Ka-band altimeter for AltiKa/SARAL oceanography mission

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Abstract
In partnership with scientific laboratories and industry, and for several years, CNES has studied the feasibility of a high-resolution ocean topography mission based upon a new class of wide-band Ka-band altimeter. AltiKa payload will be embarked in the SARAL satellite at the same time as the Argos3 instrument, in the frame of a cooperation between CNES and ISRO (Indian Space Research Organization) with an expected launch mid-2010.
The mission objectives, the instrument description status and expected performances are given in this poster.

Mission

AltiKa payload

- **A Ka-band altimeter**
  - single frequency instrument : ionospheric effects are negligible
  - enhanced bandwidth : vertical resolution and thus error budget improvement
- **A dual-frequency radiometer (24/37 GHz)**
  - required for tropospheric correction
  - Embedded in the altimeter
- **A Laser Retro-reflector Array**
  - minimum for orbitography and system calibration
- **DORIS** (Doppler Orbitography and Radiopositioning Integrated by Satellite)
  - required for achieving very high accuracy orbitography in low earth orbit (orbitography need)
  - measurements link with past or simultaneous missions like T/P, ENVISAT, JASON 1/2 in a well monitored terrestrial reference frame

Mission objectives

Central objective :

- ocean mesoscale circulation
- data assimilation in a global ocean model

Contribution to :

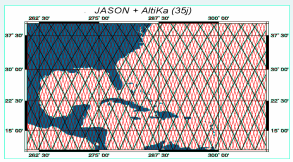
- Continental ice studies
- Sea-state analysis & forecast
- Low rain detection and characterization
- Coastal/inland water altimetry
- Mean sea level

Orbit : same as ERS and Envisat

✓ Polar (incl. = 98,55°) Sun-Synchronous orbit (6:00/18:00), 800 km altitude, low eccentricity
✓ ground track repetitivity period : 35 days

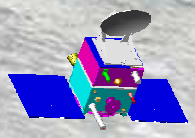
At least 2 satellites are needed to measure mesoscale variations of the ocean

Example of combined sampling of JASON-2 (10 days) and AltiKa



Payload status

- Altimeter/radiometer delivery : April 2009
- DORIS delivery : April 2009



View of the SARAL satellite

Mission status

AltiKa payload will fly in the frame of a cooperation with ISRO (Indian Space Research Organisation).

- AltiKa payload will be embarked on the SARAL satellite
- Demonstration of the Ka-band altimetry as a complement to Jason 2 (post-ENVISAT altimetry gap filler)
- Launch foreseen mid-2010

Instrument description

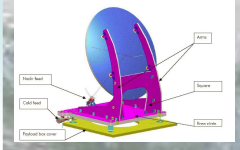
Main characteristics

Parameter	Value
Altimeter band	35.75 GHz ± 250 MHz
Pulse bandwidth	500 MHz
Pulse duration	110 µs
Altimeter Pulse repetition frequency	~ 3.8 kHz (adjustable along the orbit)
Echo averaging (altimeter)	~ 25 ms
Spectrum analyser (altimeter)	128 points
Altimeter Link budget	11 dB (sigma naught = 6.5 dB)
Antenna diameter	1000 mm
Focal length	700 mm
Offset	100 mm
Radiometer band	23.8 GHz ± 200 MHz 37 GHz ± 500 MHz
Radiometric resolution	< 0.4 K
Radiometric accuracy	< 3 K
Radiometer averaging	200 ms
Data rate	38 kbits/s
Mass (altimeter+radiometer)	< 42 kg
Power consumption (altimeter+radiometer)	< 100 W

The AltiKa instrument consists of a Ka-band altimeter which functions are based on proven concepts and already developed sub-systems, as it inherits from Siral (CRYOSAT mission) and Poseidon3 (JASON2 mission), and an embedded dual frequency radiometer.

- Altimeter function is based on the full Deramp technique
- Radiometer function is based on the direct detection principle. The radiometer radiofrequency unit (RFU) consists of two RF receivers, which are developed by EADS ASTRIUM.

The radiometer must be switched-off during radar altimeter emission.

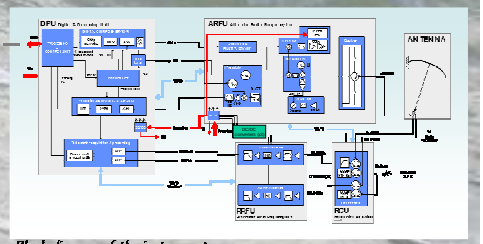


The antenna is common for altimeter and radiometer and is composed of

- A fixed offset reflector
- A three-band feed
- A sky horn pointing to deep space

Calibration modes

❑ Calibration-1 : provides with the altimeter point target response (complex spectrum). The transmission channel is looped back to the corresponding receiver input through the calibration attenuator. In order to obtain a high resolution for this response, the central frequency of the spectrum analyzer can be scanned by a step thinner than the frequency resolution.
❑ Calibration-2 : provides with the altimeter receiver transfer function after Deramp (in the frequency domain) by averaging the natural thermal noise in the reception channel over a long period. Altimeter analysis window has to be positioned to a range that guarantees the absence of returned echoes.
❑ Radiometer calibration : RCU can commute every N seconds to a sky horn pointing to deep space (cold reference) or to a load at ambient temperature (hot reference)

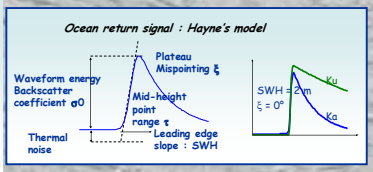


Block diagram of the instrument

On board algorithms and expected performances

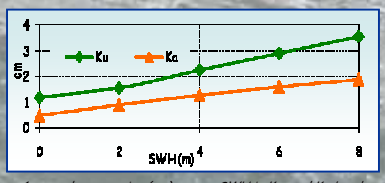
Optimisation of the acquisition : tracking mode

- conventional tracking loop (range and gain) :
  - Automatic Gain control (AGC) first order loop
  - Range second order loop
- use of DORIS Diode navigator message + on-board stored DEM to improve tracking in coastal and in-land water regions
- Additional high data rate mode: (I,Q) samples downloaded for speckle and echo analysis in coastal region



Expected results on sea surface

- Accuracy of the altimeter range measurement over sea surface : **about 1 cm for a SWH of 2 meters**
- Improvement of about 40% on the range noise versus Ku-band performances
  - Better estimate of the velocity fields (topography gradients) and better analysis of the eddies structure along-track



1 second range noise (cm) versus SWH in Ku- and Ka-bands

Rain and cloud effect in Ka-band

Effect of rain

- Rain has an effect on the Signal to Noise ratio
- CNES/CLS study on rain rates from TRMM/TMI data shows that :
  - Average for one year and all geographical areas show that around 3% of data will be unavailable
  - Unavailability can reach 10% locally depending on season (e.g. Bengal Golf)

Effect of clouds

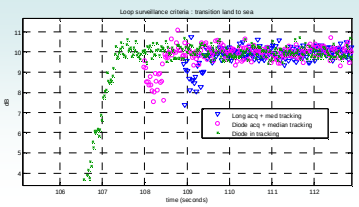
- Clouds or rain cells smallest than AltiKa antenna footprint introduce distortions on the waveform and errors on parameters

Study using MODIS data : preliminary results show that this effect increases reasonably the noise on measurements and that for a certain amount of data (less than 10%), a dedicated processing will be necessary

Expected behaviour on other surfaces

- Interest of coupling the altimeter with DORIS Diode navigator (experimental modes) :
  - Maximum acquisition duration < 500 ms (instead of > 2 s in autonomous acquisition)
  - An optimised on-board DEM greatly improves the tracking behaviour in transitions especially from land to water and over continental waters

Performances of the different tracking options over an example of land to sea transition : waveforms are expected to give accurate retracking outputs as soon as the Signal to Noise ratio (vertical axis on the figure beside) exceeds 9 dB.
Improving data acquisition data of 1 second means being able to get closer to the coast of about 7 km.



Comparison of tracked points between different tracking options