Direction-of-Arrival Estimation for Radar Ice Sounding Surface Clutter Suppression

Ice sounding radars are able to measure ice sheets by profiling their glaciological features from the surface to the bedrock. The current airborne and, in particular, future space-based systems are suffering from off-nadir surface clutter, which can mask the depth signal of interest. The most recent surface clutter suppression techniques are based on multi-phase-center systems combined with sophisticated coherent postprocessing. The performance of the techniques can be improved by accurate direction-of-arrival (DOA) estimates of the surface clutter. This paper deals with data-driven DOA estimation for surface clutter signals, which includes a formulation of the mathematical foundation of spatial aliasing. DOA estimation is applied to data acquired with the P-band POLarimetric Airborne Radar Ice Sounder at the Jutulstraumen Glacier, Antarctica. The effects of spatial aliasing related to a large phase center spacing are analyzed, and an unwrapping procedure is presented and applied to the data. Finally, DOA estimation of full-scene data is analyzed and used to show an along-track and incidence (off-nadir) angle dependent variation of the effective scattering center of the surface return, which is caused by a varying penetration depth.