ALTIIKA INSTRUMENT : IN-FLIGHT STABILITY AND PERFORMANCES

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1. AltiKa concept
2. Altimeter activities during assessment phase
3. Estimated altimeter stability and performances
4. Radiometer principle
5. Radiometer estimated performances
6. Conclusion
ALTICA : A NEW CONCEPT

- First Altimeter in Ka-band
- Saral, cooperation with ISRO, was launched on the February 25th, 2013
- Single frequency Ka-band altimeter with an enhanced bandwidth
- Includes a radiometer instrument
  - Dual-frequency radiometer (23.8 GHz +/- 200 MHz & 37 GHz +/- 500 MHz)
  - Embedded within the altimeter, shares the DPU and the antenna
The Saral/AltiKa mission and altimeter characteristics

The AltiKa altimeter:

- is the first in-flight altimeter in Ka-Band ➔ reduced ionosphere impacts
- Mono frequency instrument
- has a higher bandwidth ➔ improved vertical resolution (~ 30 cm w.r.t. 47 cm for J2) and thus error budget
- operates at 4 KHz ➔ improved spatial sampling
- has a smaller footprint (5.7 km w.r.t. 9.6 km for J2) ➔ improved coastal approach
- has higher sensitivity to atmospheric water

<table>
<thead>
<tr>
<th></th>
<th>AltiKa</th>
<th>Jason-2 (Ku)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>35.75 GHz</td>
<td>13.575 GHz</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>480 MHz</td>
<td>320 MHz</td>
</tr>
<tr>
<td>PRF</td>
<td>~4 KHz (variable)</td>
<td>2 KHz</td>
</tr>
<tr>
<td>Antenna Beam</td>
<td>0.6</td>
<td>1.29</td>
</tr>
<tr>
<td>WF rate</td>
<td>40 Hz</td>
<td>20 Hz</td>
</tr>
</tbody>
</table>
In flight assessment phase: altimeter activities

- **Calibrations**
  - In routine 3 calibrations per day (PTR and LPF)
  - 20-March-2013: Succession of PTR during 200 minutes
  - 27-March-2013: Expertise LPF (long acquisition)
  - Several calibrations of the gain steps used in AGC loop

- **Tracking modes**
  - All the tracking modes have been tested successfully
  - Recommendation:
    - Operational mode = acquisition Diode with median tracker

- **Cross maneuvers**
PTR analysis

Routine PTR: observed evolutions are as expected. In the ground processing, PTR parameters are averaged on a 3-day basis to reduce the noise.
LPF analysis

Routine LPF: Very good stability since launch
In the ground processing LPF parameters are averaged on 7 days basis to reduce the noise
Expertise calibrations : 200 min PTR

Objective : to assess the altimeter stability within temperature range
Principle = 1 calibration every 10 minutes during 200 minutes

Conclusion :
- Very good stability of the PTR characteristics

Legend :
Amplitude of the PTR
ARFU temperature
DPU temperature

0.02 dB
Expertise calibrations: CNG

Objective: to estimate the 62 gain steps values (2 adjustable amplifiers on board)

- Parameters used in the scaling factor for Sigma0 retrieval
- Calibration performed every 3 months in routine and the values can be updated in the altimeter characterization file if needed
  - Next one is planned today!
- Observed evolution is within method accuracy ➔ very stable

*Differences between measured and ground used CAG values*
NADIR POINTING OF ALTIKA RF BEAM : X-CROSS CALIBRATION MANEUVERS

3 X-cross calibration maneuvers have been performed

- 1\(^{st}\) X-cross maneuver on April 19\(^{th}\) : sequencer test over BIAK
- 2\(^{nd}\) X-cross maneuver on April 22\(^{nd}\) : \(-0,3 / +0,3\) in pitch then \(-0,3 / +0,3\) in roll

Square root of the off-nadir angle (mispointing) estimated through AltiKa echoes retracking

\[ \begin{align*}
0,237 \text{ deg} & \quad 0,330 \text{ deg} & \quad 0,297 \text{ deg} & \quad 0,287 \text{ deg} \\
0,270 \text{ deg} & \quad 0,296 \text{ deg} & \quad 0,295 \text{ deg} & \quad 0,283 \text{ deg}
\end{align*} \]

\( \Rightarrow \) Correction of \(-0.045 \text{ deg. in pitch direction wrt to AIT alignments}\)

- 3\(^{rd}\) X-cross maneuver on April 30\(^{th}\) :

Very good pointing accuracy achieved : estimated to be less than 0.02 deg !
SNR considerations

- Several studies have been made during AltiKa development to assess hypothesis on $\sigma_0$ and atmospheric attenuations
  - $\sigma_0$ Ka = $\sigma_0$ Ku [Topex] – 1.5 dB $\approx$ $\sigma_0$ Ku [Jason] – 3.5 dB
- Some margins have been considered in link budget during development: system margin, ageing, mispointing and rain attenuation
  - In flight assessment: better SNR than expected
    - The 3.5 dB margins allocated to mispointing, system margin and ageing provide additional capacity to withstand higher rain rates than targeted

Thus, a few data are lost due to atmospheric attenuations

Measured AltiKa $\sigma_0$

$\sigma_0$ Ka $\approx$ $\sigma_0$ Ku [Jason] – 2.5 dB

=> i.e. 1 dB greater than $\sigma_0$ hypothesis considered during development
SNR considerations

Altika Cycles 2-2
Mean, Signal to Noise Ratio MLE-4

SNR_MLE4

<table>
<thead>
<tr>
<th>Nbr</th>
<th>11880</th>
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<tbody>
<tr>
<td>Mean</td>
<td>20.51305</td>
</tr>
<tr>
<td>Std Dev</td>
<td>5.8847036</td>
</tr>
<tr>
<td>Median</td>
<td>22.676992</td>
</tr>
<tr>
<td>Min</td>
<td>3.5505074</td>
</tr>
<tr>
<td>Max</td>
<td>32.288367</td>
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High rate data ("HD mode")

- Principle: to record data at the PRF rhythm – limited to about 1 second of data.
- Time tag precision: about 1 second (difference between the command and the actual waveforms dates)
- Has been performed for expertise:
  - For correlation analysis in Ka-band (for different wave and wind conditions)
  - For analysis on transitions areas (coast, ice …)
Altimeter performances – range noise

For SWH = 2 m
1 Hz range: 0.9 cm
System requirement: 1.5 cm
Goal: 1 cm

<table>
<thead>
<tr>
<th>Altimeter parameter</th>
<th>Specifications</th>
<th>Measured on ground</th>
<th>In flight data</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Hz range</td>
<td>1.5 cm</td>
<td>0.9 cm</td>
<td>0.9 cm</td>
</tr>
<tr>
<td>1 Hz SWH</td>
<td>6.3 cm</td>
<td>5.7 cm</td>
<td>5 cm</td>
</tr>
<tr>
<td>1 Hz Sigma0</td>
<td>0.2 dB*</td>
<td>N/A</td>
<td>0.012 dB</td>
</tr>
</tbody>
</table>
Radiometer is embedded within the altimeter

- Antenna and processing units are shared between altimeter and radiometer.
- Radiometer: dual frequency, in K (23.8 GHz) and Ka bands (37 GHz)
- Footprint size (half-power beam width) diameter: 8 kms in Ka band and 12 kms in Ku band.
- The radiometer is operational in all altimeter modes (except init mode)
- No particular operations in assessment phase, it has been working since Altika switch ON
  - 1 measurement every 200 ms
  - Calibrations are done continuously, every 3 sec
    » 2 sources for calibration: 1 cold (sky horn) and 1 hot (internal load)
STABILITY AND PERFORMANCE ASSESSMENT (1/2)

- Instrument thermal environment is very stable
  - Example: hot load temperature evolution over the mission duration is about 1 C
  - These variations are taken into account into the radiometric model, through 24 thermistors from the antenna to the radiofrequency unit

- Due to gain increase, the on-board tension offset had to be adjusted to correct saturation on hot calibration counts

![Graph showing temperature variations](image)

K-band hot load T  
Ka-band hot load T

\[ \approx 1 \text{ C} \]
Radiometer performances: sensitivity estimation on calibration counts

- \( \Delta T \approx G_{mean} \times \Delta V \), \( G \): radiometer gain estimated through calibrations, expressed in V/K

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Flight data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity on cold source in K band</td>
<td>0.072 K</td>
</tr>
<tr>
<td>Sensitivity on cold source in Ka band</td>
<td>0.101 K</td>
</tr>
<tr>
<td>Sensitivity on hot source in K band</td>
<td>0.125 K</td>
</tr>
<tr>
<td>Sensitivity on hot source in Ka band</td>
<td>0.139 K</td>
</tr>
</tbody>
</table>

- During ground assessment tests, sensitivity was estimated
  - Between 0.12 and 0.16 K in Ka band for TB between 125 and 300 K
  - Between 0.1 and 0.14 K in K band for TB between 125 and 300 K
Conclusion

✓ AltiKa has a very good behavior
✓ Instrument stability and performances are very good and fully compliant with the system requirements
✓ Each mode has been tested successfully during assessment phase
✓ No functioning anomaly detected.
✓ Dedicated calibrations demonstrated a very stable behavior on orbit
✓ A very few data are lost by loss of tracking due to atmospheric attenuation