ENVISAT RA-2 AND MWR PRODUCTS AND ALGORITHMS USER GUIDE

J. Benveniste and M.P. Milagro
ESA / ESRIN

Table of Content

1 SCOPE

The present document is a brief guide for users to the Envisat 2nd generation Radar Altimeter (RA-2) and Microwave Radiometer (MWR) engineering (Level 1B) and geophysical (Level 2) Products and Algorithms. Its immediate purpose is to convey basic information to users. The RA-2/MWR Product Handbook, which is now being drafted, will contain full details of the information needed by the users to exploit the RA-2/MWR data products.

Section 2 is devoted to a brief overview of the two instruments, RA-2 and MWR.

Sections 3 and 4 of the guide describe the RA-2 and MWR products tree and the products layout.

Section 5 describes the overall RA-2 and MWR processing chain concept. It introduces the main algorithms in the processing chain.

2 INSTRUMENTS OVERVIEW

2.1 Second Generation Radar Altimeter (RA-2)

The RA-2 is a nadir looking pulse limited radar altimeter that measures with centimetrique precision the distance to the target below, be it land, ice, ocean... knowing the orbital altitude of the spacecraft, the altitude of the target is derived. From the shape and power of the echoes of the transmitted pulses, the wave heights and wind speed can be derived over ocean and surface parameters can be derived over land. It is designed on the heritage of ERS with significant improvements. In addition to the main frequency (13.575 GHz - Ku-Band), a second channel (3.2 GHz - S-Band) is operated to estimate ionospheric propagation delay and for geophysical applications. At the main operative frequency, the RA-2 will autonomously detect, acquire, lock-on and track the earliest echoes. The width (3 chirp bandwidths are available), position and gain of the tracking window will be automatically controlled to maintain the leading edge within the window. The RA-2 instrument can be operated in different modes that can be classified in two major classes: the support modes (including modes such as off-mode, Reset/Wait mode,...), used during instrument initialization and failure recovery procedures, and to perform preliminary tests; and the operation modes which include the Measurement mode, the RF and Digital BITE, and the IF calibration mode. Another novel feature is that RA-2 is also capable of collecting individual echoes (before the on-board averaging).

2.2 Microwave Radiometer (MWR)

The microwave radiometer is also a heritage from the ERS MWRs. It has two channels at 23.8 and 36.5 GHz. It is a nadir pointing sensor, which is aimed at the correction of the altimeter wet-tropospheric path delay. It also provides the water vapor and liquid water content along the satellite track. This is done by receiving and analysing the upwelling radiation from nadir at these two frequencies.

Each channel operates in Dicke mode, comparing the antenna temperature to an internal reference temperature at a switching frequency of 1 KHz. The output signal from the synchronous detector is integrated and sampled every 150 ms and transmitted to the ground as a numerical count, together with the reference load temperature and various internal temperatures. The two-point internal calibration is achieved by connecting the receiver input either to a sky horn receiving the cold sky background temperature or to an internal reference load. Antenna temperatures are derived, from the numerical counts and the calibration data, and corrected for side lobes contributions to produce brightness temperatures for both channels.

3 RA-2 AND MWR PRODUCTS OVERVIEW

The RA-2 and MWR Products Tree is shown in figure #1. The figure shows the input/output integration among the different RA-2/MWR products and the relationship of the RA-2 processing chain with the MWR, as well as the availability of auxiliary data, including the DORIS products.

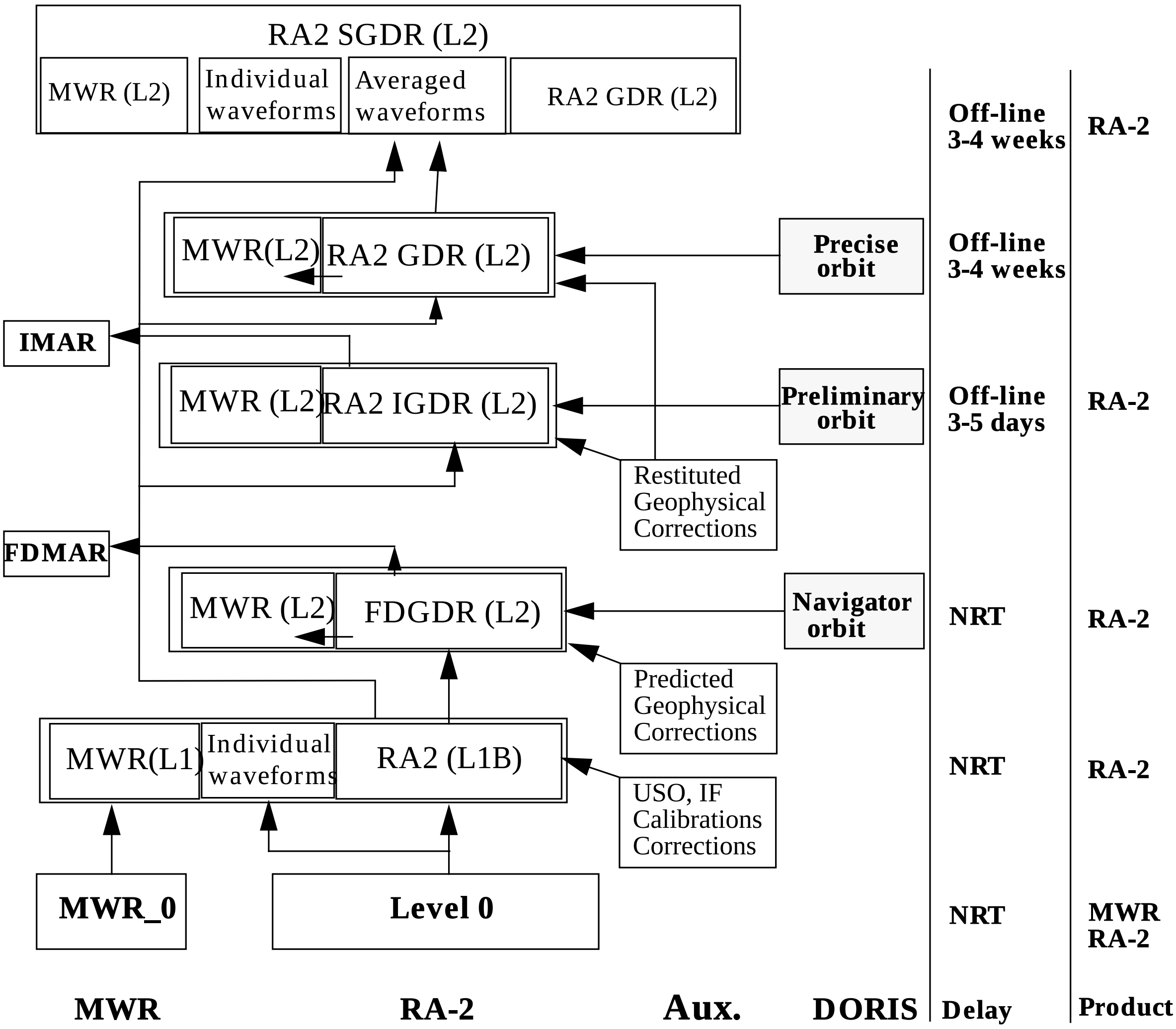

Fig. 1: Structure of RA-2 and MWR Products Tree

3.1 RA-2 Products

3.1.1 Level 0

Level 0 is the raw data generated from the data stream of demultiplexed downlinked Instrument Source Packets. The Level 0 product is a stream of RA-2 source packets. The time overlaps and similar artifacts are removed in near real time, although they may still contain gaps. This product is consolidated off-line.

3.1.2 Level 1B

The Level 1B product is a conversion of the Level 0 product to a product presented in calibrated engineering units, in which all of the steps demanding a detailed knowledge of the instrument itself have been performed. These steps include decoding the source packet, applying characterisation and calibration data, computing the time-tag in UTC and presenting the instrument measurements (waveforms) in engineering units. This product reflects the structure and contents of the RA-2 source packet.

3.1.3 Level 2

The Level 2 product is the science product that will be distributed to users. It basically consists of three main products: GDR (Geophysical Data Record), SGDR (Sensor GDR) and MAR (Marine Abridged Records). MAR is a reduced product extracted from GDR holding only the ocean retracker output and the geophysical corrections.

- The **GDR** is the “traditional” altimeter product, consisting of once per second measurements processed to a high level, in which the range measurement between the surface below and the satellite appears as a key parameter. It exists in three deliveries: **FDGDR** (Fast-Delivery Geophysical Data Record), **IGDR** (Interim Geophysical Data Record) and **GDR**. They essentially represents the same product, the main difference among them laying in their temporal availability and therefore in the different quality of the corrections (geophysical or engineering calibration). Both FDGDR and IGDR are intermediate products. The FDGDR is produced in less than 3 hours and then replaced by the IGDR (after 3-5 days, depending on the availability of the preliminary Doris orbit). This, in turn, is substituted by the GDR (after 50 days, depending on the availability of the precise Doris orbit). The GDR is generated by applying the same processing as for FDGDR (the four retrackers are re-run) on the Level 1B waveforms corrected for long term instrument errors, i.e. IF calibration, USO drift.

- A MAR (Marine Abridged Record) product containing an ocean oriented subset of the FDGDR or IGDR is made available for meteorological and oceanographic applications in 3 hours and 3 days. It is called, respectively, **FDMAR** and **IMAR**.

- The **SGDR** is essentially the same product as the GDR with averaged waveforms appended in the product for further analysis by the users. It also contains the individual waveforms. The SGDR is generated from the consolidated Level 1B (waveforms corrected for long term instrument variations) and from GDR (same geophysical corrections).

3.2 MWR Products

3.2.1 Level 0

The MWR data at Level 0 is the raw data generated from the demultiplexed downlinked data stream of Instrument Source Packets.

3.2.2 Level 1B

The Level 1B data are packaged into an independent Measurement Data Set (MDS) and merged into the Level 1B RA-2 product. The Level 1B product is a conversion of the Level 0 product to a dataset presented in calibrated engineering units, in which all of the steps demanding a detailed knowledge of the specifics of the instrument itself have been performed. These steps include decoding the source packet, applying characterisation and calibration data, computing the time-tag in UTC.

3.2.3 Level 2

The Level 2 data are stored as an independent Measurement Data Set of the Level 2 RA-2 products. The format is the same as for the Level 1B Measurement Data Set. The Level 2 product is a geolocated geophysical product. The Level 1B product is transformed into Level 2 product through-higher level processing to convert engineering units, brightness temperatures, into geophysical quantities, water vapor, liquid water content.

4 GENERAL PRODUCT LAYOUT

There are two strong specific requirements gathered from the user community: the products have to be global (i.e., not segmented by surface type), and segmented in pole to pole ascending and descending pass files. This has been taken into account for all the geophysical products except for near real time (NRT) products which are constrained by downlinking of the data; their segmentation will be driven by the dump over the ground station, so they can be delivered to users without delay.

The RA-2/MWR products are formatted according to the ENVISAT Payload Data Segment structure (see: “Envisat Mission: Product Summary Overview”, RD1).

All products will follow the same basic structure, consisting of:

- the Main Product Header (MPH). The MPH contains information which is common to all ENVISAT products and auxiliary data and its structure is common to all Envisat products and auxiliary data. It is in an ASCII format.

- a Specific Product Header (SPH). The SPH is in an ASCII format and contains information which describes the specific product as a whole. It will vary between different products. The SPH also contains Data Sets Descriptors (DSDs) which are used to point and describe the various Data Sets that make up a product.

- one or more Measurement Data Sets (MDSs). The Measurement Data Set (MDS) contains the instrument's scientific measurements. Measurement Data Sets are in mixed-binary format and each is composed of Data Set Records (DSR).

Product Confidence Data (PCD) are located in the SPH and within each DSR and provide an evaluation of the overall quality of the product (SPH) and quality of each measurement (DSR). PCD data is designed to demonstrate whether the product has met certain minimum quality standards.

The figure #2 summarizes the general product layout.

MPH ->	Main Product Header (MPH) Generic
SPH ->	Secondary Product Header (SPH) Contains Data Set Descriptors (DSD) to describe Measurement Data Sets (MDS) DSD 1 DSD 2 ... DSD n
MDS 1 ->	Data Set Record (DSR) - no. 1
	Data Set Record (DSR) - no. 2
	... ...
	Data Set Record (DSR) - no. *"last of MDS 1"*
MDS 2->	Data Set Record (DSR) - no. 1
	Data Set Record (DSR) - no. 2
	... ...
	Data Set Record (DSR) - no. *"last of MDS 2"*
...	...
MDS n->	Data Set Record (DSR) - no. 1
	Data Set Record (DSR) - no. 2
	... ...
	Data Set Record (DSR) - no. *"last of MDS n"*

Fig. 2: Envisat generalized product structure

5 PROCESSING ALGORITHMS

5.1 RA-2 Level 1B

The level 1B processor receives the level 0 product and auxiliary files as input and outputs engineering calibrated waveforms, geolocated and dated.

Its main functionality is:

- Decoding of Level 0 data (from the Source Packets and Level 0 headers)
- Interfacing with the Calibration Processor and the Characterization Data Base
- Decoding of auxiliary / calibration files
- Science Data processing and units conversion
- Internal calibration data processing
- PTR data processing in order to obtain flight calibration parameters from PTR measurements
- IF calibration processing (i.e. correction of the waveform samples for the IF filter shape distortions)
- USO drift correction
- Window Time Reference Extraction for the instrument errors and Doppler shift corrections
- AGC Calibration in order to retrieve the instrument calibration factor needed to evaluate the backscatter coefficient at Level 2
- Datation and geolocation
- Science Data and processing quality control
- Output Product Generation.

5.2 MWR Level 1B

The main functions are:

- Level 0 data extraction and decoding, to organise input data as an engineering foundation for Level 1b processing
- antenna temperature retrieval using level 0 archived data coming from in-flight calibration and main antenna measurement itself
- brightness temperature evaluation using radiometer pre-flight and in-flight calibration data, antenna calibration results and land / sea flag
- antennae axis registration in order to spatially align the two paths signals
- Level 1B MDS formatting.

5.3 RA-2 and MWR Level 2

In order to retrieve the geophysical parameters over all types of surface (ocean, ice or land, sea-ice, etc.), four specialised retrackers are run in parallel all the time (over all surfaces):-

- Ocean retracker: optimised for ocean surfaces, it is based on a modification of the Hayne model,

- Ice 1 retracker: optimised for general continental ice sheets, it is a model-free retracker called Offset Centre of Gravity echo model; it is used for ERS and will ensure continuity of the measurements,

- Ice 2 retracker: optimised for ocean-like echoes from continental ice sheet interior, it is a Brown-based model retracking algorithm,

- Sea Ice retracker: optimised for specular returns from sea-ice, it is a threshold retracking scheme for peaky waveforms.

A brief overview of the main functions of the nominal FDGDR level 2 processing is given here below:

- The time tag, latitude, longitude, orbit altitude and orbit altitude rate from the averaged measurements are calculated from the elementary Level 1b ones

- The ice1 retracking (Offset Center-of-Gravity retracker) is performed in Ku and S bands, while the sea ice (threshold) retracking is calculated only for Ku band.

  • Echo direction calculation in order to determine from which direction the returned echo power came.
  • Slope-corrected elevation calculation determined from the OCOG retracked range and the echo direction
  • Delta-Doppler range contribution determined from a full vector calculation using the spacecraft velocity and position, and the echo direction

- The ice 2 and ocean retrackings are performed in Ku and S bands. The ocean retracking algorithm is nominally initialised by the outputs of the ice2 retracking algorithm, and it accounts for the mispointing information derived from the platform data.

- Elementary physical parameters (i.e. Ocean and ice 2 altimeter ranges, significant waveheight, ocean and ice2 backscatter coefficients and square of the off-nadir angle derived from Ku-band waveforms) are derived from the ocean and ice 2 retracking outputs, and then averaged.

- The elementary estimates of the ocean and ice2 altimeter ranges are corrected for Doppler effects

- The surface type (ocean/land) is derived from a bathymetry/topography file, and then, in case of ambiguity, from information coming from the altimeter itself.

- The MWR brightness temperatures and the radiometer land flag are interpolated to the altimeter time tag of the averaged measurements

- The backscatter coefficient atmospheric attenuations are computed in Ku and S bands, using brightness temperatures

- The Ku / S ocean backscatter coefficients are corrected for the atmospheric attenuation and the 10 m altimeter wind speed is derived (from the Ku band estimates)

-The MWR level 2 parameters (wet tropospheric correction, water vapour and cloud liquid water contents) are computed from the brightness temperatures, using in particular the altimeter wind speed as a correction term

- The two components (U and V) of the 10 m wind vector are provided using forecasted meteorological fields

- The sea state bias is computed in Ku / S bands

- Two types of ionospheric corrections are computed in Ku / S bands:

- dual-frequency altimeter, backed up by the measurements from DORIS data
- correction derived from the Bent model using sunspot numbers

- Parameters computed using analysed meteorological fields:

- wet and dry tropospheric corrections due to permanent gases of the troposphere, and the sea surface atmospheric pressure at measurement
- sea surface height correction due to atmospheric loading (inverted barometer effect)
- mean sea surface pressure over ocean

- The non-equilibrium ocean tide height is computed from two algorithms (orthotide algorithm and harmonic components algorithm)

- Calculation of the height of the tidal loading induced by the ocean tide

- Calculation of the solid earth tide and the height of the long period equilibrium tide

- The pole tide height (geocentric tide height due to polar motion) is computed using pole locations

- The height of the mean sea surface above the reference ellipsoid is computed

- The height of the geoid is computed

- The ocean depth or land elevation is computed using a bathymetry / topography file

- The parameters of the MWR DSRs of the output product are computed:

- the altimeter wind speed is interpolated to radiometer time tags
- the MWR level 2 parameters (i.e. the wet tropospheric correction due to water vapour in the troposphere, and the water vapour and cloud liquid water contents), are computed at MWR time tag, from the MWR brightness temperatures and using the altimeter wind speed interpolated at MWR time tag as a correction term.

5.4 Test Data

Test data coming from the instruments flight models are processed up to level 1B and 2 by the reference processors built within the Expert Support Laboratories (Alenia, CLS, MSSL). They are used as expected output in the testing of the Envisat Ground Segment RA-2 / MWR processor.

This data is the source of pre-launch simulated data products that is distributed to future Envisat users. They are accompanied with an info-note that gives details on their content (RD2: “Readme file for the pre-launch RA-2 / MWR Sample Products CD-ROM”).

6 CONCLUSION

The Fast Delivery data (FDGDR) will be processed in the receiving stations and delivered in less than 3 hours. The Interim Geophysical Data Record (IGDR) and the final precision Geophysical Data Record (GDR) products will be processed off-line at the Processing and Archiving Centre in Toulouse, France, with the same algorithms than the Fast Delivery processor.

The main objective of the ENVISAT system is to provide required data products to the users. The ENVISAT User Services is the unique interface to the user community. The User Services will register our data requests, both Fast Delivery and Off-line, and organise the acquisition, processing and products delivery. It is accessible using a WWW browser via a Unified User Services Interface. This means that Users will be able to access ENVISAT data services at any station or centre via an identical user interface.

In summary, the GDR products will be built from four specialised retrackers running in parallel over all surfaces. The data coverage will be up to 81.5°N and S in a dense ground track layout (35-day repeat cycle). The ENVISAT ground system will deliver global NRT data in less than 3 hours. These will already be of near GDR quality as they will be built with the same algorithms and will contain the good quality orbit produced in real time by the DORIS Navigator. The full exploitation of the data from RA-2 demands high-quality absolute calibration at Ku and S bands for the three instrument parameters as well as a very accurate cross-calibration with previous altimeter data during overlapping flights, to provide the user community with a continuous and consistent altimetric time series.

7 REFERENCES

RD1	SP-1221	Envisat Mission: Product Summary Overview
RD2	RA-TN-ESR-GS-0014	Readme file for the pre-launch RA-2/MWR Sample Products CD-ROM

8 ACRONYMS

ADA	Algorithms Definition and Accuracy
AGC	Automatic Gain Control
BITE	Built In Test Equipment
DORIS	Doppler Orbitography and Radiopositioning Integrated by Satellite
DPM	Detailed Processing Model
DSD	Data Set Descriptor
ECMWF	European Centre for Medium-range Weather Forecasts
FDGDR	Fast-Delivery Geophysical Data Record
GDR	Geophysical Data Record
IF	Intermediate Frequency
IGDR	Interim Geophysical Data Record
IODD	Input/Output Data Definition
IPF	Instrument Processing Facility
MAR	Marine Abridged Record
MCD	Measurement Confidence Data
MDS	Measurement Data Set
MPH	Main Product Header
MWR	Microwave Radiometer
NRT	Near Real Time
PCD	Product Confidence Data
PDS	Payload Data Segment
SGDR	Sensor Geophysical Data Record
SPH	Specific Product Header
SWH	Significant Wave Height
TDS	Test Data Set
USO	Ultra Stable Oscillator
UTC	Universal Time Coordinated