Can We Really Achieve 300-Meter Resolution from A SAR Altimeter?

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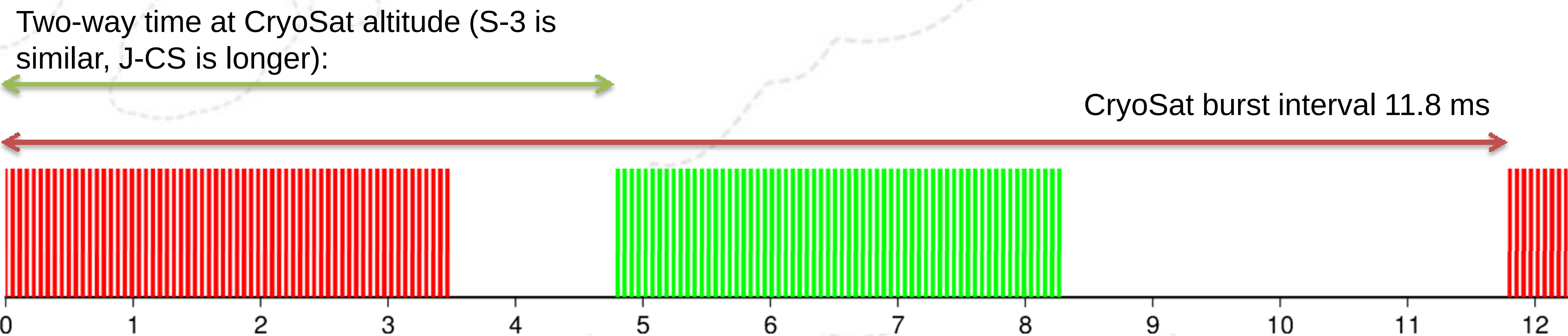
Cryosat-2 SAR pulse timing



For CryoSat N = 64 and PRF = 18 kHz give a burst duration of ~3.5 ms (But the burst-to-burst interval is ~11.8 ms)

Why 300 m ?

- We can apply SAR theory and come up with **~300m** as the along-track **sampling** (not resolution, but sampling) that we can expect from SAR processing of the CryoSat SAR mode data.

- This number, 300 m, can be derived either as Keith Raney did in his delay-Doppler theory, by considering the Doppler shifts we can sample, or by simply computing the phase interference in a coherent sum, treating the 64 transmit/receive points as a phased array antenna.

However….

- …both the above theoretical calculations assume that **all 64 echoes in a burst can be processed coherently**, and contribute equally to resolving a point on the ground.
- This may seem paradoxical, in light of previous work by Ed Walsh [papers in 1974 and 1982] which found that conventional pulse-limited echoes should decorrelate after a time (~0.5ms) equal to about 9 pulse emissions of CryoSat's SAR mode.
- If echoes decorrelate after only 9, how can we process 64 of them coherently to get 300 m ? If in fact we can process only 9, then the along-track narrowing of the footprint is not narrowed all the way to 300 m, but rather something like 300 m times (64/9), **or about 2.1 km.**

What happens

- In fact what happens is that we receive power from throughout the pulse-limited footprint. A narrow strip, perhaps 300 m across, within this footprint remains phase-coherent, while the rest of the footprint becomes phase incoherent after 9 or so pulse echoes are received.

- This means that we can, in fact, narrow the footprint to something on the order of 300 m, but with very poor signal to noise ratio. **In effect, all the pulse-limited footprint area outside the 300 m strip is contributing noise**

Does it still make sense to go for 300m?

- In a situation where there are **abrupt changes in backscatter over 300 m**, such as in a coastal zone, river, lead in sea ice, etc., it makes perfect sense to devote all 64 echoes to coherent processing for aperture synthesis.
- However, in a situation where there is essentially homogeneous backscatter throughout the entire pulse-limited footprint [open ocean without rain or slicks], it **might make more sense to sacrifice some of the footprint narrowing in order to achieve better signal-to-noise**.

An optimization problem

- there is an optimization problem to study the trade-off between combining echoes coherently, to narrow the footprint, versus incoherently, to reduce speckle noise and improve the signal to noise ratio.

- Walter has done some experiments with this (Remko helped) but not yet achieved clear recommendations.

Sampling vs resolution issue

- while the *sampling* of the footprint narrowing is spaced about 300 m along-track, the *resolution* is another issue.
- To avoid side lobes leaking adjacent 300 m boxes, one should Hamming [or other] window the aperture, and this widens the resolution to something like 400 m along-track. (The sampling remains unchanged, but the resolution spreads out.)

Summary

- we can and should try to narrow the footprint in the coastal zone, rivers, leads in ice, anywhere that has great heterogeneity in backscatter within a pulse-limited footprint.
- But over the open ocean, this may be sub-optimal and there may be a better strategy, trading off coherent and incoherent processing to **optimize a trade between footprint narrowing and noise reduction**.