Stepped-Frequency Synthetic Aperture Radar Imaging via Polar Format Algorithm

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Introduction

One of the key challenges to synthetic aperture radar (SAR) technology is to improve the resolution of images produced. Employing stepped-frequency chirp signal (SFCS) is an efficient way to improve SAR range resolution, retaining the benefits of low instantaneous bandwidth. However, subpulse concatenation results in higher sidelobe level of the range compressed SFCS, compared to that of a solid chirp, which impairs image quality.

Polar format algorithm (PFA) is one of the prevailing SAR imaging algorithms due to its inherent nonlinear and nonplanar motion compensation capability, sliding echo receiving window, and compatibility with autofocus algorithms. Although SFCS processing within PFA is covered in literature, almost all developments address platform linear motion, and none of papers concerns range sidelobe reduction problem.

Objective

To develop PFA implementation which

- incorporates SFCS processing
- provides low level of range sidelobes
- considers nonlinear SAR platform motion

Sidelobe suppression method

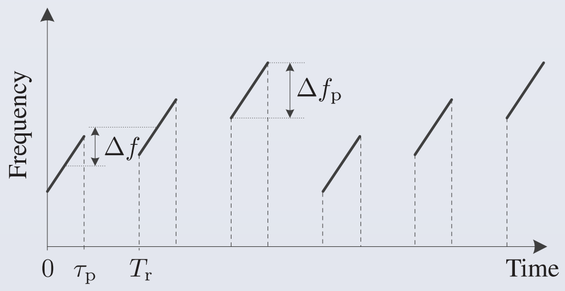

Fig.1: SFCS (3 carrier frequencies)

The key idea is to introduce a minor frequency overlap between subpulses: $\Delta f < \Delta f_\mathrm{p}$. Subpulses of reference signal should have smooth edges of width, proportional to the frequency overlap.

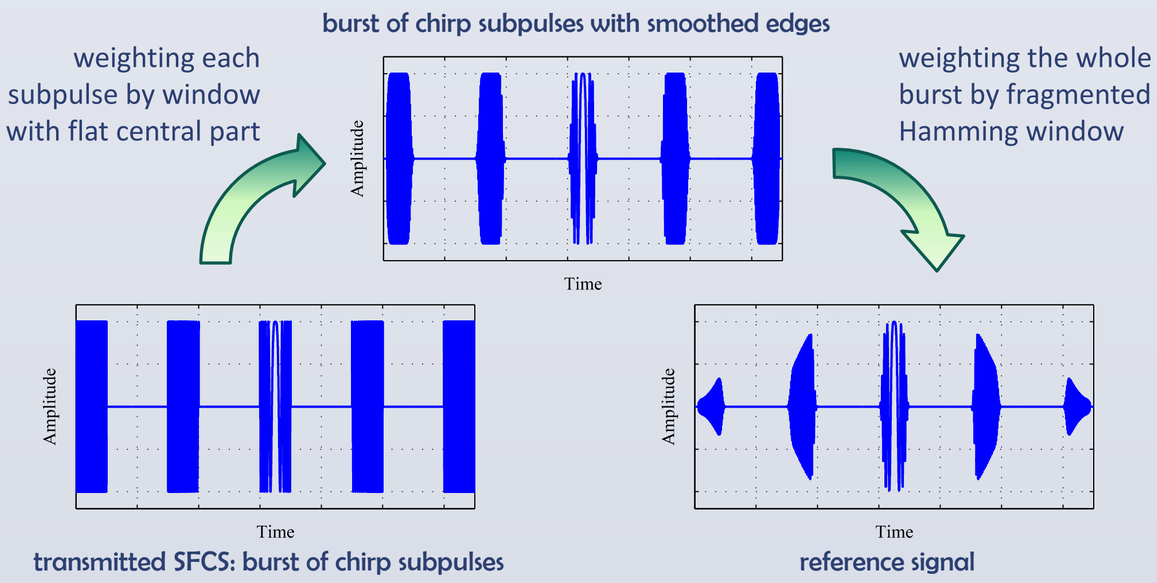

Fig.2: Reference signal synthesis

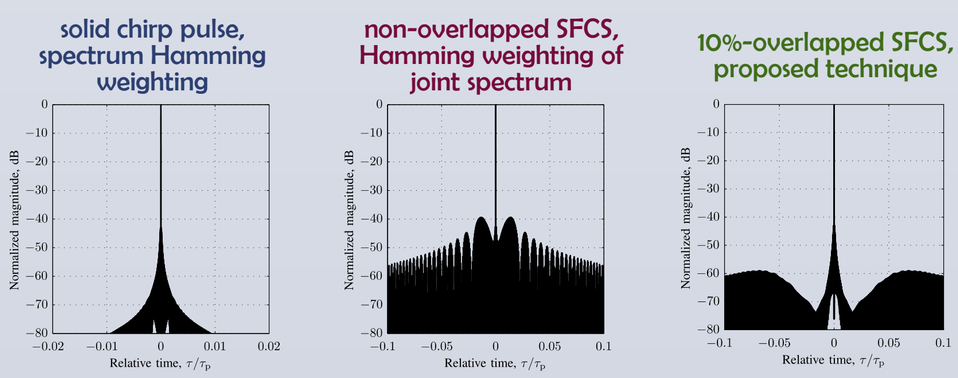

Fig.3: Solid chirp and SFCS sidelobes, $\tau_\mathrm{p}\Delta f_\mathrm{p} = 2000$

References

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Processing flow

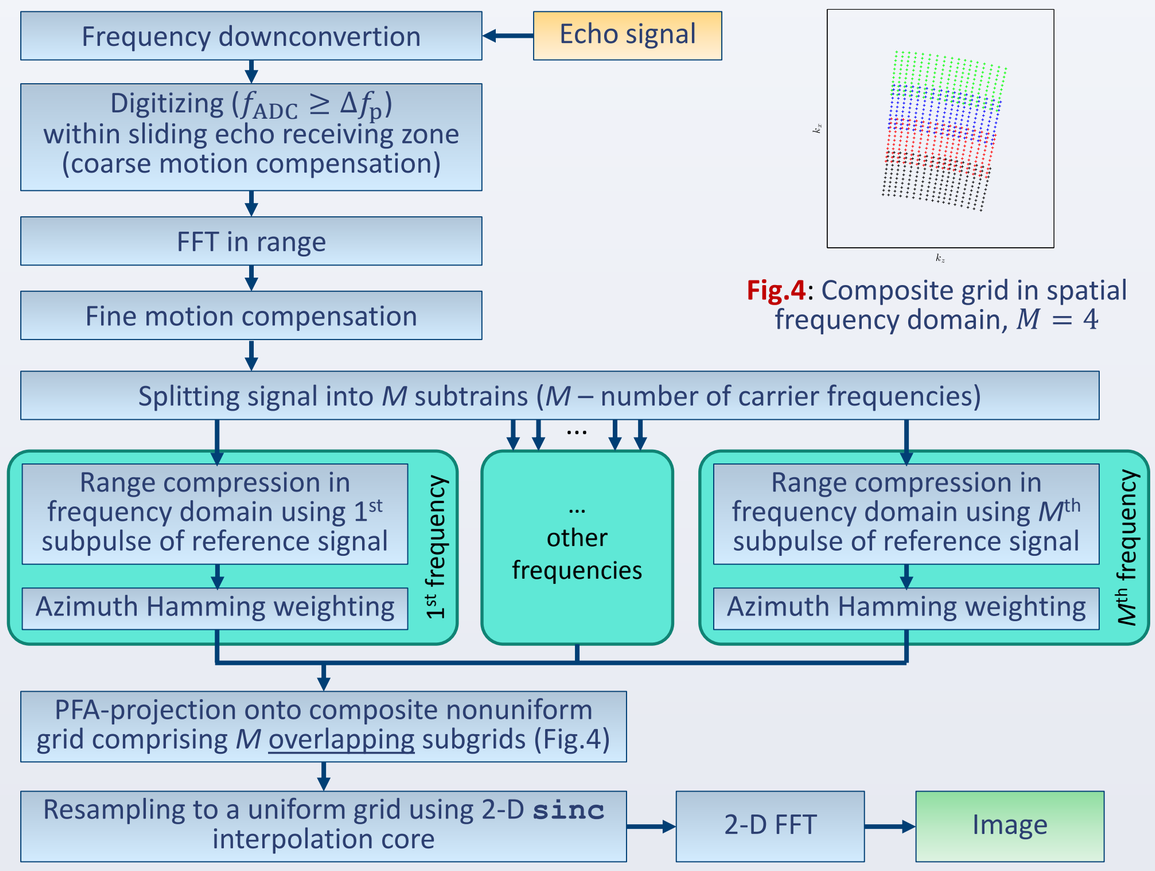


Fig.4: Composite grid in spatial frequency domain, $M = 4$

Simulation results

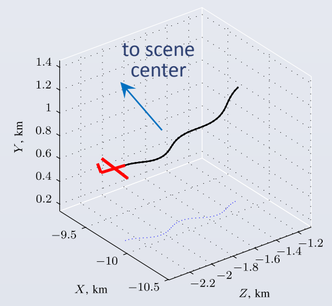
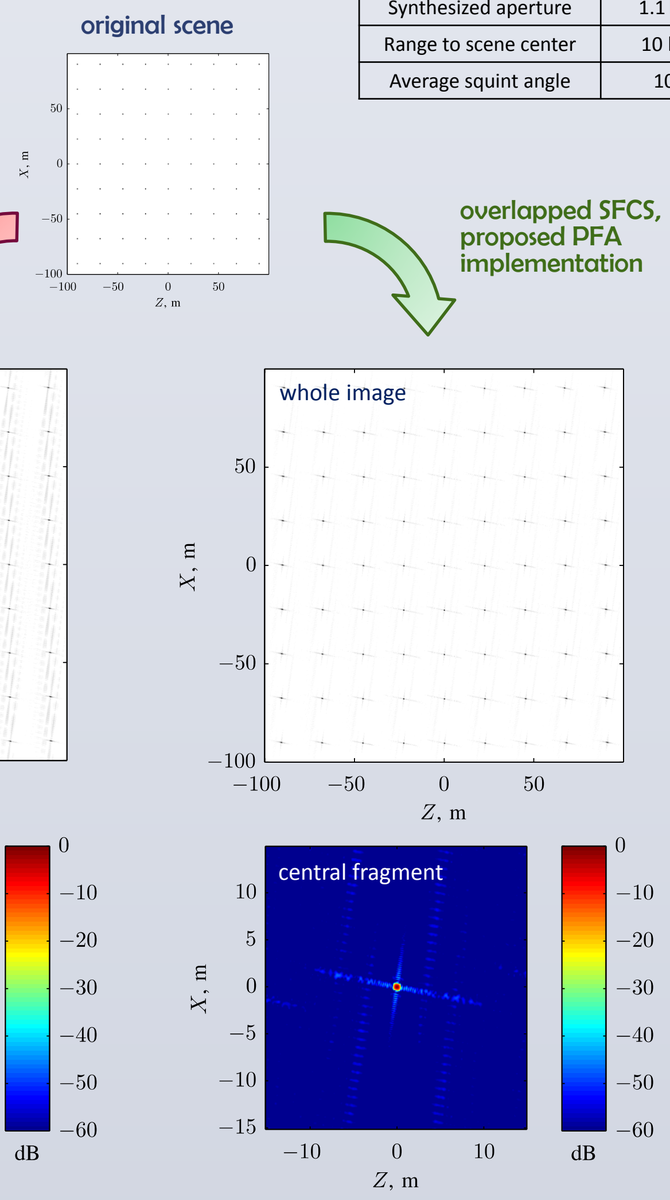


Fig.5: Flight trajectory

Parameter	Value
Central carrier frequency	6 GHz
Pulse bandwidth Δf_p	200 MHz
Frequency shift Δf	170 MHz
Number of subpulses M	4
Pulse duration τ_p	2 μs
Synthesized aperture	1.1 km
Range to scene center	10 km
Average squint angle	10°



Conclusion

Presented PFA implementation

- employs SFCS with minor frequency overlap between subpulses
- provides improved range sidelobe suppression
- raises no limitations on platform motion
- treats spatial-variant range migration between subpulses
- has computational efficiency close to conventional PFA