isardSAT

S6 P4 Numerical retracker

– Algorithms Technical Baseline Description –

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Control Document

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Table of contents

List of Figures

List of Tables

List of Symbols

Indexes:

i	Beam number
l_i	Beam index
j	Two-way incremental time index
t_j	Two-way incremental time
t'_j	Two-way incremental time after delay compensation
b'_i	Index of the beam pointing to a specific surface

Variables, constants and functions:

α	Earth curvature
c	Light Velocity
$\delta\theta_{look}$	Angular Doppler resolution
δt_{l_i}	Time delay applied to beam l_i
e_{meas}	Noise floor of the measured multilooked power waveform
e_{model}	Noise floor of the modelled multilooked waveform
G_0	Boresight antenna gain
γ	Beamwidth parameter
$\mathrm{H}_{\mathrm{mask}}(t'_j, l_i)$	delay/Doppler mask matrix
H_s	Significant wave height
j_0	First range gate considered in the fitting
j_L	Leading edge sample
j_N	Range gate before leading edge with notable power increase
j_P	Range gate closest to leading edge with a power peak
k_0	Epoch
θ_p, α_r	Mispointing angles
$\boldsymbol{\theta}$	Three-dimensional parameter vector
θ_{3dB}	Half-power antenna beamwidth

θ_{look}	Look angles
$\boldsymbol{\theta}_0$	Initial guess of the geophysical parameters estimates vector
θ_{look,b'_i}	Look angle of the i-th beam pointing to a specific surface
λ_s	Ocean skewness
λ	Radar wavelength
h	Satellite altitude
N_s	Number of range samples (non zero-padded)
N_p	Number of pulses per burst
N_{eff}	Number of effective looks
OS_AL	Oversampling along track
OS_AC	Oversampling across track
P_u	Waveform amplitude
$P(t_j, l_i)$	Power waveform at time t_j and Doppler index l_i
$p(t_j)$	Probability density function of the heights at time t_j
$\mathrm{P_{FSIR}}(t_j, l_i)$	Flat surface impulse response at time t_j and Doppler index l_i
$\mathrm{P_I}(t_j, l_i)$	Average surface impulse response at time t_j and Doppler index l_i
$\mathrm{P_{PTR}}(t_j, l_i)$	Point target response at time t_j and Doppler index l_i
$\mathrm{P_{DC}^{mask}}(t_j, l_i)$	Power waveform after delay compensation and masking
$\mathrm{P_{AIR}}(l_i)$	Azimuth point target response
$\mathrm{P_{RIR}}(t_j)$	Range point target response
$\mathrm{P_{DC}}(t'_j, l_i)$	Waveforms forming the stack after delay compensation
PRF	Pulse repetition frequency
PRI	Pulse repetition interval
R	Earth's radius
r_j	Residual of the optimisation function
$\rho(t_j)$	Range projected on the surface
$\rho_L(\cdot)$	Loss function
$s_j \equiv s(t'_j)$	Noise-free modelled multilooked waveform
$\tilde{s}(t'_j)$	Noisy modelled multilooked waveform
σ_s	Root mean square height relative to the mean sea level
σ^0	Normalized backscatter radar cross section

t	Two-way incremental time
T_s	Sampling period
$\dot{U}(\cdot)$	Heaviside function
$\boldsymbol{v}_s$	Satellite velocity vector
y_{t_j,l_i}	Along track distance at time t_j and Doppler look l_i
ZP	Zero padding factor
ϕ_{t_j,l_i}	Azimuth angle at time t_j and Doppler index l_i
ψ_j	Measured power waveform at sample j
ψ_{max}	Maximum power of the measured power waveform

1 Introduction

1.1 Scope of the document

This document contains the theoretical description and implementation of a numerical retracker performed as part of the WP160 of the CCN #6 [AD. 2] of the contract Poseidon-4 Ground Processor Prototype [AD. 3].

The scope of this document is to describe the algorithms technical baseline of the retracker for Poseidon-4 (P4), the Sentinel-6 (S6) mission altimeter.

1.2 Acronyms

AIR	Azimuth impulse response
CAL1	Calibration file
DDP	delay/Doppler Processing (usually written as SAR processing)
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
ESA	European Space Agency
FFT	Fast Fourier Transform
GMSL	Global mean sea level
HR	High Resolution (referred to the DDP products)
L1B	Level-1B. Output file with fully calibrated multilooked unfocussed SAR power echoes for HR
LSQ	Least-squares
LUT	Look-up-table
MSE	Mean square error
P4	Poseidon-4
PDAP	Payload Data Acquisition and Processing
PRI	Pulse Repetition Interval
PTR	Point Target Response
PRF	Pulse Repetition Frequency
RIR	Range Impulse Response

RMS	Root-mean-square
SSH	Sea surface height
S6	Sentinel-6
SAR	Synthetic Aperture Radar
UTC	Universal Time Coordinated
ZP	Zero Padding

1.3 Reference

Unless stated otherwise, the latest issue of the documents at the date of the issue of this document is valid. The valid issue of the documents is recorded in the document status list. In the following, each document item consists of 3 entries: bookmark ID (specific to this document), document title.

1.3.1 Applicable documents

AD. 1 Sentinel-6 P4 L1 GPP - Algorithm Technical Baseline Description. JC-DS-ISR-SY-0013, issue 7.a, 6 November 2019.

AD. 2 Contract Change Notice No. 6 to Contract No. 4000112536/14/NL/BJ

1.3.2 Reference documents

Nelder, J. A. and Mead, R. (1965). A Simplex Method for Function Minimization. *Comput. J.*, 7:308–313.

Ray, C., Martin-Puig, C., Clarizia, M. P., Ruffini, G., Dinardo, S., Gommenginger, C., and Benveniste, J. (2015). SAR altimeter backscattered waveform model. *IEEE Transactions on Geoscience and Remote Sensing*, 53(2):911–919.

1.4 Assumptions

In the following sub-section we provide a list of further assumptions used in the development of this software.

1.4.1 L1B input products

The L1B input files used by the retracker are listed and defined in §2.1.

1.4.2 Auxiliary files

The software configuration and constant files shall be managed by the user. The instrument characterisation file shall be defined by the instrument team. The list of auxiliary files used by the software is provided in §2.3

1.5 Conventions and remarks

1.5.1 Scope of sections

Each of the algorithms described in this document follows the same general structure. The purpose and scope section gives a brief description of the algorithm, followed by a data block diagram that shows the main steps that are performed. The mathematical description included in each algorithm provides a description of the algorithm in mathematical terms. The terminology used in the mathematical description is usually generic and uses mathematical symbols. After that, the input and output variables destination is provided in order to ease the understanding of the whole chain.

1.5.2 Block diagrams legend

All the block diagrams have the same legend, for the sake of clarity. The legend is shown in Figure 1-1.

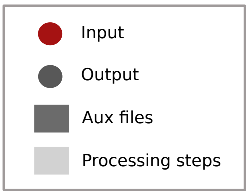

Figure 1-1: Colour and symbols diagram legend.

1.5.3 Product types

The different product types according to their level of processing are:

- L1B HR: Fully calibrated and geolocated power echoes.
- CAL1 L1B Pulse CAL, CAL1 L1B SAR: output of calibration processor
- L2 HR: output ocean geophysical retrievals not corrected for atmospheric and geophysical effects.

2 Input files description

This section contains the description and reference of all the input data files. These files can be divided in:

- L1B products
- Calibration products
- Auxiliary files

The following chapters provide a list of the input files with a brief description, and Table 2-1 below indicates for each input file if it is mandatory or optional.

Table 2-1: Input data list of the retracker

Data	
L1B HR	Mandatory
CAL1 L1B Pulse CAL	Optional
CAL1 L1B SAR	Optional
Characterisation file	Mandatory
Retracker configuration file	Mandatory
Constant file	Mandatory

2.1 L1B products

2.1.1 L1B HR product

The L1B HR product is the final output of the L1 HR processor. It contains geo-located and fully calibrated multilooked High Resolution power echoes in Ku-band.

2.2 Calibration products

2.2.1 CAL1 L1B Pulse CAL product

The CAL1 L1B Pulse CAL is the output of the Pulse CAL Processor. It contains oversampled CAL1 power waveforms along the orbit for Ku-band.

2.2.2 CAL1 L1B SAR product

The CAL1 L1B SAR is the output of the CAL1 SAR Processor. It contains an oversampled CAL1 power waveforms for Ku-band.

2.3 Auxiliary files

2.3.1 Characterisation file (CHD)

The characterisation file contains the system on-ground characterisation.

2.3.2 Retracker Configuration file (CNF)

The configuration file contains all processing parameters, which can be modified by the user.

2.3.3 Constants file (CST)

The constants file contains the main physical constants used by the processor.

3 Auxiliary data selection

This section describes the procedures to select the right set of the parameters of the different calibration files.

3.1 CAL1 L1B selection

3.1.1 Purpose and scope

The purpose of this algorithm is to select the impulse response stored in CAL1 L1B products according to the processing flags defined in the retracker configuration file.

3.1.2 Data block diagram

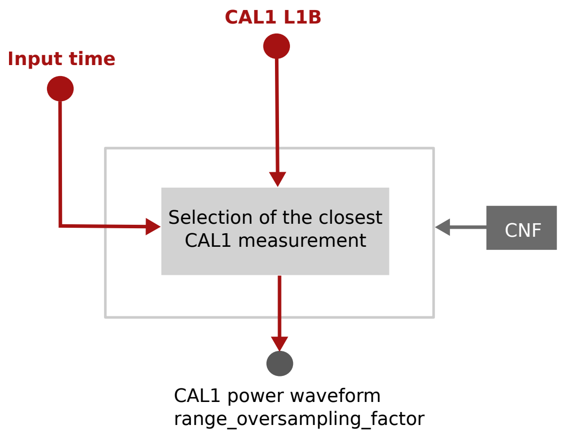

Figure 3-2: CAL1 Pulse CAL selection block diagram. CAL1 SAR products contain a sole measurement.

3.1.3 Mathematical description

The processor will check the `PTR_type_ac` retracker configuration flag to select the type of impulse response in range (RIR). If it is set to `'numerical'`, then follow the next steps.

The source is defined by the user in the `run_` file. The processor will check whether this source corresponds to a CAL1 L1B Pulse CAL or a CAL1 L1B SAR product. If a Pulse CAL file is detected, then for each altimeter time tag (in UTC), the selected values corresponds to the closest CAL1 time tag (in UTC) from the L1B Pulse Cal processing product. Alternatively, a sole measurement is stored in the CAL1 product, and this is the one selected.

3.1.4 Input variable list

Table 3-2: Input variable list of the Auxiliary data selection

Field name	Description	Units	Type
time_l1b	Time in UTC of the L1B HR product	s	double
time_l1CAL	Time in UTC of the CAL1 L1B product	s	double
PTR_type_ac	String indicating the PTR across track used for the convolutional model: 'analytical' (sinc), 'numerical'	–	string

3.1.5 Output variable list

Table 3-3: Output variable list of the Auxiliary data selection

Field name	Description	Units	Type
index_from_l1CAL	Array of indices of the CAL1 time vector closest to the L1B HR time vector	–	int
cal1_power_waveform	The CAL1 waveform corresponding to the current index_from_l1CAL index, converted to Watt via waveform_scale_factor	W	double
range_oversampling_factor	Oversampling factor applied to the CAL1 waveform	–	int

4 Numerical retracker

4.1 Introduction

Cite like this (Ray et al., 2015) or (Ray et al., 2015; Nelder and Mead, 1965)

4.2 Pre-processing

4.2.1 Purpose and scope

The objective of this processing step is to generate...

4.2.2 Block diagram

The block diagram depicted in Figure 4-3 illustrates the main pre-processing steps.

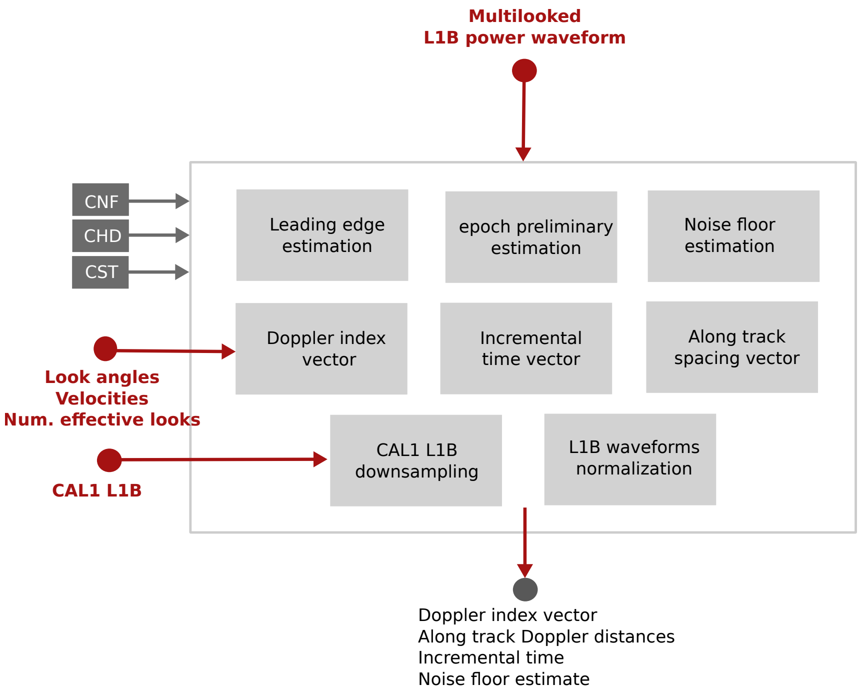

Figure 4-3: Pre-processing block diagram.

4.2.3 Mathematical description

4.2.3.1 Leading edge estimation

An estimate of the leading edge...

4.2.3.2 Incremental time

The two-way incremental ranging time vector t, dependent on the epoch k_0, is equally spaced and ranges from

$$t_0 = \left(-\left(N_s - \frac{N_s}{2}\right)\mathtt{ZP} + \left(\frac{Ns \cdot \mathtt{ZP}}{2} - k_0\right)\right) \cdot \frac{T_s}{\mathtt{ZP}} \tag{4-1a}$$

to

$$t_{N_s \cdot \mathtt{ZP} \cdot \mathtt{OS\_AL} - 1} = \left(\left(N_s - \frac{N_s}{2}\right)\mathtt{ZP} + \left(\frac{Ns \cdot \mathtt{ZP}}{2} - k_0\right)\right) \cdot \frac{T_s}{\mathtt{ZP}} \tag{4-1b}$$

where ...

4.2.4 Input variable list

4.2.5 Output variable list

Annex A. Flat surface impulse response with non-zero mispointing

A.1 Purpose and scope

A.2 Mathematical description

End of document