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

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CryoSat-2 SAR pulse timing

Two-way time at CryoSat altitude (S-3 is similar, J-CS is longer):

CryoSat burst interval 11.8 ms

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.