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Radar Altimeter Ground Processing Requirement

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Document Change Log

Only changes since the document maintenance was taken over by ESA are recorded here.

Issue	Date	Sheet	Description of Change
5 a	8.6.1990	10–22	reissued
		26–30	reissued
		32	reissued
5 b	3.8.1990	26	introduction of k_f
		30	modification to equation 4.6.2–2
5 c	19.9.1990	17	simplification of correction table indexing
5 d	16.11.1990	14	modification of standard deviation formula
5 e	4.4.1991	12	changes to MMCC supplied parameters
		14	operational improvement of external corrections
5 f	31.10.1991	29	scaling of FFT sample telemetry
		30	FFT sample scaling and renumbering
5 g	5.2.1993	11, 13 ...	introduction of INTER function
		13, ...	identification of measurement units
		13, 21	explicit requirement for "default" flag
		14	modification of mean and standard deviation calculation, with rejection of outliers
		16	correction of dimension error in κ_1
		18	identification of parameters
		21	modification of AGC computation to include discriminator value
		40, 41	correction of product size error
		41	requirement for incomplete products not to be discarded
5 h	12.3.1994	11	Addition of Ice Mode processing
		11	Management of Ice/Ocean Mode calibration processing
		12c	Addition of Ice Mode processing parameters
		12c	Additional parameter for outlier rejection test
		13, 13b, 14	Section numbering and titles
		13b, 13c	New section describing Ice Mode processing
		14	Correction of test condition by root term, and introduction of scaling coefficient for outlier table.
		26	Additional parameters for Ice mode processing
		29	Calculation of height calibration in Ice Mode, use of dedicated ice mode parameters and section name
		30	Section name
6	31.3.93	all	Reissued with ESA reference number
		all	New page numbers
		1	Closer definition of Scope

Issue	Date	Sheet	Description of Change
		2	Additional reference document
		3	Replacement of altimeter description by reference
		4, 11, 29…31	Addition of Microwave Radiometer processing
		4	Removal of diagram
		5, 11	Addition of default wet correction
		5, 6	Elimination of unused parameters (A_p; $T_{H, LOC}$; $e_{1,H}$; $e_{0,H}$)
		5, 7, 8	Replacement of ground calibration vector by scalar
		6	Change of "source" of some parameters introduced in Issue 5 h
		10	Change of sign of Doppler correction
		12, 13	Addition of slope and offset for SWH
		14	Elimination of unused parameters (P_{REF}; $d_{1,v}$; $d_{0,v}$)
		14	Addition of AGC fine adjustment table
		14, 15	Addition of ocean-ice adjustment factor
		14	Addition of discriminator telemetry scaling factor
		15	New method for computation of sigma-0 value
		15	Introduction of scaling factor for AGC discriminator
		17	Removal of unused parameters (UTC_0, SBT_0, PER_0, SBT, TAB_{LOC}, α_{HTL}, β_{HTL})
		18	Removal of HTL time constant compensation(TAB_{LOC})
		19	Change of "source" of parameters introduced in Issue 5 h
		23	Rewording of specification of tenth set of waveforms.
		24	Removal of redundant paramter (MASK)
		25	Replacement of bit masks by explicit bit flags.
		25	Removal of illustration
		28	Reference to ice-mode packets
6 a	5 Sept 1996	10	Additional explanatory text
		10	Reformatting of text to clarify outlier removal procedure.
		14	Removal of ε_{AGC}, table A_{fi} and change of table $A^G{}_{ref}$
		15	Use of a two-dimensional table $A^G{}_{ref}$ instead of two one-dimensional tables A_{fi} and $A^G{}_{ref}$
		15	Removal of discriminator correction

Table of Contents

1 SCOPE

This document defines the Fast Delivery Ground Processing Algorithm Requirements for the ERS–1 Radar Altimeter. It does not include the basic tasks of decoding the telemetry stream, and assumes that the relevant parameters have been extracted for ingestion into the algorithms presented here.

The preparation of the results into the formatted data product is not described.

2 APPLICABLE DOCUMENTS

2.1 Applicable Documents

The following documents of latest issue in effect form part of this specification.

1. Kiruna Station Requirements Specification (ER-RS-DSF-GS-0002)
2. Satellite to Ground Segment Interface Specification (ER-IS-DSF-SY-0010)

2.2 Reference Documents

1. ERS-1 Satellite Requirements Specification (ER-RS-DSF-SA-0002)
2. Radar Altimeter Data Chain (ER-RP-ESA-SY-0004)
3. ERS-1 Algorithms for Orbit Prediction and for the Determination of Related Static and Dynamic Altitude and Groundtrace Quantities (ER-RP-ESA-SY-0001)
4. DPMC/SAR/LRDPF/MMCC Time Handling and Processing (TN: ORM/1664/CG/sml)

3 OVERALL SYSTEM DESCRIPTION

The ERS-1 Radar Altimeter (RA), its operation modes and fundamentals of the data processing, are provided in Reference Document 2: RA Data Chains, ER-RP-ESA-SY-0004.

4 GROUND PROCESSING PERFORMANCE REQUIREMENTS

4.1 General

Ground processing is only performed for source packets from from Ocean or Ice Tracking modes. These sometimes contain Open-Loop Calibration data in addition to the normal tracking data, which shall also be processed. The selection of these source packets is specified in Section 4.8.

The ground processing functions are listed below:

- calculation of Altitude (H) above the surface;
- calculation of Significant Waveheight (SWH) when in Ocean Tracking Mode;
- calculation of backscatter coefficient ($\sigma°$) and windspeed (v);
- calculation of the localisation of the products;
- product confidence checks;
- calculation of wet tropospheric correction from Microwave Radiometer data.

The detailed algorithms of these processing functions are defined in the following chapters.

The detailed telemetry format indicates if TM values are signed or unsigned. Scaling with respect to the binary point shall not be applied, unless specifically stated, as such scaling is normally included in the constants supplied from the MMCC.

All algorithms shall be carried out in floating-point arithmetic, unless explicitly stated otherwise. All computations concerned with altitude shall be carried out in double precision floating point arithmetic.

The `INDEX` function referred to in this document is defined as:

```
INDEX (x, a0, a1) = NINT ((x - a0)/a1)
```

where `NINT` is the rounded nearest integer (nearest neighbour) function. An additional function, `INTER`, is also referred to; this is a linear interpolation function. All tables used in this document start with the index value zero if not otherwise stated.

In the Open Loop Calibration (Section 4.6) height and gain corrections will be determined. These values are the reference parameters τ^F_{ref} and A^F used in the Ground Processing, as identified in the following chapters. In the Ocean and Ice Tracking Modes these values shall be used to correct the measurement data, after smoothing in an $\alpha\beta$-filter. Correction values shall be obtained with both Ice chirps and Ocean chirps. Management of results from each type of chirp shall be performed so that each is smoothed separately, as specified.

Microwave Radiometer data shall be extracted from the ATSR data stream and processed as specified to obtain Brightness Temperature measurements. These shall then be further used to obtain the wet tropospheric correction for the RA height measurement. This latter transformation is only known to be valid over ocean. However the transformation, and the application of the correction, shall be performed over all surfaces.

4.2 Altitude (H)

4.2.1 Variables

Name	Units	Type	Length	Source	Description
τ_C	TM units	REAL*8	1		Smoothed internal calibration height correction
$\tau_{C,d}$	TM units	REAL*8	1	MMCC	Default smoothed internal calibration height correction
ε	TM units	REAL*8	1		Internal calibration height error
ε_d	TM units	REAL*8	1	MMCC	Default internal calibration height error
α	–	REAL*8	1	MMCC	α filter coefficient
β	–	REAL*8	1	MMCC	β filter coefficient
A	TM units	REAL*8	1		α correction term
B	TM units	REAL*8	1		β correction term
x	TM units	REAL*8	1		Estimated rate of change of calibration correction
x_d	TM units	REAL*8	1	MMCC	Default rate of change of calibration correction
P_0	1/10 mb	INT*2	161×320	MMCC	Atmospheric pressure table
$P_{0,d}$	1/10 mb	INT*2	1	MMCC	Default atmospheric pressure
T_{max}	d	REAL*4	1	MMCC	Pressure field time-window
K_{dry}	10m/mb	REAL*8	1	MMCC	Pressure to height error conversion factor
ΔH_{wet}	m	REAL*8	1		Wet tropospheric height correction from the ATSR micro-wave radiometer data
$\Delta H_{wet,\,d}$	m	REAL*8	1	MMCC	Default wet tropospheric height correction
ΔH_{iono}	m	REAL*8	1		Ionospheric height correction, from an independent ESA-supplied module in the FD processing
$F_{10.7}$	–	REAL*4	1	MMCC	Solar flux
N_s	#	INT*2	1	MMCC	Ionospheric correction skip interval
τ	–	BYTE*4	N	TM	Time Delay
τ^F_{ref}	TM units	REAL*8	1		Height Error from Open Loop Calibration
τ^F_{off}	–	REAL*8	1	MMCC	Flight time offset value (5 PRI)
τ^G_{ref}	s	REAL*8	1	MMCC	Prelaunch calibration value
τ_{sc}	s	REAL*8	1	MMCC	Time dealy scaling factor
$TAB_{\tau 1}$	s	REAL*8	256	MMCC	sea-state dependent correction table
$TAB_{\tau 2}$	s	REAL*8	256	MMCC	sigma-0 dependent correction table
T	–	REAL*8	1	MMCC	USO Clock period correction factor
ϕ	rad	REAL*4	1		geodetic satellite and nadir latitude
λ	rad	REAL*4	1		geographic satellite and nadir longitude

Name	Units	Type	Length	Source	Description
$\dot{H}$	ms^{-1}	REAL*8	1		Height rate from orbit propagator
μ	s^{-2}	REAL*8	1	MMCC	Chirp rate
f	s^{-1}	REAL*8	1	MMCC	Carrier frequency
c	ms^{-1}	REAL*8	1	MMCC	Speed of light
ΔH_{cal}	m	REAL*8	1	MMCC	External calibration altitude correction
N	#	INT*2	1	TM	Number of measurement blocks
$a_{1,H}; a_{0,H}$	–	REAL*4	1, 1	MMCC	Step size and offset of table $TAB_{\tau 1}$
$b_{1,H}; b_{0,H}$	–	REAL*4	1, 1	MMCC	Step size and offset of table $TAB_{\tau 2}$
$c_{1,H}; c_{0,H}$	–	REAL*4	1, 1	MMCC	Step size and offset of table P_0 (1st index)
$d_{1,H}; d_{0,H}$	–	REAL*4	1, 1	MMCC	Step size and offset of table P_0 (2nd index)
$t_{w,H}$	m	REAL*8	1	MMCC	Warning threshold height
$\overline{H}$	m	REAL*8	1		Mean of satellite altitude
S_H	m	REAL*8	1		Standard deviation of satellite altitude
PRI	s	REAL*4	1	MMCC	Pulse repetition interval
τ^I_C	TM units	REAL*8	1		Smoothed internal calibration height correction
$\tau^I_{C,d}$	TM units	REAL*8	1	MMCC	Default smoothed internal calibration height correction
ε^I	TM units	REAL*8	1		Internal calibration height error
ε^I_d	TM units	REAL*8	1	MMCC	Default internal calibration height error
A^I	TM units	REAL*8	1		α correction term
B^I	TM units	REAL*8	1		β correction term
x^I	TM units	REAL*8	1		Estimated rate of change of calibration correction
x^I_d	TM units	REAL*8	1	MMCC	Default rate of change of calibration correction
MWA	TM units	BYTE*2	64	TM	Waveform samples
L	–	REAL*4	1	MMCC	Threshold for waveform samples
k^I_f	s	REAL*8	1	MMCC	Filter separation to seconds conversion factor
κ_τ	–	REAL*4	1	MMCC	TAU table multiplication factor

If the source is not specified then the quantity is computed during the processing. Such internal variables are not all specified here. Furthermore indices are not identified and only locally identified in the specification (*ie* they are reused without implication on their usage within the algorithms).

4.2.2 Ocean Mode Time Delay Algorithm (Ocean Chirp)

The input time delays $\tau(n)$ have an offset added and are corrected with the smoothed in-flight height correction $\tau^F{}_{ref}$ from the 'Open Loop Calibration'. All of these terms are in 'telemetry units' (*ie* the 32-bit word from the source packet interpreted as an unsigned integer). A scaling factor from telemetry units to seconds is applied, and the on-ground calibration term (also in seconds) added.

$$\tau_{cor}(n) = \tau_{sc}[\tau(n) - \tau_C(i) + \tau^F{}_{off}] + \tau^G{}_{ref} \qquad (4.2.2\text{–}1)$$

$\tau_C(i)$ is obtained by smoothing the Ocean chirp open-loop calibration data as follows. For each new value of open-loop calibration, $\tau^F{}_{ref}$, calculate:

$$\varepsilon = \tau^F{}_{ref} - \tau_C \qquad (4.2.2\text{–}2)$$

$$A = \alpha\,\varepsilon \qquad (4.2.2\text{–}3)$$

$$B = \beta\,\varepsilon \qquad (4.2.2\text{–}4)$$

$$x(j) = x(j-1) + B \qquad (4.2.2\text{–}5)$$

where τ_C is the current value of $\tau_C(i)$, and the index i increments for each data-block during a continuous operation of the altimeter in ocean mode. It is not reset in each source packet, unlike n. The index j increments with every new value of $\tau^F{}_{ref}$. Before the first value of $\tau^F{}_{ref}$ is available (at the start of the data-set) the quantity ε shall be set equal to an externally supplied default value ε_d. This condition shall be indicated by a flag.

For every data-block, i, calculate the new value $\tau_C(i)$ from the equations:

$$\tau_C = \tau_C(i-1) + x(j) + A \qquad (4.2.2\text{–}6)$$

The initial values of x and τ_C shall be the default values x_d and $\tau_{C,\,d}$.

All of the quantities used in the computation of $\tau_C(i)$ are in 'telemetry units'.

With $\sigma_{s,\,cor}(n)$ from equation 4.3.2–1, τ_{cor} is corrected using a table which compensates for the effect of IF-filter ripple and sea state bias. At this stage the computation is in units of seconds.

$$\tau_1(n) = \tau_{cor}(n) + \mathrm{TAB}_{\tau 1}[\mathrm{INTER}(\sigma_{s,\,cor}(n), a_{0,\,H}, a_{1,\,H})] \qquad (4.2.2\text{–}7)$$

With $\sigma^\circ{}_1$ from equation 4.4.2–1, $\tau_1(n)$ is corrected as a function of σ°.

$$\tau_2(n) = \tau_1(n) + \mathrm{TAB}_{\tau 2}[\mathrm{INTER}(\sigma^\circ{}_1(n), b_{0,\,H}, b_{1,\,H})] \qquad (4.2.2\text{–}8)$$

The tables $\mathrm{TAB}_{\tau 1}$ and $\mathrm{TAB}_{\tau 2}$ are updated no more than once per month after the Commissioning Phase. The tables are externally provided together with the coefficients which map σ onto the allowed index range.

4.2.3 Ice Mode Time Delay Algorithm (Ice Chirp)

The input time delays $\tau(n)$ have an offset added and are corrected with the smoothed in-flight height correction $\tau^F{}_{ref}$ from the 'Open Loop Calibration'. All of these terms are in 'telemetry units' (*ie* the 32-bit word from the source packet interpreted as an unsigned integer). A scaling factor from telemetry units to seconds is applied, and the on-ground calibration term (also in seconds) added.

$$\tau_{cor}(n) = \tau_{sc}[\tau(n) - \tau^I{}_C(i) + \tau^F{}_{off}] + \tau^G{}_{ref} \quad \textbf{(4.2.3-1)}$$

$\tau^I{}_C(i)$ is obtained by smoothing the Ice Chirp open-loop calibration data as follows. For each new value of Ice Chirp open-loop calibration, $\tau^F{}_{ref}$, calculate:

$$\varepsilon^I = \tau^F{}_{ref} - \tau^I{}_C \quad \textbf{(4.2.3-2)}$$

$$A^I = \alpha\, \varepsilon^I \quad \textbf{(4.2.3-3)}$$

$$B^I = \beta\, \varepsilon^I \quad \textbf{(4.2.3-4)}$$

$$x^I(j) = x^I(j-1) + B^I \quad \textbf{(4.2.3-5)}$$

where $\tau^I{}_C$ is the current value of $\tau^I{}_C(i)$, and the index i increments for each data-block during a continuous operation of the altimeter in ice mode. It is not reset in each source packet, unlike n. The index j increments with every new value of $\tau^F{}_{ref}$. Before the first value of $\tau^F{}_{ref}$ is available (at the start of the data-set) the quantity ε^I shall be set equal to an externally supplied default value $\varepsilon^I{}_d$. This condition shall be indicated by a flag.

For every data-block, i, calculate the new value $\tau^I{}_C(i)$ from the equations:

$$\tau^I{}_C = \tau^I{}_C(i-1) + x^I(j) + A^I \quad \textbf{(4.2.3-6)}$$

The initial values of x^I and $\tau^I{}_C$ shall be the default values $x^I{}_d$ and $\tau^I{}_{C,d}$.

All of the quantities used in the computation of $\tau^I{}_C(i)$ are in 'telemetry units'.

A correction to compensate for the displacement of the echo leading edge from the tracking point is computed and applied as follows:

The FFT samples in the telemetry shall be re-ordered to obtain the range 0 ... 63 from the telemetry order, which is:

32, 33, 34 ... 63, 0, 1 ... 31

and then the reordered FFT samples shall be divided by the fixed constant 32, to obtain the values *MWA(i)*, for $i = 0 \ldots 63$.

The *MWA* values are compared to an externally supplied threshold, *L*, and converted to a binary value accordingly:

$$R(i) = \begin{cases} 1 & MWA(i) > L \\ 0 & MWA(i) \le L \end{cases} \quad \textbf{(4.2.3-7)}$$

The width of the echo signal, *W*, is then computed as:

$$W = \sum_{i=5}^{63} R_i \qquad \text{(4.2.3-8)}$$

The position of the centre of gravity of the echo, G, is computed as:

$$G = \begin{cases} \dfrac{\sum_{i=5}^{63} iR_i}{W} & W \neq 0 \\ 32 & W = 0 \end{cases} \qquad \text{(4.2.3-9)}$$

And finally the time delay corresponding to the position of the leading edge, τ_2, is computed as follows:

$$\tau_2 = \left(G - \frac{W}{2} - 32\right)k_f^I + \tau_{cor}(n) \qquad \text{(4.2.3-10)}$$

where k_f^I is the conversion factor from FFT spacing to time units, for Ice Mode.

4.2.4 Time Delay to Mean Altitude Conversion

The conversion to units of metres, the Doppler effect compensation for the height rate interaction with the downchirp (signified by the parameter μ having a negative sign) and height rate correction to the localisation reference are performed according to:

$$H_1(n) = \frac{\tau_2(n)cT}{2} + \Delta H_{dop} + 50\dot{H}PRI(10.5 - n) \qquad \textbf{(4.2.4-1)}$$

with

$$\Delta H_{dop} = -\frac{f\dot{H}}{\mu} \qquad \textbf{(4.2.4-2)}$$

where $\dot{H}$ is given by the orbit propagator.

The RA FD-product Satellite Altitude is given as the mean and standard deviation according to the following algorithm:

1. Given the array of altitudes $H_1[1 \ldots 20]$, create an array $X[1] = 1, X[2] = 2, \ldots, X[20] = 20$. Set $N = 20$.
2. Fit a straight line in the least squares sense to the array of N points, calculating intercept d and slope m, such that $H_1 = mX + d$. Calculate the squares of the deviations of the H_1 points from the fitted line, $D[1 \ldots N]$:

   $D[i] = (H_1[i] - mX[i] - d)^2$

   The standard deviation of the altitude is defined as

   $$S_H = \sqrt{\frac{\sum_{i=1}^{N} D[i]}{N-2}} \qquad \textbf{(4.2.4-3)}$$

   Define the largest individual value of D to be D_{max}.

   If $\sqrt{D_{max}} \leq \kappa_\tau TAU_{95}[N] S_H \sqrt{\frac{N-2}{N}}$ then skip to step 4 otherwise perform step 3.

   TAU_{95} is a table of tau values for 95% confidence with up to 20 degrees of freedom; it is multiplied by an externally supplied factor κ_τ.

   $TAU_{95}\,[2 \ldots 20] =$

   {0.000, 1.000, 1.414, 1.714, 1.926, 2.078, 2.194, 2.286, 2.361, 2.425, 2.480, 2.529, 2.572, 2.610, 2.646, 2.678, 2.707, 2.735, 2.760}

   Note that this is not a Student's t test. [Reference: NOAA Technical Report NOS 65 NGS 1, "The Statistics of Residuals and the Detection of Outliers", Allen J. Pope, May 1976]
3. Modify arrays X and H_1 to exclude the outlier with deviation D_{max}, and decrement N. If $N \geq 10$ then go back to step 2, else continue to step 4.
4. Calculate the mean uncorrected altitude:

   $$H_2 = 10.5m + d \qquad \textbf{(4.2.4-4)}$$

tau-test and d-max correctly implemented in LRDPF and the corrected altitude:

$$\bar{H} = H_2 - \Delta H_{cal} - \Delta H_{wet} - \Delta H_{iono} - K_{dry} P_0[\mathrm{INTER}(\lambda, c_{0,H}, c_{1,H}), \mathrm{INTER}(\phi, d_{0,H}, d_{1,H})] \quad (4.2.4\text{-}5)$$

where ΔH_{cal} is an externally provided constant, representing the RA bias derived from a dedicated post-launch calibration campaign. P_0 is an externally provided table of atmospheric pressure updated at least daily. The validity of this pressure table is determined by searching for the table with validity date closest to the altimeter measurement date. If there is no table within T_{max} days of the measurement date, then an externally provided default value $P_{0,d}$ shall be used. The pressure values are converted to a height correction value compensating for the propagation delay in the dry gases of the atmosphere by multiplication by an externally supplied constant, K_{dry} A data-type conversion must also be performed as the pressure table is in `INTEGER*2` form.

ΔH_{wet} is a term compensating for propagation delays caused by tropospheric water vapour. This correction shall be derived from processing of the ATSR microwave radiometer data, as specified in Section 4.10. If no microwave radiometer are available then the default value $\Delta H_{wet,\,d}$ shall be used.

ΔH_{iono} compensates for propagation delays in the ionosphere. It shall be generated by an independent (CFE) software modules running during the fast-delivery processing. This module requires as input $F_{10.7}$ which is externally supplied from the MMCC, together with geodetic latitude and longitude, and the processed source packet time, from equation 4.5.2–2 of Section 4.5.2. The ionospheric correction module shall not be called for every source-packet, but once per N_s source-packets.

The standard deviation S_H is provided in the output product, and is compared to a threshold value ($t_{w,H}$). Exceeding this threshold results in a warning error message attached to the RA output product.

4.3 Significant Waveheight (SWH)

4.3.1 Variables

Name	Units	Type	Length	Source	Description
κ_1, κ_2	m^2, m^2	REAL*4	1, 1	MMCC	Return echo slope to σ_S conversion factors
$\sigma_S{}^G{}_{ref}$	m	REAL*4	32	MMCC	Prelaunch calibration values
TAB_S	m	REAL*4	256	MMCC	AGC correction table
s	#	BYTE*2	N	TM	Return echo slope
N	#	INT*2	1	TM	Number of measurement blocks
$t_{w,\,SWH}$	m	REAL*4	1	MMCC	Warning threshold SWH
$c_{1,SWH}$; $c_{0,SWH}$	–	REAL*4	1, 1	MMCC	Step size and offset of table $\sigma_S{}^G{}_{ref}$
$a_{1,SWH}$; $a_{0,SWH}$	–	REAL*4	1, 1	MMCC	Step size and offset of table TAB_S
m_s	–	REAL*4	1	MMCC	SWH slope correction factor
c_s	–	REAL*4	1	MMCC	SWH offset correction factor
$\overline{SWH}$	m	REAL*4	1		Mean of SWH
S_{SWH}	m	REAL*4	1		Standard deviation of SWH

If the source is not specified then the quantity is computed during the processing. Such internal variables are not all specified here. Furthermore indices are not identified and only locally identified in the specification (*ie* they are reused without implication on their usage within the algorithms).

4.3.2 SWH Algorithm

The telemetered return echo slope is tested for a zero value; if it equals zero then the block is discarded, adjusting the value N and issuing a warning in the output product. If not, the return echo slope s is converted to σ_S via the conversion factors κ_1 and κ_2:

$$\sigma_S(n) = \sqrt{\frac{\kappa_1}{s^2(n)} - \kappa_2} \qquad (4.3.2\text{–}1)$$

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The σ_S values are corrected with the pre-launch characterisation values:

$$\sigma_{S,cor}(n) = \sigma_S(n) - \sigma_S{}^G{}_{ref}[\mathrm{INTER}(\sigma_S(n), c_{0,SWH}, c_{1,SWH})] \qquad (4.3.2\text{–}2)$$

with $n \in [1, N]$. The σ_S value used as pointer to the table is given by equation 4.3.2–1.

With $\sigma°_1$ from equation 4.4.2–1, $\sigma_{S,cor}(n)$ is corrected as a function of $\sigma°$. This table is nominally zero, as a correction of this type was not considered necessary during pre-launch characterization. However the capability to include a $\sigma°$ -dependent correction is provided in case such a dependency is discovered during the flight operations.

$$\sigma_{S1}(n) = \sigma_{S,cor}(n) + \mathrm{TAB}_s[\mathrm{INTER}(\sigma°_1(n), a_{0,SWH}, a_{1,SWH})] \qquad (4.3.2\text{–}3)$$

The table TAB_S is nominally not updated, and is externally provided, together with the coefficients which map $\sigma°_1$ onto the allowed index range.

The conversion of σ_{S1} to SWH is accomplished by multiplication with a constant and a linear correction, according to:

$$S\hat{W}H(n) = m_s(4\sigma_{S1}(n)) - c_s \qquad (4.3.2\text{–}4)$$

No further corrections are applied to $S\hat{W}H$.

The RA FD-product Significant Waveheight is given as the mean and standard deviation according to:

$$\overline{SWH} = \frac{1}{N}\sum_{n=1}^{N} S\hat{W}H(n) \qquad (4.3.2\text{–}5)$$

$$S_{SWH} = \sqrt{\sum_{n=1}^{N} \frac{(S\hat{W}H(n) - \overline{SWH})^2}{(N-1)}} \qquad (4.3.2\text{–}6)$$

The standard deviation S_{SWH} is compared to a threshold value ($t_{w,SWH}$). Exceeding this threshold results in a warning error message attached to the RA output product.

4.4 Wind Speed (v)

4.4.1 Variables

Name	Units	Type	Length	Source	Description
A_C	dB	REAL*4	1		Smoothed internal calibration AGC correction
$A_{C,d}$	dB	REAL*4	1	MMCC	Default smoothed internal calibration AGC correction
ε	dB	REAL*4	1		Internal calibration AGC error
ε_d	dB	REAL*4	1	MMCC	Default internal calibration AGC error
α	–	REAL*4	1	MMCC	α filter coefficient
β	–	REAL*4	1	MMCC	β filter coefficient
A	dB	REAL*4	1		α correction term
B	dB	REAL*4	1		β correction term
x	dB	REAL*4	1		Estimated rate of change of calibration correction
x_d	dB	REAL*4	1	MMCC	Default rate of change of calibration correction
A_{TM}	dB	BYTE*2	N	TM	Automatic Gain Control (AGC)
P_V	–	REAL*4	1	MMCC	Conversion factor for A_{TM}
A^F	dB	REAL*4	1		AGC output from Open Loop Calibration
A^G_{ref}	dB	REAL*4	64×2	MMCC	Correction values for the integer and fractional part of AGC
H_{ref}	m	REAL*4	1	MMCC	Reference satellite altitude
H_0	m	REAL*4	1		Satellite altitude from orbit propagator
TAB_{A2}	ms^{-1}	REAL*4	256	MMCC	$\sigma°$ to wind conversion table
N	#	INT*2	1	TM	Number of measurement blocks
$c_{1,v}$; $c_{0,v}$	–	REAL*4	1, 1	MMCC	Step size and offset of table TAB_{A2}
$t_{w,v}$	–	REAL*4	1	MMCC	Warning threshold windspeed
$\bar{v}$	ms^{-1}	REAL*4	1		Mean of windspeed
S_v	ms^{-1}	REAL*4	1		Standard deviation of windspeed
δ_{AGC}	dB	REAL*4	1	MMCC	Ice-Ocean Adjustment Factor
ε_{SC}	–	REAL*4	1	MMCC	Telemetry scaling factor for discriminator value

If the source is not specified then the quantity is computed during the processing. Such internal variables are not all specified here. Furthermore indices are not identified and only locally identified in the specification (*ie* they are reused without implication on their usage within the algorithms).

4.4.2 Sigma-0 / Wind Speed Algorithm

The telemetered AGC values, consisting of 6 integer and 6 fractional bits, shall be converted to a compensated backscatter coefficient, $\sigma°_1$, in the following way:

1. The 6 bit integer AGC value (0 … 63) shall be used as pointer to the first dimension of a table, A^G_{ref}, having 64 entries. The referenced element of this table shall be called $\sigma°_{int}$.
2. The 6 bit fractional AGC value (0 … 63) shall be used as a pointer to the second dimension of table, A^G_{ref}, having 64 values. The referenced element of this table shall be called $\sigma°_{frac}$.
3. A linearised value of sigma-0, $\sigma°_{TM}$ shall be formed from the sum $\sigma°_{int} + \sigma°_{frac}$.

The values $\sigma°_{TM}(n)$ shall then be corrected with the smoothed inflight AGC correction A_C:

$$\sigma°_1(n) = \sigma°_{TM}(n) - A_C(i) \quad \text{(4.4.2-1)}$$

~~Note that the AGC discriminator value provided in the telemetry is multiplied by the externally provided scaling factor ε_{SC}.~~

$A_C(i)$ is obtained by smoothing the open-loop calibration data, from both Ocean and Ice Chirps, as follows. For each new value of open-loop calibration, A^F, calculate:

$$\varepsilon = A^F - A_C \quad \text{(4.4.2-2)}$$

$$A = \alpha\,\varepsilon \quad \text{(4.4.2-3)}$$

$$B = \beta\,\varepsilon \quad \text{(4.4.2-4)}$$

$$x(j) = x(j-1) + B \quad \text{(4.4.2-5)}$$

where A_C is the current value of $A_C(i)$, and the index i increments for each data-block during a continuous operation of the altimeter in ocean mode. It is not reset in each source packet, unlike n. The index j increments with each new value of A^F. Before the first value of A^F is available (at the start of the data-set) the quantity ε shall be set equal to an externally supplied default value ε_d. This condition shall be identified by a flag.

For every data-block, i, calculate the new value $A_C(i)$ from the equations:

$$A_C = A_C(i-1) + x(j) + A \quad \text{(4.4.2-6)}$$

The initial values of x and A_C shall be the default values x_d and $A_{C,d}$.

No atmospheric attenuation correction is made to $\sigma°_1$.

The satellite altitude value from the orbit propagator, H_0, shall be used for the correction of the $\sigma°_1$ value according to:

$$\sigma°(n) = \sigma°_1(n) - 30\log(H_{ref}/H_0) \quad \text{(4.4.2-7)}$$

If the mode is Ice Tracking, then an externally supplied parameter δ_{AGC}, the ocean-ice adjustment factor, shall be added to $\sigma°$.

From the $\sigma°$ value the wind speed $v(n)$ is extracted by an externally supplied model, in the form of a one-dimensional look-up table TAB_{A2}. This table is referenced by linear interpolation of nearest neighbours. The table has a nominal update rate of once per month.

$$v(n) = TAB_{A2}[\mathrm{INTER}(\sigma°(n), c_{0,v}, c_{1,v})] \quad \text{(4.4.2-8)}$$

The RA FD-product Wind Speed is given as the mean and standard deviation according to:

$$\bar{v} = \frac{1}{N}\sum_{n=1}^{N} v(n) \qquad (4.4.2\text{-}9)$$

$$S_v = \sqrt{\sum_{n=1}^{N} \frac{(v(n)-\bar{v})^2}{(N-1)}} \qquad (4.4.2\text{-}10)$$

The standard deviation S_v is compared to a threshold value ($t_{w,v}$). Exceeding this threshold results in a warning error message attached to the RA output product.

4.5 Localisation Algorithm

4.5.1 Variables

Name	Units	Type	Length	Source	Description
UTC	d	BYTE*24	1		UTC time
N_{PRI}	–	INT*2	1	MMCC	Number of PRI corrections
PRI	s	REAL*4	1	MMCC	Pulse repetition interval
T_H	s	REAL*8	1	MMCC	Time offset for height correction
$T_{H, LOC}$	s	BYTE*24	1		Processed source packet time
ϕ	rad	REAL*8	1		Processed source packet geodetic latitude
λ	rad	REAL*8	1		Processed source packet geographic longitude
$\dot{H}$	ms^{-1}	REAL*8	1		Altitude rate from orbit propagator
H_0	m	REAL*4	1		Altitude from orbit propagator

4.5.2 Localisation Algorithm

The time information defined by the satellite time code (ER-IS-DSF-0010, Figure 4.4.3.4–1, bytes 6 – 10) in the Source Packet Secondary Header shall be converted to UTC according to Reference Document 4. The resulting UTC value shall then be corected as follows:

$$T_2 = \mathrm{UTC} + N_{\mathrm{PRI}} \circ \mathrm{PRI} \qquad (4.5.2\text{–}1)$$

The applied correction ($N_{\mathrm{PRI}} \circ \mathrm{PRI}$) offsets the Source Packet datation so that T_2 corresponds to the transmision instant of the RA pulse (first measurement of block 10) exactly at the centre of the source packet.

To account for the propagation delay, as the satellite time refers to the RA pulse transmission instant, T_2 is corrected as follows:

$$T_{\mathrm{H,\,LOC}} = T_2 + T_{\mathrm{H}} \qquad (4.5.2\text{–}2)$$

Calculation of the localisation of FD products in terms of geodetic latitude / longitude shall be performed using the orbit propagator model (see Reference Document 3), the orbit state vector supplied from the DPMC and with the time $T_{\mathrm{H,\,LOC}}$.

Additionally $\dot{H}$ and H_0 shall be computed from the orbit propagator at time $T_{\mathrm{H,\,LOC}}$.

4.6 Open Loop Calibration

4.6.1 Variables

Name	Units	Type	Length	Source	Description
κ_1	TM Units	REAL*8	1	MMCC	Time delay reference value for open loop calibration
κ^I_1	TM Units	REAL*8	1	MMCC	Time delay reference value for Ice Chirp open loop calibration
κ_4	–	REAL*4	1	MMCC	Power reference value for open loop calibration
κ^I_4	–	REAL*4	1	MMCC	Power reference value for Ice Chirp open loop calibration
k_f	TM Units	REAL*8	1	MMCC	Conversion factor from the FFT filter spacing to time units
k^I_f	TM Units	REAL*8	1	MMCC	Conversion factor from the FFT filter spacing to time units, for Ice Chirps
MWA	–	INT*2	64	TM	Waveform Samples
τ^F_{ref}	TM Units	REAL*8	1		Calibration height correction value
A^F	dB	REAL*4	1		Calibration $\sigma°$ correction value

If the source is not specified then the quantity is computed during the processing. Such internal variables are not all specified here. Furthermore indices are not identified anmd only locally identified in the specification (*ie* they are reused without implication on their usage within the algorithms)

4.6.2 Open Loop Calibration Algorithm

4.6.2.1 Open Loop Time Delay and σ° Calibration (Ice chirp mode)

The open loop calibration waveform is a Single Point Target Response (SPTR). When this is generated using the ice chirp it is used to generate time delay and σ° correction values:

$$\tau^F{}_{ref} = (N_f - 32)\, k^I{}_f + \kappa^I{}_1 \qquad \textbf{(4.6.2-1)}$$

where

$$N_f = (z_2 - z_1)(x^2{}_1 - x^2{}_3) - (z_3 - z_1)(x^2{}_1 - x^2{}_2) \,/\, 2[(x_2 - x_1)(z_3 - z_1) - (x_3 - x_1)(z_2 - z_1)\,] \qquad \textbf{(4.6.2-2)}$$

where x_1, x_2 and x_3 are three contiguous, consecutive indices of $MWA(x)$ which hold the maximum values of MWA (typically x_2 will hold the maximum value, and x_1 and x_3 will be the adjacent values on each side—however either x_1 or x_3 could be equal to x_2). The range of x is from 0 to 63. Note that the MWA values in the telemetry need to be re-ordered to obtain the range 0... 63, as the telemetry order is:

32, 33, 34... 63, 0, 1... 31

The values of z_1, z_2 and z_3 are then obtained from:

$$z_1 = \ln\,(\mathrm{MWA}(x_1)) \qquad \textbf{(4.6.2-3)}$$

$$z_2 = \ln\,(\mathrm{MWA}(x_2)) \qquad \textbf{(4.6.2-4)}$$

$$z_3 = \ln\,(\mathrm{MWA}(x_3)) \qquad \textbf{(4.6.2-5)}$$

and

$$A^F = 10\log\left\{\frac{\sum_{i=1}^{63} MWA(i)}{\kappa_4^I}\right\} \qquad \textbf{(4.6.2-6)}$$

where $\kappa^I{}_4$ is an externally supplied parameter.

Note that the values MWA shall be derived from the telemetry values of FFT samples by dividing the telemetry data by the fixed constant 32.

4.6.2.2 Open Loop Time Delay and σ° Calibration (Ocean chirp)

When the open loop SPTR waveform is generated with an ocean chirp, then time delay and σ° corrections are generated, as follows:

$$\tau^F{}_{ref} = (N_f - 32)\, k_f + \kappa_1 \qquad (4.6.2\text{–}7)$$

where

$$N_f = (z_2 - z_1)(x^2{}_1 - x^2{}_3) - (z_3 - z_1)(x^2{}_1 - x^2{}_2) \;/\; 2[(x_2 - x_1)(z_3 - z_1) - (x_3 - x_1)(z_2 - z_1)\,] \qquad (4.6.2\text{–}8)$$

where x_1, x_2 and x_3 are three contiguous, consecutive indices of MWA(x) which hold the maximum values of MWA (typically x_2 will hold the maximum value, and x_1 and x_3 will be the adjacent values on each side—however either x_1 or x_3 could be equal to x_2). The range of x is from 0 to 63. Note that the MWA values in the telemetry need to be re-ordered to obtain the range 0... 63, as the telemetry order is:

32, 33, 34... 63, 0, 1... 31

The values of z_1, z_2 and z_3 are then obtained from:

$$z_1 = \ln(\mathrm{MWA}(x_1)) \qquad (4.6.2\text{–}9)$$

$$z_2 = \ln(\mathrm{MWA}(x_2)) \qquad (4.6.2\text{–}10)$$

$$z_3 = \ln(\mathrm{MWA}(x_3)) \qquad (4.6.2\text{–}11)$$

and

$$A^F = 10\log\left\{\frac{\sum_{i=1}^{63} MWA(i)}{\kappa_4}\right\} \qquad (4.6.2\text{–}12)$$

where κ_4 is an externally supplied parameter.

Note that the values MWA shall be derived from the telemetry values of FFT samples by dividing the telemetry data by the fixed constant 32.

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4.7 Product Confidence Checks (Peakiness)

4.7.1 Variables

Name	Units	Type	Length	Source	Description
MWA	–	INT*2	64	TM	Waveform Samples
N	–	INT*2	1	TM	Number of measurement blocks
$t_{w,PP}$	–	REAL*4	1	MMCC	Warning threshold peakiness
PP	–	REAL*4	1		Peakiness

If the source is not specified then the quantity is computed during the processing. Such internal variables are not all specified here. Furthermore indices are not identified and only locally identified in the specification (*ie* they are reused without implication on their usage within the algorithms).

4.7.2 Peakiness Algorithm

From the tenth set (out of the 20 in the source packet) of MWA samples the total and the maximal power are calculated:

$$I = \sum_{i=1}^{64} MWA(i) \qquad (4.6.2\text{-}1)$$

$$P = \max\{\mathrm{MWA(i)}\} \qquad i \in [1 \ldots 64] \qquad (4.6.2\text{-}2)$$

The Peakiness parameter is then given by:

$$PP = 31.5\frac{P}{I} \qquad (4.6.2\text{-}3)$$

The value of PP is compared to a threshold value $t_{w,\,PP}$. Exceeding this value results in a warning message attached to the RA output product.

4.8 Processed Data

4.8.1 Variables

Name	Units	Type	Length	Source	Description
N_0	–	INT*2	1	MMCC	Minimum number of Tracking Mode blocks

4.8.2 Processed Data Algorithms

The relevant data blocks to be processed within the Ocean and Ice Tracking mode source packets are identified by bits within the "Mode and Status Identifier" (bytes $n + 0$ and $n + 1$ of the Auxiliary Data Blocks, ref: ER-IS-DSF-SY-0010, Figure 4.4.3.4–5).

4.8.2.1 Open Loop Calibration Data Blocks

If the bits 7 and 10 are set equal to 1 then Section 4.6.2.1 is applicable.

If the bit 7 is set equal to 1 and bit 10 is 0 then Section 4.6.2.2 is applicable.

The open loop calibration processing is performed only if the corresponding source packet was received without parity error nor frame checksum error, otherwise it is discarded.

4.8.2.2 Ocean Tracking Mode Data Blocks

If any of the bits 0, 2 or 4 are set equal to 1, and bit 7 is not set, then all processing steps specified for Ocean Tracking Mode are applicable.

If any of the bits 1, 3 or 5 are set equal to 1, and bit 7 is not set, then all processing steps specified for Ice Tracking Mode are applicable.

The processing is performed only if the number, N, of valid Tracking Mode data blocks found within one source packet is equal or greater than an externally defined value N_0, otherwise the corresponding product record shall be flagged.

4.8.2.3 Complementary Explanations and Requirements

The RA automatically activates, at typical intervals of 30 s, the open loop calibration mode, alternating between the two chirp types (ocean and ice). The open loop calibration result is reported in a fixed position in the source packet, in the second data block. The preceeding and following data blocks shall be discarded.

4.9 Error Handling

4.9.1 Variables

Name	Units	Type	Length	Source	Description
TINT	ms	INT*4	1	MMCC	Time interval between 2 consecutive source packets in tracking mode
TDELTA	ms	INT*4	1	MMCC	Half window size around the packet time interval

4.9.2 Error Handling Procedures

The following rules specify the actions to be taken in case of erroneous data at both the RA processing inputs, and at the RA FD product level.

4.9.2.1 Assumptions and Definitions

The RA raw data file may contain RA source packets with overlapping time sequences, obsolete packets, parity or checksum errors. For the RA processing input a source packet is invalid if:

- it contains BOTH parity and checksum errors;
- a SYNC error was detected during its transfer;
- it was not generated by the RA (*ie* switch-off or not received packet).

A source packet is valid if it is not invalid.

A valid source packet may contain parity or checksum errors but not both. A RA FD product shall always contain 77 data set records, equally spaced in time, by about 0.98 s. Blank data set records shall be inserted as needed to ensure this spacing as well as the correct number of records per product.

4.9.2.2 Data File Handling and Processing

Assuming request of FD RA products generation between times t_1 and t_2 (UTC time) the following rules apply:

The RA processing shall start with the first valid, error-free packet having a satellite time (after conversion to UTC) equal or greater than t_1. Let t be the time of this packet. At this stage the processing is defined as being "synchronised".

If t is greater than t_1, blank records spaced by 0.98 s, and if necessary, blank products will be generated to fill the gap.

After synchronisation the expected value for the next acceptable packet will be:

- expected time = last accepted time + TINT (±TDELTA);
- expected packet sequence counter = last value + 1.

The raw data file shall be read until either:

1. There is a valid packet which has the expected values (see Note 1);
2. There is an error-free, valid packet with time exceeding the expected time;
3. There are no more packets in the file.

In the case of 1 or 2 this packet shall be used to compute the expected value of time and packet sequence counter for the next one.

Note 1: A non-error-free valid packet shall be accepted only if both its time and packet sequence counter fit with the expected values;

Note 2: Such a rule shall filter the acquisition mode packets in order to maintain data set records stored at 0.98 s intervals, while indicating the reason for these blank records (*eg* acquisition, time gap *etc*).

Create blank data set records as necessary, at 0.98 s intervals, to cover the time gap between time-ordered valid packets.

A blank data record has the same structure as a normal data set record with the only valid data being the UTC time, localisation and the instrument mode ID byte. Bit 8 of this byte shall be set to indicate when blank data set records have been createdto fill a time gap on the raw data file. All the other bytes of the blank data set record shall be set to the value 1.

A blank product is a collection of 77 consecutive data set records.

If a valid packet is selected, but does not have either Ocean or Ice Mode Tracking packet ID then a blank data record shall be created, in the same format as above, the second byte of the source packet ID being reproduced as the instrument mode ID within the blank data record.

If a valid packet is selected and contains an Ocean or Ice Mode packet ID then this packet shall be processed according to Section 4.8. If this packet is not error-free then calibration values contained in the auxiliary data of the source packet shall be ignored.

The processing is terminated upon the following conditions:

- The first validpacket processed with a time greater or equal to t_2;
- No more packets available in the raw data file.

If, at termination, a product contains less than 77 data set records then it shall be filled with blank data set records.

4.10 Microwave Radiometer

4.10.1 Variables

Name	Units	Type	Length	Source	Description
T_r	K	REAL*4	1	TM	Temperature of the waveguide in the main antenna circuit
T_{ref}	K	REAL*4	1	TM	Reference load temperature
T_d	K	REAL*4	1	TM	Dicke circulator temperature
T_{cal}	K	REAL*4	1	TM	Calibration circulator temperature
T_{hc}	K	REAL*4	1	TM	Hot/Cold circulator temperature
T_c	K	REAL*4	1	TM	Hot load temperature
R_{ant}		REAL*4	1		Antenna temperature
RE		REAL*4	1		Residual in main antenna circuit
T_{cc}	K	REAL*4	1	TM	Skyhorn temperature
T_h	K	REAL*4	1	TM	Temperature of the waveguide in the skyhorn circuit
C_{hot} C_{off} C_{cold} C_{ant}		REAL*4	1	TM	Radiometric counts for the Hot load/Offset/Sky horn/ Antenna
ϕ'		INT*4	1		Latitude related integer
θ		REAL*4	2	MMCC	Efficiency in the principal antenna's main lobe
T_{ls}		REAL*4	2×19	MMCC	Table of mean temperatures detected by the secondary lobes in the main antenna
a		REAL*4	24	MMCC	Temperature related coefficients
b		REAL*4	6	MMCC	Temperature related coefficients
c		REAL*4	2	MMCC	Temperature related coefficients
T_0		REAL*4	1	MMCC	Sky horn temperature including secondary lobe contribution
$T_{i,j}$		REAL*4	4×32	MMCC	Reference temperatures for conversion in K degrees
k		REAL*4	1	MMCC	Coefficient for temperature conversion
TINT	ms	INT*4	1	MMCC	Time interval between 2 consecutive altimeter source packets in tracking mode

If the source is not specified then the quantity is computed during the processing. Such internal variables are not all specified here. Furthermore indices are not identified and only locally identified in the specification (*ie* indices are reused at various places in the specification without implication on their usage within the algorithms)

The telemetry data refered to in the table as separate variables of type REAL*4 are in fact telemetered as a series of INTEGER values. The REAL*4 type and identification as individual variables is the state after the conversion to temperature (in units of Kelvin degrees) which is described in the next section.

6, 9, 22, 25
from ref (Tref)
and ambient (T_c) loads

!! [Cal & Ref resistances not checked and filtered as in T.N. 45]

[Eq 4.7.2-3 should not be done for elements 3, 4, 19, 20] !!

If NOT ←
what happens?

TN-32

4.10.2 Water Vapour Correction Algorithm

The instrument temperature data in the telemetry shall be first converted into Kelvin degrees, as follows.

Each temperature measurement is performed through precise measurement of platinum PT100 resistances. Four of the thirty two successive (one every 150 ms) temperature measurements are calibration measurements of reference values which serve to reduce errors due to drift of the resistance measurement system. These four calibration resistances are elements 3, 4, 19 and 20 of the 32 elements in a frame.

For the telemetered (resistance/ temperature) values, $R(i)$, $i = 1\ldots32$, the following operations shall be performed for the aforementioned conversion.

1. Correction for bias due to time constant of measuring system when large differences of temperature occur between two consecutive measurements:

$$R(i) = R(i) + k[R(i) - R(i-1)] \qquad i = 2\ldots32 \tag{4.7.2-1}$$

$$R(1) = R(1) + k[R(1) - R(32)] \tag{4.7.2-2}$$

2. Conversion of resistance values, $R(i)$, to temperature, $T(i)$:

$$T(i) = \frac{R(i) - R(j)}{R(j+1) - R(j)}[T_{i,j+1} - T_{i,j}] + T_{i,j} \qquad i = 1\ldots3 \tag{4.7.2-3}$$

where j is chosen so that $R(j) < R(i) < R(j+1)$ with $j = 1\ldots4$ corresponding to the four calibration measurements.

$T_{i,j}$ is the reference temperature for resistance i which is the temperature at which the measured resistance of i is equal to the reference resistance j.

$T(i)$ is the temperature in degrees Kelvin corresponding to data $R(i)$.

In the following equations the left subscript i indicates one of the two channels: the 24 GHz channel or the 36 GHz channel. First the Brightness Temperature, ${}_iTB$, is computed by:

$${}_iTB = \frac{[{}_iR_{ant} - (1 - {}_i\theta) \times {}_iT_{ls}(\phi')]}{{}_i\theta} \tag{4.7.2-4}$$

$$R_{ant} = {}_ic_1 \times {}_iR_{pa} - {}_ic_2 \times {}_iT \tag{4.7.2-5}$$

$${}_iR_{pa} = {}_ib_1 \times {}_iT_{ref} + {}_iRE - \frac{{}_iC_a}{{}_ig} + {}_ib_2 \times T_d - {}_ib_3 \times {}_iT_{cal} + {}_ib_6 \times T_{hc} - {}_ib_4 \times {}_iT_c \tag{4.7.2-6}$$

where

$${}_iC_a = {}_iC_{ant} - {}_iC_{off}$$

And the gain g is determined as follows:

$${}_ig = \frac{{}_iC_{cold} - {}_iC_{hot}}{{}_ia_0 - {}_iR_1} \tag{4.7.2-7}$$

$${}_iR_1 = {}_ia_f \times T_{fc} + {}_ia_h \times {}_iT_{hc} - {}_ia_c \times {}_iT_c \tag{4.7.2-8}$$

$$ {}_iRE = \frac{{}_iCC}{{}_ig} - [{}_ib_1 \times {}_iT_{ref} + {}_ib_2 \times T_d - {}_ia_2 \times T_{fc} - {}_ia_3 \times T_{hc} - {}_ia_6 \times {}_iT_{cal} - {}_ia_4 \times {}_iT_c - {}_ia_5] \quad \textbf{(4.7.2-9)} $$

$$ {}_iCC = {}_iC_{hot} - {}_iC_{off} \quad \textbf{(4.7.2-10)} $$

ϕ' is a latitude dependent variable and is chosen as the largest integer in the interval [1...18] so that $(\phi' - 9) \times 10 > \phi$, where ϕ is the true latitude from the orbit propagator.

The temperature T_{fc} is:

$$ {}_iT_{fc} = T_0 + {}_ia_l \times T_{cc} + {}_ia_h \times T_h \quad \textbf{(4.7.2-11)} $$

T_0 is determined from a supplied table (2×19) giving predetermined latitude dependant values of the sky temperature including the side lobe contributions. ϕ' allows to select the value for T_0 from this table.

The correct registration of the Brightness Temperature values, *TB*, to compensate for the view angles of the antenna beams, which are not precisely nadir viewing, and to align the values of *TB* with the altimeter source packets, requires further evaluation, as follows.

The results of the processing specified above are a series of *TB* values associated with times corresponding to the sub-satellite position. The two values of *TB*, one for each frequency, correspond to positions ahead of and behind the sub-satellite point. The separation from the sub-satellite point is given by $H\tan({}_i\psi)$, where ${}_i\psi$ is a pair of externally supplied parameters, and H is provided by the orbit propagator.

The value of *TB* for each frequency shall be computed by averaging together all the individually located *TB* values which pass through the sub-satellite point during the interval TINT (the RA source packet duration) centred on the time $T_{H,\,LOC}$.

The averaged Brightness Temperatures, *TB*, is then used to determine the wet tropospheric correction ΔH_{wet}.

$$ \Delta H_{wet} = 230.8 - 72.85 \times \ln(290 - TB_{24}) + 28.79 \times \ln(280 - TB_{36}) \quad \textbf{(4.7.2-12)} $$

5 VERIFICATION REQUIREMENTS

Besides the standard procedures as identified, for example, in the ERS–1 software standards (Reference Document 2: ER-RS-DSF-SY-0010) the functional performance of the Low Rate Processor shall be verified by means of simulated RA raw data, provided externally. The data formats shall comply with Reference Document 2: ER-RS-DSF-SY-0010 and the data content shall be as expected from the satellite.