ALTICRYO:
A CNES Altimetry Concept Study For Cryosphere Monitoring

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Outline

Context

- **Programmatic context**
  - CNES: scientific community asks for AltiKa-2
  - ESA: studies on Cryosat Follow-on
  - EU: polar component of Copernicus evolution and NG
- **Phase 0 study**
  - Preliminary design study
- **Study of altimetry system (mission/instrument/processing) dedicated to the cryosphere monitoring = AltiCryo**
  - Specific needs taken as main mission objectives

Objectives

- **Propose an altimetry concept optimized for cryosphere (sea ice and ice sheets) and based on the SARAL/AltiKa heritage**
  - Ka-Band
  - Range resolution ~30cm
  - A single antenna shared by the altimeter and the radiometer

… taking into account lessons learned from AltiKa & Cryosat

  - Improve the observation of the steep zones
  - Avoid waveforms saturation

- **Potential platform = Proteus (PL=300kg/300W) or Myriade Ev° (PL=150kg/150W)**
  - No interferometric capability
  - Compact altimeter design

Users needs

- **Based on current knowledge and physical measurement capabilities**
  - User Requirement Document for the AltiCryo study
  - Notes from User meeting held in Paris in February 2017 (and co-organized with ESA)


AltiCryo User Requirement Document


Notes from AltiCryo User Meeting

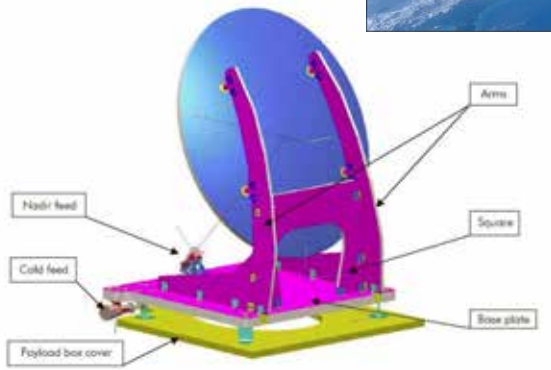
- **Major critical users requirements**
  - Very high latitudes coverage to monitor Arctic multi-year ice and West-Antarctica: **~90° inclination**
  - Need of high spatial resolution and precision: **SAR or SARIn** mode
  - Improved knowledge of snow penetration effects and snow thickness measurements over sea ice: **bi-frequency Ka/Ku altimeter**
  - Temporal resolution vs. inter-track spacing: **Repeat cycle ≈ 1 month**
  - Low product delivery latency: **24 hours** for data assimilation down to few hours for navigation

Altimeter Specifications (1/5)

Orbit

- ~720 km, with an inclination of 88° (idem CryoSat)
  - No Sun-Synchronous Orbit with i> 88° for the considered altitudes range

Antenna



- Shared by altimeter and radiometer (K/Ka or Ku/K/Ka)
- Diameter of 1 m or 1.2 m

Radar mode

- Ka/Ku-bands altimeter with a SAR mode complying with the following conditions:
  - PRF ≥ 1.2*Bdop → to avoid ambiguities
  - PRF (Ku) = PRF(Ka)
  - Range resolution of AltiKa: B=480MHz for Ka and Ku-band
  - Number of uncorrelated echoes per second allowing the computation of a PLRM echo → link with past LRM missions

Altimeter Specifications (2/5)

❖ Tracking

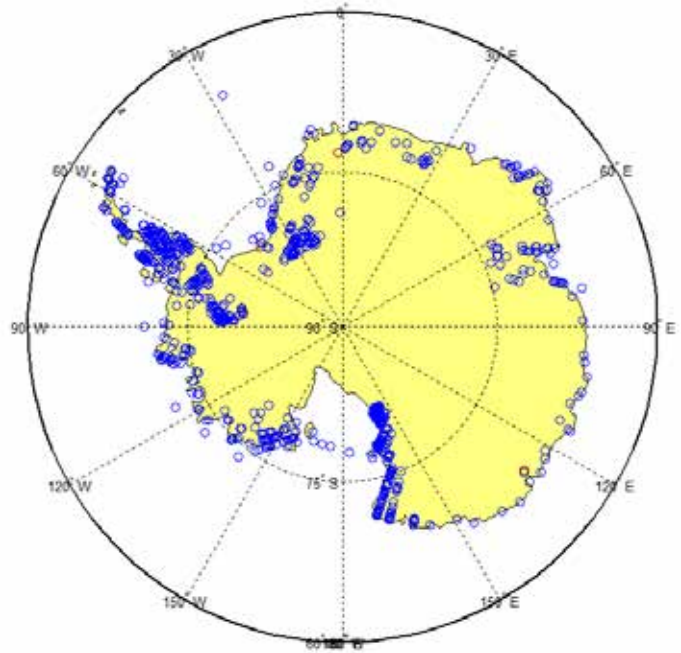
- ➢ Closed loop
  - o Difficulties encountered over margins in OL on S3A
- ➢ Increased tracking window length
- ➢ Median or EDP algorithms

❖ Tracking band

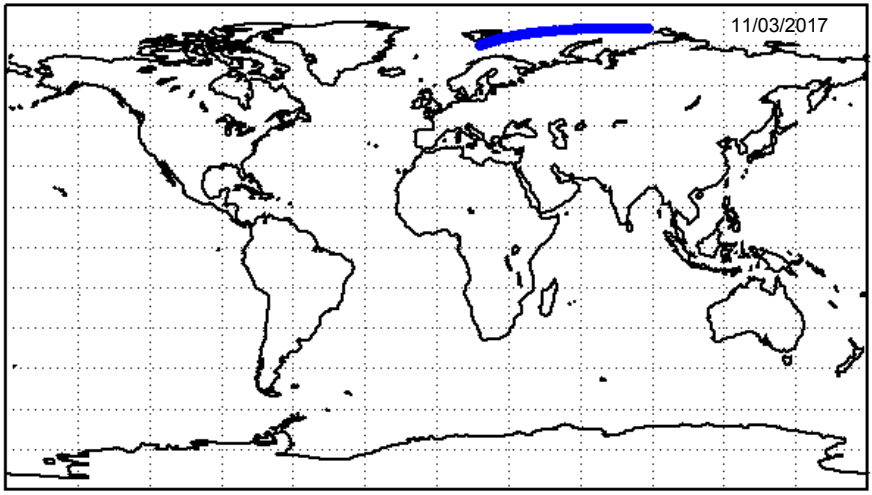
- ➢ Land ice
  - o Large antenna aperture to cover ice margins
    - Observable slope = half antenna aperture
    - Analysis of SARAL/AltiKa tracks over Antarctica

➔ **Ku-band**

AltiKa data gaps over ice margins



Altimeter Specifications (3/5)

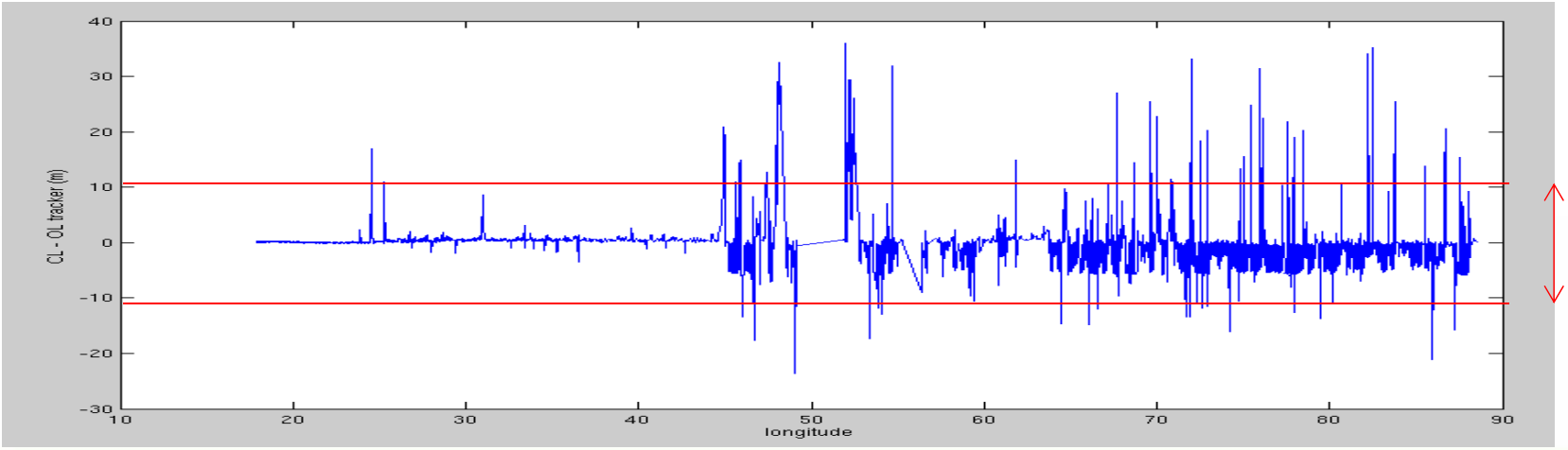


❖ Tracking band

- ➢ Sea ice:
  - o Narrow antenna aperture to limit off-nadir tracking
    - Analysis of S3A range on a sea ice track:

    Tracking in Ku-band beyond the Ka-band aperture?

➔ **Ka-band**



θ_{3dB} Ka

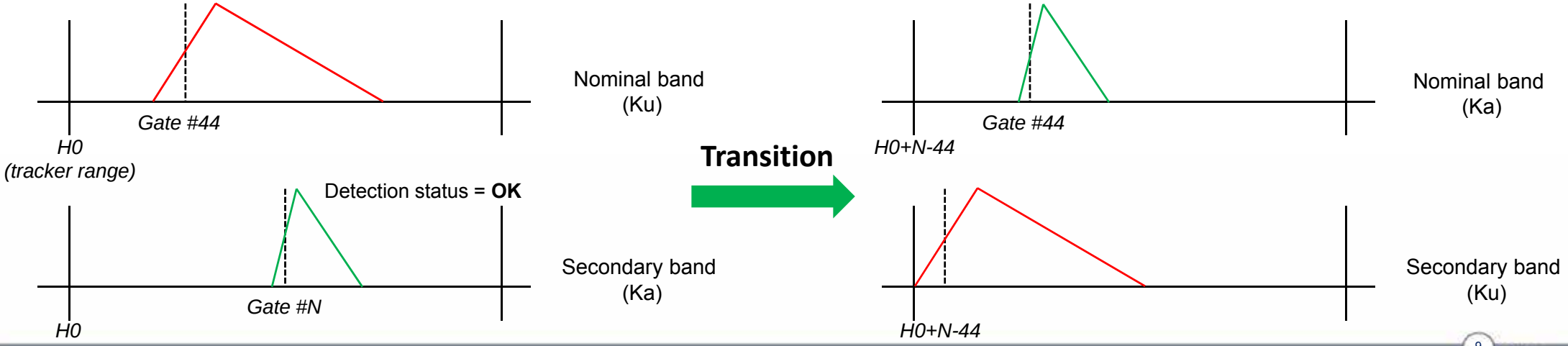
Sentinel-3 range in closed-loop mode (tracker+epoch), with respect to expected nadir range (orbit – MSS).

Comparison with Ka footprint.

Altimeter Specifications (4/5)

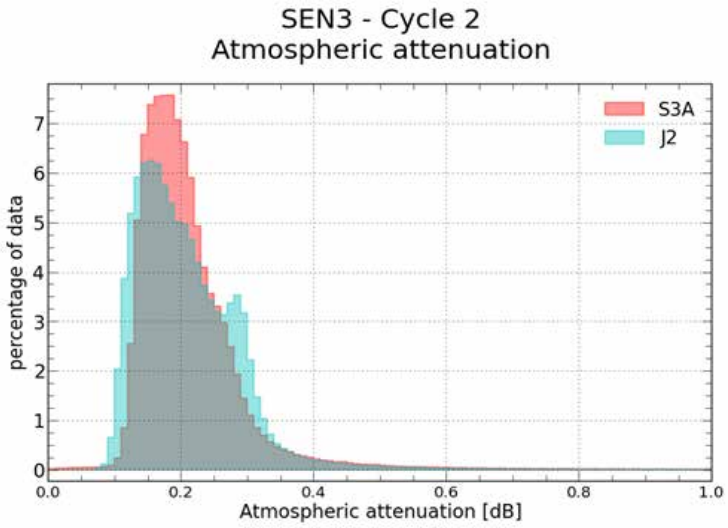
Tracking transitions

- Same tracking window defined for the 2 bands
- Secondary band controlled by the nominal one
- A tracking status is continuously computed in the secondary band (echo detection, rising edge position)
- Example of a land-to-sea transition (Ku → Ka)



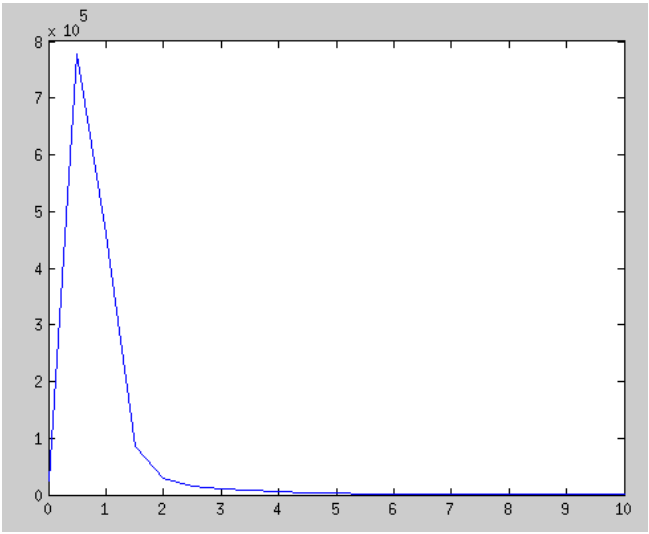
Altimeter Specifications (5/5)

- **Atmospheric attenuation: typical values instead of worst case ones**
  - Ku: 0.3dB based on J3 and S3 feedback (instead of 1dB)
  - Ka: 1dB based on AltiKa feedback (instead of 3dB)

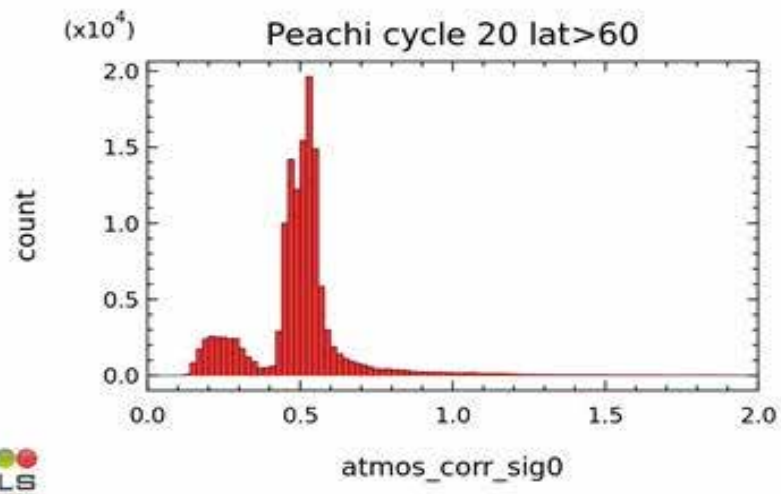


	Mean (dB)	σ (dB)	Nbr
S3A	0.213	0.159	403257
J2	0.209	0.110	465383

AltiKa atmospheric attenuation over ocean (1 cycle)



AltiKa atmospheric attenuation over ice (1 cycle)

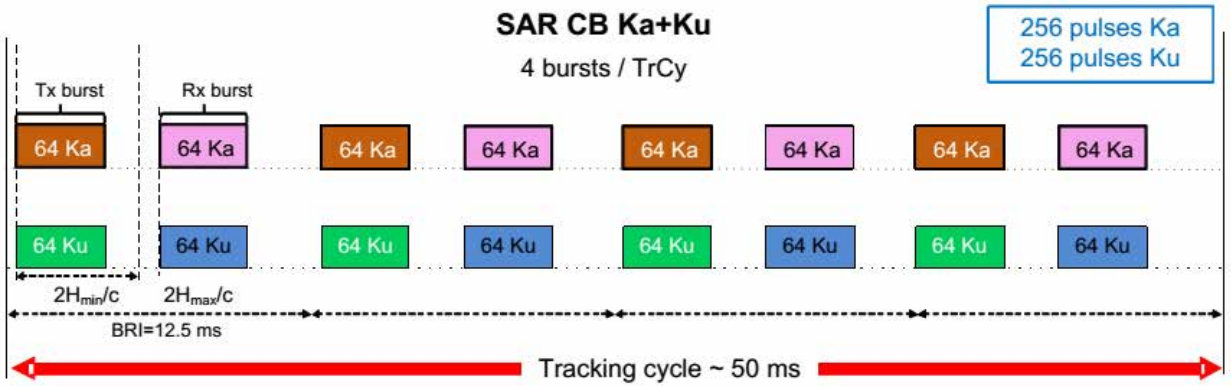


Instrumental configuration (1/6) ➔ TAS study

❖ Simultaneous Tx/Rx in both Ka- & Ku- bands

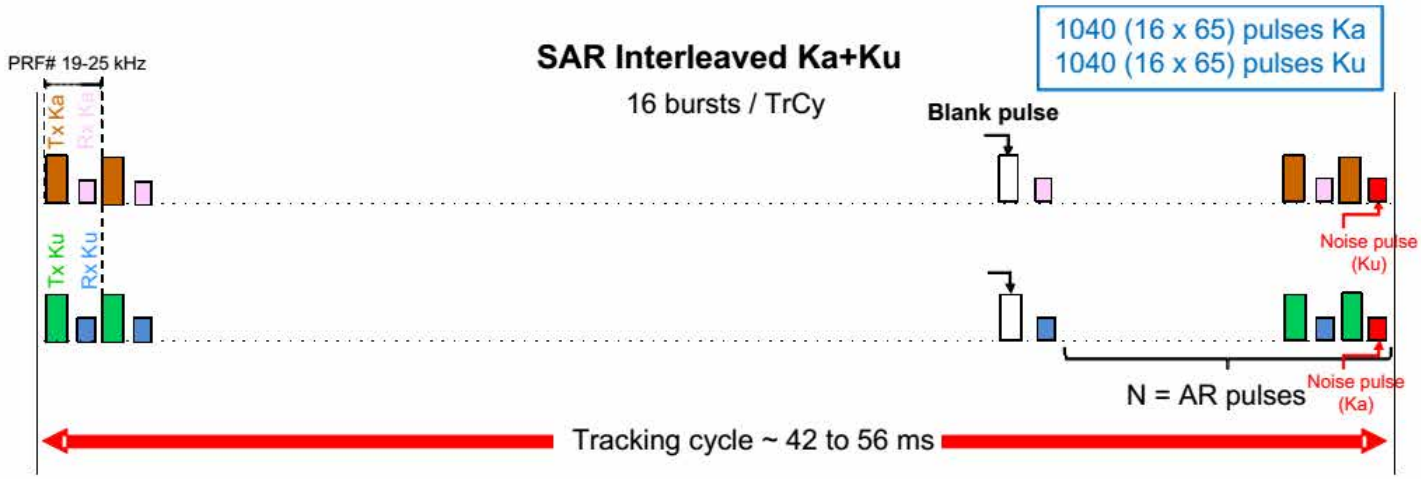
➢ Closed-Burst

- For 1.2m antenna:
  res(Ka) ~ 100m
  res(Ku) ~ 275m



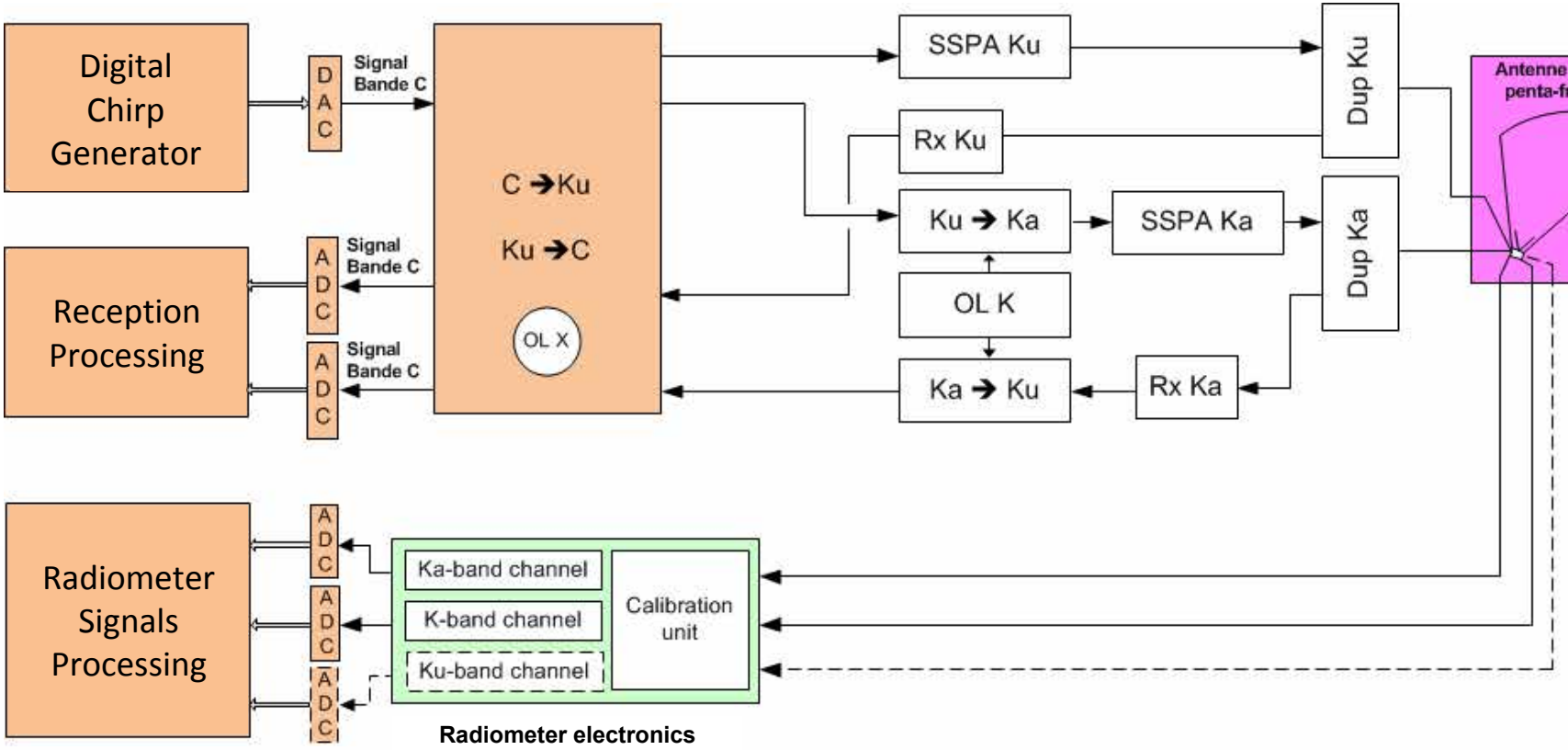
➢ Interleaved

- Variable PRI
- PLRM = LRM
- Burst size can be chosen to have res(Ka) ~ res(Ku)



Instrumental configuration (2/6)

❖ Choice of a digital architecture



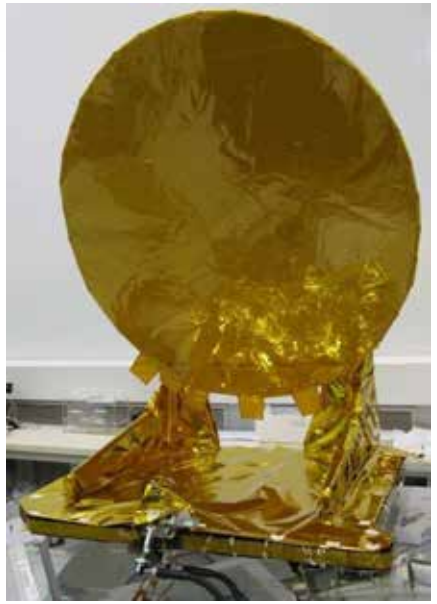
- PTR stability
- Digital part consumption ↘ volume ↘

Instrumental configuration (3/6)

❖ Antenna trade-off

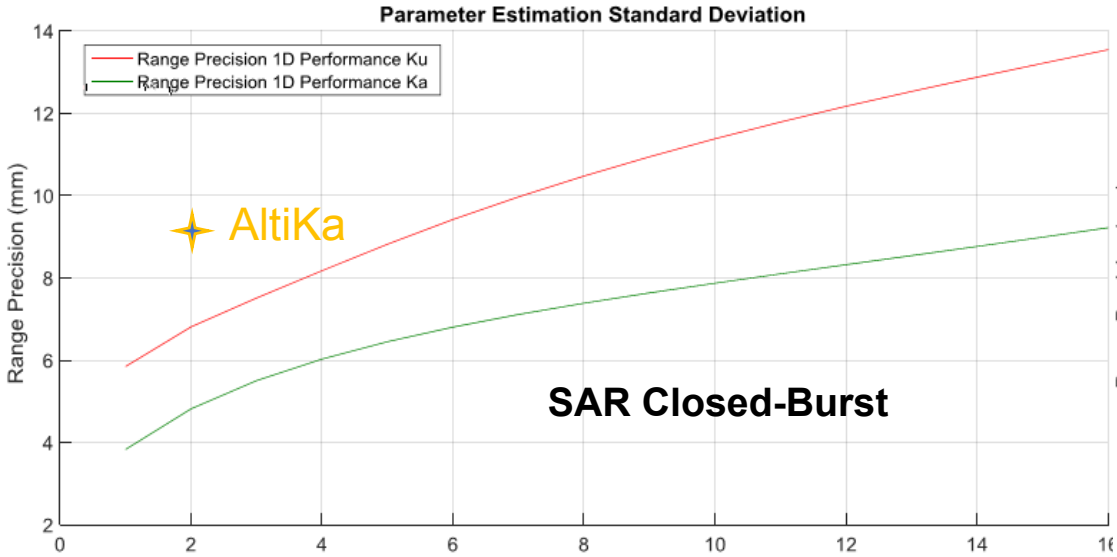
- **Difficult to design a penta-frequencies** antenna satisfying the efficiency requirements.
  Problems encountered with the additional radiometer Ku-band frequency.
- However, **good estimation of the wet troposphere** (and classification of ice types) seems to be achievable with only the K- and Ka-bands on the radiometer
  - Recent improvement in wet tropospheric correction inversion over ocean
  - Availability of the altimeter sigma0 in Ku-band & in Ka-band
  - Co-localization of altimeter and radiometer signals.

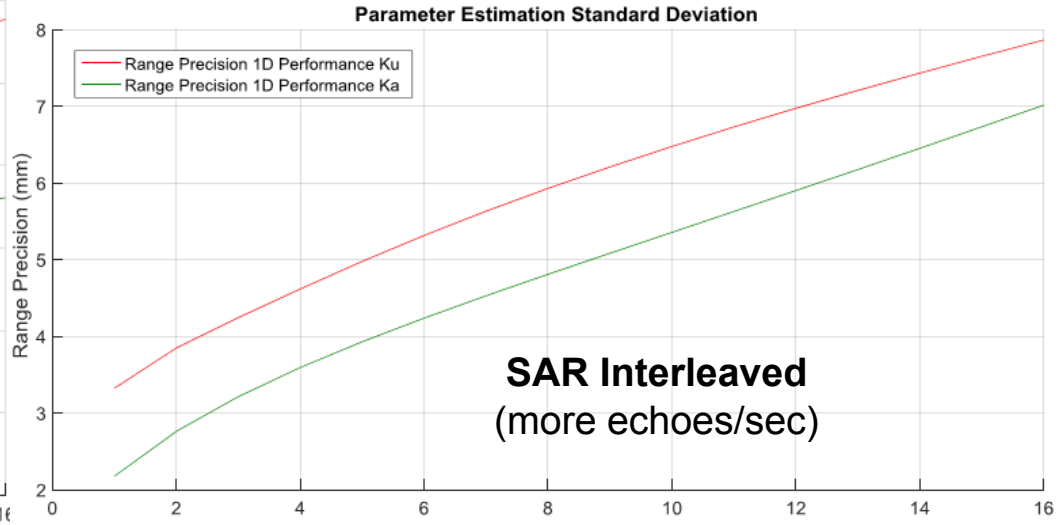
➔ A quadri-frequencies antenna (Ka/Ku altimeter, K/Ka radiometer) satisfies the needs



Instrumental configuration (4/6)

- **Link budgets**
  - OK in SAR interleaved mode with 1.2m antenna (and also in SAR CB)
- **1hz simulated range noise (MLE3) as a function of SWH**
  - Performance over ocean = well-known reference

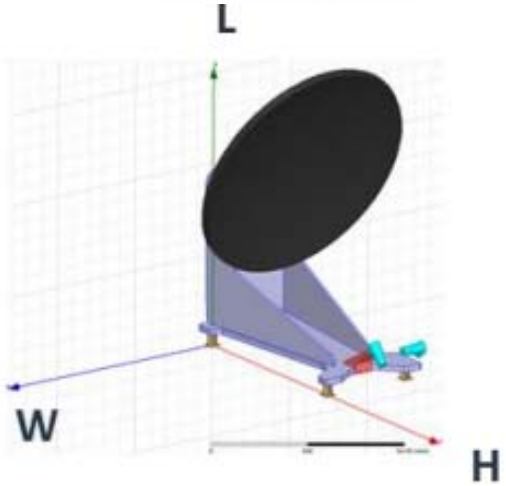




Instrumental configuration (5/6)

MVC budgets

AltiCryo Instrument	Mass	Volume (LxWxH)	Consumption SAR Closed-Burst	Consumption SAR Interleaved
DPU	5 kg	330 x 120 x 270 mm3	40 W	40 W
RFU	13 kg	415 x 350 x 240 mm3	50 W	105 W
Antenna Ø 1.2m	18 kg	1450 x 1200 x 1300 mm3		
Harness	3 kg			
Total	**39 kg**		**90 W**	**145 W**



Reduced to **100 W** with middle-term technologies (GaN, power supply,…)

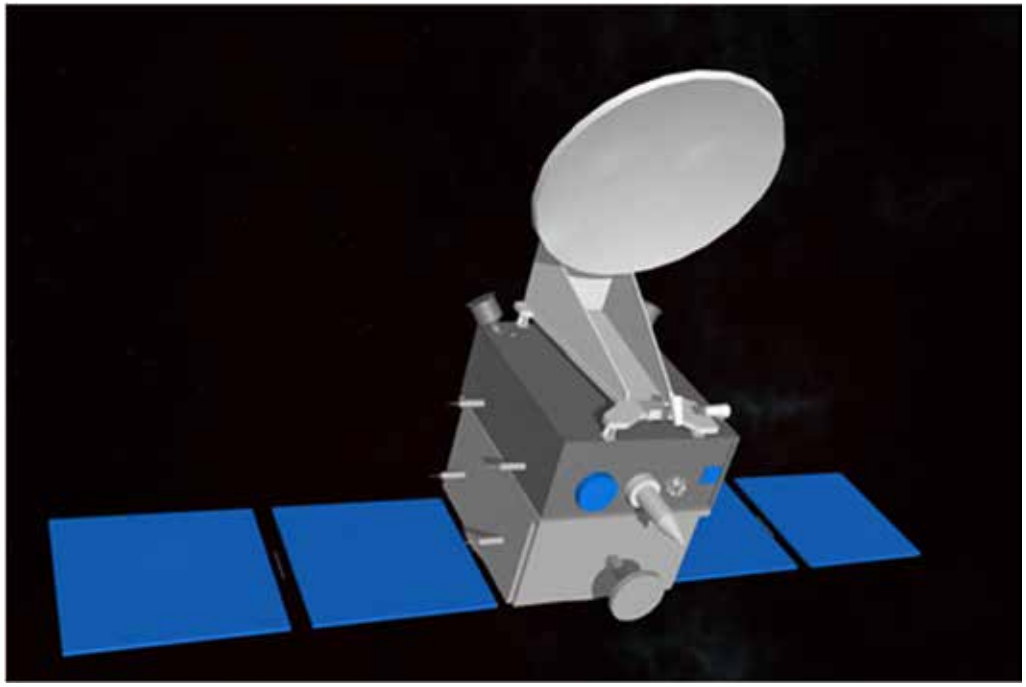
TM budgets

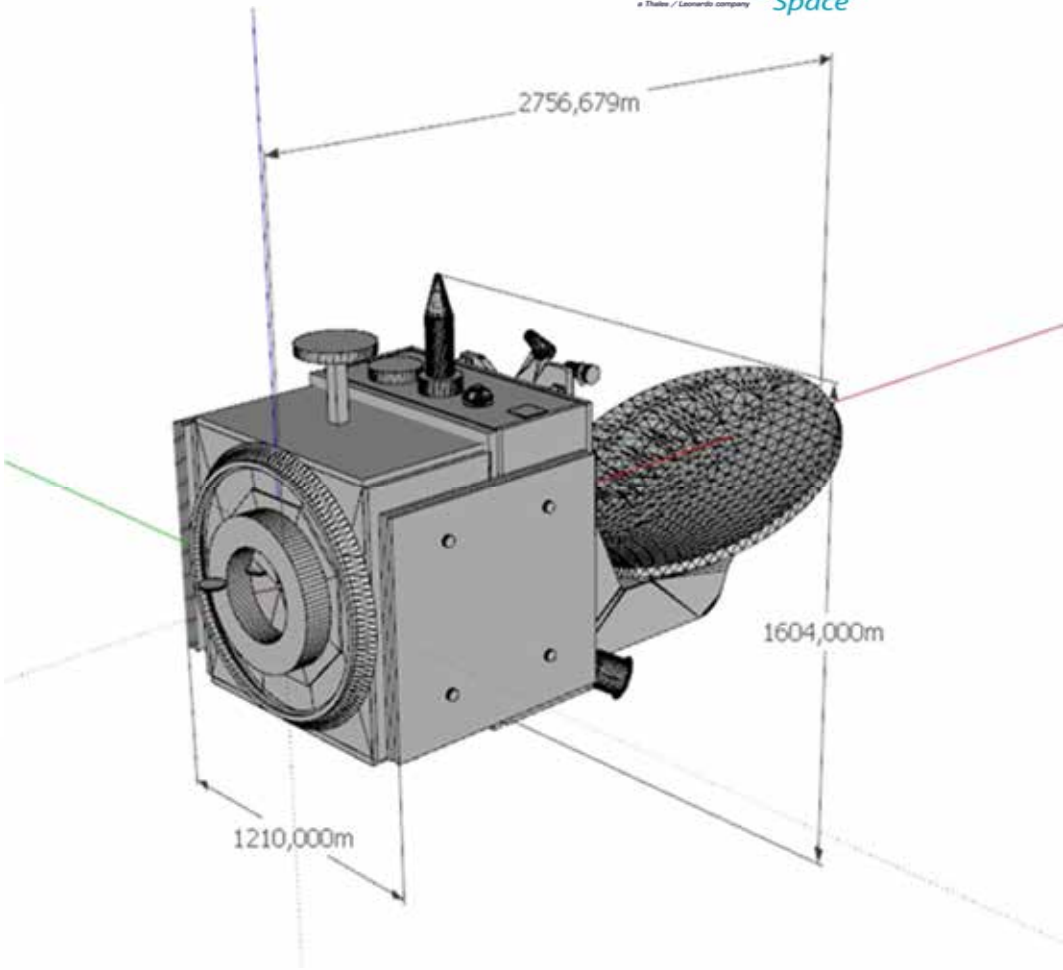
AltiCryo Mode	Data Rate	Assumptions
Sea surfaces		
SAR Closed-Burst	**42 Mbps**	Header: 126 bytes – TrC=50ms – 8 bits/sample I or Q
SAR Interleaved	**162 Mbps**	Header: 126 bytes – TrC=52.9ms – 8 bits/sample I or Q
Land surfaces		
SAR Closed-Burst	**84 Mbps**	Header: 126 bytes – TrC=50ms – 8 bits/sample I or Q
SAR Interleaved	**323 Mbps**	Header: 126 bytes – TrC=52.9ms – 8 bits/sample I or Q

Reduction possible for small PF (Tracking window size, on-board data processing)

Instrumental configuration (6/6)

- **Accommodation**
  - Antenna configuration ø 1.2m
  - Proteus-150 (= Myriade Evolution)





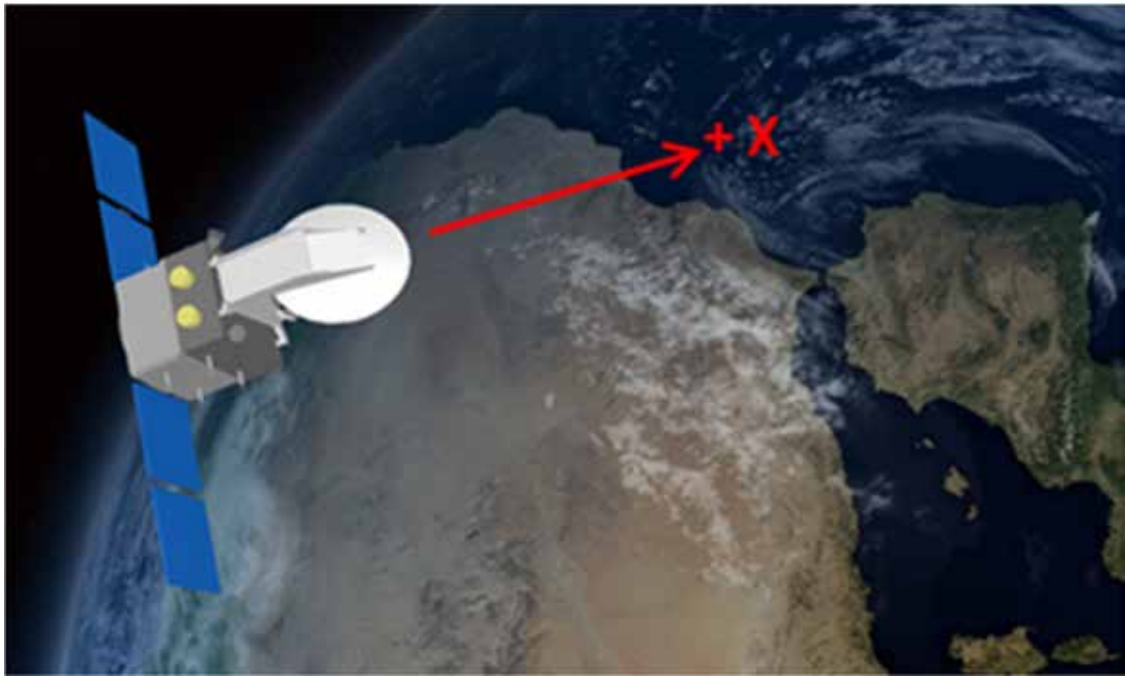
Perspectives

- **Processing: SAR/SARin comparison over ice margins and sea ice**
  - **Ice margins**: to compare the slope correction in SAR (based on auxiliary DEM) and SARin mode (based on the measured phase difference at POCA)
  - **Sea ice**: to compare the off-nadir lead detection in SAR mode (based on waveform classification + sigma0 threshold + local maximum selection) with the actual cross-track distance to nadir measured in SARin mode (based on the phase difference)
  - **On-going study with CLS**, should end next January

For now, no new altimetry mission decided on CNES side…

… but this study also contributes to draw the best CryoSat follow-on concept!

Thank you



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... back-up slides ...

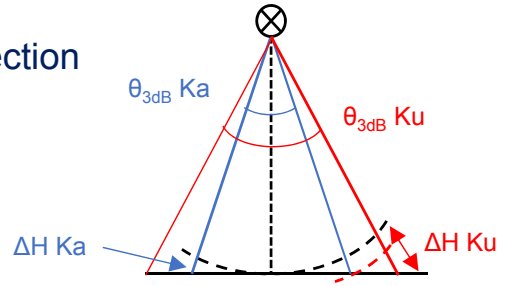
Altimeter Specifications

❖ Tracking window

➢ Choice of the tracking window length (L)

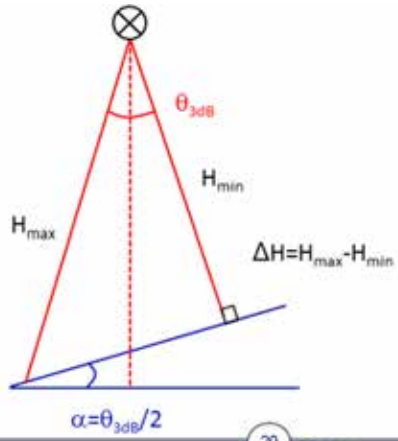
- o Sea ice: L > ΔH = Difference between distance in nadir direction and in 3dB beam direction

Configuration	Ka - 1 m Surfaces de mer	Ku - 1 m Surfaces de mer		Ka - 1.2 m Surfaces de mer	Ku - 1.2 m Surfaces de mer
θ 3 dB	0,61°	1,42°		0,50°	1,18°
ΔH à θ3dB/2	**10,2 m**	**55,3 m**		**6,9 m**	**38,2 m**
Longueur fenêtre de tracking	**64,0 m**	**64,0 m**		**64,0 m**	**64,0 m**
Durée fenêtre de tracking	0,43 us	0,43 us		0,43 us	0,43 us



- o Land ice: L > ΔH = Difference between distance min and max at 3dB beam edge for a slope of θ3dB/2

Configuration	Ka - 1 m Surfaces de terre	Ku - 1 m Surfaces de terre		Ka - 1.2 m Surfaces de terre	Ku - 1.2 m Surfaces de terre
θ 3 dB	0,61°	1,42°		0,50°	1,18°
ΔH dans faisceau 3 dB pour pente = θ3dB/2	**40,8 m**	**221,1 m**		**27,4 m**	**152,7 m**
Longueur fenêtre de tracking	**64,0 m**	**255,8 m**		**64,0 m**	**255,8 m**
Durée fenêtre de tracking	0,43 us	1,71 us		0,43 us	1,71 us



Altimeter Specifications

❖ Sigma0 assumptions

○ Bande Ku – Spécifications Cryosat-2 :

Mode	Echo type	σ0 min	SNR (*)
LRM	Ocean echoes + ice echoes	0 dB	8 dB
SAR CB	Ocean echoes + ice echoes	0 dB	18 dB
SARIn CB	Ocean echoes + ices echoes (ice margins)	-10 dB	18 dB

*(*) : SAR processing gain **(#12 dB)** included in SNR*

Tracking sur surfaces de terre :

➔ Spéc : SNR (**) = 6 dB @ σ0 = 0 dB

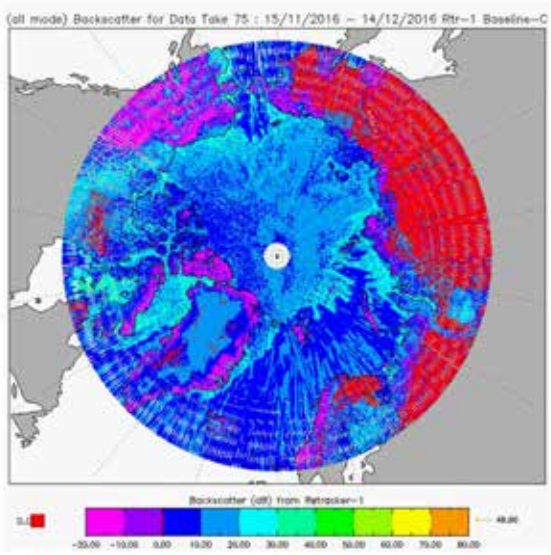
➔ Objectif : SNR (**) = 6 dB @ σ0 = -10 dB

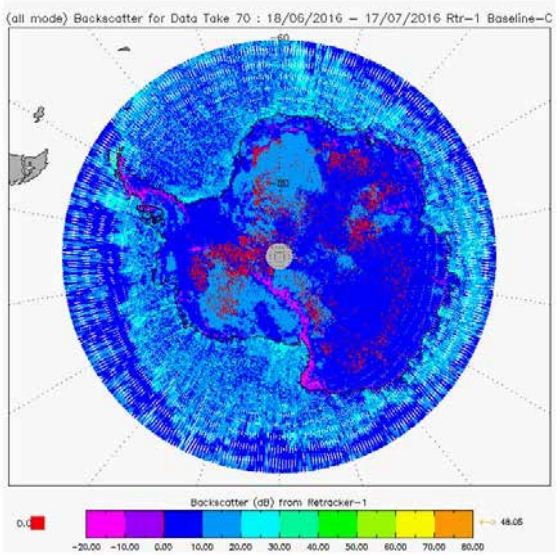
○ Bande Ka - Tracking sur surfaces de mer :

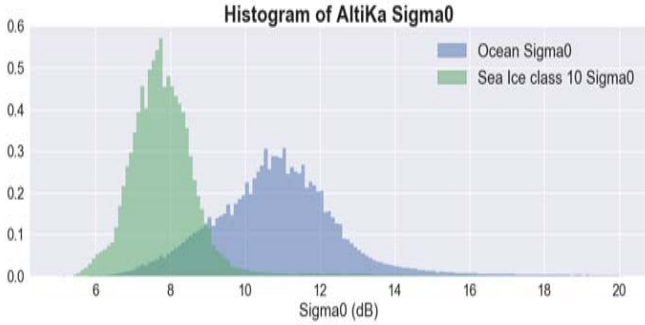
➔ Spéc : SNR (**) = 6 dB @ σ0 = 5 dB

➔ Objectif : SNR (**) = 6 dB @ σ0 = 0 dB

(**) : SNR avant traitement SAR

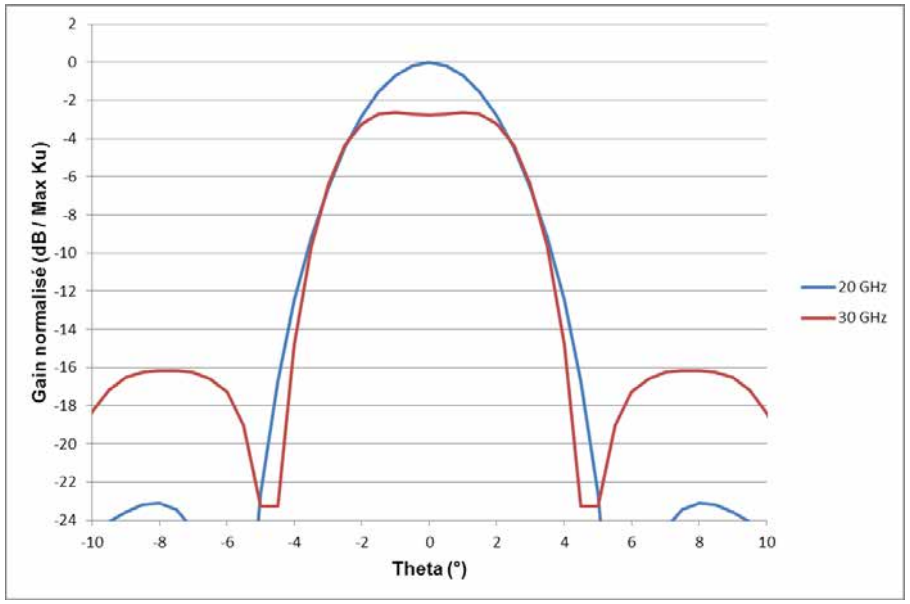






Instrumental configuration

- **Ice sea users asked for the same aperture in both bandwidth**



Use of a shaping →
Loss of the Gaussian waveform

- Unacceptable for the PRF: PRF = 46.9 kHz (1.2m antenna)
- Unacceptable for the link budget :
  - SNR (Ka SAR) = -1.4dB (1.2m antenna), to be compared with th CY req. of 18dB!