27-31 October 2014,
OSTST meeting,
Lake Constance, Germany

Impact of the oversampling method on the radar altimeter estimates

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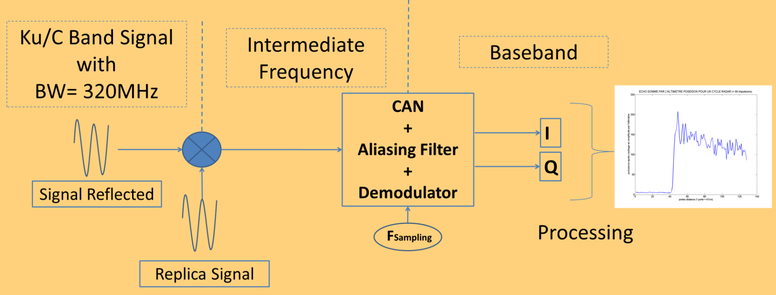
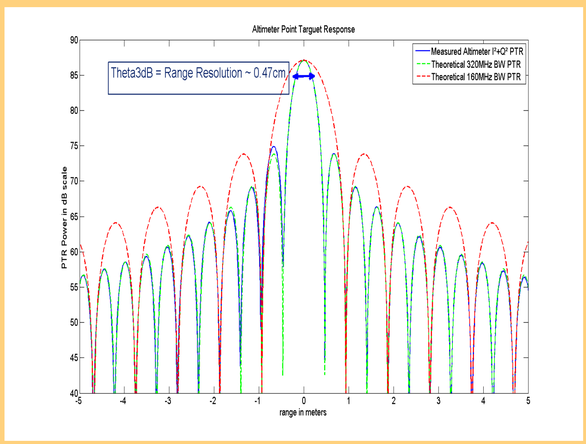
ABSTRACT Recent paper published by W. Smith (NOAA) *et al. (Waveform Aliasing in Satellite radar altimetry, IEEE TGRS, 2014)* based on Jensen's results (*Radar altimeter gate tracking: Theory and extension*, *IEEE TGRS, 1999*) recommends to use 0-padding processing on ocean altimeter waveforms to compensate for on-board aliasing. This aliasing is explained by the author as a consequence of the squaring of the (I,Q) signals that would reduce the actual altimeter bandwidth from 320MHz to 160MHz (for Ku band altimeter).

First, we will present the altimeter architecture to explain why the altimeter bandwidth and accuracy are well preserved. Then, the 0-padding effects will be analyzed directly on the altimeter waveforms to understand the impacts on the measurements. At last, we will assess the method with real Cryosat-2 PLRM data over ocean.

Architecture of the altimeter system





After de-ramp operation, the data processing is not dependent anymore of the 320MHz Bandwidth of the emitted signal.
In particular, the sampling frequency (Fsampling) depends on the altimeter architecture and is very small with respect to BW.

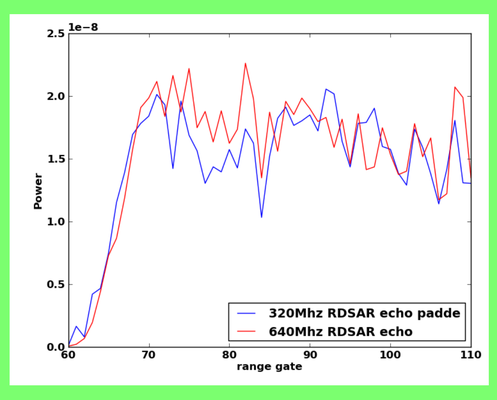
The square function applied on I & Q signal to compute the echo energy has therefore no impact on the altimeter resolution. This is illustrated by the real Point Target Response which fits accurately a 320MHz bandwidth theoretical PTR.

At instrument level, all necessary precautions have been taken to avoid any corruption of the radar information.

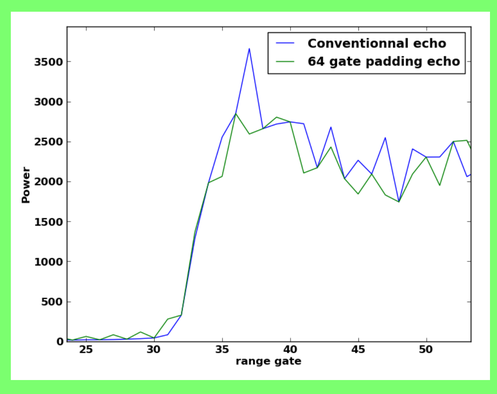
Effects of zero-padding operation

Padding by zeroes the original time sequence corresponds mathematically to multiply it by a rectangular window (of the chirp bandwidth in width), equivalent in turn **to convolve the spectrum with a sinc function** (transform of the rectangle function) in the frequency domain. Therefore, 0-padding is an interpolation method using amplitude and phase signals. It does not create information and generate **bin-to-bin correlation. This is the reason why we decided to assess accurately this method.**

This example shows two 20-Hz power spectrum simulated with and without zero-padding methods, over identical sea-state condition. One spectral waveform is processed at 640MHz sampling rate, the other one generated in complex at 320MHz is oversampled by a factor of two. While we were expected to get similar echoes, we can observe that they do not match so well.



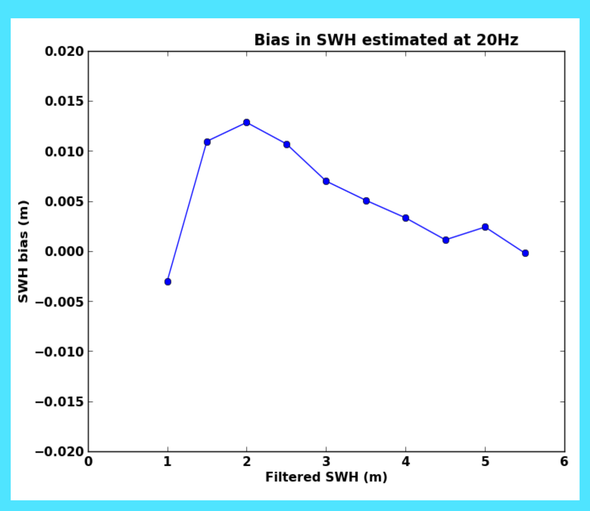
There is another way of looking at this. A real pseudo-LRM 128-samples spectral waveform is compared to the same waveform reduced first to 64-samples then oversampled by a factor of two. We can clearly see that interpolating a N-point waveform by zero padding the associated time-domain sequence will not give the same result as a 2N-point waveform.

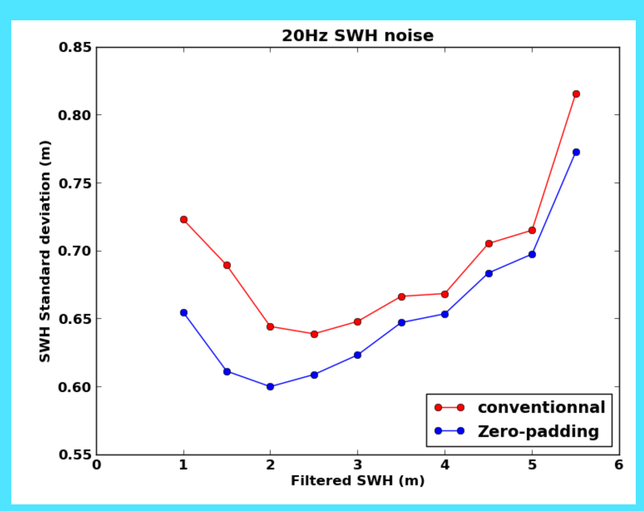


This 0-padding method does not allow reconstructing the true information which has been removed.

Assessment of the zero-padding method over open ocean

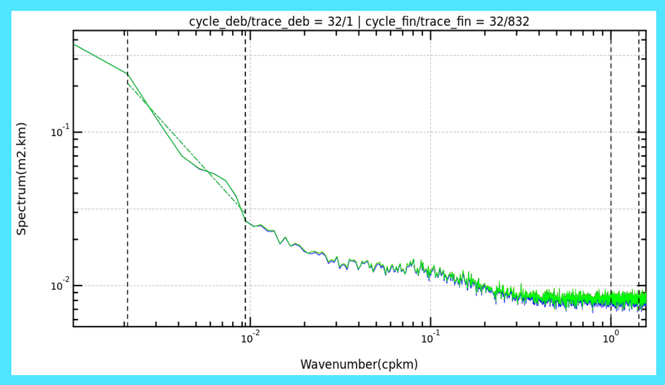
One-month of pseudo-LRM (RDSAR) CY2 data from the Pacific box has been generated by the CPP (with complex zero-padding method and not) and the estimated sea-state parameters are then compared.





On SWH, the assessment highlights an interesting 20Hz **noise reduction** on estimates (~7% at 2m) introduced by the 0-padding without generating significant biases.

The SLA spectra analysis shows both methods measure **exactly the same** content of the oceanic signal from low to high wavelength, and very similar noise level.



Conclusions

The altimeter architecture insures a 320MHz bandwidth resolution.

The time domain zero-padding method is limited to an interpolation process that does not create any additional information.

However, the assessment shows this method does provide an interesting SWH noise reduction without introducing significant biases, that makes it attractive for ocean waveforms processing.

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Acknowledgements: this work is supported by CNES.