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Advancing remote sensing

SAR Altimetry Training Course:

Delay Doppler Altimeter Instrument Calibration

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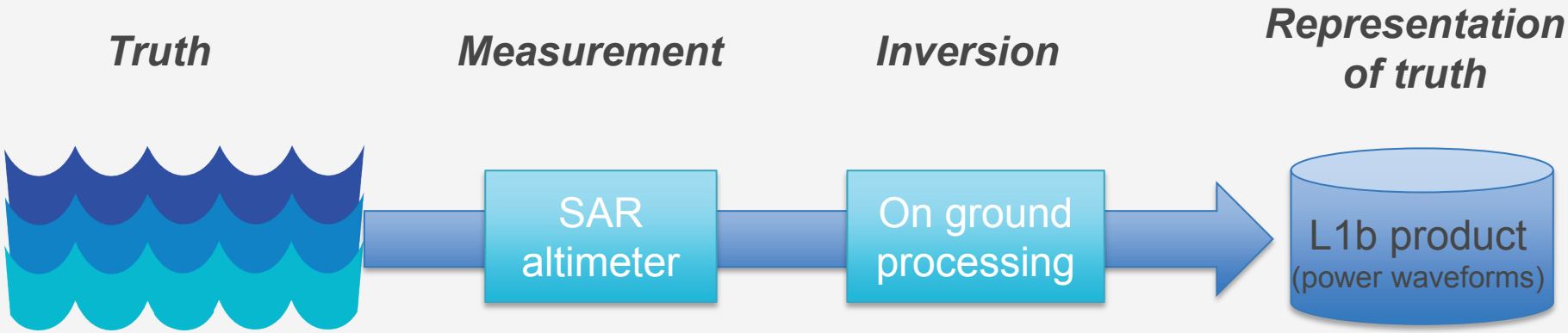
Outline

- SAR Altimeter acquisition and calibration
- SAR altimeter calibration corrections
  - What do they measure?
  - What is the impact on data quality?
- Calibration of CryoSat FBR products
- Conclusions and questions

SAR altimeter acquisition

The acquisition is an «open loop» measurement of the reality

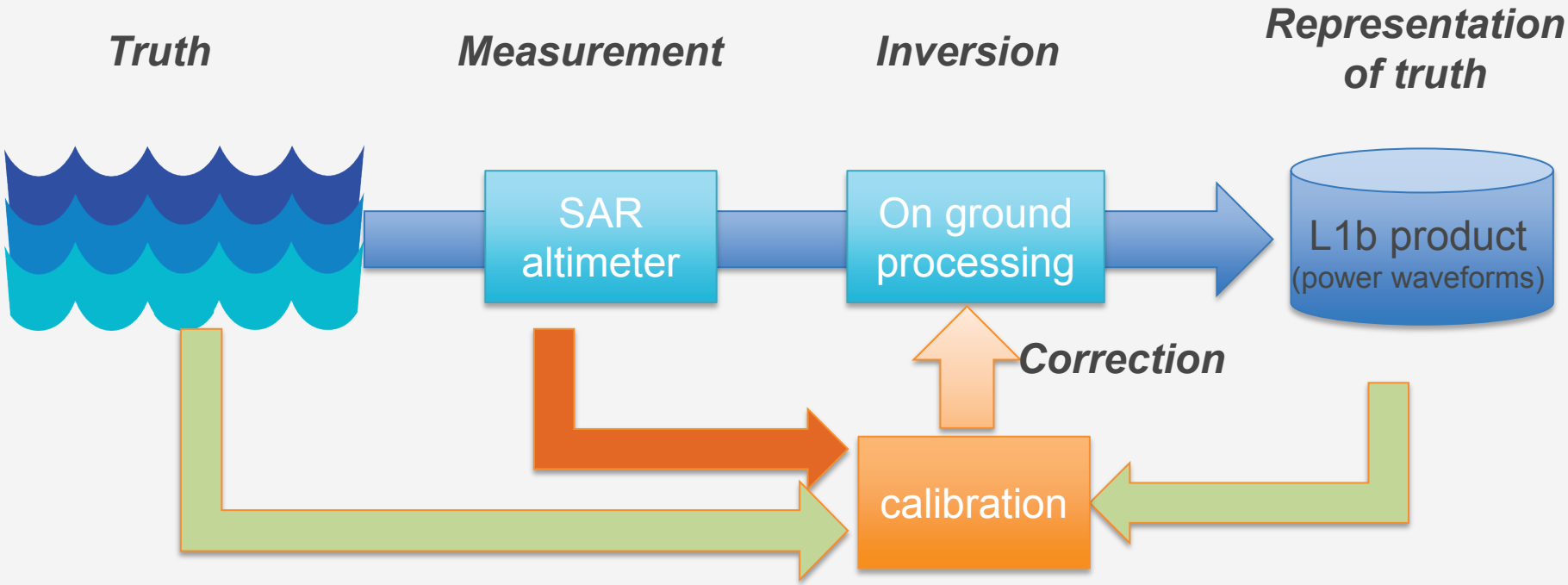


The power waveforms are affected by any distortion introduced by the acquisition, unless that these distortion are properly compensated

SAR altimeter calibration

Definition of Calibration

Calibration is the procedure for converting the Instrument measurement output data into the required physical units under a certain accuracy

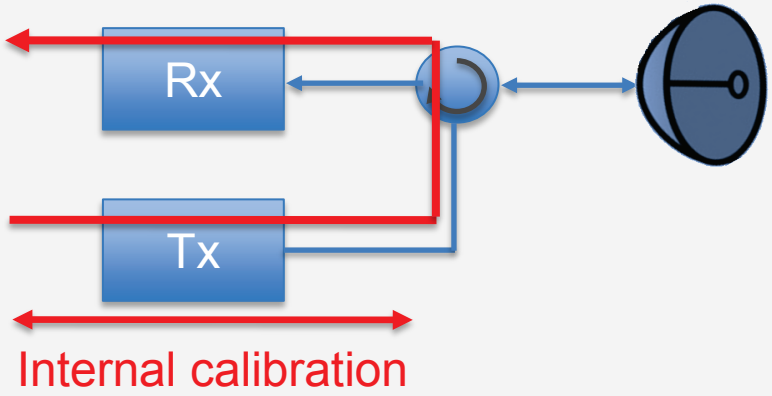


The calibration introduces a correction feedback to reach the required quality of the data

Instrument internal calibration

The instrument internal calibration

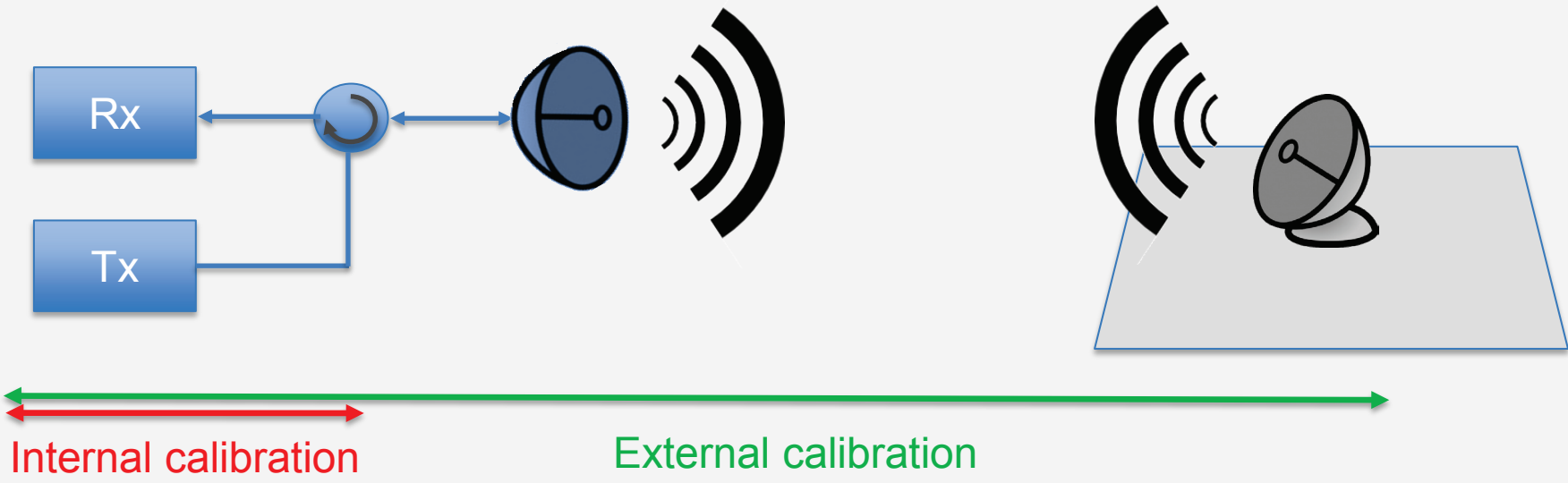
- is aimed at characterizing the distortion introduced by the instrument
- usually involves the signal paths in the digital elements of the instrument
- is commanded regularly on-board according to an instrument calibration plan
- the resulting calibration corrections are applied during on-ground processing



End-to-end external calibration

The end-to-end external calibration

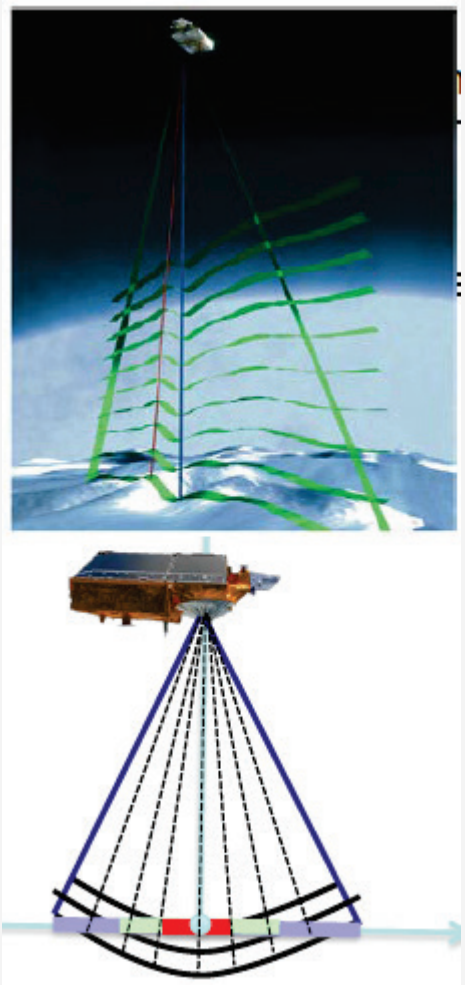
- is aimed at characterizing the end-to-end distortion introduced by the whole acquisition
- involves the Radio Frequency elements of the instrument
- exploits known target on-ground (man-made or natural)



SAR altimeter calibration corrections

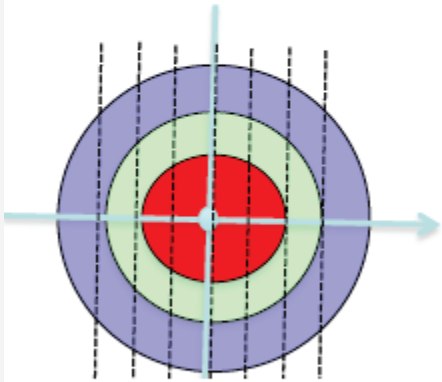
Item to be corrected	Correction	Low Resolution	SAR	SAR Interferometric
Range Impulse Response	Gain Variation	✓	✓	✓
	Path delay	✓	✓	✓
Azimuth Impulse Response	Pulse-to pulse amplitude and phase		✓	✓
Frequency Instrument Response	Low Pass Filter	✓	✓	✓
Power scaling	Automatic Gain Controll	✓	✓	✓
Phase difference	Phase difference between two rx chains			✓

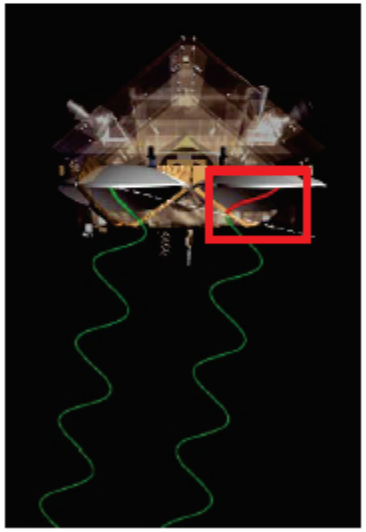
CryoSat: the first SAR altimeter



SAR: Over sea ice, coherently transmitted echoes are combined, to reduce the illuminated surface area to carry out HR measurements

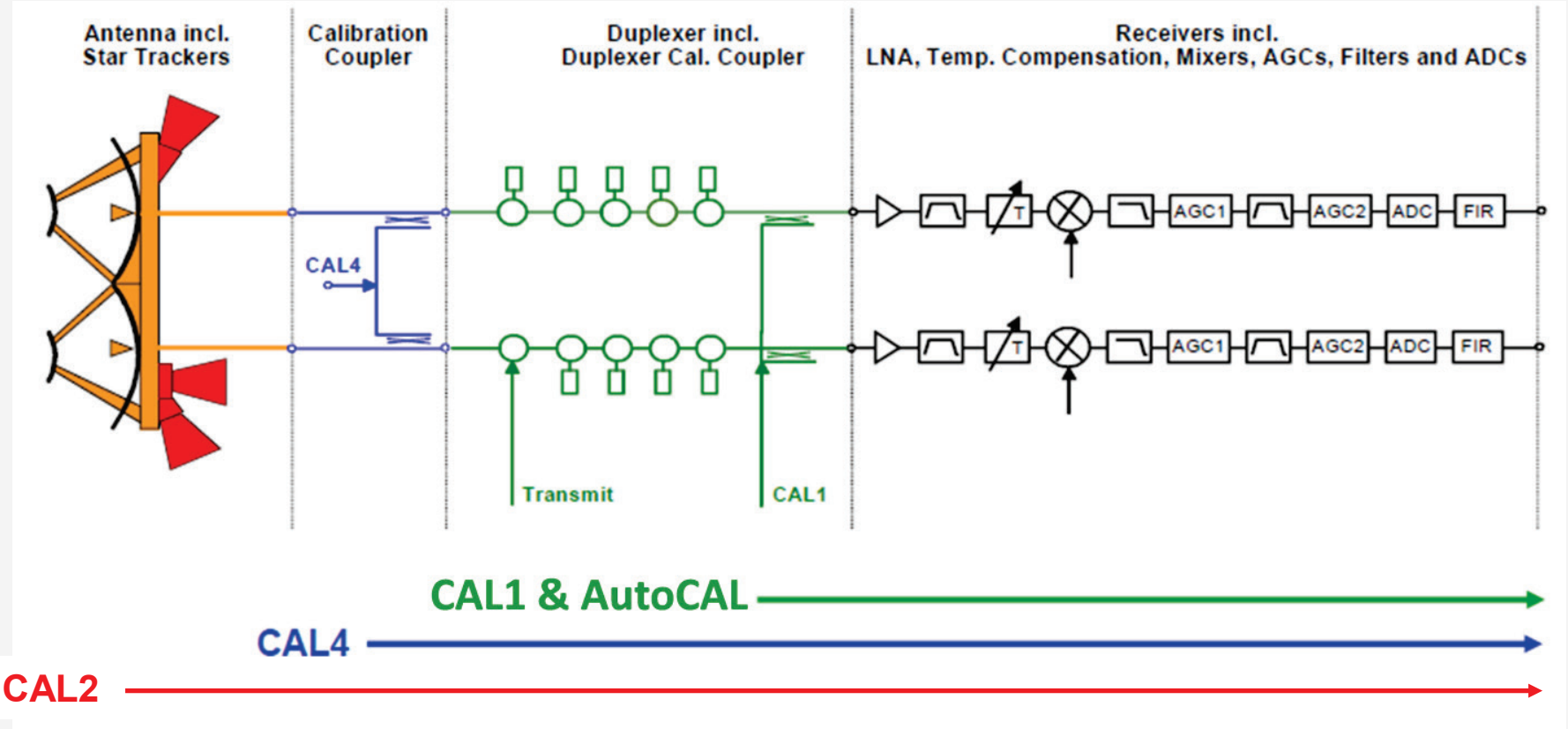
SARIn: Around ice sheet margins and glaciers. Uses a 2nd antenna as an interferometer to determine the across-track angle to the earliest radar returns





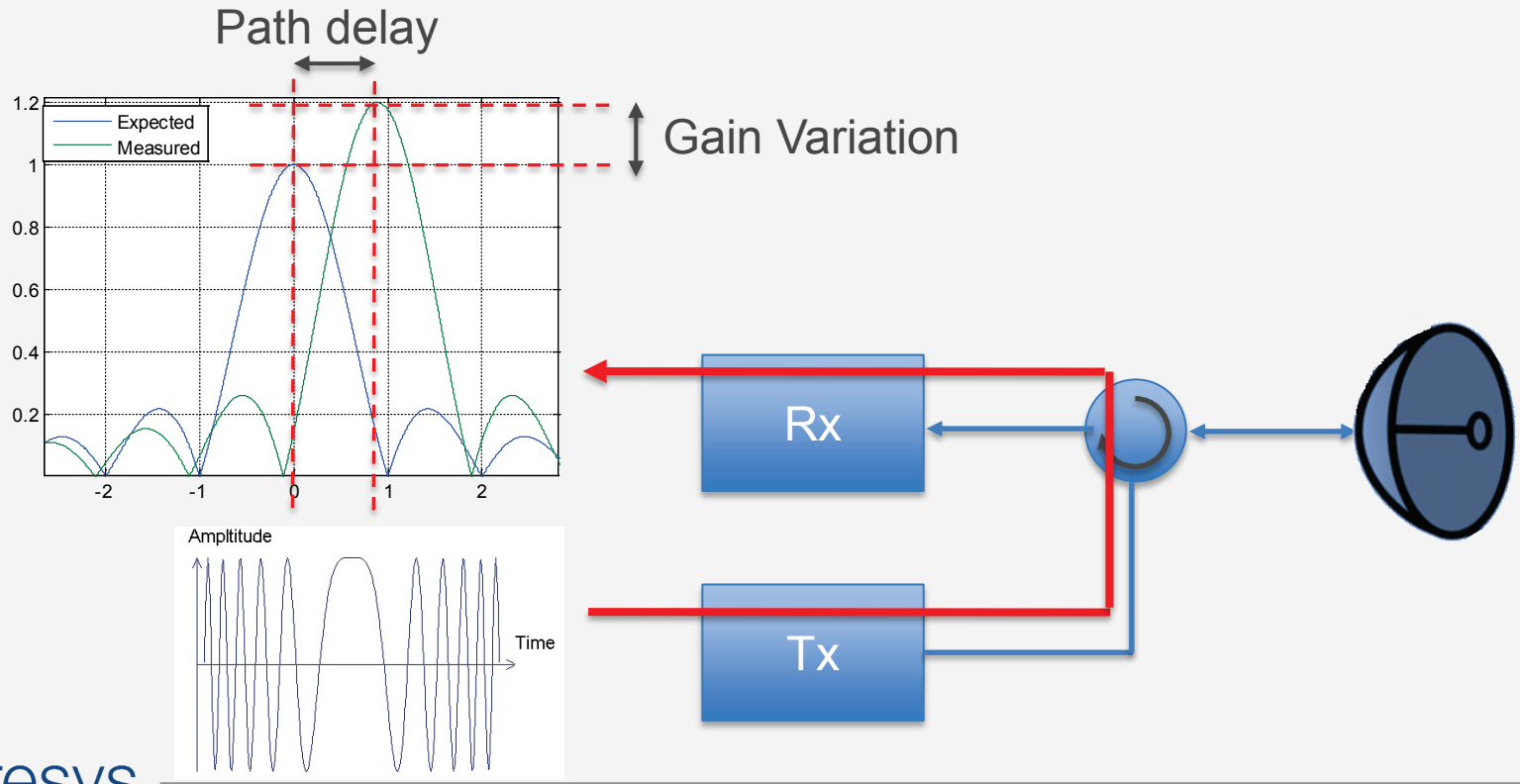
CryoSat: SIRAL internal calibration

- SIRAL Calibration Paths



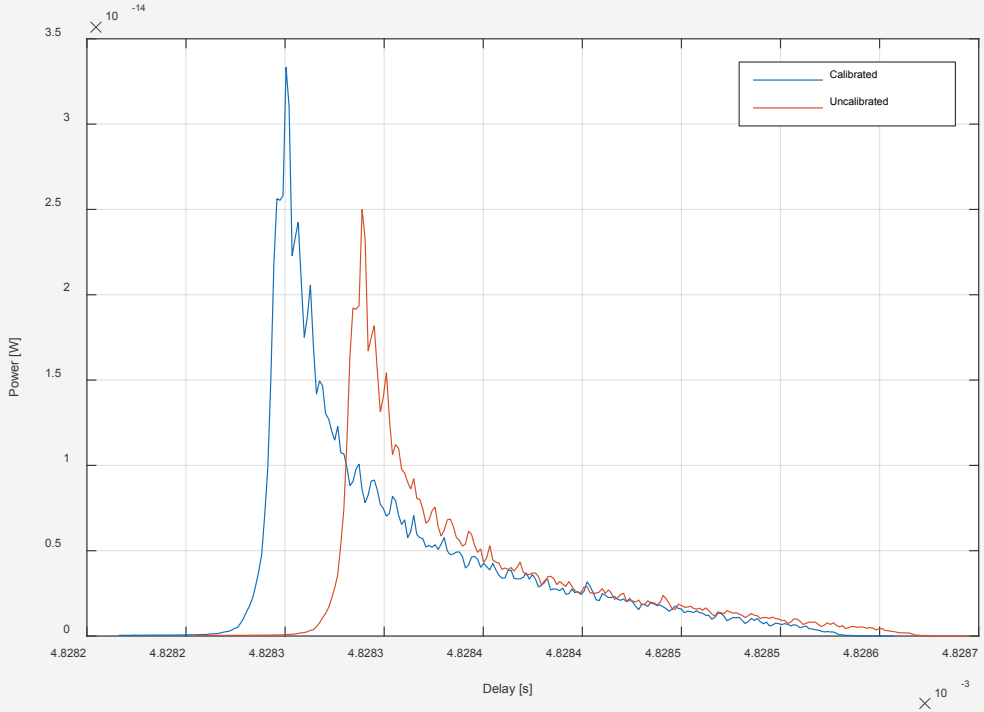
Calibration of Range Impulse Response

- **Objective:** measuring the internal path delay and the gain variation introduced by the instrument to the Range Impulse Response
- The calibration of Range Impulse Response is performed by CAL1 in CryoSat



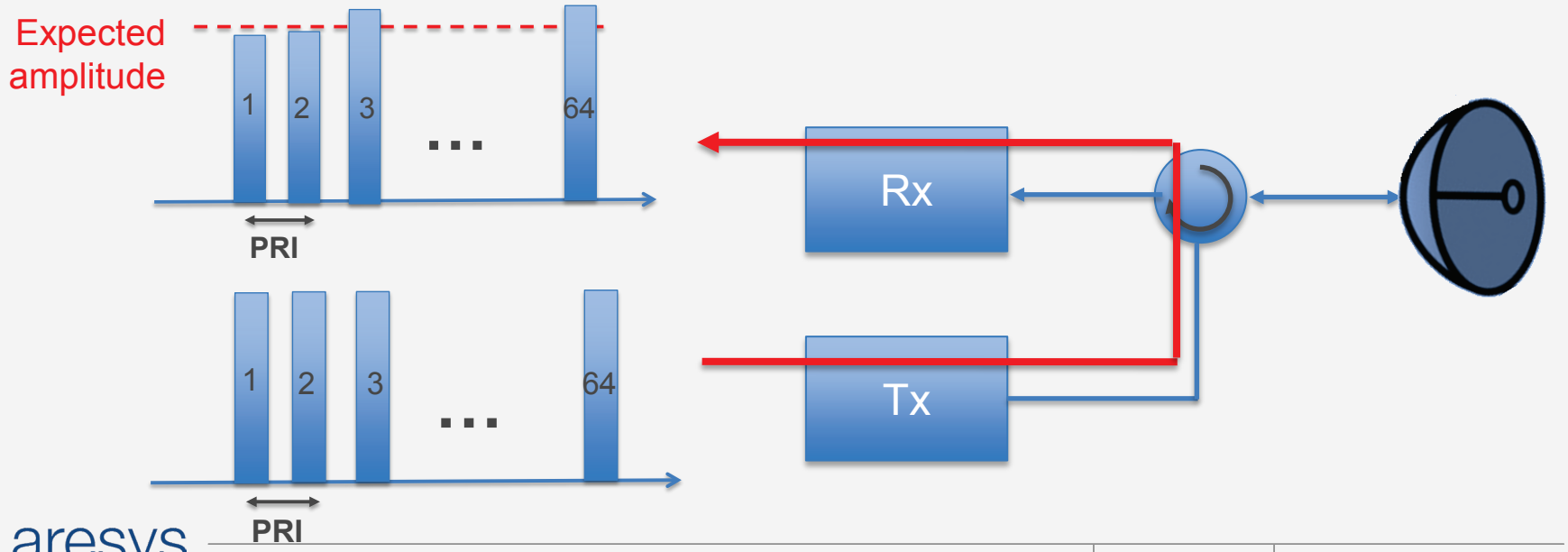
Calibration of Range Impulse Response

- Without applying Range Impulse Response calibration corrections, the power waveforms is expected to be scaled in power and shifted in delay.
- Direct impact on L2 performance for ocean acquisitions is expected (e.g. sigma0 and SSH).



Calibration of Azimuth Impulse Response

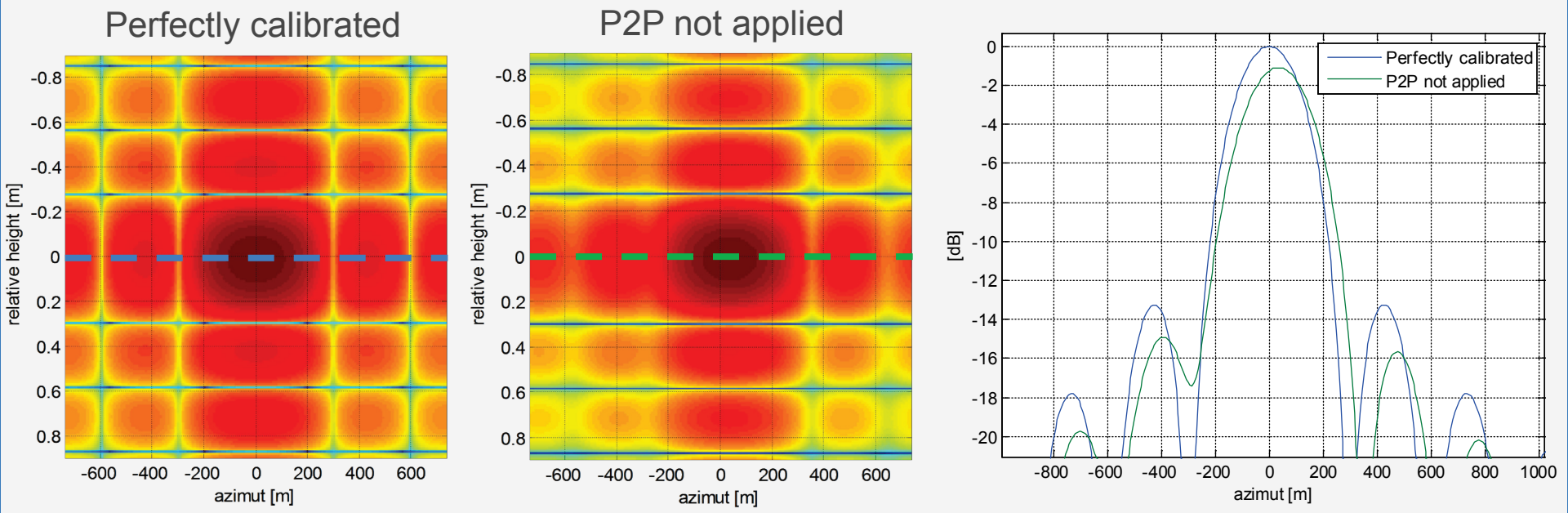
- **Objective:** measuring the pulse-to-pulse power gain variation and pulse-to-pulse phase variation between successive pulses in the burst
- the power gain as well the phase varies among the individual echoes as a result of hardware effects arising from the power-up of the transistors at the start of each burst
- The calibration of Azimuth Impulse Response is performed by CAL1 in CryoSat



Calibration of Azimuth Impulse Response

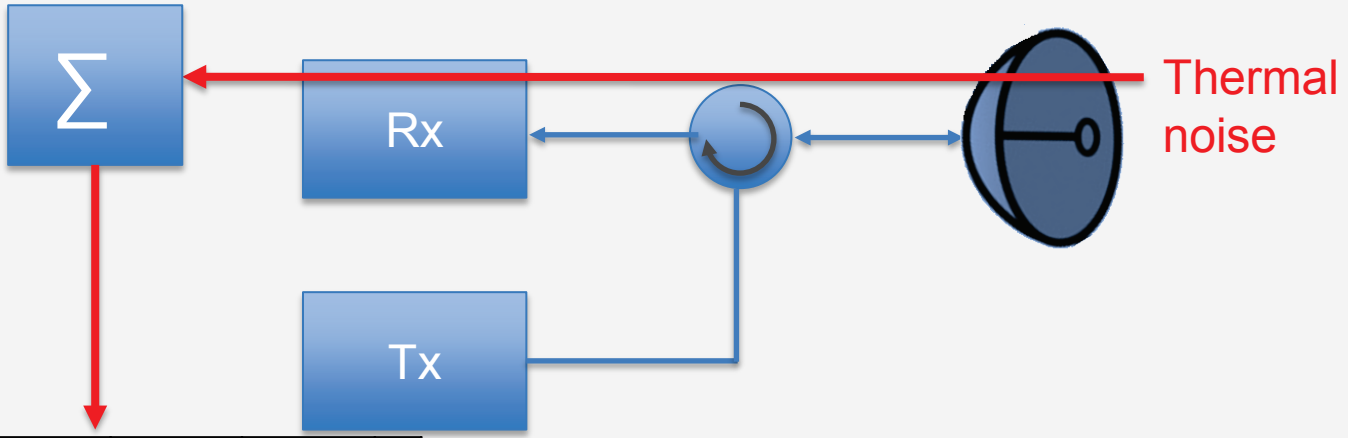
- Incorrectly applying pulse-to-pulse (amplitude and phase) calibration correction, a distortion of the Azimuth Impulse Response is expected, resulting in a worsening in the sense of resolution, PSLR, peak power and peak position.

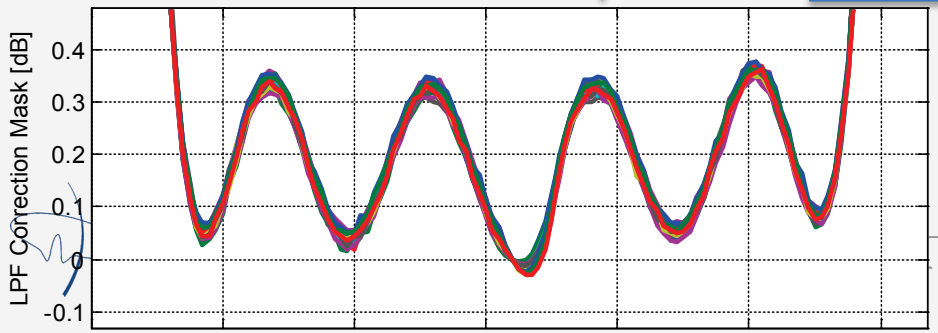
- From CryoSat point-target simulation (not real CS data) and exaggerating the impact of CAL



Frequency Instrument Response

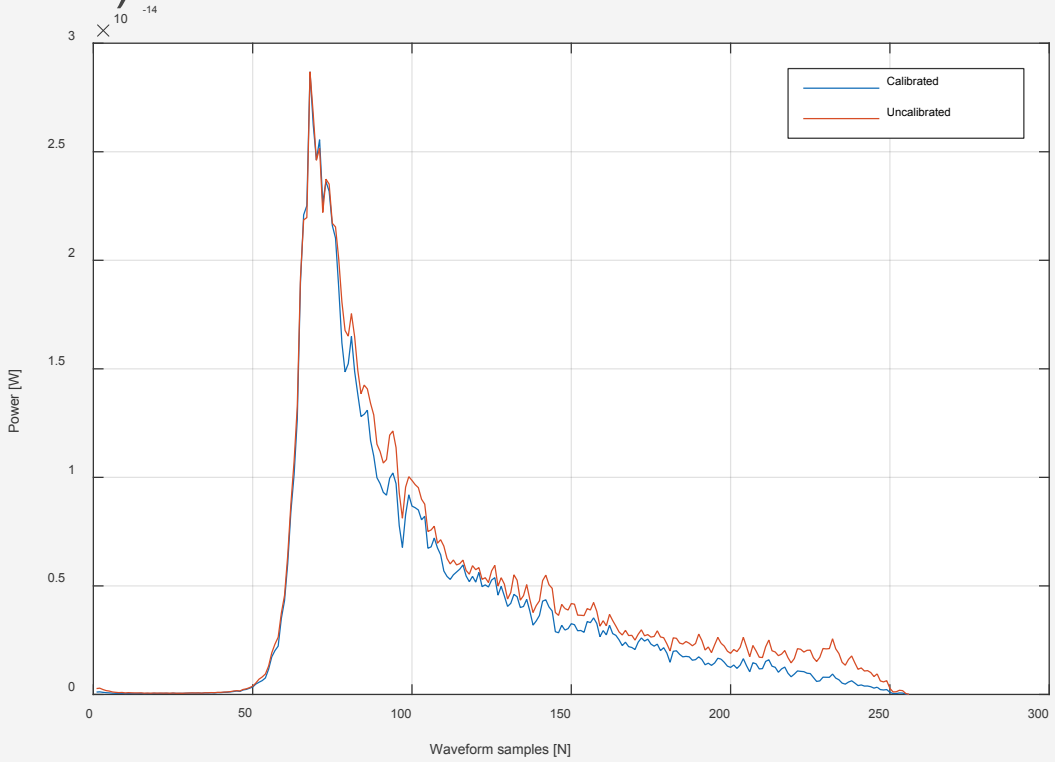
- **Objective:** characterizing the instrument gain across the frequency band in Rx
- It is performed by acquiring thermal noise in absence of transmission and integrating the noise over a certain period of time
- The calibration of Frequency Instrument Response is performed by CAL2 in CryoSat





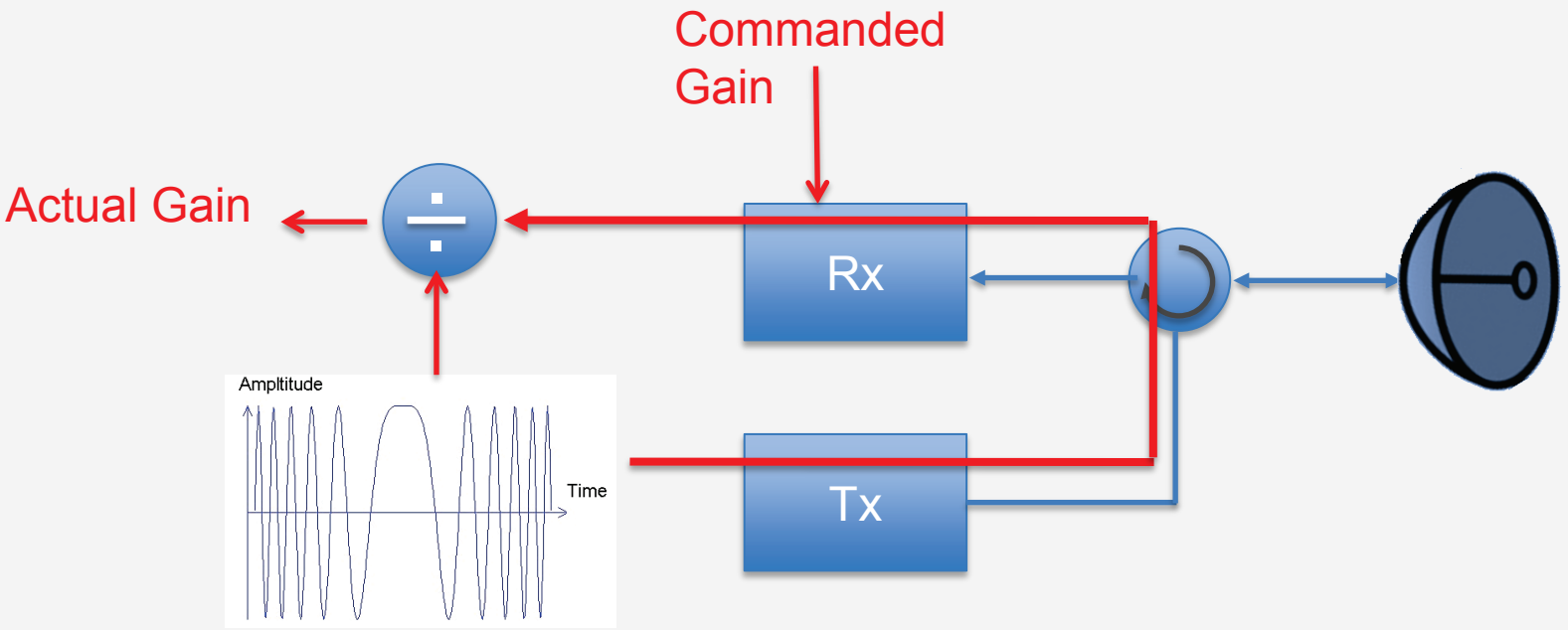
Frequency Instrument Response

- Without applying LPF correction, the shape of L1b waveform is expected to be modulated by the Low Pass Filter instrument response function as function of the delay.
- Direct impact on L2 performance for ocean acquisitions is expected (e.g. SWH, roll, misfit).



Calibration of power scaling

- **Objective:** characterizing the Automatic Gain Control stages
- It is performed measuring the difference between the commanded gain to the AGC and the actual gain added to the signal
- The calibration of power scaling is performed by Complex CAL1 (also known as Autocal) in CryoSat

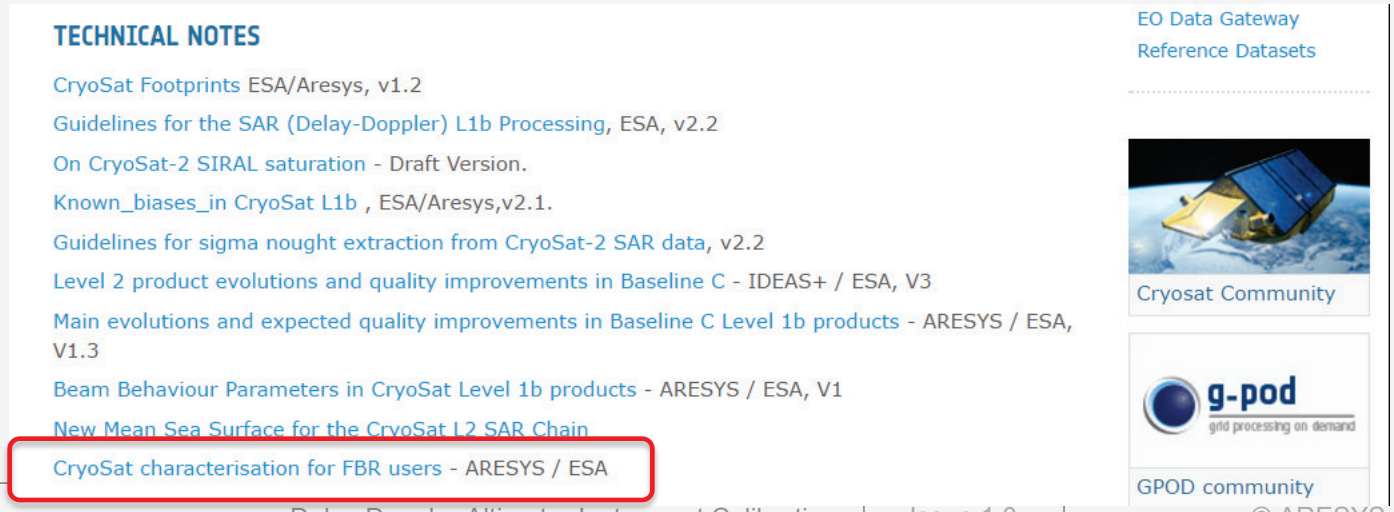


Calibration: L1b vs FBR products

- L1b products contain power waveforms already calibrated for the instrument : user does not need to apply instrument calibration
- FBR (also known as L1a) contain the received complex echoes: user needs to apply instrument calibration

HOW TO CALIBRATE CRYOSAT FBR PRODUCTS?

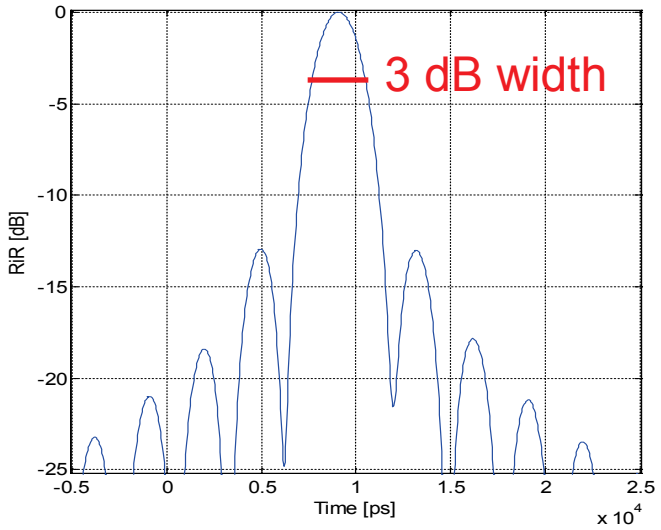
At the CRYOSAT WIKI it can be found the “CryoSat characterizarion for FBR users”



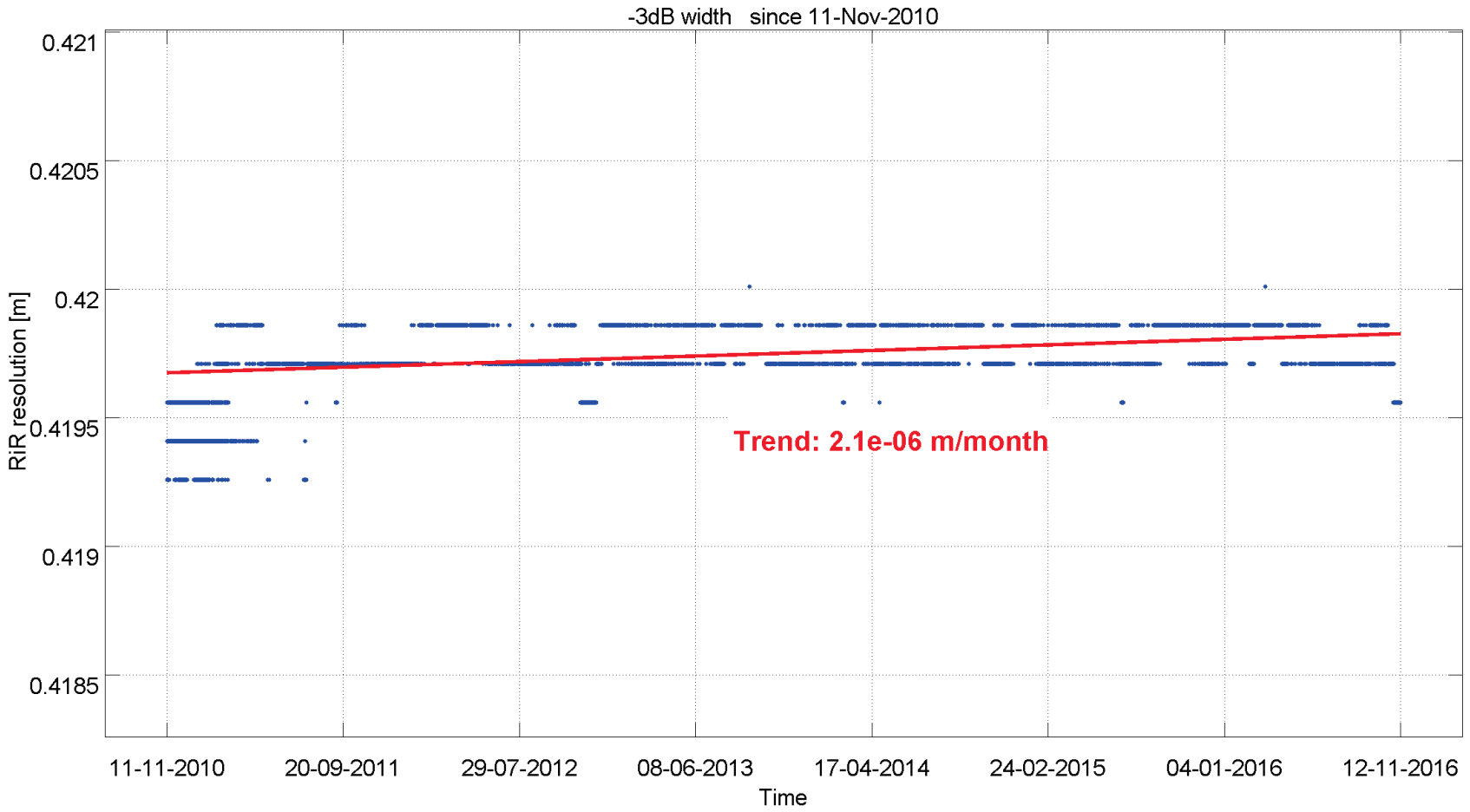
Calibration monitoring

- The calibration are routinely commanded and performed on-board
- Their continuous monitoring allows to track the status of the instrument
- Objective is to answer to the following questions: are the performance of the instrument within the system requirement?

Example:
monitoring the -3dB width of the Range Impulse Response allows to monitor the performance of the instrument in the sense of range resolution



Range resolution for CryoSat SAR mode



Requirement on -3dB width: 0.394 m < -3dB width < 0.436 m

Conclusions

- Correcltly applying the calibration correction during on-ground processing is a crucial step to reconstruct the geophysical quantities observed
- The calibration corrections for SAR altimeter have been discussed
- Users need to apply the calibration corrections on their own when using FBR products and guidelines are available for CryoSat