks for beam b
sDR-RX	RX is the spectrally de-ramped baseband receive signal from the distributed target scattering element located at position (x, y) on the surface of the Earth.

Note: To simplify the notation, the dependence on b is not shown explicitly in the equation above.

To determine the form of $s_{DR\text{-}RX,}$ it is now necessary to consider the pulse transmitted from the radar, its backscattering by the distributed target scattering element and its subsequent reception by the radar.

The pure baseband transmit signal is given by the following:

$$s_{TX}^{BB}(p) = a_{TX}(p)\left[H\left[p + \frac{T_{TX}(b)}{2}\right] - H\left[p - \frac{T_{TX}(b)}{2}\right]\right]\exp\left(2\pi i\alpha(b)p^2\right)$$

Equation 159

Where $a_{TX}(p)$ is the amplitude function of the pure baseband transmit pulse, $T_{TX}(b)$ is duration of the transmit pulse for beam b, $\alpha(b)$ is such that $2\alpha(b)$ is the linear frequency modulation rate for beam b which may be positive or negative. The amplitude function, $a_{TX}(p)$ is described by a third order polynomial:

$$a_{TX}(p) = A_{TX0} + A_{TX1}\,p + A_{TX2}\,p^2 + A_{TX3}\,p^3$$

Equation 160

The baseband transmit signal, after corruption by the transmit chain spectral transfer characteristic, is given by the following:

$$s_{TX}^{CBB}(q) = \int_{-\infty}^{+\infty} h_{TX}(q-p)s_{TX}^{BB}(p)dp$$ *Equation 161*

Where h_{TX} is the time domain transmit path filter function. The RF transmit signal is given by:

$$s_{TX}^{RF}(q) = s_{TX}^{CBB}(q)\exp\left(+2\pi i f_{UC} q\right)$$ *Equation 162*

Where f_{UC} is the up-conversion frequency—which is also the radar carrier frequency. The RF receive signal is given by:

$$\begin{aligned} & s_{RX}^{RF}(q, T(k,j), b, \mathbf{P}_{SAT}, \mathbf{P}_{ANT}(b); x, y) \\ & = K(T(k,j), b, \mathbf{P}_{SAT}, \mathbf{P}_{ANT}(b); x, y) s_{TX}^{RF}(q - T_{RDT}(q; T(k,j), x, y)) \end{aligned}$$ *Equation 163*

The function K determines the amplitude of the signal from the distributed target scattering element (and here, also, all constant transmit-path and receive-path amplitude changing effects) and T_{RDT} is the radar delay time function. Both functions are discussed explicitly below. The baseband receive signal is given by:

$$\begin{aligned} & s_{RX}^{BB}(q, T(k,j), b, \mathbf{P}_{SAT}, \mathbf{P}_{ANT}(b); x, y) \\ & = s_{RX}^{RF}(q, T(k,j), b, \mathbf{P}_{SAT}, \mathbf{P}_{ANT}(b); x, y) \exp\left(-2\pi i f_{DC} q\right) \end{aligned}$$ *Equation 164*

Where f_{DC} is the down-conversion frequency. The baseband receive signal, after corruption by the receive chain spectral transfer characteristic, is given by this:

$$\begin{aligned} & s_{RX}^{CBB}(t, T(k,j), b, \mathbf{P}_{SAT}, \mathbf{P}_{ANT}(b); x, y) \\ = & \int_{-\infty}^{+\infty} h_{RX}(t-q) s_{RX}^{BB}(q, T(k,j), b, \mathbf{P}_{SAT}, \mathbf{P}_{ANT}(b); x, y) dq \end{aligned}$$ *Equation 165*

Where h_{RX} is the time domain receive path filter function. The spectrally de-ramped baseband receive signal is given by:

$$\begin{aligned} & s_{RX}^{DR}(t, T(k,j), b, \mathbf{P}_{SAT}, \mathbf{P}_{ANT}(b); x, y) \\ & = s_{RX}^{CBB}(t, T(k,j), b, \mathbf{P}_{SAT}, \mathbf{P}_{ANT}(b); x, y) \Xi_{DR}(t; b) \end{aligned}$$ *Equation 166*

Where the spectral deramping function is given by the following expression:

$$\begin{aligned} \Xi_{DR}(t;b) = & \left[H\left(t - T_{DR}(b) + \frac{T_{DRW}(b)}{2} \right) - H\left(t - T_{DR}(b) - \frac{T_{DRW}(b)}{2} \right) \right] \\ & \exp\left(-2\pi i \alpha(b)(t - T_{DR}(b))^2 \right) \end{aligned}$$ *Equation 167*

For the computation of the inverse impulse response functions and deblooming kernels, the instrument spectral transfer characteristics must be included:

$$h_{TX}(t) = \int_{-\infty}^{+\infty} H_{TX}(f)\exp(+2\pi i f t)df$$

Equation 168

and

$$h_{RX}(t) = \int_{-\infty}^{+\infty} H_{RX}(f)\exp(+2\pi i f t)df$$

Equation 169

H_{TX} is assumed to be unity and H_{RX} is estimated using an average Rx filter shape together with the assumption that the Rx chain does not distort the echo phase.

The amplitude function K is given by the following equation with σ_0 function set equal to unity:

$$K(T(k,j), b, \mathbf{P}_{SAT}, \mathbf{P}_{ANT}(b); x, y)$$
$$= \sqrt{\frac{\lambda^2 P_{TX-P} g_{RX}}{(4\pi)^3 L_{TX}(b, SP_{NOMINAL}) L_{RX}(b, SP_{NOMINAL})}} \sqrt{\frac{G^2{}_{ACT}(x, y; T(k,j), b, \mathbf{P}_{SAT}, \mathbf{P}_{ANT}(b))\sigma_0(x, y)}{s(x, y; T(k,j))^4 \exp(+2\ell_{ATM}(x, y) h_{ATM}(x, y) \sec(i(x, y; T(k,j))))}}$$

$$x = x(\nu, T)$$
$$y = y(\nu, T)$$

Equation 170

Where:

λ	is the radar carrier wavelength
P_{TX-P}	is the nominal peak RF power at the SSPA output—any amplitude characteristic is accounted for by $a_{TX}(p)$ which is less than or equal to unity for all values of p.
g_{RX}	is the nominal setting of the receive chain gain
$L_{TX}(b)$	is the nominal transmit path losses for beam b
$L_{RX}(b)$	is the nominal receive path losses for beam b
G	is the antenna one-way power gain at (x,y) at time T(k,j)
s	is the slant range to (x,y) from the radar at time T(k,j)
l_{ATM}	is the nominal dry air atmospheric loss—may vary as a function of latitude and longitude
h_{ATM}	is the height of the atmosphere —may vary as a function of latitude and longitude
i	is the incidence angle at (x,y) at time T(k,j)

The function $T_{RDT}(q)$ is the radar delay time function which is given by the following expression (assuming that all higher order terms can be neglected: powers of time and radar-target accelerations):

$$T_{RDT}(q) = \Delta_{RADAR} + \frac{2s(x,y)}{c} + \frac{2v_R(x,y)q}{c}$$

Equation 171

Where Δ_{RADAR} is the delay within the radar, s(x,y) is the slant range from the radar to the distributed target scattering element located at position (x,y) on the surface of the Earth and $v_R(x,y)$ is the relative speed between the radar and the distributed target scattering element; the relative speed is negative when the radar is closing in on the target.

For testing the "Inverse Impulse Response Function / Deblooming Kernels" module it shall be possible to load an analytic function antenna gain pattern with a specific selectable antenna depointing / orientation.

6.2.8 Tx Filter Shape Computation

Presently, the Tx path spectral transfer characteristic is assumed to be unity. Later a standard analytic filter function may be used whose parameters are estimated off-line in the cal/val facility using ASCAT transmit pulses captured by the transponders.

6.2.9 Noise / Echo Processing Equivalence Function and Echo Normalisation Function

The function c(b) used to make the noise processing equivalent to the echo processing for Measurement Mode (assuming that the eight point FIR azimuth summation and the noise azimuth summation have been properly normalised) is given by the following:

$$c_M(b) = \frac{\left|\int \omega_{M\text{-}E}(t,m,b)\,dt\right|^2}{\left|\int \omega_{M\text{-}N}(t,b)\,dt\right|^2} \quad \text{for } m = 1$$

Equation 172

The function c(b) used to make the noise processing equivalent to the echo processing for Calibration Mode (assuming that the eight point FIR azimuth summation and the noise azimuth summation have been properly normalised) is given by the following:

$$c_C(b) = \frac{\left|\int \omega_{C\text{-}E}(t,m,b)\,dt\right|^2}{\left|\int \omega_{C\text{-}N}(t,b)\,dt\right|^2} \quad \text{for } m = 1$$

Equation 173

For the computation of the above functions the same implementation of the on-board processing algorithm will be used on ground as that used on board. Presently, in the on-board processing, $\omega_{M\text{-}E}$ is equal to $\omega_{M\text{-}N}$ and $\omega_{C\text{-}N}$ but $\omega_{C\text{-}E}$ is different.

The echo normalisation function is obtained by summing the range look summation weightings used for each of the looks; it is thus given by the following:

$$\chi(i,b) = \sum_{m=1}^{m=M(b)} \rho(\, \nu(i), m, b\,)$$

Equation 174

6.2.10 Gain Compression Monitoring

If a Special Measurement Mode Source Packet for Gain Compression Monitoring arrives at the ASCAT PGF, its RFU Drive Level Setting, D and its Effective Transmitted Power, $c_{TX}(j,b)$ are determined. These parameters together with the Special Measurement Mode Source Packet from which they were obtained are stored in a file. The RFU Drive Level Setting is known from the Parameter Configuration Field of the Source Packet. The Effective Transmitted Power is computed using the following equation:

$$c_{TX}(j,b) = \frac{1}{4}\sum_{i=1}^{i=4}\left[\left(\frac{P_{CAL}(j,i,b)}{P_I(j,i,b)} \right) P_T(\, j,i,b\,) \right]$$

Equation 175

where the powers P_T , P_I and P_{CAL} are the same as those used in the power-gain product algorithm. This computation of the Effective Transmitted Power can be justified by noting the following. Firstly, the symmetrical use of the same drive level setting twice at different times, in the gain compression estimation sequence, effectively removes any linear thermally induced receiver chain gain variation over the estimation time. Secondly, the nominal gain compression estimation sequence is executed in a relatively short time interval (circa 250 seconds).

After the gain compression estimation sequence has ended, the Average Effective Transmitted Power, C is computed for each drive level setting used in the sequence. The approximately first 10 seconds of data at each drive level is excluded from the average in order to avoid using of data where the RFU tracking loop has not yet stabilised. Thus C is computed using the following equation:

$$C = Log_{10}\left[\frac{1}{B(J_{END} - J_{BEGIN} + 1)} \sum_{j=J_{BEGIN}}^{j=J_{END}} \sum_{b=1}^{b=B} c_{TX}(j,b) \right]$$

Equation 176

Thus after each Gain Compression Monitoring Measurement Sequence, a set of RFU Drive Level Settings D_n and the corresponding Average Effective Transmitted Power Measurements, C_n are available for the N Drive Level Settings in the Gain Compression Monitoring Measurement Sequence:

$$\left\{ (\, C_n \,, D_n \,)\,;\, n = 1, \ldots, N \right\}$$

Equation 177

The nominal Gain Compression Monitoring Sequence is carried out once per month using a sequence of nine drive level settings: D_{NOM}, $D_{C2/C8}$, $D_{C3/C7}$, $D_{C4/C6}$, D_{NOM}, $D_{C4/C6}$, $D_{C3/C7}$, $D_{C2/C8}$, D_{NOM}. The following two parameters are computed for each gain compression monitoring sequence:

$$P_{TEST-GCM} = Abs\left[\frac{(\, C_4 + C_6 + C_2 + C_8 \,)}{4} - \frac{(\, C_3 + C_7 \,)}{2} \right]$$

Equation 178

$$Z_{\mathrm{GAIN\ COMPRESSION}} = \frac{1}{2}\left(C_4 + C_6 - C_2 - C_8 \right)\frac{\left(D_{\mathrm{NOM}} - D_{C2/C8} \right)}{\left(D_{C4/C6} - D_{C2/C8} \right)} + \frac{\left(C_2 + C_8\right)}{2} - \frac{\left(C_1 + C_5 + C_9\right)}{3} + \Delta_{GC}(\mathrm{Sat})$$

Equation 179

The tests on these parameters are then performed and the following flags are generated:

$$\begin{aligned} F_{\mathrm{TEST-GCM}} &= 0 \quad \text{if} \quad P_{\mathrm{TEST-GCM}} < T_{\mathrm{TEST-GCM}} \ \&\ 1 \ \text{otherwise} \\ F_{\mathrm{GCM\text{-}HIGH}} &= 1 \quad \text{if} \quad Z_{\mathrm{GAIN\ COMPRESSION}} > T_{\mathrm{GCM\text{-}HIGH}} \ \&\ 0 \ \text{otherwise} \\ F_{\mathrm{GCM\text{-}LOW}} &= 1 \quad \text{if} \quad Z_{\mathrm{GAIN\ COMPRESSION}} < T_{\mathrm{GCM\text{-}LOW}} \ \&\ 0 \ \text{otherwise} \end{aligned}$$

Equation 180

The two derived parameters, the three flags, the set of RFU drive level settings and associated Average Effective Transmitted Power Measurements and the UTC time of the first special measurement mode source packet of the sequence are reported Mission Control / Operations and written to a file. Immediate action and further investigations are required if any one of these tests fails (i.e. if any of these three flags are non-zero).

As an exceptional, if a non-nominal Gain Compression Monitoring Sequence is run, the set of RFU drive level settings and associated Average Effective Transmitted Power Measurements and the UTC time of the first special measurement mode source packet of the sequence are reported Mission Control / Operations and written to a file.

For the case of both a Nominal Gain Compression Monitoring Sequence and an Exceptional Gain Compression Monitoring Sequence, the relevant processing/file construction is triggered by the ending of the sequence / the arrival of new normal measurement mode source packets.

6.3 Algorithms Related to Geometry

6.3.1 System Geometry and Reference Frames

See [RD 1] for detailed specifications. The system geometry is dependent on the Earth model (shape and rotation), the METOP satellite orbit, the METOP satellite attitude and the pointing of the ASCAT antenna beams. The frames of reference used are described below. Their equivalence with the definitions in [AD 6] is also indicated.

The Earth model of the World Geodetic System 84 will be used; in this model the shape of the surface of the Earth is specified as an ellipsoid. The position $\mathbf{S}_T$, the velocity $\mathbf{V}_T$ and acceleration $\mathbf{A}_T$ of the satellite are given in the Terrestrial Reference Frame by an orbit propagator as a function of orbit time (UTC). The orbit propagator also provides the sub-satellite (nadir) position $\mathbf{G}_T$ and the nadir ground track velocity $\mathbf{U}_T$ as a function of orbit time (UTC). The outwards normal at the sub-satellite (nadir) position is $\mathbf{N}_T$; it is given by the following equation:

$$\mathbf{N}_T = \frac{x_T(\mathbf{G}_T)\hat{\mathbf{x}}_T + y_T(\mathbf{G}_T)\hat{\mathbf{y}}_T + \dfrac{z_T(\mathbf{G}_T)\hat{\mathbf{z}}_T}{(1-f_E)^2}}{\sqrt{x_T^2(\mathbf{G}_T) + y_T^2(\mathbf{G}_T) + \dfrac{z_T^2(\mathbf{G}_T)}{(1-f_E)^4}}}$$

Equation 181

The orbit propagator also allows the actual satellite orbit to be compared to the satellite orbit used to generate the Power to σ_0 Normalisation Tables and the Deblooming Kernels.

The attitude software provides the actual satellite attitude and the nominal satellite attitude as a function of orbit time (UTC). The actual satellite attitude is the best available knowledge of satellite attitude at a given time encompassing the satellite attitude steering law and the satellite attitude distortion model (when established). The nominal satellite attitude is the satellite attitude given by the nominal satellite attitude steering law and is the attitude used to generate the Power to σ_0 Normalisation Table and the Deblooming Kernels.

The Terrestrial Reference Frame (T)

This reference frame is a generic one, identical to the IERS Terrestrial Reference Frame in [AD 6].

The origin is the centre of the Earth. The z_g-axis coincides with the conventional Earth rotation axis pointing North. The x_g-axis is perpendicular to the z_g-axis and passes through the conventional Greenwich meridian. The y_g-axis completes the right-handed coordinate frame. The location of an object near the Earth's surface may be specified in terms of east longitude, geodetic latitude and geodetic height.

The Satellite Position Related Coordinate System (P)

This reference frame is used in the ASCAT PGF.

The origin is the centre of the Earth. The x_{sr}-y_{sr} plane lies in the momentary orbit plane with the x_{sr}-axis passing through the satellite centre of gravity. The y_{sr}-axis is chosen such that the satellite velocity has a positive component in the y_{sr}-direction. The z_{sr}-axis completes the right-handed coordinate frame.

The Orbital Reference Frame (L)

This reference frame is a generic one, identical to the Local Relative Yaw Steering Frame in [AD 6].

The origin is the satellite centre of gravity. The z_L axis is parallel to the outward local normal at the satellite nadir position. The y_L axis points in the direction of the velocity of the sub-satellite point relative to the surface of the Earth, given by the Earth model. The x_L axis completes the right-hand coordinate frame.

The Spacecraft Reference Frame (S).
This reference frame is a generic one, identical to the Satellite Reference Frame in [AD 6] The origin is the satellite centre of gravity. The x_S axis is parallel to the outward normal (from the satellite) at the adaptor separation plane. The z_S axis is parallel to the outward normal (from the satellite) of the payload bay walls above which the stowed solar array is held fixed. The y_S axis completes the right-hand coordinate frame. If the spacecraft pointing law was perfectly obeyed in flight then the z_S axis would be parallel to and in the same sense as that of the z_L axis, the y_S axis would be parallel to and in the opposite sense to the y_L axis and the x_S axis would be parallel to and in the opposite sense to the x_L axis.

The Nominal Antenna Coordinate Systems (N(b))
This reference frame is used in the ASCAT PGF. The origin is the satellite centre of gravity. The z_N axis is parallel to the outward normal of the radiating face of antenna b. The x_N axis is parallel to the short sides of antenna b and points roughly towards the Earth. The y_N axis is parallel to the long sides of antenna b and completes the right- handed coordinate system. The Nominal Antenna Coordinate System is defined in relation to the nominal mechanical boresight pointing and orientation.

The Actual Antenna Coordinate Systems (A(b))
This reference frame is used in the ASCAT PGF. The origin is the satellite centre of gravity. The orientation is defined, with reference to the N(b) coordinate system, by three consecutive rotations through three Euler angles. First, a right-handed rotation through the skew depointing angle about the +Z N(b) axis. Second, a right-handed rotation through the elevation depointing angle about the resulting +Y axis. Finally, a right-handed rotation through the azimuth depointing angle about the resulting +X axis. The Actual Antenna Coordinate System is defined in relation to the actual electrical boresight pointing and orientation.

The Node Reference Frame for Node K(N) (K(N))
This reference frame is used in the ASCAT PGF. The origin is the position of node N on the surface of the Earth, specified by the vector $K_T(N)$. See also Section 6.3.4. The z_K axis is parallel to the outwards local normal from the surface of the Earth at the position of the node. The x_K axis is perpendicular to the ground track velocity vector and points from near swath to far swath. The y_K axis completes a right-hand coordinate system.

6.3.2 Transformation Between Reference Frames

See [RD 1] for complete specifications. The following transformation laws are required to transform quantities between the various reference frames.

The transformations between the Terrestrial Reference Frame and the Satellite Position Related Coordinate System are defined by the following equations, where $\mathbf{S}_T$ and $\mathbf{V}_T$ are respectively, the satellite position vector and the satellite velocity vector in the Terrestrial Reference Frame.

$$\begin{aligned}
\mathbf{x}_T &= [\mathbf{T}_{P->T}]\,\mathbf{x}_P \\
\mathbf{x}_P &= [\mathbf{T}_{P->T}]^T\,\mathbf{x}_T \\
[\mathbf{T}_{P->T}] &= [\mathbf{a}_1/|\mathbf{a}_1|, \mathbf{a}_2/|\mathbf{a}_2|, \mathbf{a}_3/|\mathbf{a}_3|] \\
\mathbf{a}_1 &= \mathbf{S}_T \\
\mathbf{a}_2 &= (\mathbf{S}_T \wedge \mathbf{V}_T) \wedge \mathbf{S}_T \\
\mathbf{a}_3 &= \mathbf{S}_T \wedge \mathbf{V}_T
\end{aligned}$$

Equation 182

The transformations between the Satellite Position Related Coordinate System and the Orbital Reference Frame are defined by the following equations, where $\mathbf{U}_P$ is the ground track velocity at the sub-satellite position in the Satellite Position Related Coordinate System and $\mathbf{N}_P$ is the outward normal unit vector at the sub-satellite position in the Satellite Position Related Coordinate System.

$$\begin{aligned}
\mathbf{x}_P &= [\mathbf{T}_{L->P}]\,\mathbf{x}_L + \mathbf{S}_P \\
\mathbf{x}_L &= [\mathbf{T}_{L->P}]^T\,(\mathbf{x}_P - \mathbf{S}_P) \\
[\mathbf{T}_{L->P}] &= [\mathbf{a}_1/|\mathbf{a}_1|, \mathbf{a}_2/|\mathbf{a}_2|, \mathbf{a}_3/|\mathbf{a}_3|] \\
\mathbf{a}_1 &= \mathbf{U}_P \wedge \mathbf{N}_P \\
\mathbf{a}_2 &= \mathbf{U}_P \\
\mathbf{a}_3 &= \mathbf{N}_P
\end{aligned}$$

Equation 183

The transformations between the Orbital Reference Frame and the Spacecraft Reference Frame are defined by the following equations, where $\Delta\alpha_{ROLL}$, $\Delta\beta_{PITCH}$ and $\Delta\gamma_{YAW}$ are, respectively, the roll, pitch and yaw angles of the spacecraft at the relevant along-track time in the orbit.

$$\mathbf{x}_L = [\mathbf{T}_{S->L}]\mathbf{x}_S$$
$$\mathbf{x}_S = [\mathbf{T}_{S->L}]^T \mathbf{x}_L$$

$$[\mathbf{T}_{S->L}] = \mathbf{A}_{ROLL}(\Delta\alpha_{ROLL})\mathbf{A}_{PITCH}(\Delta\beta_{PITCH})\mathbf{A}_{YAW}(\Delta\gamma_{YAW})\mathbf{B}$$

$$\mathbf{A}_{ROLL}(\Delta\alpha_{ROLL}) = \begin{bmatrix} +\cos(\Delta\alpha_{ROLL}) & 0 & +\sin(\Delta\alpha_{ROLL}) \\ 0 & +1 & 0 \\ -\sin(\Delta\alpha_{ROLL}) & 0 & +\cos(\Delta\alpha_{ROLL}) \end{bmatrix}$$

$$\mathbf{A}_{PITCH}(\Delta\beta_{PITCH}) = \begin{bmatrix} +1 & 0 & 0 \\ 0 & +\cos(\Delta\beta_{PITCH}) & -\sin(\Delta\beta_{PITCH}) \\ 0 & +\sin(\Delta\beta_{PITCH}) & +\cos(\Delta\beta_{PITCH}) \end{bmatrix}$$

$$\mathbf{A}_{YAW}(\Delta\gamma_{YAW}) = \begin{bmatrix} +\cos(\Delta\gamma_{YAW}) & -\sin(\Delta\gamma_{YAW}) & 0 \\ +\sin(\Delta\gamma_{YAW}) & +\cos(\Delta\gamma_{YAW}) & 0 \\ 0 & 0 & +1 \end{bmatrix}$$

$$\mathbf{B} = \begin{bmatrix} -1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & +1 \end{bmatrix}$$

Equation 184

The transformations between the Spacecraft Reference Frame and the Nominal Antenna Coordinate System, for beam b, are defined by the following equations, where θ_M is 33.5 degrees and $\theta_{F/A}$ is 43 degrees. The following conversion is employed:

- b = 1 is ANTRF
- b = 2 is ANTRM
- b = 3 is ANTRA
- b=4 is ANTLF
- b = 5 is ANTLM
- b = 6 is ANTLA.

Note: If the on-ground characterised antenna pointings and orientations are known these shall be used instead of the theoretically-desired baseline values given below.

$$\mathbf{x}_{S} = [\mathbf{T}_{N(b)->S}]\mathbf{x}_{N(b)}$$
$$\mathbf{x}_{N(b)} = [\mathbf{T}_{N(b)->S}]^{T}\mathbf{x}_{S}$$

$$[\mathbf{T}_{N(1)->S}] = \mathbf{a}_{Z}(\pi/4)\mathbf{a}_{Y}(\pi + \theta_{F/A})\mathbf{B}$$
$$[\mathbf{T}_{N(2)->S}] = \mathbf{a}_{Y}(\pi + \theta_{M})\mathbf{B}$$
$$[\mathbf{T}_{N(3)->S}] = \mathbf{a}_{Z}(7\pi/4)\mathbf{a}_{Y}(\pi + \theta_{F/A})\mathbf{B}$$
$$[\mathbf{T}_{N(4)->S}] = \mathbf{a}_{Z}(7\pi/4)\mathbf{a}_{Y}(\pi - \theta_{F/A})$$
$$[\mathbf{T}_{N(5)->S}] = \mathbf{a}_{Y}(\pi - \theta_{M})$$
$$[\mathbf{T}_{N(6)->S}] = \mathbf{a}_{Z}(\pi/4)\mathbf{a}_{Y}(\pi - \theta_{F/A})$$

$$\mathbf{a}_{Y}(\psi) = \begin{bmatrix} +\cos(\psi) & 0 & +\sin(\psi) \\ 0 & +1 & 0 \\ -\sin(\psi) & 0 & +\cos(\psi) \end{bmatrix}$$

$$\mathbf{a}_{Z}(\psi) = \begin{bmatrix} +\cos(\psi) & -\sin(\psi) & 0 \\ +\sin(\psi) & +\cos(\psi) & 0 \\ 0 & 0 & +1 \end{bmatrix}$$

$$\mathbf{B} = \begin{bmatrix} -1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & +1 \end{bmatrix}$$

Equation 185

The transformations between the Nominal Antenna Coordinate Systems and the Actual Antenna Coordinate Systems are defined by the following equations, where the following is true:

- $\Delta\psi_{SKEW}(b)$ is the skew depointing angle for beam b,
- $\Delta\theta_{ELE}(b)$ is the the elevation depointing angle for beam b,
- $\Delta\phi_{AZI}(b)$ is the the azimuth depointing angle for beam b

These angles are determined in flight via transponder calibration.

$$\mathbf{x}_{N(b)} = [\mathbf{T}_{A(b)->N(b)}]\mathbf{x}_{A(b)}$$
$$\mathbf{x}_{A(b)} = [\mathbf{T}_{A(b)->N(b)}]^{T}\,\mathbf{x}_{N(b)}$$

$$[\mathbf{T}_{A(b)->N(b)}] = \mathbf{A}_{SKEW}(\Delta\psi_{SKEW}(b))\mathbf{A}_{ELE}(\Delta\theta_{ELE}(b))\mathbf{A}_{AZI}(\Delta\varphi_{AZI}(b))$$

$$\mathbf{A}_{AZI}(\sigma) = \begin{bmatrix} +1 & 0 & 0 \\ 0 & +\cos(\sigma) & -\sin(\sigma) \\ 0 & +\sin(\sigma) & +\cos(\sigma) \end{bmatrix}$$

$$\mathbf{A}_{ELE}(\sigma) = \begin{bmatrix} +\cos(\sigma) & 0 & +\sin(\sigma) \\ 0 & +1 & 0 \\ -\sin(\sigma) & 0 & +\cos(\sigma) \end{bmatrix}$$

$$\mathbf{A}_{SKEW}(\sigma) = \begin{bmatrix} +\cos(\sigma) & -\sin(\sigma) & 0 \\ +\sin(\sigma) & +\cos(\sigma) & 0 \\ 0 & 0 & +1 \end{bmatrix}$$

Equation 186

The transformations between the Terrestrial Reference Frame and the Node Reference Frame for Node N are defined by the following equations, where $\mathbf{K}_T(N)$ is the node position of node N and $\mathbf{M}_T(N)$ is the outward local normal at the node position of node N.

$$\mathbf{x}_{T} = [\mathbf{T}_{K(N)->T}]\mathbf{x}_{K(N)} + \mathbf{K}_{T}(N)$$
$$\mathbf{x}_{K(N)} = [\mathbf{T}_{K(N)->T}]^{T}\left(\mathbf{x}_{T} - \mathbf{K}_{T}(N)\right)$$

$$[\mathbf{T}_{K(N)->T}] = [\mathbf{a}_1/|\mathbf{a}_1|, \mathbf{a}_2/|\mathbf{a}_2|, \mathbf{a}_3/|\mathbf{a}_3|]$$

$$\mathbf{a}_1 = I_{SWATH}(b)\left(\mathbf{U}_T \wedge \mathbf{M}_T(N)\right)$$
$$\mathbf{a}_2 = I_{SWATH}(b)\left(\mathbf{M}_T(N) \wedge \left(\mathbf{U}_T \wedge \mathbf{M}_T(N)\right)\right)$$
$$\mathbf{a}_3 = \mathbf{M}_T(N)$$

Equation 187

Where:

$$\mathbf{M}_T(N) = \frac{x_T(\mathbf{K}_T(N))\hat{\mathbf{x}}_T + y_T(\mathbf{K}_T(N))\hat{\mathbf{y}}_T + \dfrac{z_T(\mathbf{K}_T(N))\hat{\mathbf{z}}_T}{(1-f_E)^2}}{\sqrt{x_T^2(\mathbf{K}_T(N)) + y_T^2(\mathbf{K}_T(N)) + \dfrac{z_T^2(\mathbf{K}_T(N))}{(1-f_E)^4}}}$$

$$I_{SWATH}(b) = 1 - 2H[b - 3.5]$$

Equation 188

6.3.3 Localisation and Datation Times

See [RD 1] for the complete specification. Localisation is performed in the following manner. The solution range v.s. discriminator signal frequency equation must lie on the surface of the Earth model ellipsoid and it must also lie in the centre plane of the actual antenna gain pattern for a given beam b. Let the point (ν_0,T_0,b) in discriminator signal frequency (ν_0) and orbit time (T_0) space for beam b correspond to the point (x_T(b),y_T,(b),z_T(b)) on the surface of the ellipsoid in the Terrestrial Reference Frame, described by the vector $\mathbf{P}_T$(b) and let the satellite position and satellite velocity in the terrestrial Reference Frame be described, respectively, by the following vectors $\mathbf{S}_T(T_0)$ and $\mathbf{V}_T(T_0)$.The range v.s. discriminator signal frequency equation may be rewritten in the form:

$$f_{OFFSET}(b) - \frac{4\,\alpha(b)\left|\mathbf{P}_T(b) - \mathbf{S}_T(T_0)\right|}{c} - \frac{2\,\mathbf{V}_T(T_0)\bullet\left(\mathbf{P}_T(b) - \mathbf{S}_T(T_0)\right)}{\lambda_{UC}\left|\mathbf{P}_T(b) - \mathbf{S}_T(T_0)\right|} - \nu_0 = 0$$

Equation 189

The vector $\mathbf{P}_T(b) - \mathbf{S}_T(T_0)$ is the slant range vector from the satellite to the target position in the Terrestrial Reference Frame. The condition that the point lies on the surface of the ellipsoid is expressed by the following equation:

$$x_T^2(b) + y_T^2(b) + \frac{z_T^2(b)}{(1-f_E)^2} - a_E^2 = 0$$

Equation 190

The condition that the point lies in the centre plane of the actual antenna gain pattern is expressed by the following equations:

$$\mathbf{n}_T(b,T_0)\bullet\left(\mathbf{P}_T(b) - \mathbf{S}_T(T_0)\right) = 0$$

$$\mathbf{n}_T(b,T_0) = \left[\mathbf{T}_{A(b)\to T}(T_0)\right]\hat{\mathbf{y}}_{A(b)}$$

Equation 191

The above three non-linear simultaneous equations may be solved numerically by an iterative technique. An estimated solution, to start the iterative technique, can be obtained by various methods.

The orbit time T_0 to be used in the above equations for normal measurement mode echo data is given by the following equation:

$$T_0 = T_{UTC-FIRST-IN-SP/E} + \Delta(N_{FIR} - 1)/2 + \delta_{ECHO-MEAS}(b)$$	*Equation 192*

Where $T_{UTC\text{-}FIRST\text{-}IN\text{-}SP/E}$ is the UTC time associated with the first PRI contribution to that echo source packet and where $\delta_{ECHO\text{-}MEAS}$ is given by:

$$\delta_{ECHO-MEAS}(b) = g_0 + T_{TX}(b)/2 + s_{MID-NOM}(b)/c \quad \text{for real data}$$ $$\delta_{ECHO-MEAS}(b) = 0 \quad \text{for test data}$$	*Equation 193*

where g_0 is the guard time preceding transmission, $T_{TX}(b)$ is the transmitted pulse duration and $s_{MID\text{-}NOM}(b)$ is the nominal slant range to mid swath for a specific beam.

The orbit time T_0 to be used in the above equations for calibration mode echo data is given by the following equation:

$$T_0 = T_{UTC-FIRST-IN-SP/E} + \delta_{ECHO\text{-}CAL}(b, \mathrm{TRANS})$$	*Equation 194*

The offset $\delta_{ECHO\text{-}CAL}$ has to be estimated individually for each transponder peak present in a calibration source packet from the position of the peak and the ASCAT calibration timeline parameters for the calibration antenna and the disposal antenna. It is effectively given by:

$$\delta_{ECHO-CAL}(b, \mathrm{TRANS}) = g_0 + T_{TX}(b, \mathrm{CAL})/2 + s_{TRANS}(b)/c + \Delta_{TRANS}/2 \quad \text{for real data}$$	*Equation 195*

where:

g_0	is the guard time preceding transmission.
$T_{TX}(b,CAL)$	is the transmitted pulse duration from the calibration antenna.
$s_{TRANS}(b)$	is the slant range to the transponder under consideration which is estimated from discriminator signal frequency where the transponder peak occurs.
Δ_{TRANS}	is the internal delay of the transponder under consideration.

For measurement mode noise source packets the localisation times are given by the following equation:

$$T_0 = T_{UTC-FIRST-IN-SP/N} + \Delta(N_{NOISE} - 1)/2 + \delta_{NOISE-MEAS}(b)$$	*Equation 196*

Where $T_{UTC\text{-}FIRST\text{-}IN\text{-}SP/N}$ is the UTC time associated with the first PRI contribution to that noise source packet and $\delta_{NOISE\text{-}MEAS}$ is given by:

$$\begin{aligned}\delta_{NOISE-MEAS}(b) &= g_0 + T_{TX}(b) + g_1 + T_{DRW}(b) \\ &\quad + g_2 + T_{CALW} + g_3(b) + T_{NOISE}/2 \quad \text{for real data} \\ \delta_{NOISE-MEAS}(b) &= 0 \quad \text{for test data}\end{aligned}$$

Equation 197

where:

g_0	is the guard time preceding transmission.
$T_{TX}(b)$	is the transmitted pulse duration.
g_1	is the guard time between pulse transmission and echo reception / deramping window.
$T_{DRW}(b)$	is the duration of the echo reception / deramping window.
g_2	is the guard time between the echo reception / deramping window and the calibration window.
T_{CALW}	is the calibration window.
$g_3(b)$	is the guard time between the calibration window and the noise window.
T_{NOISE}	is the duration of the noise window.

For calibration mode noise source packets the localisation times are given by the following equation:

$$T_0 = T_{UTC-FIRST-IN-SP/N} + \Delta_{PRI}(N_{NOISE} - 1)/2 + \delta_{NOISE-CAL}(b)$$

Equation 198

Where $T_{UTC\text{-}FIRST\text{-}IN\text{-}SP/N}$ is the UTC time associated with the first PRI contribution to that noise source packet and $\delta_{NOISE\text{-}CAL}$ is given by:

$$\begin{aligned}\delta_{NOISE-CAL}(b) &= g_0 + \frac{T_{TX}(b,CAL) + T_{TX}(b,DIS)}{2} + \frac{g_1(b,CAL) + g_1(b,DIS)}{2} \\ &\quad + \frac{T_{DRW}(b,CAL) + T_{DRW}(b,DIS)}{2} + g_2 + T_{CALW} \\ &\quad + \frac{g_3(b,CAL) + g_3(b,DIS)}{2} + T_{NOISE}/2 \quad \text{for real data} \\ \delta_{NOISE-CAL}(b) &= 0 \quad \text{for test data}\end{aligned}$$

Equation 199

Where:

g_0	is the guard time preceding transmission.
$T_{TX}(b,CAL)$	is the transmitted pulse duration for the calibration antenna.
$T_{TX}(b,DIS)$	is the transmitted pulse duration for the disposal antenna.
$g_1(b,CAL)$	is the guard time between pulse transmission and echo reception / deramping window for the calibration antenna.
$g_1(b,DIS)$	is the guard time between pulse transmission and echo reception / deramping window for the disposal antenna.

$T_{DRW}(b,CAL)$	is the duration of the echo reception / deramping window for the calibration antenna.
$T_{DRW}(b,DIS)$	is the duration of the echo reception / deramping window for the disposal antenna.
g_2	is the guard time between the echo reception / deramping window and the calibration window
T_{CALW}	is the calibration window.
$g_3(b,CAL)$	is the guard time between the calibration window and the noise window for the calibration antenna.
$g_3(b,DIS)$	is the guard time between the calibration window and the noise window for the disposal antenna.
T_{NOISE}	is the duration of the noise window.

6.3.4 Node Positions and Geometrical Parameters

See complete specifications in [RD 1].

6.3.4.1 Node Positions

A row of nodes is generated on either side of the satellite ground track at a distance D_{ALONG}, measured along-track on the satellite ground track arc, from the previous rows of nodes. Thus rows of nodes are generated at orbit times T_i given by the following equation:

$$T_i = T_{i-1} + \frac{D_{ALONG}}{\left|U_T(T_{i-1})\right|}$$ *Equation 200*

The first rows of nodes, on either side of the satellite ground track, are generated at orbit time T_0. The position of the mid-swath nodes, located on either side of the satellite nadir track, is given by the following equations where for all relevant input parameters their values at time T_i are used:

$$\mathbf{R}_T(\mathrm{mid}) = \mathbf{S}_T + \lambda_f \mathbf{Q}_T$$ *Equation 201*

$$\mathbf{Q}_T = I_{SWATH}(b)\left(\mathbf{U}_T \wedge \mathbf{N}_T\right)\sin(\theta_{LOOK}) - \mathbf{N}_T \cos(\theta_{LOOK})$$

$$I_{SWATH}(b) = 1 - 2H[b\text{-}3.5]$$ *Equation 202*

Since $\mathbf{R}_T$(mid) must lie on the surface of the Earth, its coordinates must satisfy the equation of the ellipsoid thus it is established that:

$$\lambda_f = \frac{-B - \sqrt{B^2 - 4AC}}{2A}$$ *Equation 203*

$$A = \frac{x^2(\mathbf{Q}_T) + y^2(\mathbf{Q}_T)}{a_E^2} + \frac{z^2(\mathbf{Q}_T)}{b_E^2}$$ *Equation 204*

$$B = 2\left(\frac{x(\mathbf{S}_T)x(\mathbf{Q}_T) + y(\mathbf{S}_T)y(\mathbf{Q}_T)}{a_E^2} + \frac{z(\mathbf{S}_T)z(\mathbf{Q}_T)}{b_E^2}\right)$$ *Equation 205*

$$C = \frac{x^2(\mathbf{S}_T) + y^2(\mathbf{S}_T)}{a_E^2} + \frac{z^2(\mathbf{S}_T)}{b_E^2} - 1$$ *Equation 206*

The positions of the nodes are given by the following equation where the node index n runs from $-N_N$ to $+N_N$ and the parameter I_{SWATH} indicates the swath. The nodes lie in a plane whose intersection with the Earth model ellipsoid defines an ellipse, centred at $\mathbf{C}_T$, with semi-major and semi-minor axes of length a_{EE} and b_{EE} respectively. The unit vectors of the semi-major and semi-minor axes in a right-hand coordinate system are $\mathbf{a}^\wedge{}_T$ and $\mathbf{b}^\wedge{}_T$ respectively

$$\mathbf{K}_T(n, I_{SWATH}) = a_{EE}\,\hat{\mathbf{a}}_T \cos(\zeta(n)) + b_{EE}\,\hat{\mathbf{b}}_T \sin(\zeta(n)) + \mathbf{C}_T$$ *Equation 207*

$$\zeta(n) = \beta + \frac{d_N(n)}{\sqrt{a_{EE}^2 \sin^2(\beta) + b_{EE}^2 \cos^2(\beta)}}$$ *Equation 208*

$$\beta = \arctan2\left[\frac{\hat{\mathbf{b}}_T.(\mathbf{R}_T(mid) - \mathbf{C}_T)}{b_{EE}}, \frac{\hat{\mathbf{b}}_T.(\mathbf{R}_T(mid) - \mathbf{C}_T)}{a_{EE}}\right]$$ *Equation 209*

$$\begin{aligned} \arctan2(x,y) &= \arcsin(\,x/\sqrt{x^2+y^2}\,) \quad \text{for} \quad y \geq 0 \\ &= \pi\,\mathrm{sign}(\,x/\sqrt{x^2+y^2}\,) - \arcsin(\,x/\sqrt{x^2+y^2}\,) \quad \text{otherwise} \end{aligned}$$ *Equation 210*

$$\begin{aligned} d_N(n,b) &= -I_{SWATH}(b) \sum_{i=N_N+n+1}^{i=N_N} D_{ACROSS} \quad \text{for} \quad n < 0 \\ &= 0 \quad \text{for} \quad n = 0 \\ &= +I_{SWATH}(b) \sum_{i=N_N+1}^{i=N_N+n} D_{ACROSS} \quad \text{for} \quad n > 0 \end{aligned}$$ *Equation 211*

Where D_{ACROSS} is the across-track node separation. The parameters determining the ellipse are given by the following equations:

$$\mathbf{C}_T = \frac{\mathbf{U}_T . \mathbf{G}_T}{a_E^2 (x^2(\mathbf{U}_T) + y^2(\mathbf{U}_T)) + b_E^2 z^2(\mathbf{U}_T)} \begin{pmatrix} a_E^2 x(\mathbf{U}_T) \\ a_E^2 y(\mathbf{U}_T) \\ b_E^2 z(\mathbf{U}_T) \end{pmatrix}$$

Equation 212

$$\hat{\mathbf{a}}_T = \frac{1}{\sqrt{x^2(\mathbf{U}_T) + y^2(\mathbf{U}_T)}} \begin{pmatrix} y(\mathbf{U}_T) \\ -x(\mathbf{U}_T) \\ 0 \end{pmatrix}$$

Equation 213

$$\hat{\mathbf{b}}_T = \frac{1}{|\mathbf{U}_T| \sqrt{x^2(\mathbf{U}_T) + y^2(\mathbf{U}_T)}} \begin{pmatrix} x(\mathbf{U}_T) z(\mathbf{U}_T) \\ y(\mathbf{U}_T) z(\mathbf{U}_T) \\ -x^2(\mathbf{U}_T) - y^2(\mathbf{U}_T) \end{pmatrix}$$

Equation 214

$$a_{EE} = \left| \frac{-B_1 - \sqrt{B_1^2 - 4A_1C_1}}{2A_1} \right|$$

$$A_1 = \frac{x^2(\hat{\mathbf{a}}_T) + y^2(\hat{\mathbf{a}}_T)}{a_E^2} + \frac{z^2(\hat{\mathbf{a}}_T)}{b_E^2}$$

$$B_1 = 0$$

$$C_1 = \frac{x^2(\mathbf{C}_T) + y^2(\mathbf{C}_T)}{a_E^2} + \frac{z^2(\mathbf{C}_T)}{b_E^2} - 1$$

Equation 215

$$b_{EE} = \left| \frac{-B_2 - \sqrt{B_2^2 - 4A_2C_2}}{2A_2} \right|$$

$$A_2 = \frac{x^2(\hat{\mathbf{b}}_T) + y^2(\hat{\mathbf{b}}_T)}{a_E^2} + \frac{z^2(\hat{\mathbf{b}}_T)}{b_E^2}$$

$$B_2 = 0$$

$$C_2 = \frac{x^2(\mathbf{C}_T) + y^2(\mathbf{C}_T)}{a_E^2} + \frac{z^2(\mathbf{C}_T)}{b_E^2} - 1$$

Equation 216

6.3.4.2 Node Incidence and Azimuth Angles

The incidence angle at a point on the Earth's surface is defined as the angle between the vector from the point to the satellite and the unit vector along the outwards normal at the point. Let $\mathbf{K}_T$ be the position vector of a node on the Earth's surface and let $\mathbf{M}_T$ be the unit vector along the outwards normal at the node, then the incidence angle at the node is given by:

$$i = \arccos\left[\frac{(\mathbf{S}_T - \mathbf{K}_T).\mathbf{M}_T}{|\mathbf{S}_T - \mathbf{K}_T|}\right]$$

Equation 217

The azimuth angle is defined as the angle between the North pointing unit vector tangential to the local meridian and the projection of the vector from the point to the satellite on to the local tangent plane, measured clockwise. The azimuth angle is given by:

$$\phi_{AZIMUTH} = \arccos\left[\frac{\mathbf{J}_{K(N)} . \mathbf{V}^t_{K(N)}}{|\mathbf{V}^t_{K(N)}|}\right] \mathrm{sign}\left[z(\mathbf{J}_{K(N)} \wedge \mathbf{V}^t_{K(N)})\right]$$

Equation 218

Where:

$$\mathbf{V}^t_{K(N)} = \begin{pmatrix} x(\mathbf{V}_{K(N)}) \\ y(\mathbf{V}_{K(N)}) \\ 0 \end{pmatrix}$$

$$\mathbf{V}_{K(N)} = (\mathbf{T}_{K(N)->T})^{-1}(\mathbf{S}_T - \mathbf{K}_T(N))$$

Equation 219

And:

$$\mathbf{J}_{K(N)} = (\mathbf{T}_{K(N)->T})^{-1}\,\mathbf{J}_T$$

$$\mathbf{J}_T = \begin{pmatrix} -\sin\theta_{LAT}\cos\vartheta_{LON} \\ -\sin\theta_{LAT}\sin\vartheta_{LON} \\ \cos\theta_{LAT} \end{pmatrix}$$

Equation 220

Where:

$$\theta_{LAT} = \arcsin\left(\frac{z(\mathbf{K}_T(N))/(1-f_E)^2}{\sqrt{x^2(\mathbf{K}_T(N)) + y^2(\mathbf{K}_T(N)) + z^2(\mathbf{K}_T(N))/(1-f_E)^4}}\right)$$

Equation 221

$$\vartheta_{LON} = \arccos\left(\frac{x(\mathbf{K}_T(N))}{\sqrt{x^2(\mathbf{K}_T(N)) + y^2(\mathbf{K}_T(N))}} \right) \mathrm{sign}\left(y(\mathbf{K}_T(N)) \right)$$

Equation 222

The adaptation of this algorithm for the case of individual σ_0 values is straightforward. $\mathbf{K}_T$ is replaced by $\mathbf{P}_T$, the position vector of an individual σ_0 value on the Earth's surface and $\mathbf{M}_T$ is understood to be the outwards normal unit vector at $\mathbf{P}_T$.

6.3.4.3 Ground Range

Ground range should be computed in the following way, using a spherical Earth approximation. If $\mathbf{G}_T$ is the sub-satellite (nadir) position as defined in Section 6.3.1 and $\mathbf{x}$ is an arbitrary point on the surface of the Earth then the ground range, r_g is given by the following:

$$r_g = \left| \mathbf{G}_T \right| \phi$$

$$\text{where} \quad \cos(\phi) = \frac{\mathbf{x} \cdot \mathbf{G}_T}{\left|\mathbf{x}\right| \left|\mathbf{G}_T\right|}$$

Equation 223

For data from a given beam b, $\mathbf{x} = \mathbf{P}_T(b)$ and for data from a given node, $\mathbf{x} = \mathbf{K}_T(N)$. See Section 6.3.3 and Section 6.3.4.1.

7 CONTENTS OF THE PRODUCT GENERATION FUNCTION PRODUCTS

In the following section, a description of the data contents of the EUMETSAT Core Ground Segment ASCAT Products is given. The list of data and the organisation of the files is given purely for description and is not the existing product format. The product format is specified in [AD 2] and [AD 3]. Internal data sets reflect the configuration and the state of the ASCAT PGF and must be accessible from outside the ASCAT PGF.

Dynamic data sets are created by the ASCAT PGF as it is running and static information is loaded and/or generated in response to a command by the user. Static information may be loaded to change the configuration only when the ASCAT PGF is not running; however, it may be created while the ASCAT PGF is running.

The orbit is specified in the product headers and internal data sets in the following way. The state vectors (position and velocity) at the ascending node prior to the dump are given together with the ascending node time, T_0. This information is provided together with the time interval for which the information is applicable. This information is provided for all time intervals covering the dump, thus covering T_1 to T_N. Thus the following information is provided:

$(R_0, V_0 ,T_0 ; T_1 \text{->} T_2)$

$(R_0, V_0 ,T_0 ; T_2 \text{->} T_3)$

.....

$(R_0, V_0 ,T_0 ; T_{N-1} \text{->} T_N)$

The satellite attitude is specified in the product headers and internal data sets in the following way. The satellite attitude law is specified together with the time interval for which the information is applicable. This information is provided for all time intervals covering the dump, thus covering T_1 to T_N. Thus the following information is provided:

$(LAW_0 ; T_1 \text{->} T_2)$

$(LAW_1 ; T_2 \text{->} T_3)$

.....

$(LAW_{N-1} ; T_{N-1} \text{->} T_N)$

The LAW_i can take the following values (with the ASCAT operating): OPM, OCM, FCM and "OFP" (out of plane). The satellite attitude law is normally OPM (yaw steering with local normal pointing) in which case the nominal attitude is determined simply by functions of $(T-T_0)$ where T_0 is the time of the ascending node prior to the dump. In OCM the roll, pitch and yaw angles are all zero. In FCM the roll, pitch and yaw angles are determined by another law. And in "OFP" the attitude is so different from OPM that any data will in any case be invalid.

Orbit and attitude for the current satellite and time period are always required for processing whether this processing is NRT, backlog or reprocessing. Note: The orbit and attitude data is probably not needed for NRT processing in the CGS because this information is always available within the CGS as a function of time from the Flight Dynamics function. This information however may be needed for CGS reprocessing and will almost certainly be needed if the data is reprocessed at another facility.

The instrument operation is specified in the product headers and internal files in the following way. The instrument parameters are specified together with the time interval for which the information is applicable. This information is provided for all time intervals covering the dump, thus covering T_1 to T_N. Thus the following information is provided:

$(IP_0 ; T_1 \text{ -> } T_2)$

$(IP_1 ; T_2 \text{ -> } T_3)$

.....

$(IP_{N-1} ; T_{N-1} \text{ -> } T_N)$

The set of instrument parameters IP_i fully describe the *-ith* instrument operation present in the dump.

7.1 ASCAT Level 0 Product

Block I

- The METOP Satellite (1 or 2 or 3) - from CVCDU Transfer Frame Header
- Acquisition Ground Station
- UTC T_0 time of first echo line of dump
- UTC T_0 time of last echo line of dump
- Orbit Start Number and Orbit End Number of the dump

Block II

For every source packet in that dump:

<u>ASCAT Source Packet</u>

- Packet Primary Header:
  - Version Number
  - Type
  - Secondary Header Flag
  - Application Process Identification
  - Segmentation Flags
  - (Source Sequence Count)
  - Packet Length
- Secondary Header (which is a 64 bit time stamp equal to UTC at Time Tag)
- SBT at Time Tag
- PRI Count at Time Tag
- Tag Field / Ground Processor Flags
- PRI Count
- On-board Software Configuration
- On-board Parameter Configuration
- Spare - Could be manufacturer's serial number
- Instrument Configuration
- SFE Temperatures 1-6
- Antenna Temperatures 1-12
- Receiver Gain
- Out-of-Range Count
- Integrated Transmitted Powers 1-4
- Integrated Reflected Powers 1-4
- Integrated Calibration Powers 1-4
- Calibration Powers 1-4
- 256 words of application data
- Packet Error Control Field

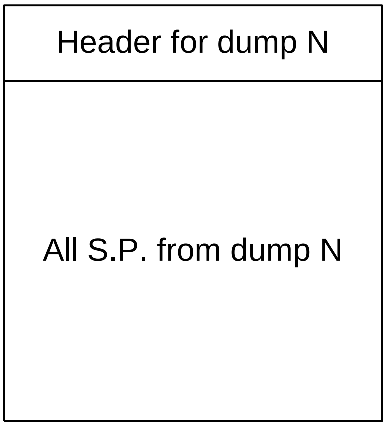


Figure 6: ASCAT Level 0 Product Contents Structure

7.2 ASCAT Level 1A Product

As explained in sections 5 and 6, the generation of the Rx filter shape for a given time requires use of past and future noise packets. Thus at the end of a given dump there are approximately 5 minutes of echo measurements, for which only a degraded Rx filter shape estimate is available, due to the fact that the necessary noise packets from next dump are not yet available.

The PGF pauses at the end of a dump, until the data from the next dump is available. When the next dump is available, those last minutes of data from the previous dump are processed with the correct Rx filter shape, which is now available. Consequently, those last few minutes of data from the previous dump, processed at nominal quality, are included at the beginning of the present dump.
See Figure 7.

To summarise, the first echo included in a given product corresponds to the first echo that could not be processed nominally in the previous dump due to the non availability of the correct Rx filter shape. Header information is provided in the product for the present (main) dump, as well as for the data present from the previous one.

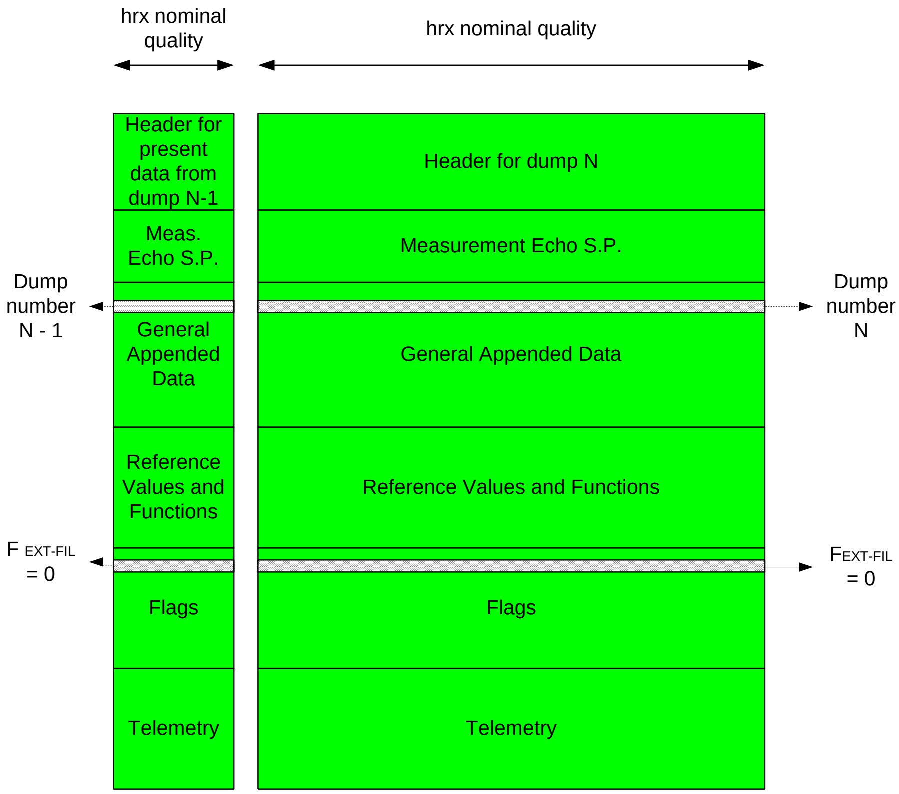


Figure 7: ASCAT Level 1A Product Contents Structure illustrating the situation at the end of a dump during which the radar operated continuously

Block I

- UTC T_0 time of first line of echo from Dump N-1
- UTC T_0 time of last line of echo from Dump N-1
- UTC T_0 time of first line of echo from Dump N
- UTC T_0 time of last line of echo from Dump N

The following Block I / Header information is provided for both the present dump and the data from the previous dump which is included in this product:

- The METOP Satellite (1, 2 or 3)
- A set of N Satellite Position Vectors, Satellite Velocity Vectors, Ascending node UTC times and their applicable UTC time intervals for propagating the orbit over the time interval corresponding to the data dump
- A set of N Satellite Attitude Laws and their applicable UTC time intervals for propagating the attitude over the time interval corresponding to the data dump
- Parameters of Applicable Attitude Distortion for the data dump (if available and applicable)
- Acquisition Ground Station
- Orbit Start Number and Orbit End Number of the dump
- Instrument Parameters for each Level 1A product resulting from an instrument operation in the dump, labelled by the applicable UTC time interval

- Processing Parameters for each Level 1A product resulting from an instrument operation in the dump, labelled by the applicable UTC time interval
- Transponder Parameters (as given in the Transponder Information Internal File)

Block II

For every Measurement echo source packet in the main dump and those from the previous dump:

ASCAT Measurement Mode Echo Source Packet

- Packet Primary Header:
  - Version Number
  - Type
  - Secondary Header Flag
  - Application Process Identification
  - Segmentation Flags
  - Source Sequence Count
  - Packet Length
- Secondary Header (which is a 64 bit time stamp equal to UTC at Time Tag)
- SBT at Time Tag
- PRI Count at Time Tag
- Tag Field / Ground Processor Flags
- PRI Count
- On-board Software Configuration
- On-board Parameter Configuration
- Spare - Could be manufacturer's serial number
- Instrument Configuration
- SFE Temperatures 1-6
- Antenna Temperatures 1-12
- Receiver Gain
- Out-of-Range Count
- Integrated Transmitted Powers 1-4
- Integrated Reflected Powers 1-4
- Integrated Calibration Powers 1-4
- Calibration Powers 1-4
- 256 words of application measurement mode echo data
- Packet Error Control Field

General Appended Data

- Orbit Number
- UTC Time associated to Source Packet (T_E)
- Ascending / Descending Pass Indicator
- Right/Left swath indicator

Appended Reference Values and Functions

- Noise power value
- Rx Filter shape function (256 values)
- Power-Gain Product value
- Power to σ_0 Normalisation Function and its Roll, Pitch and Yaw Derivatives for Nominal Satellite Pointing (256 × 4 values)
- Name of File containing applicable set of Deblooming Kernel Functions
- The latitude and longitude of each echo power sample in the echo source packet (256 × 2 values)
- The UTC time associated to the echo data ($T_{0,}$ the localisation time)
- The ground range of each echo power sample (256 values)
- The incidence angle and azimuth angle of each echo power sample in the echo source packet (256 × 2 values)
- Discriminator frequency and sample index (256 × 2 values)
- Coordinates in the Terrestrial Reference Frame (x,y,z) (256 × 3 values)

Appended Quality Flags and Qualifiers

- Flag F_{ECHO}
- Flag M_{ECHO}
- Flag C_{ECHO}
- Flag I_{ECHO}
- Flag F_{NOISE}
- Flag M_{NOISE}
- Flag C_{NOISE}
- Flag I_{NOISE}
- Flag F_{PG}
- Flag V_{PG}
- Flag $F_{EXT\text{-}PG}$
- Flag F_{FILTER}
- Flag V_{FILTER}
- Flag $F_{EXT\text{-}FIL}$
- Flag $F_{TEL\text{-}FILTER}$
- Flag F_{ORBIT}
- Flag $F_{ATTITUDE}$
- Flag F_{OMEGA}
- Flag F_{MAN}

- Flag F_{DSL}
- Flags $F_{S/A}$ (256 values)
- Flag $F_{E\text{-}TEL\text{-}PRES}$
- Flag $F_{E\text{-}TEL\text{-}IR}$
- Flags F_{LAND} (256 values)
- Flag F_{CE}
- Flag V_{CE}
- Flag F_{OA}
- Flag F_{TEL}

Appended Interpolated Telemetry Data

The following parameters interpolated to the UTC time T_0 associated to the echo source packet:

Equipment Power Bus Voltages:

- DPU_A_Volt (Word 15)
- DPU_B_Volt (Word 23)
- RFU_A_Volt (Word 16)
- RFU_B_Volt (Word 24)
- SFE_A_Volt (Word 17)
- SFE_B_Volt (Word 25)
- HPA_A_Volt (Word 18)
- HPA_B_Volt (Word 26)

Equipment Power Bus Powers:

- DPU_A_Pow (Word 19)
- DPU_B_Pow (Word 27)
- RFU_A_ Pow (Word 20)
- RFU_B_ Pow (Word 28)
- SFE_A_ Pow (Word 21)
- SFE_B_ Pow (Word 29)
- HPA_A_ Pow (Word 22)
- HPA_B_ Pow (Word 30)

Equipment Reference Voltages:

- Offset_AD (Word 46)
- Gain_AD (Word 47)
- Fwd/Cal_ADC_VR1 (Word 48)
- Fwd/Cal_ADC_VR2 (Word 49)
- Refl_ADC_VR1 (Word 50)
- Refl_ADC_VR2 (Word 51)
- Main_ADC_VR1 (Word 52)
- Main_ADC_VR2 (Word 53)

Unit / Equipment Temperatures:

- tSSPA1_A (Word 123)
- tSSPA2_A (Word 124)
- tEPC_A (Word 125)
- tRFU_A (Word 126)
- tDPU_A (Word 127)
- tSSPA1_B (Word 128)
- tSSPA2_B (Word 129)
- tEPC_B (Word 130)
- tRFU_B (Word 131)
- tDPU_B (Word 132)
- tPDU (Word 121)
- tICU (Word 122)

7.3 ASCAT Level 1B Products

The full-resolution Level 1B product has an equivalent structure to the Level 1A product, as it is shown in the top panel of Figure 8.

The data in Level 1B averaged product, both at 25 km and 50 km resolution, is given by line of nodes, and then by node. The time associated with a line of nodes is the orbit time, which is approximately the same as the time of illumination of the mid-beam. Each node contains data associated with up to three averaged normalised backscatter values collocated at the node position, corresponding to data taken at the different orbit times when each of the three beams illuminated the given node.

For this reason and due to the beam geometry, σ_0 for nodes near the dump boundary are computed with data sensed on both sides of the dump boundary.

The time difference between the illumination from the fore/aft beams and the mid beam for a node in the far swath is plus/minus three minutes approximately.

As in the case of the previous products, the intention is to provide the user with the necessary complete product at nominal quality for further wind processing. Consequently, processing of dump N starts effectively with the processing of data from dump N–1.

A mid-beam time unambiguously labels a node line. Each node line can be labelled by the UTC orbit time, which corresponds approximately to the time of the mid beam. Each node contains a triplet of σ_0.

Concerning the header information, it is provided in the product for the present (main) dump, as well as for the data present from the previous one, in both the full-resolution and the averaged Level 1B products.

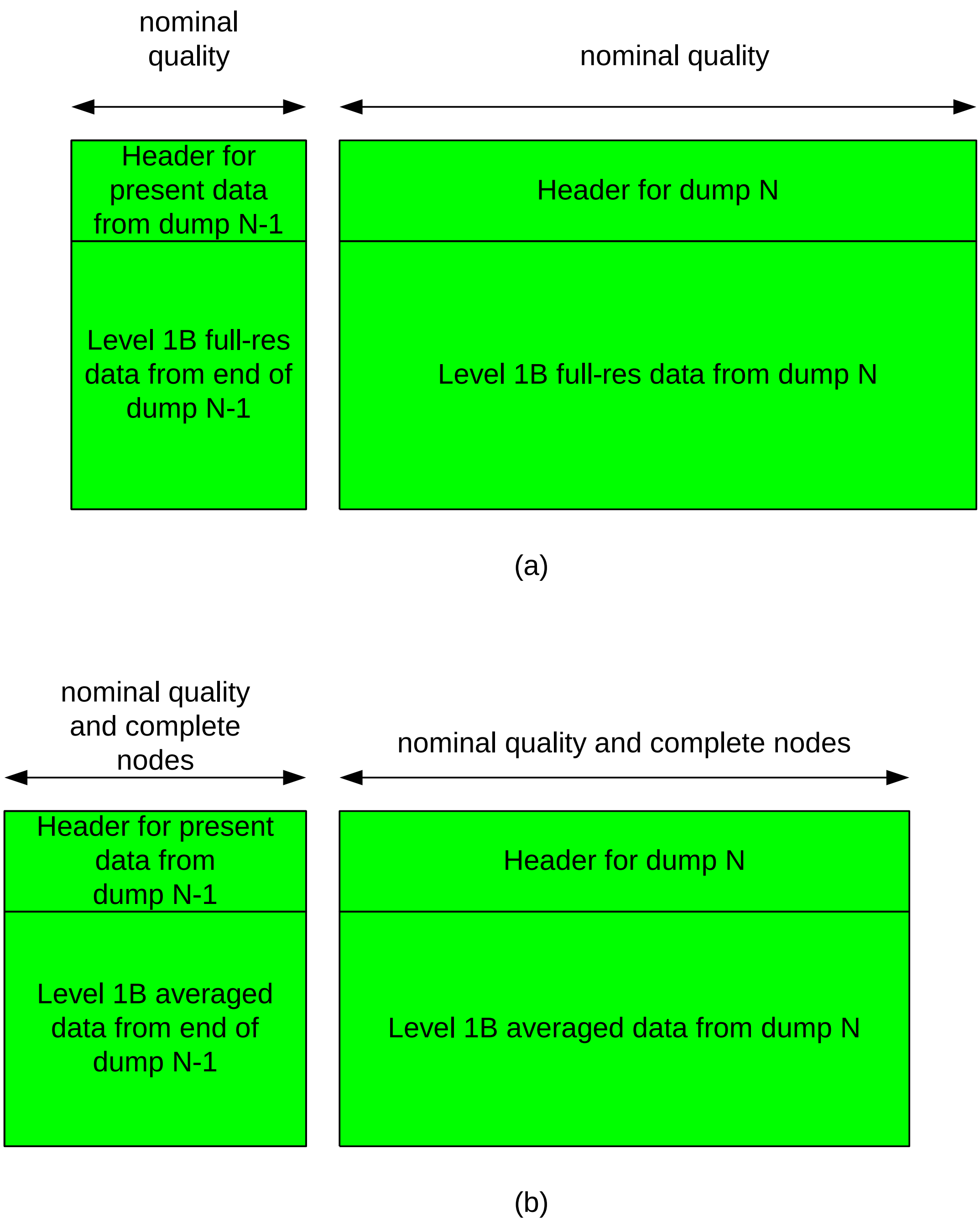


Figure 8: ASCAT Level 1B full-resolution product (a) and Level 1B averaged product (b) contents structure illustrating the situation at the end of a dump during which the radar operated continuously

7.3.1 Level 1B- 50 km Spatial Resolution

Block I

- Mid-Beam UTC T_0 orbit time of first line of nodes from Dump N-1
- Mid-Beam UTC T_0 orbit time of last line of nodes from Dump N-1
- Mid-Beam UTC T_0 orbit time of first line of nodes from Dump N
- Mid-Beam UTC T_0 orbit time of last line of nodes from Dump N

The following Block I / Header information is provided for both the present dump and the data from the previous dump which is included in this product:

- The METOP Satellite (1, 2 or 3)
- Orbit Start Number and Orbit End Number of the dump
- Main Acquisition Ground Station
- Instrument Parameters for each Level 1B product resulting from an instrument operation in the dump, labelled by the applicable UTC time interval
- Processing Parameters for each Level 1B product resulting from an instrument operation in the dump, labelled by the applicable UTC time interval
- Transponder Parameters (as given in the Transponder Information Internal File)

Block II

For every row of 42 50 km resolution nodes:

- UTC orbit time of line of Nodes (broadside to mid)
- Azimuth angle bearing of Nadir Track Velocity.

For every 50 km resolution node:

- Swath indicator (right or left)
- Node Number
- Latitude
- longitude
- height of atmosphere used
- loss per unit length of atmosphere used

For each node σ_0 value:

- σ_0 value (Fore)
- Incidence Angle (Fore)
- Azimuth Angle (Fore)
- Kp (Fore)
- f_F (Fore)
- f_V (Fore)
- f_{OA} (Fore)
- $f_{S/A}$ (Fore)
- f_{TEL} (Fore)
- $f_{EXT\text{-}FIL}$ (Fore)
- f_{LAND} (Fore)
- F_{Kp} (Fore)

- σ_0 Value Classification = Good, Usable or Bad (Fore)
- σ_0 value (Mid)
- Incidence Angle (Mid)
- Azimuth Angle (Mid)
- Kp (Mid)
- f_F (Mid)
- f_V (Mid)
- f_{OA} (Mid)
- $f_{S/A}$ (Mid)
- f_{TEL} (Mid)
- $f_{EXT-FIL}$ (Mid)
- f_{LAND} (Mid)
- F_{Kp} (Mid)
- σ_0 Value Classification = Good, Usable or Bad (Mid)
- σ_0 value (Aft)
- Incidence Angle (Aft)
- Azimuth Angle (Aft)
- Kp (Aft)
- f_F (Aft)
- f_V (Aft)
- f_{OA} (Aft)
- $f_{S/A}$ (Aft)
- f_{TEL} (Aft)
- $f_{EXT-FIL}$ (Aft)
- f_{LAND} (Aft)
- F_{Kp} (Aft)
- σ_0 Value Classification = Good, Usable or Bad (Aft)

7.3.2 Level 1B- 25 km Spatial Resolution

Block I

- Mid-Beam UTC T_0 orbit time of first line of nodes from Dump N-1
- Mid-Beam UTC T_0 orbit time of last line of nodes from Dump N-1
- Mid-Beam UTC T_0 orbit time of first line of nodes from Dump N
- Mid-Beam UTC T_0 orbit time of last line of nodes from Dump N

The following Block I / Header information is provided for both the present dump and the data from the previous dump which is included in this product:

- The METOP Satellite (1, 2 or 3)
- Orbit Start Number and Orbit End Number of the dump
- Main Acquisition Ground Station
- Instrument Parameters for each Level 1B product resulting from an instrument operation in the dump, labelled by the applicable UTC time interval
- Processing Parameters for each Level 1B product resulting from an instrument operation in the dump, labelled by the applicable UTC time interval
- Transponder Parameters (as given in the Transponder Information Internal File)

Block II

For every raw of 82 25 km resolution nodes:

- UTC orbit time of line of Nodes (broadside to mid)
- Azimuth angle bearing of Nadir Track Velocity

For every 25 km resolution node:

- Swath indicator (right or left)
- Node Number
- Latitude
- Longitude
- height of atmosphere used
- loss per unit length of atmosphere used

For each node σ_0 value:

- σ_0 value (Fore)
- Incidence Angle (Fore)
- Azimuth Angle (Fore)
- Kp (Fore)
- f_F (Fore)
- f_V (Fore)
- f_{OA} (Fore)
- $f_{S/A}$ (Fore)
- f_{TEL} (Fore)
- $f_{EXT-FIL}$ (Fore)

- f_{LAND} (Fore)
- F_{Kp} (Fore)
- σ_0 Value Classification = Good, Usable or Bad (Fore)
- σ_0 value (Mid)
- Incidence Angle (Mid)
- Azimuth Angle (Mid)
- Kp (Mid)
- f_F (Mid)
- f_V (Mid)
- f_{OA} (Mid)
- $f_{S/A}$ (Mid)
- f_{TEL} (Mid)
- $f_{EXT\text{-}FIL}$ (Mid)
- f_{LAND} (Mid)
- F_{Kp} (Mid)
- σ_0 Value Classification = Good, Usable or Bad (Mid)
- σ_0 value (Aft)
- Incidence Angle (Aft)
- Azimuth Angle (Aft)
- Kp (Aft)
- f_F (Aft)
- f_V (Aft)
- f_{OA} (Aft)
- $f_{S/A}$ (Aft)
- f_{TEL} (Aft)
- $f_{EXT\text{-}FIL}$ (Aft)
- f_{LAND} (Aft)
- F_{Kp} (Aft)
- σ_0 Value Classification = Good, Usable or Bad (Aft)

7.3.3 Level 1B- Full Resolution

Block I

- UTC T_0 time of first line of echo from Dump N-1
- UTC T_0 time of last line of echo from Dump N-1
- UTC T_0 time of first line of echo from Dump N
- UTC T_0 time of last line of echo from Dump N

The following Block I / Header information is provided for both the present dump and the data from the previous dump which is included in this product:

- The METOP Satellite (1, 2 or 3)
- Orbit Start Number and Orbit End Number of the dump
- Acquisition Ground Station
- Instrument Parameters for each Level 1B full resolution product resulting from an instrument operation in the dump, labelled by the applicable UTC time interval
- Processing Parameters for each Level 1B full resolution product resulting from an instrument operation in the dump, labelled by the applicable UTC time interval
- Transponder Parameters (as given in the Transponder Information Internal File)

Block II

- UTC time of line of full resolution σ_0 samples (T_0 time / localisation time)
- Beam Number
- Azimuth angle bearing of Nadir Track Velocity
- Orbit Number
- Ascending / Descending Pass Indicator

256 Values of the following parameters:

- full resolution σ_0 value
- incidence angle
- azimuth angle
- latitude
- longitude
- land flags F_{LAND}
- Solar array reflection Flags $F_{S/A}$
- height of atmosphere used
- loss per unit length of atmosphere used

Appended Quality Flags and Qualifiers

- Flag F_{ECHO}
- Flag M_{ECHO}
- Flag C_{ECHO}
- Flag I_{ECHO}
- Flag F_{NOISE}
- Flag M_{NOISE}
- Flag C_{NOISE}
- Flag I_{NOISE}
- Flag F_{PG}
- Flag V_{PG}
- Flag $F_{EXT\text{-}PG}$
- Flag F_{FILTER}
- Flag V_{FILTER}
- Flag $F_{EXT\text{-}FIL}$
- Flag $F_{TEL\text{-}FILTER}$
- Flag F_{ORBIT}
- Flag $F_{ATTITUDE}$
- Flag F_{OMEGA}
- Flag F_{MAN}
- Flag F_{DSL}
- Flag $F_{E\text{-}TEL\text{-}PRES}$
- Flag $F_{E\text{-}TEL\text{-}IR}$
- Flag F_{CE}
- Flag V_{CE}
- Flag F_{OA}
- Flag F_{TEL}

7.4 Internal Files and Products

The contents listed in the following files are a minimum list of information required by the ASCAT PGF as it is specified in this document. Other information may be required in these files due to implementation reasons, thus the following list does not restrict the final contents of the files.

Some of these data sets shall have a fixed size, and any generation of the information content will create a new version of the file (denoted by 'static'). Other files shall be updated every time additional data arrives to the PGF, and this additional data shall be appended, its size therefore gradually increasing (denoted by 'dynamic').

7.4.1 ASCAT GAIN AT ANGULAR POSITION Internal Product (dynamic)

For all calibration echo source packets acquired over the mission lifetime:

Block I

- METOP Satellite (1, 2 or 3)
- Antenna Beam Number b
- Nominal Satellite Attitude
- Actual Satellite Attitude
- Acquisition Ground Station
- Orbit Number
- UTC Time associated to Calibration Source Packet ($T_{UTC\text{-}FIRST\text{-}IN\text{-}SP/E}$)
- Ascending / Descending Pass Indicator Flag
- Satellite Position Vector, Satellite Velocity Vector, Ascending node UTC time for propagating the orbit at the time of calibration source packet acquisition
- Satellite Attitude Law at the time of calibration source packet acquisition
- Parameters of Applicable Attitude Distortion for the data dump (if available and applicable)
- Instrument Parameters at the time of calibration source packet acquisition
- Processing Parameters at the time of calibration source packet acquisition
- Flag $V_{CE\text{-}CAL}$
- Flag $F_{OAS\text{-}CAL}$

From Transponder 1:

- One-Way Power Gain, G
- Angular Position, (θ, ϕ) in Nominal Antenna Coordinate N(b)
- Transponder position actual in terrestrial reference frame
- Transponder position estimated in terrestrial reference frame
- Transponder internal delay
- Transponder backscattering cross-section
- Transponder 1 Nominal Operation Flag
- Data Presence Flag = Present / Absent

From Transponder 2:

- One-Way Power Gain, G
- Angular Position, (θ, ϕ) in Nominal Antenna Coordinate N(b)
- Transponder position actual in terrestrial reference frame
- Transponder position estimated in terrestrial reference frame
- Transponder internal delay
- Transponder backscattering cross-section
- Transponder 2 Nominal Operation Flag
- Data Presence Flag = Present / Absent

From Transponder 3:

- One-Way Power Gain, G
- Angular Position, (θ, ϕ) in Nominal Antenna Coordinate N(b)
- Transponder position actual in terrestrial reference frame
- Transponder position estimated in terrestrial reference frame
- Transponder internal delay
- Transponder backscattering cross-section
- Transponder 3 Nominal Operation Flag
- Data Presence Flag = Present / Absent

Block II

For every Calibration echo source packet:

ASCAT Calibration Mode Echo Source Packet

- Packet Primary Header:
  - Version Number
  - Type
  - Secondary Header Flag
  - Application Process Identification
  - Segmentation Flags
  - Source Sequence Count
  - Packet Length
- Secondary Header (which is a 64-bit time stamp equal to UTC at Time Tag)
- SBT at Time Tag
- PRI Count at Time Tag
- Tag Field / Ground Processor Flags
- PRI Count
- On-board Software Configuration
- On-board Parameter Configuration
- Spare - Could be manufacturer's serial number
- Instrument Configuration
- SFE Temperatures 1-6
- Antenna Temperatures 1-12
- Receiver Gain
- Out-of-Range Count
- Integrated Transmitted Powers 1-4
- Integrated Reflected Powers 1-4
- Integrated Calibration Powers 1-4
- Calibration Powers 1-4
- 256 words of calibration mode echo data
- Packet Error Control Field

Appended Reference Values and Functions

- Noise power value
- Rx Filter shape function
- Power-Gain Product value

Appended Quality Flags and Qualifiers

- Flag M_{ECHO}
- Flag C_{ECHO}
- Flag I_{ECHO}
- Flag F_{NOISE}
- Flag M_{NOISE}
- Flag C_{NOISE}
- Flag I_{NOISE}
- Flag F_{PG}
- Flag V_{PG}
- Flag $F_{EXT-PG-CAL}$
- Flag F_{FILTER}
- Flag V_{FILTER}
- Flag $F_{TEL-FILTER}$
- Flag F_{TIME}
- Flag F_{MAN}
- Flag F_{DSL}
- Flag $F_{S/A}$
- Flag $F_{E-TEL-PRES}$
- Flag $F_{E-TEL-IR}$
- Flags $F_{LAND}(n)$
- Flag V_{CE-CAL}
- Flag $F_{OAS-CAL}$

Appended Interpolated Telemetry Data

The following parameters interpolated to the $T_{UTC\text{-}FIRST\text{-}IN\text{-}SP/E}$ time of the calibration echo source packet together with their quality flags:

Equipment Power Bus Voltages:

- DPU_A_Volt (Word 15)
- DPU_B_Volt (Word 23)
- RFU_A_Volt (Word 16)
- RFU_B_Volt (Word 24)
- SFE_A_Volt (Word 17)
- SFE_B_Volt (Word 25)
- HPA_A_Volt (Word 18)
- HPA_B_Volt (Word 26)

Equipment Power Bus Powers:

- DPU_A_Pow (Word 19)
- DPU_B_Pow (Word 27)
- RFU_A_ Pow (Word 20)
- RFU_B_ Pow (Word 28)
- SFE_A_ Pow (Word 21)
- SFE_B_ Pow (Word 29)
- HPA_A_ Pow (Word 22)
- HPA_B_ Pow (Word 30)

Equipment Reference Voltages:

- Offset_AD (Word 46)
- Gain_AD (Word 47)
- Fwd/Cal_ADC_VR1 (Word 48)
- Fwd/Cal_ADC_VR2 (Word 49)
- Refl_ADC_VR1 (Word 50)
- Refl_ADC_VR2 (Word 51)
- Main_ADC_VR1 (Word 52)
- Main_ADC_VR2 (Word 53)

Unit / Equipment Temperatures:

- tSSPA1_A (Word 123)
- tSSPA2_A (Word 124)
- tEPC_A (Word 125)
- tRFU_A (Word 126)
- tDPU_A (Word 127)
- tSSPA1_B (Word 128)
- tSSPA2_B (Word 129)
- tEPC_B (Word 130)
- tRFU_B (Word 131)
- tDPU_B (Word 132)
- tPDU (Word 121)
- tICU (Word 122)

7.4.2 ASCAT ANTENNA GAIN PATTERNS AND ORIENTATIONS Internal Product (static)

For each of the six ASCAT antennas:

Identification

- Satellite Identification
- Antenna Beam Number b
- Reference Number of Estimated Gain Pattern and Orientation
- Creation Date & Time of this File

Data Input Selection

- UTC Time Intervals used { (t1, t2), (t3, t4), ... , (tn-1, tn) }
- Passes used identifier: Ascending Only, Descending Only or Both
- Set of Transponders Used (1, 2, 3, 1&2, 2&3, 1&3, 1&2&3)
- Antenna Gain Range below Peak Gain to be used in this AGPO estimation run
- Flag set to 1 if GAPE data was edited out of the above selection / Flag set to 0 otherwise
- All Measurements (G, θ, ϕ) used labelled by UTC time, transponder number & A/D pass indicator

Estimated Parameters

- Estimated Set of Coefficients c_{nm}
- Estimated Set of Depointing Angles: Skew, Elevation & Azimuth
- Final value of Energy Measure at end of iterative procedure
- The Energy Measures at the end of each simulated annealing cycle labelled by the following:
  (i) cycle temperature,
  (ii) cycle number index at that temperature and
  (iii) step number in parameter refinement schedule (typically $10 \times 20 \times 7$ values)

Control Parameters

- Degree of Polynomial in n (elevation) (fixed at 18)
- Degree of Polynomial in m (azimuth) (fixed at 10)
- Parameter Refinement Schedule as defined on Page 42 in [AD11] (7 cycles)
- Maximum Number of Steps in each Levenberg-Marquart Iteration
- Lamda Parameter Initial Value in Levenberg-Marquart Iteration (fixed at 0.001)
- Lamda Parameter Reduction Factor in Levenberg-Marquart Iteration (fixed at 0.25)
- Lamda Parameter Increment Factor in Levenberg-Marquart Iteration (fixed at 5.0)
- Flag indicating Combined Algorithm (F=1) or only Levenberg-Marquart Algorithm (F=0)
- Flag indicating Linear (F=0) or Exponential (F=1) Temperature Reduction in Simulated Annealing
- Number of Calibration Cycles for initialising Simulated Annealing
- Number of Temperatures to be used in Simulated Annealing
- Number of Cycles at each Temperature in Simulated Annealing
- Scale Factor for Thermal Fluctuations in Simulated Annealing
- Probability of Accepting Energy Increase in Simulated Annealing

Nominal Antenna Gain Pattern Parameters

- Parameters of the Nominal Theoretical Antenna Gain Patterns used for Antenna Beam Number b as defined in Section 8.3

Auxiliary Parameters Required for Use of AGPO Data (which may require off-line refinement) for each beam, b:

- $T_{HIGH}(b)$
- $T_{LOW}(b)$
- $\alpha_{ALL}(b)$
- $\alpha_{AL}(b)$
- $\alpha_{AH}(b)$
- $\alpha_{AHH}(b)$
- $\Delta_A(b)$

Auxiliary Characterisation Parameters

- Average UTC Time of Estimation
- Standard Deviation of Times of Estimation

- Actual Antenna Electrical Boresight Pointing relative to P_{SAT}
- Nominal Antenna Electrical Boresight Pointing relative to P_{SAT}
- Threshold Setting for Transponder Measurement Rejection
- Number of Transponder Measurements Rejected
- List of Rejected Transponder Measurements

7.4.3 ASCAT NORMALISATION TABLE Internal Product (static)

There shall be one NT LUT per antenna (6 files in total). The contents of each of them are the following:

Block I

- Satellite Identification
- Antenna Beam Number b
- Reference Number of this Normalisation Table
- Creation Date & Time of this Normalisation Table File
- Reference Number of Estimated Gain Pattern and Orientation File used and creation date / time
- Instrument Parameters used
- Processing Parameters used
- Position Vector, Velocity Vector and Ascending Node UTC time
- Attitude Law as a function of UTC time from Ascending Node Time
- Valid Deviation from Nominal Orbit Permitted
- Valid Deviation from Nominal Attitude Permitted
- Number of lines of Nominal Normalisation Factors in Normalisation LUT
- Number of lines of Roll Derivative of Normalisation Factors in Normalisation LUT
- Number of lines of Pitch Derivative of Normalisation Factors in Normalisation LUT
- Number of lines of Yaw Derivative of Normalisation Factors in Normalisation LUT

Block II

- Nominal Normalisation Factors: 256 values for each orbit time together with orbit time T.
- Sensitivity to roll mispointing: 256 values for each orbit time together with orbit time T.
- Sensitivity to pitch mispointing: 256 values for each orbit time together with orbit time T.
- Sensitivity to yaw mispointing: 256 values for each orbit time together with orbit time T.

7.4.4 ASCAT DEBLOOMING KERNELS Internal Product (static)

Block I

- Satellite Identification
- Antenna Beam Number b
- Reference Number of this Deblooming Kernels Table
- Creation Date & Time of this Deblooming Kernels File
- Instrument Parameters used
- Processing Parameters used
- Position Vector, Velocity Vector and Ascending Node UTC time
- Attitude Law as a function of UTC time from Ascending Node Time
- Instrument Configuration
- Valid Deviation from Nominal Orbit Permitted
- Valid Deviation from Nominal Attitude Permitted

Block II

For all times around the orbit:

256 functions $K_{DEBLOOM}(f_0, f, T_0, T; b)$ for beam b from orbit time T_i to T_{i+1}

7.4.5 ASCAT INSTRUMENT PARAMETERS Internal File(s) (static)

For Measurement Mode

Chirp Rate / Fore-Right
Chirp Rate / Mid-Right
Chirp Rate / Aft-Right
Chirp Rate / Fore-Left
Chirp Rate / Mid-Left
Chirp Rate / Aft-Left

Chirp start frequency words:

ch_start_freq[tx, fore-Right]
ch_start_freq[tx, mid-Right]
ch_start_freq[tx, aft-Right]
ch_start_freq[tx, fore-Left]
ch_start_freq[tx, mid-Left]
ch_start_freq[tx, aft-Left]

De-ramp start frequency words:

ch_start_freq[rx, fore-Right]
ch_start_freq[rx, mid-Right]
ch_start_freq[rx, aft-Right]
ch_start_freq[rx, fore-Left]
ch_start_freq[rx, mid-Left]
ch_start_freq[rx, aft-Left]

For Calibration Mode

Chirp Rate / Fore-Right
Chirp Rate / Mid-Right
Chirp Rate / Aft-Right
Chirp Rate / Fore-Left
Chirp Rate / Mid-Left
Chirp Rate / Aft-Left

Chirp start frequency words:

ch_start_freq[tx, fore-Right]
ch_start_freq[tx, mid-Right]
ch_start_freq[tx, aft-Right]
ch_start_freq[tx, fore-Left]
ch_start_freq[tx, mid-Left]
ch_start_freq[tx, aft-Left]

De-ramp start frequency words:

ch_start_freq[rx, fore-Right]
ch_start_freq[rx, mid-Right]
ch_start_freq[rx, aft-Right]
ch_start_freq[rx, fore-Left]
ch_start_freq[rx, mid-Left]
ch_start_freq[rx, aft-Left]

Pulse amplitude distortion parameters - $A_{TX0}(b)$, $A_{TX1}(b)$, $A_{TX2}(b)$, $A_{TX3}(b)$
Number of noise windows averaged on board - N_{NOISE}
Number of echo windows averaged on board - N_{FIR}
Overlap of echo window averaged on board - fixed at 50%

FIR Filter Coefficients - $\beta(i)$, $g(k, j)$
Number of Range Looks for beam b - M(b)
Range Look Summation Weights for beam b - $\alpha_n(i)$, $\rho(\nu, m, b)$

FIR Filter Function - $\omega_{FIR}(t)$
FIR Filter Function Duration - z_{FIR}
FIR Look Fractional Overlaps - $x_{FIR}(j,m)$

Range Look Duration - T_{RL}, z_{RAN}
Range Look Fractional Overlaps - x(n,s)
ADC frequency sampling discriminator signal - ν_{ADC}

Highest signal frequency effectively present in the discriminator signal - ν_{HIGH}
Number of samples in the range look Fast Fourier Transform - N_{FFT}

Calibration frequency - f(cal)
Frequency of the sample above the calibration frequency - f(icalp)
Frequency of the sample below the calibration frequency - f(icalm)
Sample index corresponding to f(icalp) - icalp
Sample index corresponding to f(icalm) - icalm

Coupler to coupler loss for each beam and switch path - L_{CC} (b, SP)

Instrument characterisation functions - F_T [P_{TM}, θ_{SFE4}, RC]
Instrument characterisation functions - F_I [P_{IM}, θ_{SFE4}, RC]
Instrument characterisation functions - F_R [P_{RM}, θ_{SFE5}, RC]

Transmit path losses - L_{TX} (b, SP)
Receive path losses - L_{RX} (b, SP)
Radar internal delay - Δ_{RADAR}
LO4 mixer frequency - f_{LO4}

Gain Compression offset for each scatterometer - Δ_{GC}(Sat)

For Measurement Mode Operation Only:

Guard Time G0 / Mid
Transmit Pulse Duration / Mid
Guard Time G1 / Mid
Echo Reception Window Duration / Mid
Guard Time G2 / Mid
Calibration Window / Mid
Guard Time G3 / Mid
Noise Window / Mid
Guard Time G4 / Mid
Guard Time G0 / Side
Transmit Pulse Duration / Side
Guard Time G1 / Side
Echo Reception Window Duration / Side
Guard Time G2 / Side
Calibration Window / Side
Guard Time G3 / Side
Noise Window / Side
Guard Time G4 / Side
Nominal Slant Range to mid swath for beam b – $s_{MID\text{-}NOM}(b)$
Range Look Window Parameters - $c_{M\text{-}E}$ (b)
Range Look Window Parameters - $p_{M\text{-}E}$ (b)

For Calibration Mode Operations Only:

Guard Time G0 / Mid - Cal
Transmit Pulse Duration / Mid -Cal
Guard Time G1 / Mid - Cal
Echo Reception Window Duration / Mid - Cal
Guard Time G2 / Mid - Cal
Calibration Window / Mid - Cal
Guard Time G3 / Mid - Cal
Noise Window / Mid - Cal
Guard Time G4 / Mid - Cal
Guard Time G0 / Opposite Side / Side Beam - Disposal
Transmit Pulse Duration / Opposite Side / Side Beam - Disposal
Guard Time G1 / Opposite Side / Side Beam - Disposal

Echo Reception Window Duration / Opposite Side / Side Beam - Disposal
Guard Time G2 / Opposite Side / Side Beam - Disposal
Calibration Window / Opposite Side / Side Beam - Disposal
Guard Time G3 / Opposite Side / Side Beam - Disposal

Noise Window / Opposite Side / Side Beam - Disposal
Guard Time G4 / Opposite Side / Side Beam - Disposal
Guard Time G0 / Same Side / Other Side Beam - Disposal
Transmit Pulse Duration / Same Side / Other Side Beam - Disposal
Guard Time G1 / Same Side / Other Side Beam - Disposal
Echo Reception Window Duration / Same Side / Other Side Beam - Disposal
Guard Time G2 / Same Side / Other Side Beam - Disposal
Calibration Window / Same Side / Other Side Beam - Disposal
Guard Time G3 / Same Side / Other Side Beam - Disposal
Noise Window / Same Side / Other Side Beam - Disposal
Guard Time G4 / Same Side / Other Side Beam - Disposal
Guard Time G0 / Side - Cal
Transmit Pulse Duration / Side - Cal
Guard Time G1 / Side - Cal
Echo Reception Window Duration / Side - Cal
Guard Time G2 / Side - Cal
Calibration Window / Side - Cal
Guard Time G3 / Side - Cal
Noise Window / Side - Cal
Guard Time G4 / Side - Cal
The Range Look Window Parameters - c_{C-E} (b)
The Range Look Window Parameters - p_{C-E} (b)

7.4.6 ASCAT PGF PROCESSING PARAMETERS Internal File(s) (static)

Radar carrier frequency - f_{uc}
Nominal radar RF transmit power in-pulse - P_{TX-P}
Nominal receive chain gain setting - g_{RX}
Nominal atmospheric loss per unit length as a function of position on the surface of the Earth - l_{ATM}
Nominal height of the atmosphere as a function of position on the surface of the Earth - h_{ATM}
Threshold for Out-of-Range count.- T_{OORC}
Number of noise source packets in a noise segment - M_{SEG}
Number of noise segments in a noise block - M_{BLOCK}
Number of samples in the filter which smoothes noise over frequencies - N_{h-FIL}
Coefficients of the filter which smoothes noise over frequencies - $\alpha_{h-FIL}(n)$
Start sample number for noise power estimation - S
End sample number for noise power estimation - E
Number of power gain values in the along-track average - N_{PG}
Normalisation factors (set at the start of commissioning) - $C_{CAL}(b)$
Power gain estimation Γ switch - on / off
Rx filter shape method estimation switch
Rx filter shape estimation parameter X
Flag Parameter T_{PG}
Flag Parameter T_{PG-CAL}
Flag Parameter T_{FILTER}
Flag Parameter T_{TIME}

EUMETSAT set telemetry parameter ranges (upper and lower limits)
Flag Parameter $F_{COM/OP}$
Flag Parameter F_{CAL}
Flag Parameter $F_{DEBLOOM}$
For each node number, n and beam number, b for "25 km processing":

- Hamming Parameter Along Track (n, b)
- Window Length Along Track (n, b)
- Hamming Parameter Across Track (n, b)
- Window Length Across Track (n, b)

Along track node spacing for "25 km processing" - D_{ALONG}
Across track node spacing for "25 km processing" - D_{ACROSS}
For each node number, n and beam number, b for "50 km processing":

- Hamming Parameter Along Track (n, b)
- Window Length Along Track (n, b)
- Hamming Parameter Across Track (n, b)
- Window Length Across Track (n, b)

Along track node spacing for "50 km processing" - D_{ALONG}

Across track node spacing for "50 km processing" - D_{ACROSS}

Look angle defining position of node number 0 (mid swath): θ_{LOOK}

Time delay after the first source packet time ($T_{UTC\text{-}IRST\text{-}IN\text{-}SP/E}$) given to the processor, in order to generate the first node of nodes - ΔT_{FLN} (only for testing purposes)

Antenna gain range below peak gain to be used when building GAP estimates data set

Integration range about the peak of transponder echoes - δ_{TRANS}

Control Parameters for AGPO

- Degree of Polynomial in n (elevation) (fixed at 18)
- Degree of Polynomial in m (azimuth) (fixed at 10)
- Parameter Refinement Schedule as defined in page 42 in [AD 1] (7 cycles).
- Maximum Number of Steps in each Levenberg-Marquart Iteration
- Lamda Parameter Initial Value in Levenberg-Marquart Iteration (fixed at 0.001)
- Lamda Parameter Reduction Factor in Levenberg-Marquart Iteration (fixed at 0.25)
- Lamda Parameter Increment Factor in Levenberg-Marquart Iteration (fixed at 5.0)
- Flag indicating Combined Algorithm (F = 1) or only Levenberg-Marquart Algorithm (F=0)
- Flag indicating Linear (F = 0) or Exponential (F=1) Temperature Reduction in Simulated Annealing
- Number of Calibration Cycles for initialising Simulated Annealing
- Number of Temperatures to be used in Simulated Annealing
- Number of Cycles at each Temperature in Simulated Annealing
- Scale Factor for Thermal Fluctuations in Simulated Annealing
- Probability of Accepting Energy Increase in Simulated Annealing
- Value of Energy Measure set as Stopping Criterion

Nominal Antenna Gain Pattern Parameters for AGPO

- Parameters of the Nominal Theoretical Antenna Gain Pattern used for the Mid Beams as defined in [AD 11] in Annex B

- Parameters of the Nominal Theoretical Antenna Gain Patterns used for Side Beams as defined in [AD 11] in Annex B

Auxiliary Characterisation Parameters for AGPO

- Threshold Setting for Transponder Measurement Rejection - $\eta_{THRESHOLD}$

For each of the six ASCAT antennas:

Data Input Selection for AGPO

- UTC Time Intervals used { (t1, t2), (t3, t4), ... , (tn-1, tn) }
- Passes used identifier: Ascending Only, Descending Only or Both
- Set of Transponders Used (1, 2, 3, 1&2, 2&3, 1&3, 1&2&3)
- Antenna Gain Range below Peak Gain to be used in this AGPO estimation run
- Flag set to 1 if GAPE data is to be edited out of the above selection / Flag set to 0 otherwise

Auxiliary Parameters Required for Use of AGPO Data (which may require off-line refinement) for each beam, b:

- $T_{HIGH}(b)$
- $T_{LOW}(b)$
- $\alpha_{ALL}(b)$
- $\alpha_{AL}(b)$
- $\alpha_{AH}(b)$
- $\alpha_{AHH}(b)$
- $\Delta_A(b)$

Domain radius of the deblooming kernels (determining PI)

Parameters of the transmit path spectral transfer characteristic (initial taken to be absent)

Start source packet for GCM averaging - J_{BEGIN}

End source packet for GCM averaging - J_{END}

Test threshold for normal GCM - $T_{TEST\text{-}GCM}$

Overdrive threshold for normal GCM - $T_{GCM\text{-}HIGH}$

Lower threshold for normal GCM - $T_{GCM\text{-}LOW}$

Minimum drive level for exceptional GCM - D_{MIN}

Minimum drive level for exceptional GCM - D_{MAX}

Threshold for USABLE σ_0 flag - T_{USABLE}

Threshold for departure of orbit from the one used to generate the Normalisation Table - X_{ORBIT}

Threshold for departure of attitude from the one used to generate the Normalisation Table -$X_{ATTITUDE}$

7.4.7 ASCAT TRANSPONDER INFORMATION Internal File (static)

For transponder 1:

- Transponder 1 Position in Terrestrial Frame Reference coordinates (x_T , y_T , z_T)
- Transponder 1 Radar Backscattering Cross Section
- Transponder 1 Internal Delay
- Transponder 1 Nominal Operation Flag

For transponder 2:

- Transponder 2 Position in Terrestrial Frame Reference coordinates (x_T , y_T , z_T)
- Transponder 2 Radar Backscattering Cross Section
- Transponder 2 Internal Delay
- Transponder 2 Nominal Operation Flag

For transponder 3:

- Transponder 3 Position in Terrestrial Frame Reference coordinates (x_T , y_T , z_T)
- Transponder 3 Radar Backscattering Cross Section
- Transponder 3 Internal Delay
- Transponder 3 Nominal Operation Flag

7.4.8 ASCAT GAIN COMPRESSION MONITORING INFORMATION Internal Product (dynamic)

For each sequence of special source packets for gain compression monitoring the following information is provided:

- UTC time of first source packet in the sequence, $T_{UTC\text{-}IRST\text{-}IN\text{-}SP/E}$
- Normal / Exceptional Sequence Flag
- The set of Drive Level / Transmit Power Pairs in the sequence
- The source packets in the sequence

For a Nominal Sequence only:

- $Z_{GAIN\ COMPRESSION}$
- $P_{TEST\text{-}GCM}$
- $F_{TEST\text{-}GCM}$
- $F_{GCM\text{-}HIGH}$
- $F_{GCM\text{-}LOW}$

7.4.9 ASCAT MONITORING, REPORTING AND PROCESSING STATUS Internal Product (dynamic)

For NMMSP:

For each beam:

- Raw echo line E(i), for beam b, rolling average over 100 seconds (plot)
- power gain product, for beam b, rolling average over 100 seconds (value)
- noise power, for beam b, rolling average over 100 seconds (value)
- Out of Range Count, for beam b, rolling average over 100 seconds (value)
- Rx Filter Shape (plot)
- Rx gain setting (value)

Sums of the following flags over the previous 1000 seconds (values)

- Flag F_{ECHO}
- Flag M_{ECHO}
- Flag C_{ECHO}
- Flag I_{ECHO}
- Flag F_{NOISE}
- Flag M_{NOISE}
- Flag C_{NOISE}
- Flag I_{NOISE}
- Flag F_{PG}
- Flag V_{PG}
- Flag F_{FILTER}
- Flag V_{FILTER}
- Flag $F_{TEL\text{-}FILTER}$
- Flag F_{ORBIT}
- Flag $F_{ATTITUDE}$
- Flag F_{OMEGA}
- Flag F_{MAN}
- Flag F_{DSL}
- Flag $F_{S/A}$
- Flag $F_{E\text{-}TEL\text{-}PRES}$
- Flag $F_{E\text{-}TEL\text{-}IR}$

Values of the following telemetry parameters

- DPU_A_Volt
- DPU_B_Volt
- RFU_A_Volt
- RFU_B_Volt
- SFE_A_Volt
- SFE_B_Volt
- HPA_A_Volt
- HPA_B_Volt
- DPU_A_Pow
- DPU_B_Pow
- RFU_A_ Pow
- RFU_B_ Pow
- SFE_A_ Pow
- SFE_B_ Pow
- HPA_A_ Pow
- HPA_B_ Pow
- Offset_AD
- Gain_AD
- Fwd/Cal_ADC_VR1
- Fwd/Cal_ADC_VR2
- Refl_ADC_VR1
- Refl_ADC_VR2
- Main_ADC_VR1
- Main_ADC_VR2
- tSSPA1_A
- tSSPA2_A
- tEPC_A
- tRFU_A
- tDPU_A
- tSSPA1_B
- tSSPA2_B
- tEPC_B
- tRFU_B
- tDPU_B
- tPDU
- tICU
- tSFE1
- tSFE2

- tSFE3
- tSFE4
- tSFE5
- tSFE6
- tAnt1
- tAnt2
- tAnt3
- tAnt4
- tAnt5
- tAnt6
- tAnt7
- tAnt8
- tAnt9
- tAnt10
- tAnt11
- tAnt12

For CMSP:

- Beam number (value)
- UTC time associated with calibration source packet, $T_{UTC\text{-}IRST\text{-}IN\text{-}SP/E}$ (value)
- Ascending/descending pass indicator flag (value)
- Out of range count (value)
- noise power value (value)
- Rx Filter Shape function (plot)
- power gain product value (value)
- Raw echo line E(i) (plot)

The following flags (value)

- Flag M_{ECHO}
- Flag C_{ECHO}
- Flag I_{ECHO}
- Flag F_{NOISE}
- Flag M_{NOISE}
- Flag C_{NOISE}
- Flag I_{NOISE}
- Flag F_{PG}
- Flag V_{PG}
- Flag $F_{EXT\text{-}PG\text{-}CAL}$
- Flag F_{FILTER}
- Flag V_{FILTER}

- Flag $F_{TEL\text{-}FILTER}$
- Flag F_{TIME}
- Flag F_{ORBIT}
- Flag $F_{ATTITUDE}$
- Flag F_{MAN}
- Flag F_{DSL}
- Flag $F_{S/A}$
- Flag $F_{E\text{-}TEL\text{-}PRES}$
- Flag $F_{E\text{-}TEL\text{-}IR}$
- Flag $V_{CE\text{-}CAL}$
- Flag $F_{OAS\text{-}CAL}$

Values of the following telemetry parameters

- DPU_A_Volt
- DPU_B_Volt
- RFU_A_Volt
- RFU_B_Volt
- SFE_A_Volt
- SFE_B_Volt
- HPA_A_Volt
- HPA_B_Volt
- DPU_A_Pow
- DPU_B_Pow
- RFU_A_ Pow
- RFU_B_ Pow
- SFE_A_ Pow
- SFE_B_ Pow
- HPA_A_ Pow
- HPA_B_ Pow
- Offset_AD
- Gain_AD
- Fwd/Cal_ADC_VR1
- Fwd/Cal_ADC_VR2
- Refl_ADC_VR1
- Refl_ADC_VR2
- Main_ADC_VR1
- Main_ADC_VR2
- tSSPA1_A
- tSSPA2_A

- tEPC_A
- tRFU_A
- tDPU_A
- tSSPA1_B
- tSSPA2_B
- tEPC_B
- tRFU_B
- tDPU_B
- tPDU
- tICU
- tSFE1
- tSFE2
- tSFE3
- tSFE4
- tSFE5
- tSFE6
- tAnt1
- tAnt2
- tAnt3
- tAnt4
- tAnt5
- tAnt6
- tAnt7
- tAnt8
- tAnt9
- tAnt10
- tAnt11
- tAnt12

8 ASCAT PGF ALGORITHM VARIABLE TABLES

In this section, variable/settings tables are given as a key to clarify the symbols used in the equations in Section 6.

The following abbreviations are used in this section:

Abbreviation	***Means***
sp	source packet
FDF	Flight Dynamics Function, accessed via the PGE services
PCP	Processing Configuration Parameter, given in the ASCAT PGF Processing Parameters Internal File
IP	Instrument Parameter, given in the ASCAT Instrument Parameters Internal File

The following constants and their values apply to all relevant algorithms in Section 6:

Item	***Value***
Speed of light	2.99792458×10^{8} m/s
Earth Equatorial Radius	6.378137×10^{6} m
Earth oblateness coefficient	$f_e = 3.35281093 \times 10^{-3}$

The following tables are included in this section:

Name	***Content***	***Section***
ASCAT PGF Variable Table 1	Correction for Receive Chain Spectral Transfer Characteristic, Noise Subtraction and Transmit Power / Internal Gain Product Correction	Section 6.1.1
ASCAT PGF Variable Table 2	Power To σ^0 Conversion, Deblooming Subtraction and Coordinate Transformation	Section 6.1.2
ASCAT PGF Variable Table 3	Spatial Averaging	Section 6.1.3
ASCAT PGF Variable Table 4	Kp Computation	Section 6.1.4
ASCAT PGF Variable Table 5	Rx Filter Shape Computation	Section 6.2.1
ASCAT PGF Variable Table 6	Noise Power Computation	Section 6.2.2
ASCAT PGF Variable Table 7	Power Gain Product Computation	Section 6.2.3
ASCAT PGF Variable Table 8	System Geometry and Reference Frames	Section 6.3.1
ASCAT PGF Variable Table 9	Transformations between Reference Frames	Section 6.3.2
ASCAT PGF Variable Table 10	Localisation and Datation Times	Section 6.3.3
ASCAT PGF Variable Table 11	Node Positions	Section 6.3.4.1
ASCAT PGF Variable Table 12	Node Incidence and Azimuth angles	Section 6.3.4.2
ASCAT PGF Variable Table 13	Noise/Echo Processing Equivalence Function and Echo Normalisation Function	Section 6.2.9

8.1 ASCAT PGF Variables and Settings Table 1: Correction for Receive Chain Spectral Transfer Characteristic, Noise Subtraction and Transmit Power / Internal Gain Product Correction

Variables				
Name	***Range***	***Description***	***Notes***	***Source***
i	1, N_{ECHO}	Discriminator frequency sample index (along beam)		count
j	1, $N_{ECHO-PACKETS}$	Packet index (along track)		count
b	1, B	Beam number		sp
f(i)		Discriminator frequency		Equation 102
k(j)	1,$N_{NOISE-PACKETS}$	Noise packet index		Equation 4
S(i,j,b)		Corrected echo source packet sample		Equation 1
E(i,j,b)		Raw echo source packet sample		sp
λ(j,b,SP)		Power gain product correction factor		Equation 55
h_{RX}(i,k(j))		Receiver filter shape		Equation 49
c(i,b)		Correction factor to account for different on-board processing weighting functions for the echo and noise looks		Equation 172 Equation 173
χ(i,b)		Normalisation function for range look summation		Equation 174
n(k(j),b)		Noise power value		Equation 54
T_E(j,b)		Along track time associated to an echo source packet for a given beam		Equation 2
T_N(k,b)		Along track time associated to an noise source packet for a given beam		Equation 3
$T_{SBT-AT-TT}$		SBT Time at the time tag given in the source packet		sp
$T_{UTC-FIRST-IN-SP/E}$		UTC Time Tag time of the first PRI contribution to a given echo source packet		Equation 2

Variables				
Name	***Range***	***Description***	***Notes***	***Source***
$T_{UTC-FIRST-IN-SP/N}$		UTC Time Tag time of the first PRI contribution to a given noise source packet		Equation 3
$C_{PRI-COUNT}$		PRI count given in the source packet		sp
$C_{PRI-AT-TT}$		PRI count at the time tag given in the source packet		sp
L_N		Factor related to on-board noise and echo along track averaging		Equation 5

Settings			
Name	***Description***	***Value/Source***	***Notes***
B	Number of beams	6	
N_{ECHO}	Number of samples in the discriminator frequency range	256	
$N_{ECHO-PACKETS}(b)$	Maximum number of echo samples received from a particular beam during an ASCAT measurement mode sequence	implementation	independent counts for each beam
$N_{NOISE-PACKETS}(b)$	Maximum number of noise samples received from a particular beam during an ASCAT measurement mode sequence	implementation	independent counts for each beam
N_{PRI}	Number of beams firing in a beam cycle	Meas. Mode: 6 Cal. Mode: 2	
Δ_{PRI}	pulse repetition interval for a beam	IP	
N_{NOISE}	number of windows of noise averaged on-board along track from a given beam	IP	
N_{FIR}	length of the on-board along track averaging finite impulse response filter	IP	

8.2 ASCAT PGF Variables and Settings Table 2: Power To σ^0 Conversion, Deblooming Subtraction and Coordinate Transformation

Variables				
Name	***Range***	***Description***	***Notes***	***Source***
i	1, N_{ECHO}	discriminator frequency sample index (along beam)		count
j	1, $N_{ECHO\text{-}PACKETS}$	packet index (along track)		count
b	1, B	beam number		sp
f(i)		discriminator frequency		Equation 102
S(i,j,b)		corrected echo source packet sample		Equation 1
$T_E(j,b)$		along track time associated to an echo source packet for a given beam		Equation 2
N	$-N_N$, $+ N_N$	node index		count
$\sigma_0(i, T_E, b)$		Normalised radar cross-section value from a given beam, associated to a given discriminator frequency and for a given time		Equation 6
$\sigma_0^{DEBLOOM}(i,T_E,b)$		Normalised radar cross-section value corrected for deblooming, from a given beam, associated to a given discriminator frequency and for a given time		Equation 9
$\sigma_0(x_T, y_T, z_T, b)$		Normalised radar cross-section value from a given beam, corresponding to a point on the Earth in Terrestrial Reference Frame coordinates	Full-resolution σ_0 value	Equation 10

Variables				
Name	***Range***	***Description***	***Notes***	***Source***
$\sigma_0(x_{KT(N)}, y_{KT(N)}, z_{KT(N)}, b)$		Normalised radar cross-section value from a given beam, corresponding to a point on the Node Reference Frame coordinates		Equation 10
$\Omega\,(f, T_E, b, \mathbf{P}_{SAT\text{-}ACT}, \mathbf{P}_{ANT\text{-}ACT})$		Normalisation factor a given beam, associated with a given discriminator frequency and for a given time, for the actual s/c attitude and actual antenna pointing		Equation 8
$\Omega\,(f, T_E, b, \mathbf{P}_{SAT\text{-}NOM}, \mathbf{P}_{ANT\text{-}ACT})$		Normalisation factor for a given beam, associated with a given discriminator frequency and for a given time, for a nominal s/c pointing and actual antenna pointing		Equation 73
$\mathbf{P}_{ANT\text{-}ACT}(T_E, b)$		Actual pointing of the electrical boresight of an antenna beam		Equation 144 to Equation 148
$\mathbf{P}_{SAT\text{-}NOM}(T_E)$		Nominal s/c attitude (local nominal pointing + yaw steering attitude law)		FDF
$\mathbf{P}_{SAT\text{-}ACT}(T_E)$		Actual s/c attitude: Nominal attitude + attitude distortion law		FDF
$\Delta\alpha_{ROLL}$		roll angle attitude distortion		FDF
$\Delta\beta_{PITCH}$		pitch angle attitude distortion		FDF
$\Delta\gamma_{YAW}$		yaw angle attitude distortion		FDF
$S_{ROLL}(f, T_E, b, \mathbf{P}_{SAT\text{-}NOM}, \mathbf{P}_{ANT\text{-}ACT})$		Derivative of the normalisation function with respect to the roll angle		Equation 70

Variables				
Name	***Range***	***Description***	***Notes***	***Source***
$S_{PITCH}(f, T_E, b, \mathbf{P}_{SAT\text{-}NOM}, \mathbf{P}_{ANT\text{-}ACT})$		Derivative of the normalisation function with respect to the pitch angle		Equation 71
$S_{YAW}(f, T_E, b, \mathbf{P}_{SAT\text{-}NOM}, \mathbf{P}_{ANT\text{-}ACT})$		Derivative of the normalisation function with respect to the yaw angle		Equation 72
$(x_T, y_T, z_T)(i,j)$		Terrestrial Reference Frame coordinates of a normalised radar cross-section value		Equation 189 Equation 190
$(x_{\mathbf{K}T(N)}, y_{\mathbf{K}T(N)}, z_{\mathbf{K}T(N)})(i,j)$		Node Reference Frame coordinates of a normalised radar cross-section value		Equation 187 Equation 207
$K_{DEBLOOM}(f, T_E, b, \mathbf{P}_{SAT}, \mathbf{P}_{ANT})$		Deblooming Kernels		Equation 151
$\mathbf{K}_T(N)$		Position of a node N in the Terrestrial Reference Frame coordinates		Equation 207

Settings			
Name	***Description***	***Value/Source***	***Notes***
B	Number of beams	6	
N_N	Number of nodes per swath	–10 to 10 or –20 to 20	
N_{ECHO}	Number of samples in the discriminator frequency range	256	
$N_{ECHO\text{-}PACKETS}(b)$	Maximum number of echo samples received from a particular beam during an ASCAT measurement mode sequence	implementation	independent counts for each beam
SP	Switch path taken to and from the antenna port	IP	Two possible values, corresponding to the long and short paths respectively
$\mathbf{P}_{ANT\text{-}ACT}(T_E, b)$	Actual pointing of the electrical boresight of an antenna beam	PCP	Before the in-flight external calibration, use theoretical values
Ω (f, T_E, b, $\mathbf{P}_{SAT\text{-}NOM}$, $\mathbf{P}_{ANT\text{-}ACT}$)	Normalisation factor for a given beam, associated with a given discriminator frequency and for a given time, for a nominal s/c pointing and actual antenna pointing		
S_{ROLL}(f, T_E, b, $\mathbf{P}_{SAT\text{-}NOM}$, $\mathbf{P}_{ANT\text{-}ACT}$)	Derivative of the normalisation function with respect to the roll angle		
S_{PITCH}(f, T_E, b, $\mathbf{P}_{SAT\text{-}NOM}$, $\mathbf{P}_{ANT\text{-}ACT}$)	Derivative of the normalisation function with respect to the pitch angle		
S_{YAW}(f, T_E, b, $\mathbf{P}_{SAT\text{-}NOM}$, $\mathbf{P}_{ANT\text{-}ACT}$)	Derivative of the normalisation function with respect to the yaw angle		
$K_{DEBLOOM}$ (f, T_E, b, $\mathbf{P}_{SAT}$, $\mathbf{P}_{ANT}$)	Deblooming Kernels		

8.3 ASCAT PGF Variables and Settings Table 3: Spatial Averaging

Variables				
Name	***Range***	***Description***	***Notes***	***Source***
i	1, N_{ECHO}	discriminator frequency sample index (along beam)		count
j	1, $N_{ECHO\text{-}PACKETS}$	packet index (along track)		count
b	1, B	beam number		sp
$T_E(j,b)$		along track time associated to an echo source packet for a given beam		Equation 2
N	$-N_N$, $+ N_N$	node index		count
$\sigma_0 (x_{\mathbf{K}T(N)}, y_{\mathbf{K}T(N)}, z_{\mathbf{K}T(N)})$		Normalised radar cross-section value from a given beam, corresponding to a point on the Earth in Terrestrial Reference Frame coordinates		Equation 10
$\sigma_{0\ NODE} (\mathbf{K}_T(N),b,T_{ORBIT})$		Spatial-average value of the normalised radar cross-section for a given beam, at node N and for the corresponding node N orbit time	It can be at both 50 km or 25 km resolution, depending on the spatial averaging domain.	Equation 11
(x_T, y_T, z_T)		Terrestrial Reference Frame coordinates of a normalised radar cross-section value		Equation 189 Equation 190
$(x_{\mathbf{K}T(N)}, y_{\mathbf{K}T(N)}, z_{\mathbf{K}T(N)})$		Node Reference Frame coordinates of a normalised radar cross-section value		Equation 187 Equation 207
$\mathbf{K}_T(N)$		Position of a node N in the Terrestrial Reference Frame coordinates		Equation 207
T_{ORBIT}		orbit time associated with the centre of node N		Equation 200

Variables				
Name	*Range*	*Description*	*Notes*	*Source*
$W_0\,(x_{\mathbf{K}T(N)}, y_{\mathbf{K}T(N)}, \mathbf{K}_T(N), b)$		2-dimensional Hamming window: weighting function used for the spatial averaging of the normalised radar cross-sections	It can be both at 50 km or at 25 km resolution, depending on the spatial averaging domain.	Equation 12 Equation 187
$F_{0X}\,(x_{\mathbf{K}T(N)},\mathbf{K}_T(N),b)$		Component of the weighting function used for the spatial averaging of the normalised radar cross-sections. in the x axis of the Node Reference Frame	It can be both at 50 km or at 25 km resolution, depending on the spatial averaging domain.	Equation 13 Equation 187
$F_{0Y}\,(y_{\mathbf{K}T(N)},\mathbf{K}_T(N),b)$		Component of the weighting function used for the spatial averaging of the normalised radar cross-sections. in the y axis of the Node Reference Frame	It can be both at 50 km or at 25 km resolution, depending on the spatial averaging domain.	Equation 14 Equation 187

Settings			
Name	*Description*	*Value/Source*	*Notes*
B	Number of beams	6	
N_N	Number of nodes per swath	–10 to 10 or –20 to 20	
N_{ECHO}	Number of samples in the discriminator frequency range	256	
$N_{ECHO\text{-}PACKETS}(b)$	Maximum number of echo samples received from a particular beam during an ASCAT measurement mode sequence	implementation	independent counts for each beam

Settings			
$\alpha_{HX}(\mathbf{K}_T(N),b)$, $\alpha_{HY}(\mathbf{K}_T(N),b)$	Hamming parameters	PCP	LUT, Could vary as a function of across-track node position and beam number. Two different sets of values for 25 km and 50 km resolution.
$L_{HX}(\mathbf{K}_T(N),b)$, $L_{HY}(\mathbf{K}_T(N),b)$	Hamming window dimensions	PCP	LUT, Vary as a function of across-track node position and beam number. Two different sets of values for 25 km and 50 km resolution.

8.4 ASCAT PGF Variables and Settings Table 4: Kp Computation

Variables				
Name	***Range***	***Description***	***Notes***	***Source***
i	1, N_{ECHO}	Discriminator frequency sample index (along beam)		count
j	1, $N_{ECHO\text{-}PACKETS}$	Packet index (along track)		count
b	1, B	Beam number		sp
N		Normalisation of the Hamming Window		Equation 17
$\sigma_0(i, j)$		Normalised radar cross-section value from a given beam, corresponding to a point on the Earth in Terrestrial Reference Frame coordinates	This is the full-resolution σ_0 value.	Equation 6
$\sigma_{0\ NODE}$		Spatial-average value of the normalised radar cross-section for a given beam at node NODE	It can be both at 50 km or at 25 km resolution, depending on the spatial averaging domain.	Equation 11 Equation 16
T_{ORBIT}		Orbit time associated with the centre of node		Equation 201
W_0 (i, j)		Two-dimensional Hamming window: weighting function used for the spatial averaging of the normalised radar cross-sections	It can be both at 50 km or at 25 km resolution, depending on the spatial averaging domain.	Equation 12 Equation 183
var ($\sigma_{0\ NODE}$)		Variance of the σ_0 value from a given beam at node NODE		Equation 18
$\rho_{FIR}^{EFFECTIVE}$		Effective correlation due to on-board FIR filtering		Equation 19
$\rho_{INTER}^{EFFECTIVE}$		Effective inter-look correlation		Equation 19
ρ_{FIR}		Correlation due to FIR filtering		Equation 20
ρ_{INTER}		Correlation between looks		Equation 21
ρ_{INTRA}		Correlation within a look		Equation 21

Δ_f		Oversampling factor		Equation 150

Settings

Name	*Description*	*Value/Source*	*Notes*
B	Number of beams	6	
N_{ECHO}	Number of samples in the discriminator frequency range	256	
$N_{ECHO-PACKETS}(b)$	Maximum number of echo samples received from a particular beam during an ASCAT measurement mode sequence	implementation	independent counts for each beam
β	On-board along track FIR coefficients	IP	
α_n	On-board range look summation weighting coefficients	IP	
ω_{FIR}	FIR weighting function	IP	
ω_{RAN}	Range look weighting function	IP	
x(j,m)	Fraction overlap of looks j and m	IP	
z	Look duration	IP	
υ_{ADC}	ADC frequency sampling discriminator signal	IP	
$\upsilon_{HIGHEST}$	highest frequency discriminator signal	IP	

8.5 ASCAT PGF Variables and Settings Table 5: Rx Filter Shape Computation

Variables				
Name	***Range***	***Description***	***Notes***	***Source***
i	1, N_{ECHO}	discriminator frequency sample index (along beam)		count
b	1, B	beam number		sp
k(j)	1,$N_{NOISE\text{-}PACKETS}$	noise packet count		Equation 4
m(k)	1, $N_{SEG\text{-}TOTAL}$	noise segment count		Equation 53
f(i)		discriminator frequency		Equation 102
N(i,k,b)		raw noise source packet sample		sp
$T_N(k,b)$		along track time associated to an noise source packet for a given beam		Equation 3
q(i,m,b)		noise power in a noise segment		Equation 42
q(f(cal),m,b)		noise power in a noise segment, at the calibration frequency		Equation 43
h*(i,m)		estimated receiver filter shape prior to averaging (smoothing) discriminator frequencies		Equation 45 Equation 46 Equation 47
h'(i,m)		estimated receiver filter shape prior to normalising at calibration frequency		Equation 49 Equation 51 Equation 52
h_{RX} (i,m(k(j)))		final estimated receiver filter shape		Equation 48 Equation 49 Equation 50

Settings			
Name	***Description***	***Value/Source***	***Notes***
B	Number of beams	6	
N_{ECHO}	Number of samples in the discriminator frequency range	256	
$N_{NOISE\text{-}PACKETS}(b)$	Maximum number of noise samples received from a particular beam during an ASCAT measurement mode sequence	implementation	independent counts for each beam
$N_{SEG\text{-}TOTAL}(b)$	Number of noise segments obtained by averaging blocks of M_{SEG} noise samples	implementation	independent counts for each beam
M_{SEG}	Number of noise samples averaged to obtain a noise segment	PCP	
f(cal)	Calibration frequency	IP/103052 Hz	Starting values, might change in the future as a IP
f(icalp)	frequency sample above the calibration frequency f(cal)	IP/103125 Hz	Starting values, might change in the future as a IP
f(icalm)	frequency sample below the calibration frequency f(cal)	IP/102319.3359 Hz	Starting values, might change in the future as a IP
icalp	frequency sample index that gives us f(icalp)	IP/129	Starting values, might change in the future
icalm	frequency sample index that gives us f(icalm)	IP/128	Starting values, might change in the future as a IP
M_{BLOCK}	number of normalised noise segment power values averaged along track	PCP	
$N_{h\text{-}FIL}$	Number of samples in the filter that smoothes noise over frequencies	PCP	
$\alpha_{h\text{-}FIL}$	Coefficients of the filter that smoothes noise over frequencies	PCP	

8.6 ASCAT PGF Variables and Settings Table 6: Noise Power Computation

Variables				
Name	***Range***	***Description***	***Notes***	***Source***
i	1, N_{ECHO}	discriminator frequency sample index (along beam)		count
j	1, $N_{ECHO-PACKETS}$	packet index (along track)		count
b	1, B	beam number		sp
k(j)	1,$N_{NOISE-PACKETS}$	noise packet index		Equation 4
N(i,k,b)		raw noise source packet sample		sp
$h_{RX}(i,k)$		receiver filter shape		Equation 49 Equation 51 Equation 52
n(k,b)		noise power value		Equation 54

Settings			
Name	***Description***	***Value/Source***	***Notes***
B	Number of beams	6	
N_{ECHO}	Number of samples in the discriminator frequency range	256	
$N_{ECHO-PACKETS}(b)$	Maximum number of echo samples received from a particular beam during an ASCAT measurement mode sequence	implementation	independent counts for each beam
$N_{NOISE-PACKETS}(b)$	Maximum number of noise samples received from a particular beam during an ASCAT measurement mode sequence	implementation	independent counts for each beam
S, E	Start and End indexes for along-track averaging of corrected noise samples	PCP	

8.7 ASCAT PGF Variables and Settings Table 7: Power Gain Product Computation

Variables				
Name	***Range***	***Description***	***Notes***	***Source***
i	1, N_{ECHO}	discriminator frequency sample index (along beam)		count
j	1, $N_{ECHO\text{-}PACKETS}$	packet index (along track)		count
b	1, B	beam number		sp
$\lambda^*(j,b)$		estimated power gain product correction factor before along track averaging		Equation 59 or Equation 68
$\lambda(j,b)$		final estimated power gain product correction factor		Equation 55 Equation 56 Equation 57
$\Gamma(i,j,b)$		Losses term		Equation 60
$P_T(j,i,b,RC)$		Actual Transmitted Power		Equation 61
$P_R(j,i,b,RC)$		Actual Reflected Power		Equation 62
$P_I(j,i,b,RC)$		Actual Injected Power		Equation 63
$P_{TM}(j,i,b,RC)$		Measured Transmitted Power		sp
$P_{RM}(j,i,b,RC)$		Measured Reflected Power		sp
$P_{IM}(j,i,b,RC)$		Measured Injected Power		sp
$\theta_{SFE4}(j,i,b,RC)$		Temperature of the calibration coupler associated with the Tx path		sp
$\theta_{SFE5}(j,i,b,RC)$		Temperature of the calibration coupler associated with the Rx path		sp
$P_{CAL}(j,i,b,RC)$		Actual Calibration Power		Equation 64
X (a,b,c)		calibration power function		Equation 65
a (A_{CAL1})		calibration power function		Equation 66

Variables				
Name	***Range***	***Description***	***Notes***	***Source***
b (A_{CAL2})		calibration power function		Equation 67
c(A_{CAL3})		calibration power function		Equation 67
A_{CAL1}		calibration pulse complex sample		sp
A_{CAL2}		calibration pulse complex sample		sp
A_{CAL3}		calibration pulse complex sample		sp
RC		SFE diode redundancy configuration	Four possible values: A/A, A/B, B/A, B/B	sp

Settings			
Name	***Description***	***Value/Source***	***Notes***
B	Number of beams	6	
N_{ECHO}	Number of samples in the discriminator frequency range	256	
$N_{ECHO\text{-}PACKETS}(b)$	Maximum number of echo samples received from a particular beam during an ASCAT measurement mode sequence	implementation	independent counts for each beam
N_{PG}	number of λ^* values averaged along track in order to obtained a smooth λ value	PCP	
SP	Switch Path taken to and from the antenna port	IP	
$C_{CAL}(b,RC)$	internal calibration constants	PCP	Determined in-flight
$L_{CC}(b,SP)$	path losses between the Tx and Rx calibration couplers via a antenna port b	IP	Determined from characterisation data value between 0 and 1
F_T	Transmitted Power LUT	IP	LUT
F_R	Reflected Power LUT	IP	LUT
F_I	Injected Power LUT	IP	LUT

8.8 ASCAT PGF Variables and Settings Table 8: System Geometry and Reference Frames

Variables

Name	*Range*	*Description*	*Notes*	*Source*
b	1, B	beam number		sp
N	$-N_N$, $+ N_N$	node index		count
$\mathbf{x}_T = (x_T,y_T,z_T)$		Terrestrial Reference Frame (TRF)		definition
$\mathbf{x}_P = (x_P,y_P,z_P)$		Satellite Position Related Coordinate System		definition
$\mathbf{x}_L = (x_L,y_L,z_L)$		Orbital Reference Frame		definition
$\mathbf{x}_S = (x_S,y_S,z_S)$		Spacecraft Reference Frame		definition
$\mathbf{x}_{N(b)} = (x_{N(b)},y_{N(b)},z_{N(b)})$		Nominal Antenna Coordinate System for beam b		definition
$\mathbf{x}_{A(b)} = (x_{A(b)},y_{A(b)},z_{A(b)})$		Actual Antenna Coordinate System for beam b		definition
$\mathbf{x}_{K(N)} = (x_{K(N)},y_{K(N)},z_{K(N)})$		Node Reference Frame for node N		definition
$\mathbf{S}_T$		Satellite Position in the TRF		FDF
$\mathbf{V}_T$		Satellite Velocity in the TRF		FDF
$\mathbf{A}_T$		Satellite Acceleration in the TRF		FDF
$\mathbf{G}_T$		Satellite Nadir Position in the TRF		FDF
$\mathbf{U}_T$		Satellite Nadir Ground Track Velocity in the TRF		FDF
$\mathbf{N}_T$		Outwards Normal at the Satellite Nadir Position in the TRF		Equation 181

Settings

Name	*Description*	*Value/Source*	*Notes*
B	Number of beams	6	
N_N	Number of nodes per swath	–10 to 10 or –20 to 20	
f_E	Earth oblateness coefficient	constant	WGS84 Earth ellipsoid model

8.9 ASCAT PGF Variables and Settings Table 9: Transformations between Reference Frames

Variables				
Name	***Range***	***Description***	***Notes***	***Source***
b	1, B	beam number		sp
N	$-N_N$, $+ N_N$	node index		count
$\mathbf{x}_T = (x_T,y_T,z_T)$		Terrestrial Reference Frame		definition
$\mathbf{x}_P = (x_P,y_P,z_P)$		Satellite Position Related Coordinate System		definition
$\mathbf{x}_L = (x_L,y_L,z_L)$		Orbital Reference Frame		definition
$\mathbf{x}_S = (x_S,y_S,z_S)$		Spacecraft Reference Frame		definition
$\mathbf{x}_{N(b)} = (x_{N(b)},y_{N(b)},z_{N(b)})$		Nominal Antenna Coordinate System for beam b		definition
$\mathbf{x}_{A(b)} = (x_{A(b)},y_{A(b)},z_{A(b)})$		Actual Antenna Coordinate System for beam b		definition
$\mathbf{x}_{K(N)} = (x_{K(N)},y_{K(N)},z_{K(N)})$		Node Reference Frame for node N		definition
$\mathbf{S}_T$		Satellite Position in the Terrestrial Reference Frame		FDF
$\mathbf{V}_T$		Satellite Velocity in the Terrestrial Reference Frame		FDF
$\mathbf{A}_T$		Satellite Acceleration in the Terrestrial Reference Frame		FDF
$\mathbf{G}_T$		Satellite Nadir Position in the Terrestrial Reference Frame		FDF
$\mathbf{U}_T$		Satellite Nadir Ground Track Velocity in the Terrestrial Reference Frame		FDF
$\mathbf{N}_T$		Outwards Normal at the Satellite Nadir Position in the Terrestrial Reference Frame		Equation 181
$\mathbf{K}_T(N)$		Node Position in the Terrestrial Reference Frame		Equation 207
$[\mathbf{T}_{P>T}]$, $[\mathbf{T}_{P>T}]^T$		Transformation matrixes between Satellite Position Related Coordinate System and the Terrestrial Reference Frame		Equation 182
$\mathbf{U}_P$		Satellite Nadir Ground Track Velocity in the Satellite Position Related Coordinate System		Equation 182

Variables				
Name	***Range***	***Description***	***Notes***	***Source***
$\mathbf{N}_P$		Outwards Normal at the Satellite Nadir Position in the Satellite Position Related Coordinate System		Equation 182
$[\mathbf{T}_{L>P}]$, $[\mathbf{T}_{L>P}]^T$		Transformation matrixes between the Orbital Reference Frame and the Satellite Position Related Coordinate System		Equation 183
$\Delta\alpha_{ROLL}$		roll angle attitude distortion	Varies along the orbit	FDF
$\Delta\beta_{PITCH}$		pitch angle attitude distortion	Varies along the orbit	FDF
$\Delta\gamma_{YAW}$		yaw angle attitude distortion	Varies along the orbit	FDF
$[\mathbf{T}_{S>L}]$, $[\mathbf{T}_{S>L}]^T$		Transformation matrixes between the Spacecraft Reference Frame and the Orbital Reference Frame		Equation 184
$[\mathbf{T}_{N(b)>S}]$, $[\mathbf{T}_{N(b)>S}]^T$		Transformation matrixes between the Nominal Antenna Coordinate System and the Spacecraft Reference Frame, for beam b		Equation 185
$\Delta\psi_{SKEW}(b)$		Skew depointing angle for beam b	During the in-flight external calibration, they are estimated with the help of transponders (6.2.6)	Equation 144 Equation 145 Equation 146 Equation 147 Equation 148
$\Delta\theta_{ELE}(b)$		Elevation pointing angle for beam b	During the in-flight external calibration, they are estimated with the help of transponders (6.2.6)	Equation 144 Equation 145 Equation 146 Equation 147 Equation 148
$\Delta\phi_{AZI}(b)$		Azimuth pointing angle for beam b	During the in-flight external calibration, they are estimated with the help of transponders (6.2.6)	Equation 144 Equation 145 Equation 146 Equation 147 Equation 148

Variables				
Name	***Range***	***Description***	***Notes***	***Source***
$[\mathbf{T}_{A(b)>N(b)}]$, $[\mathbf{T}_{A(b)>N(b)}]^T$		Transformation matrixes between the Actual Antenna Coordinate System and the Nominal Antenna Coordinate System, for beam b		Equation 186
$\mathbf{I}_{SWATH}(b)$		Switch to indicate right or left swath, depending on beam number		Equation 188
$\mathbf{M}_T(N)$		Outward Local Normal at a node position in the Terrestrial Reference Frame		Equation 188
$[\mathbf{T}_{K(N)>T}]$, $[\mathbf{T}_{K(N)>T}]^T$		Transformation matrixes between the Node Reference Frame and the Terrestrial Reference Frame		Equation 187

Settings			
Name	***Description***	***Value/Source***	***Notes***
B	Number of beams	6	
N_N	Number of nodes per swath	–10 to 10 or –20 to 20	
θ_M	Mid antenna pointing	IP/33 | 5	Starting values, might change in the future as a IP
$\theta_{F/A}$	For and aft antenna pointings	IP/43 | 0	Starting values, might change in the future as a IP
$\Delta\psi_{SKEW}(b)$	Skew depointing angle for beam b, characterised on-ground	PCP for initial processing	Before the in-flight external calibration, these values have to be given as characterised on ground
$\Delta\theta_{ELE}(b)$	Elevation pointing angle for beam b, characterised on-ground		
$\Delta\phi_{AZI}(b)$	Azimuth pointing angle for beam b, characterised on-ground		
f_E	Earth oblateness coefficient	1/298.2572	WGS84 Earth ellipsoid model

8.10 ASCAT PGF Variables and Settings Table 10: Localisation and Datation Times

Variables				
Name	***Range***	***Description***	***Notes***	***Source***
b	1, B	beam number		sp
ν_0		discriminator frequency		Equation 102
T_0		orbit time associated with a given measurement or calibration power sample		Equation 192 Equation 196 Equation 198
$\mathbf{P}_T = (x_T(b),y_T(b),z_T(b))$		position of a measurement or calibration power sample on the surface of the Earth ellipsoid in Terrestrial Reference Frame coordinates		Equation 189 Equation 190 Equation 191
$\mathbf{S}_T$		Satellite Position in the Terrestrial Reference Frame		FDF
$\mathbf{V}_T$		Satellite Velocity in the Terrestrial Reference Frame		FDF
$\mathbf{n}_T(b,T_0)$		Unit normal vector pointing in the direction of the $y_{A(b)}$ axis in Terrestrial Reference Frame for beam b at a given orbit time	Calculated from $y_{A(b)}$, by using the transformations in Section 6.3.2	Section 6.3.2
$[\mathbf{T}_{A(b)>T}]$		Transformation matrix from the Actual Antenna Coordinate System to the Terrestrial Reference Frame	missing algorithm (but it can be figured out from the other [T]'s)	Section 6.3.2
$T_{UTC\text{-}FIRST\text{-}IN\text{-}SP/E}$		UTC Time Tag time of the first PRI contribution to a given echo source packet		Equation 2
$T_{UTC\text{-}FIRST\text{-}IN\text{-}SP/N}$		UTC Time Tag time of the first PRI contribution to a given noise source packet		Equation 3

Variables				
Name	***Range***	***Description***	***Notes***	***Source***
$f_{OFFSET}(b)$		Frequency offsets for beam b		
$\delta_{ECHO\text{-}MEAS}$				Equation 193
$\delta_{ECHO\text{-}CAL}$				Equation 195
$\delta_{NOISE\text{-}MEAS}$				Equation 196
$\delta_{NOISE\text{-}CAL}$				Equation 199
s_{TRANS}		Slant range to the transponder under consideration		Equation 202

Settings			
Name	***Description***	***Value/Source***	***Notes***
B	Number of beams	6	
N_{NOISE}	Maximum number of windows of noise averaged on-board along track from a given beam	PCP/40	On-board parameter setting
a_E	Earth Equatorial radius	constant	WGS84 Earth ellipsoid model
f_E	Earth oblateness coefficient	constant	WGS84 Earth ellipsoid model
$\alpha(b)$	Chirp rate for beam b	PCP	Instrument engineering parameter
f_{uc}	RF carrier frequency	$5.255\ 10^9$ Hz	Instrument engineering parameter
c	Speed of light	constant	constant
λ_{uc}	Radar carried wavelength	f_{uc} / c	
Δ_{TRANS}	Integration range about the peak of transponder echoes	PCP	
N_{FIR}	Length of the on-board along track averaging finite impulse response filter	PCP/8	On-board parameter setting

Settings			
Name	***Description***	***Value/Source***	***Notes***
$s_{MID\text{-}NOM}$	Nominal Slant Range to mid-swath	IP	
Δ_{PRI}	Pulse Repetition interval for any given beam ***Note***: Δ equals pulse repetition interval for a specific beam, $\Delta = 6\,\Delta_{PRI}$	IP	
g_0, g_1, g_2, g_3, T_{NOISE}, T_{CALW}, T_{TX}, T_{DRW}		IP	
$\hat{\mathbf{y}}_{A(b)}$	Unit normal vector pointing in the direction of the $y_{A(b)}$ axis in Actual Antenna Coordinate System for beam b	(0,1,0)	Section 6.3.2, geometric definition

8.11 ASCAT PGF Variables and Settings Table 9: Node Positions

Variables				
Name	***Range***	***Description***	***Notes***	***Source***
b	1, B	beam number		sp
n	$-N_N$, $+N_N$	node index		count
T_i		orbit time associated with a line of nodes	It can be both at 50 km or at 25 km resolution Equivalent to T_{ORBIT} in 6.1.3 and 6.1.4	
$\mathbf{U}_T(T_i)$		Sub-satellite Nadir Ground Track Velocity in the Terrestrial Reference Frame, associated to an orbit time		FDF
$\mathbf{S}_T = (x(\mathbf{S}_T), y(\mathbf{S}_T), z(\mathbf{S}_T))$		Satellite Position in the Terrestrial Reference Frame		FDF
$\mathbf{R}_T$ (MID)		Position on the Earth Ellipsoid of the mid swath, in the Terrestrial Reference Frame		Equation 201
$\mathbf{Q}_T (\mathbf{I}_{SWATH}) =(x(\mathbf{Q}_T), y(\mathbf{Q}_T), z(\mathbf{Q}_T))$		*Rough* slant range vector from the satellite to the mid swath position on the Earth ellipsoid, in the Terrestrial Reference Frame	*rough*: Calculated as first approximation assuming triangular geometry between the satellite position, nadir point and mid- swath point.	Equation 202
$\mathbf{I}_{SWATH}(b)$		Switch to indicate right or left swath, depending on beam number		Equation 202
λ_f		Free parameter to refine the first rough estimation of the slant range assuming an elliptical curve from the nadir point to the mid-swath position.		Equation 203 Equation 204 Equation 205 Equation 206
$\mathbf{K}_T(n, \mathbf{I}_{SWATH})$		Node Position in the Terrestrial Reference Frame		Equation 207

Variables				
Name	***Range***	***Description***	***Notes***	***Source***
$\mathbf{G}_T$		Satellite Nadir Position in Terrestrial Reference Frame		FDF
$\mathbf{U}_T = (x(\mathbf{U}_T), y(\mathbf{U}_T), z(\mathbf{U}_T))$		Satellite Nadir Ground Track Velocity in the Terrestrial Reference Frame		FDF
$\mathbf{C}_T = (x(\mathbf{C}_T), y(\mathbf{C}_T), z(\mathbf{C}_T))$		Centre of ellipse that intersects between the Earth ellipsoid in the plane that contains the satellite and the row of nodes		Equation 212
$\mathbf{a}^{\wedge}{}_T = (x(\mathbf{a}_T), y(\mathbf{a}_T), z(\mathbf{a}_T))$		Unit vector of the semi-major axis of ellipse that intersects the Earth ellipsoid in the plane that contains the satellite and the row of nodes		Equation 213
$\mathbf{b}^{\wedge}{}_T = (x(\mathbf{b}_T), y(\mathbf{b}_T), z(\mathbf{b}_T))$		Unit vector of the semi -minor axis of ellipse that intersects the Earth ellipsoid in the plane that contains the satellite and the row of nodes		Equation 214
a_{EE}		Semi-major axis of ellipse that intersects the Earth ellipsoid in the plane that contains the satellite and the row of nodes		Equation 215
b_{EE}		Semi-minor axis of ellipse that intersects the Earth ellipsoid in the plane that contains the satellite and the row of nodes		Equation 216
ζ		Variable to resolve the ellipse geometry		Equation 208
β		Variable to resolve the ellipse geometry		Equation 209 Equation 210
$d(n)$		Across-track distance of node n from mid swath position		Equation 211

Settings			
Name	***Description***	***Value/Source***	***Notes***
B	Number of beams	6	
N_N	Number of nodes per swath	–10 to 10 or –20 to 20	
D_{ALONG}	Along track node spacing	25 km or 50 km (PCP)	
D_{ACROSS}	Across track node spacing	25 km or 50 km (PCP)	
θ_{LOOK}	Look angle defining position of node number 0 (mid -swath)	PCP	Refer to RD1 for node generation geometry description
T_0	Orbit time associated with the first line of nodes	implementation	
a_E	Earth Equatorial radius	constant	WGS84 Earth ellipsoid model
b_E	Geocentric Pole distance	$b_E = a_E(1\text{-}f_E)$	WGS84 Earth ellipsoid model
f_E	Earth oblateness coefficient	constant	WGS84 Earth ellipsoid model

8.12 ASCAT PGF Variables and Settings Table 12: Node Incidence and Azimuth Angles

Variables				
Name	***Range***	***Description***	***Notes***	***Source***
i		Incidence angle		Equation 217
$\mathbf{S}_T = (x(\mathbf{S}_T), y(\mathbf{S}_T), z(\mathbf{S}_T))$		Satellite Position in the Terrestrial Reference Frame		FDF
$\mathbf{P}_T = (x_T, y_T, z_T)$		Position of the target (σ_0 or node) on the surface of the Earth ellipsoid, in Terrestrial Reference Frame coordinates		Equation 189 Equation 190 Equation 191
$\mathbf{M}_T$		Unit vector along the outwards normal to the surface of the Earth ellipsoid, at the position of the target (σ_0 or node), in Terrestrial Reference Frame coordinates		
$\phi_{AZIMUTH}$		Azimuth angle		Equation 201
$\mathbf{J}_{K(N)}$				Equation 203
$\mathbf{V}_{K(N)}^{t}$				Equation 202
$\mathbf{T}_{K(N)>T}$		Transformation matrix between the Node Reference Frame and the Terrestrial Reference Frame		Equation 187
θ_{LON}		Longitude of the position on the target		Equation 205
θ_{LAT}		Latitude of the position on the target		Equation 204

8.13 ASCAT PGF Variables and Settings Table 13: Noise/Echo Processing Equivalence Function and Echo Normalisation Function

Variables				
Name	***Range***	***Description***	***Notes***	***Source***
i	1, N_{ECHO}	Discriminator frequency sample index (along beam)		count
b	1, B	beam number		sp
m	1, M(b)	Range look count		count
c_M (i,b)		Correction factor to account for different on-board processing of the echo and noise looks, for instrument measurement mode		Equation 172
c_C (i,b)		Correction factor to account for different on-board processing of the echo and noise looks, for instrument calibration mode		Equation 172
ω_{M-E} (t, m, b)		Echo look weighting for measurement mode		Equation 79
ω_{M-N} (t, b)		Noise look weighting for measurement mode		Equation 79
ω_{C-E} (t, m, b)		Echo look weighting for calibration mode		Equation 82
ω_{C-N} (t, b)		Noise look weighting for calibration mode		
χ(i,b)		Normalisation function for range look summation		Equation 174
ν (i)		Discriminator frequency		Equation 102

Settings			
Name	***Description***	***Value/Source***	***Notes***
B	Number of beams	6	
N_{ECHO}	Number of samples the discriminator frequency range	256	
ρ (ν_0,m)	Look summation weights	PCP	
M(b)	Number of range looks per beam b	PCP	