Speckle reduction by along-track antenna pattern compensation on stacks of single look echoes

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Outline

- Speckle, multilooking and range noise
- Equivalent number of looks
- Along-track antenna pattern compensation
- Experimental results
- Conclusions

From speckle to range noise

Speckle: radar echoes are the incoherent summation of many randomly phased echoes from small scattering regions of the surface. This cause the speckle noise.

Multilooking: The main purpose of multi-looking is to reduce the speckle through summing statistically independent looks at any given surface location.

Range noise: the uncertainty on the range measure is function of the number of statistically independent looks (N)

Single look echo:

$$w_{sl}(l,r) = s(l,r) \cdot w(l,r)$$

Multilooked echo:

$$w_{ml}(l,r) = \frac{1}{N_{ML}} \sum_{l=1}^{N_{ML}} s(l,r) \cdot w(l,r) =$$

$$\approx w(l,r)\left[1 + \mathrm{N}\left(0, 1/N_{ML}\right)\right]$$

Range noise

$$\sigma_h = \frac{\sigma_p}{0.8\sqrt{N_g \cdot N}} \left[1 + \frac{2}{SNR}\right]$$

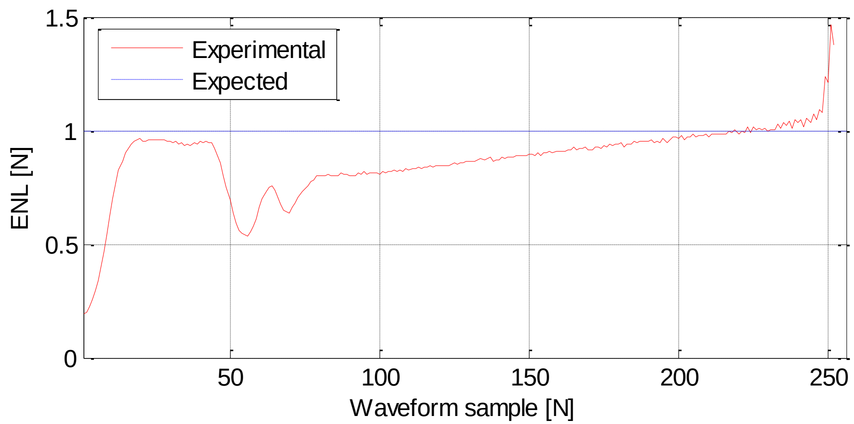
Equivalent Number of Looks

The ENL is the estimate of the effective number of statistically independent looks and it is expected to be smaller than the number of averaged single look echoes

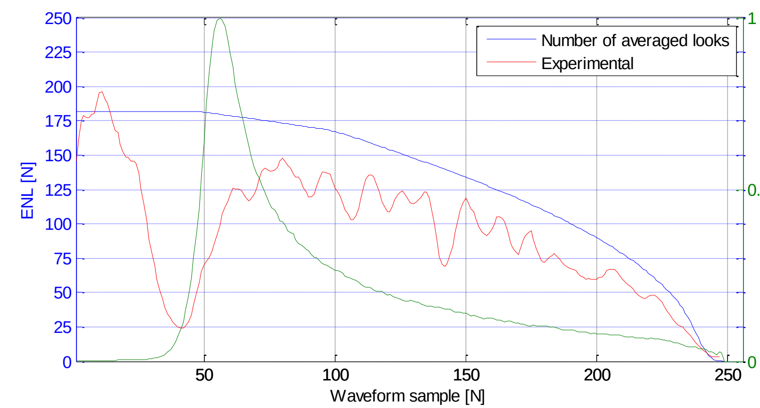
$$ENL = \frac{E[I]^2}{Var[I]} = \mu \cdot N_{ML}$$

On ocean surface, the ENL for CryoSat single look and multilooked echoes was evaluated and it resulted far from expected values

ENL for single look echoes



ENL for 20Hz multilooked echoes

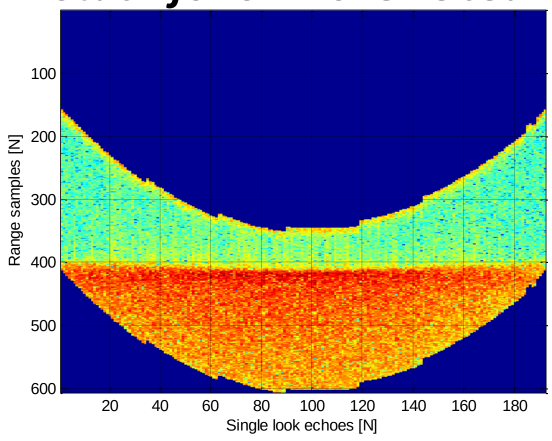


Acquisition of a stack of single looks

All the acquired single look echoes that are referred to a given point on Earth surface are gathered in a stack.

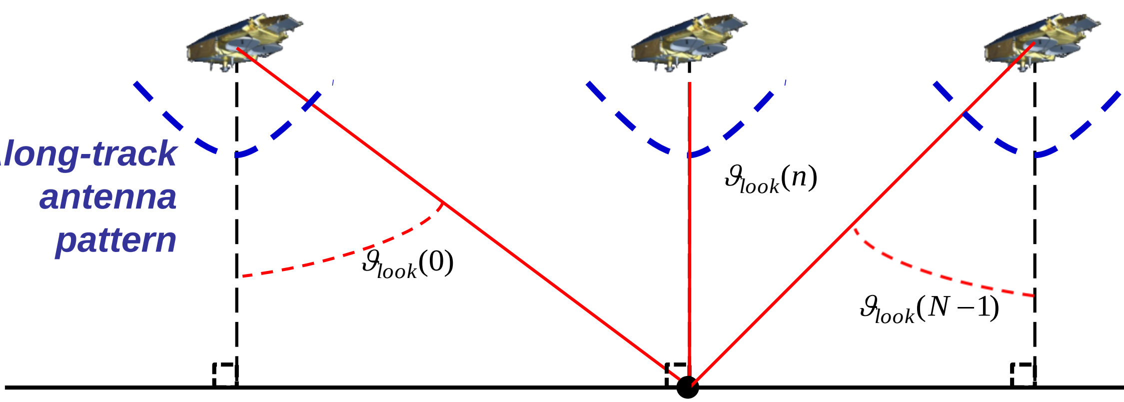
Each single look echo has been acquired for a different look angle, so that is scaled by the along track antenna pattern as function of the look angle.

Stack for SAR over Ocean

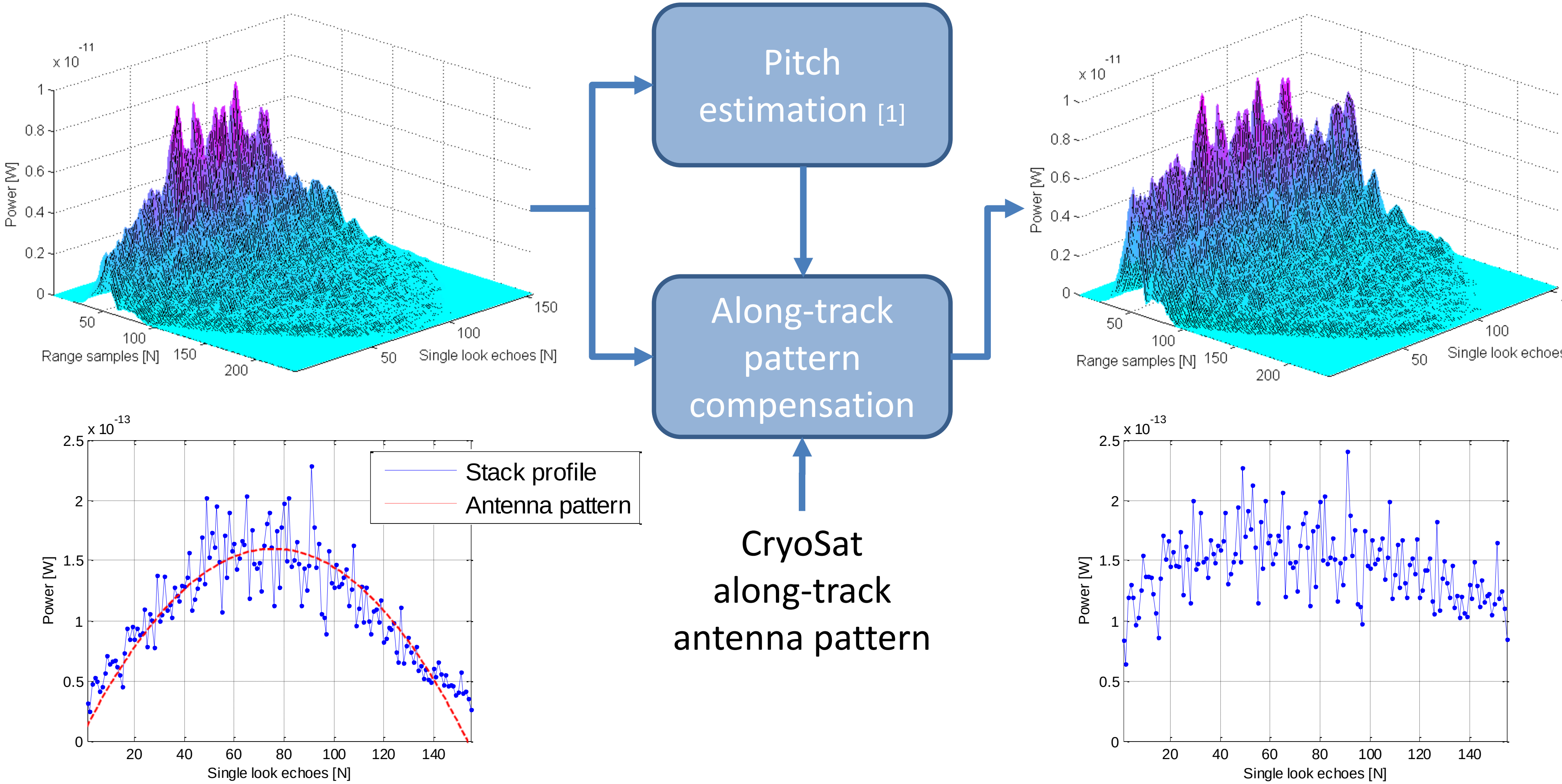


Also the speckle is scaled by the antenna pattern.

$$w_{ml}(l,r) = \frac{1}{N_{ML}} \sum_{l=1}^{N_{ML}} G_A(l) \cdot s(l,r) \cdot w(l,r)$$

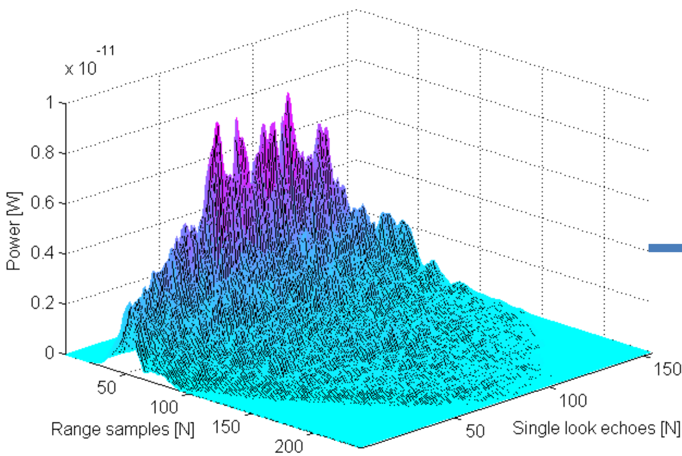


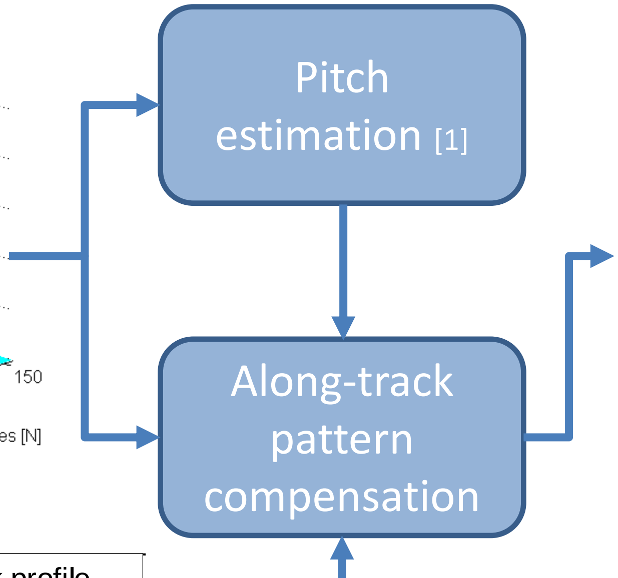
Along-track antenna pattern compensation

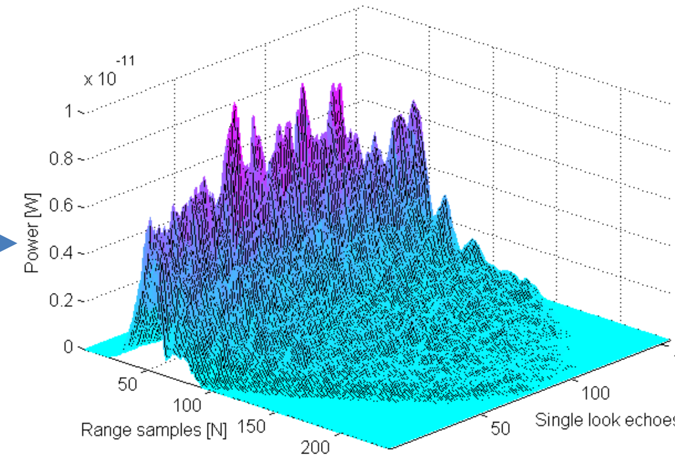


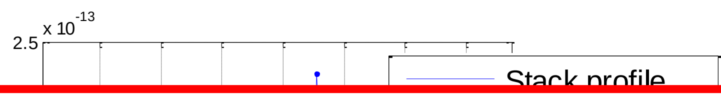
[1] “Pitch estimation for CryoSat by analysis of stacks of single look echoes”, Scagliola M., Fornari M., Tagliani N., submitted to Geoscience and Remote Sensing Letters, IEEE

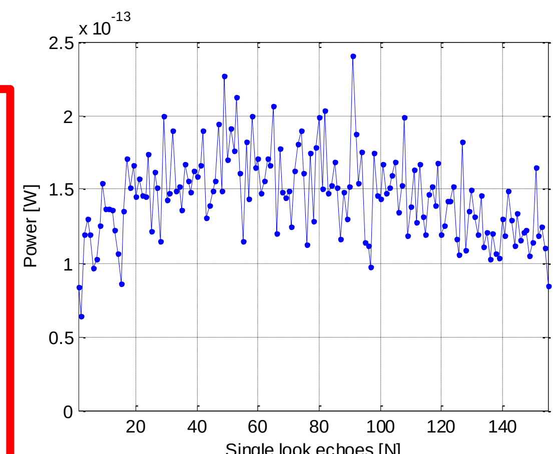
Along-track antenna pattern compensation











The speckle from all the single look echoes in the stack is raised to the same power

A better speckle reduction is expected by compensating the along-track antenna pattern

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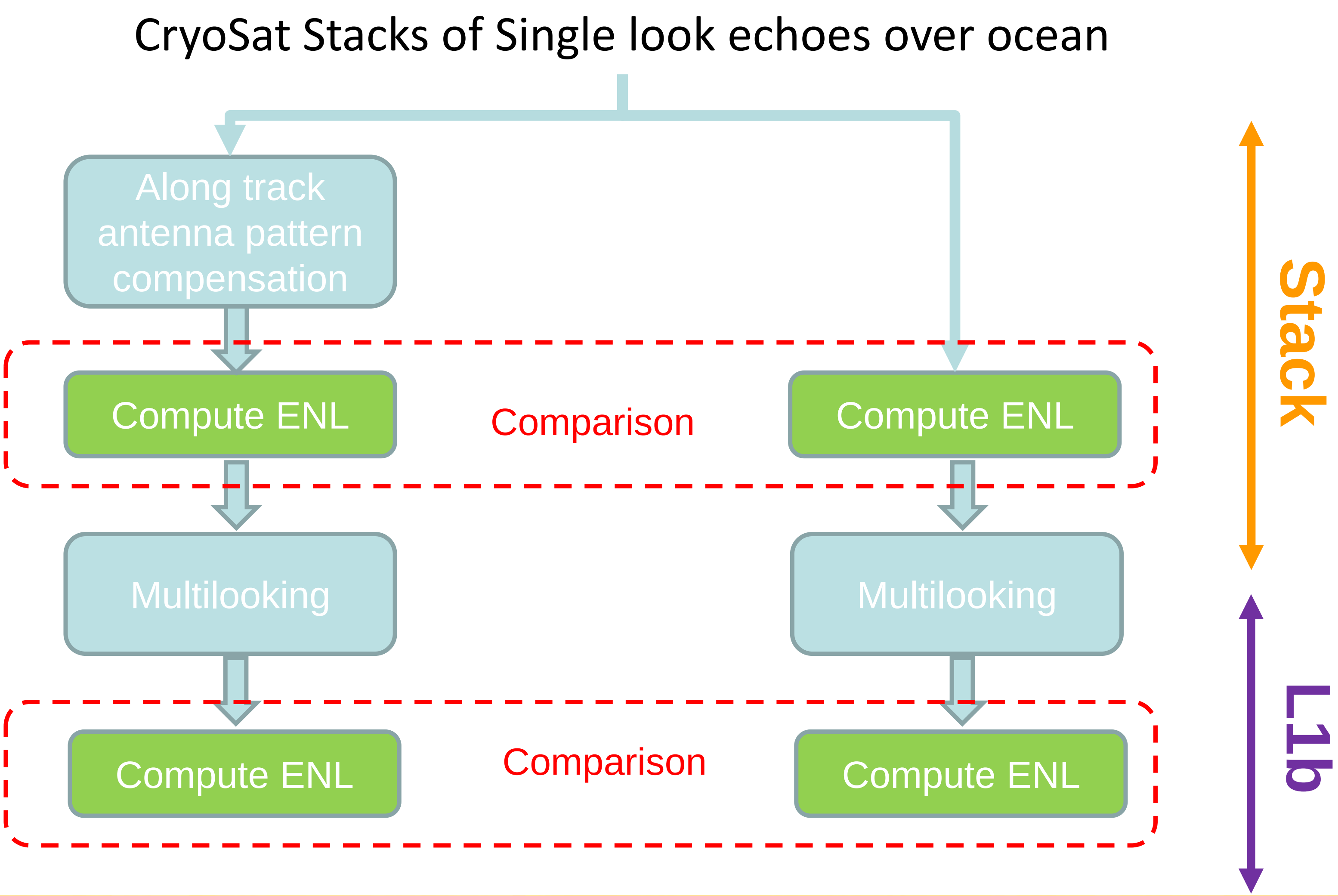
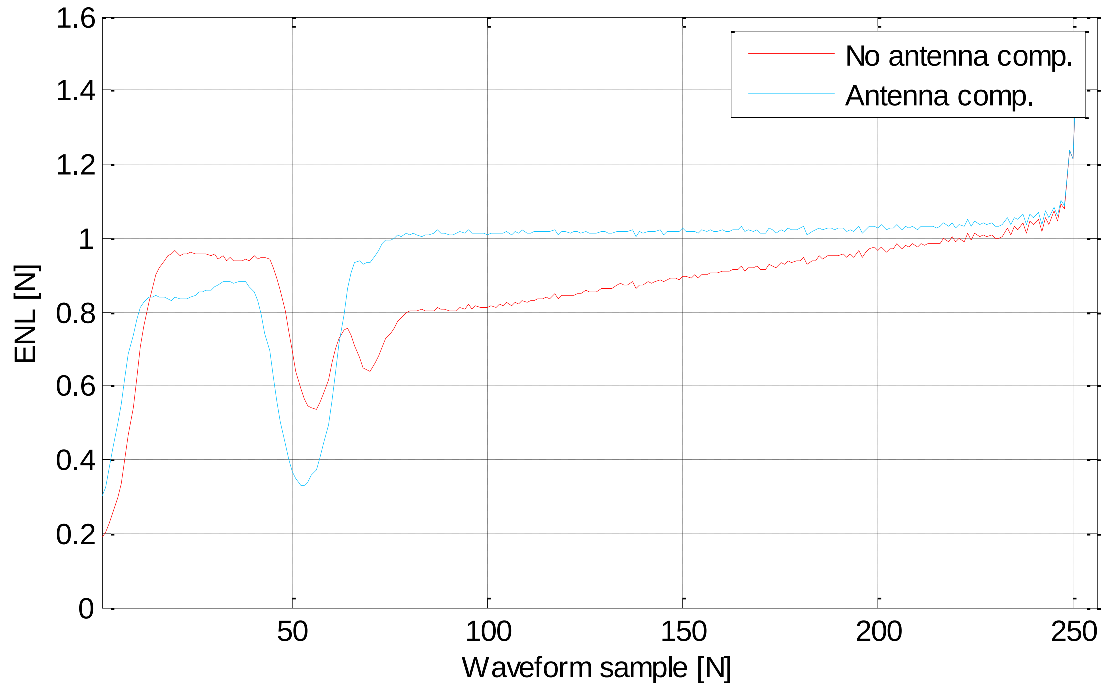
Experimental results



ENL for single look echoes

Averaging the ENL computed on 250 stacks over ocean, the ENLs in figure below have been obtained.

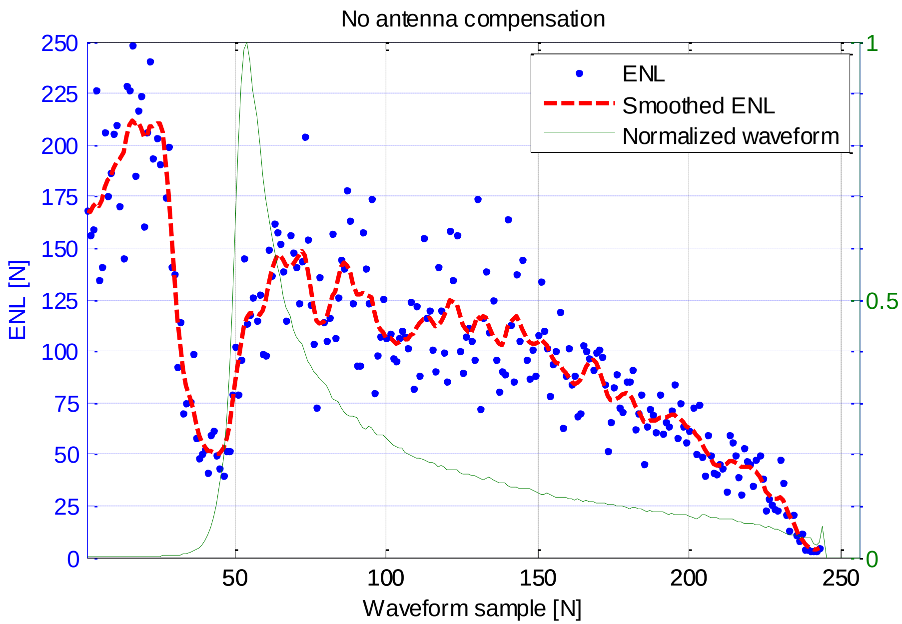
The expected value of ENL=1 is obtained only in case that the along-track antenna pattern is compensated.

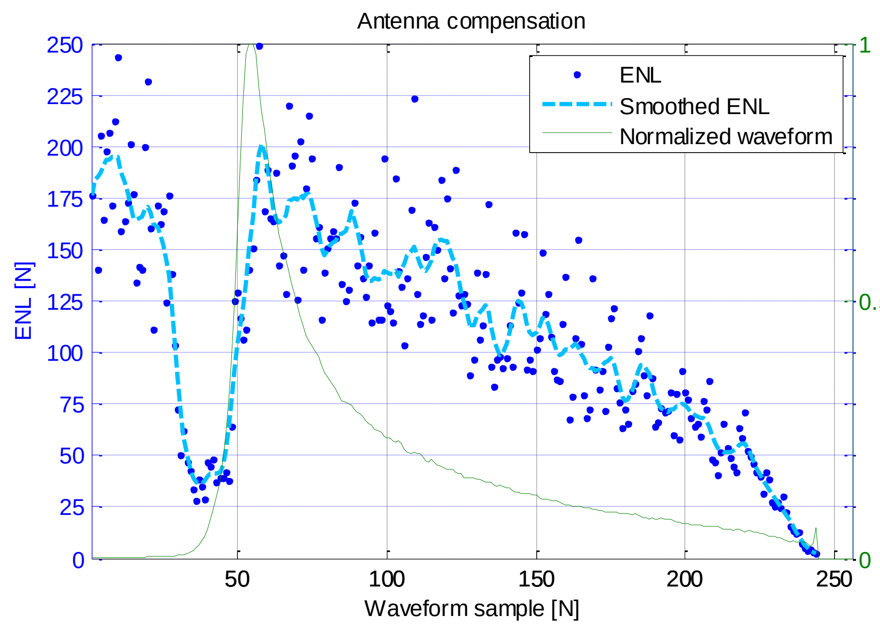


ENL for 20Hz multilooked waveforms

The ENL has been evaluated on the 20Hz multilooked waveforms by considering 50 consecutive waveforms.

By comparison it can be notice that the ENL on the 20Hz multilooked waveforms is higher just after the leading edge in case that alng-track antenna pattern is compensated.

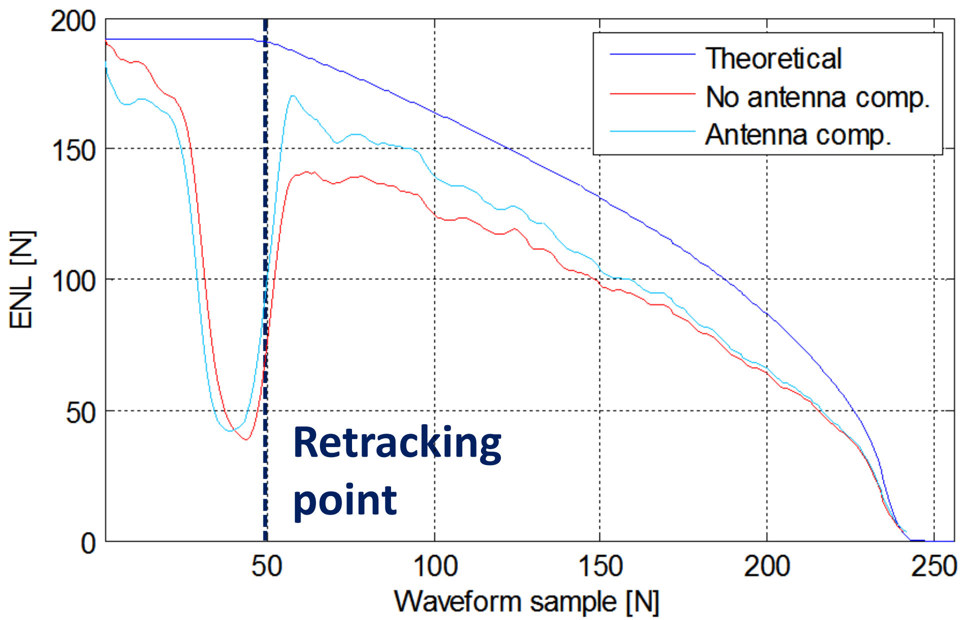




ENL for 20Hz multilooked waveforms

In figure below the average ENL on about 1500 multilooked waveforms has been compared with the number of averaged looks in the stack, that represent the upper bound for the ENL. The ENL for antenna compensation is closer to the upper bound.

When the antenna pattern compensation is applied, the ENL is higher starting from range sample 40 (all the waveforms are aligned with respect to the sample 50, which is the reracking point computed by OCOG).

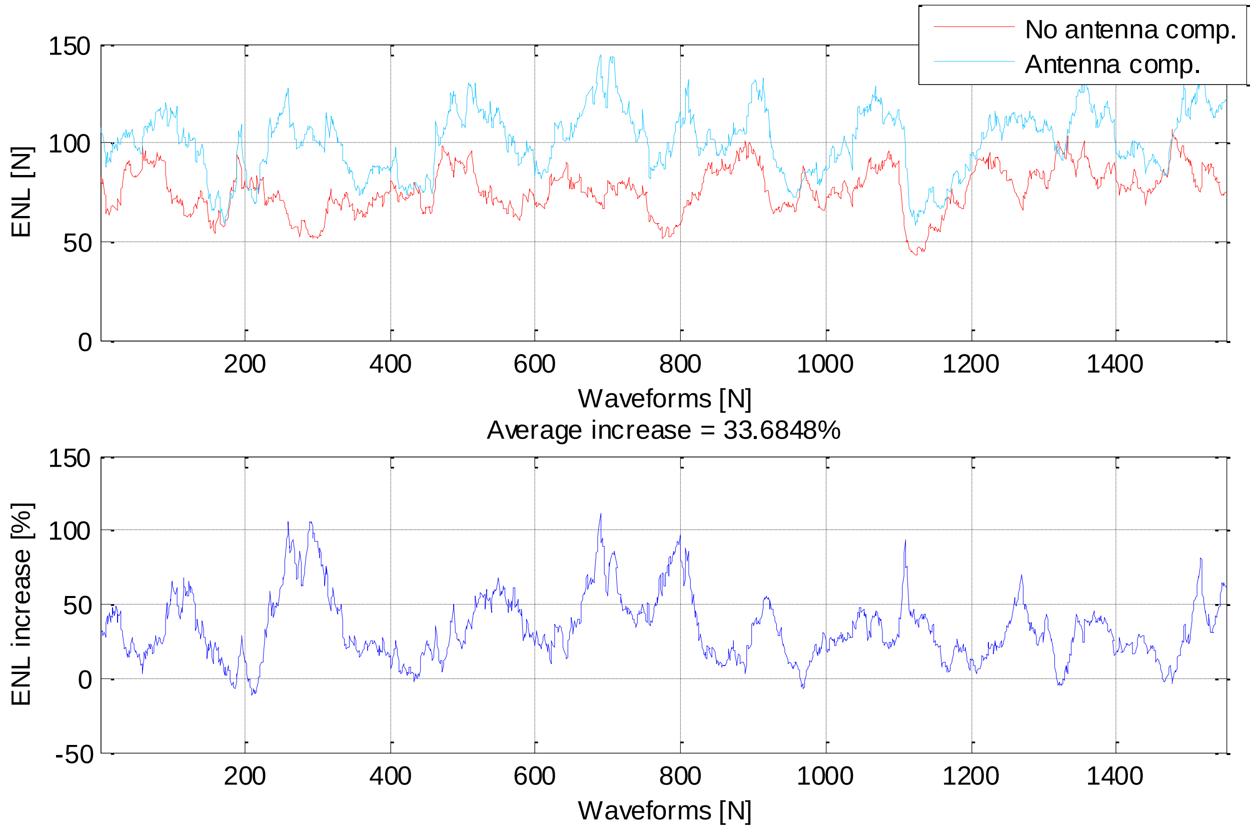


ENL increase at retracking point

Several CryoSat acquisition over ocean have been processed to evaluate the ENL increase in correspondence of the retracking point.

An average increase of about 30% has been evaluated on the CryoSat SAR acquisitions.

An example is here on the right.



Conclusions

- ENL lower than 1 has been evaluated on CryoSat stacks of single look echoes and this has been addressed to the along-track antenna pattern scaling of the echoes.
- By compensating the along-track antenna pattern on stacks of single look echoes before multilooking
  - An ENL approximately equal to 1 has been measured for single look echoes
  - An ENL increase has been measured for the 20Hz multilooked echoes
  - An ENL increase of about 30% has been measured in correspondence of the retracking point
- The next step is to verify that the variance in sea level anomaly is reduced by compensating the stack, as it is expected from ENL.