POLARIMETRIC ICE SOUNDING AT P-BAND: FIRST RESULTS

Jørgen Dall

National Space Institute, Technical University of Denmark
Ørsteds Plads 348, 2800 Kongens Lyngby, Denmark, email: jd@space.dtu.dk

1. INTRODUCTION

POLARIS (POLarimetric Airborne Radar Ice Sounder) is a P-band demonstrator developed for ESA by the Technical University of Denmark [1]. The aim is to obtain more knowledge about the electromagnetic properties of the Antarctic ice sheet at P-band and to test novel ice sounding techniques in preparation for a potential spaceborne ice sounding radar. POLARIS is a coherent system featuring aperture synthesis, pulse compression, and full polarimetry.

2. OBJECTIVE

In this paper the polarimetric capability of the POLARIS system is used to study anisotropic properties of the Greenland ice sheet. An anisotropic dielectric permittivity may result from crystal-orientation fabrics (COF), which in turn are resulting from mechanical deformations of the ice sheet, e.g. near the ice-divide in Greenland, where the ice is stretched in the direction perpendicular to the ice divide. Knowledge about mechanical deformations can be used to explain present ice velocities and to infer past climate.

The anisotropy of the dielectric permittivity leads to two phenomena: birefringence and reflections at abrupt COF changes, which can be observed with a polarimetric ice sounder like the POLARIS system. Radar polarimetry has already proved a promising glaciological tool, e.g. [2], [3].

3. METHOD

In May 2008, a proof-of-concept campaign was conducted in Greenland in order to test the newly integrated system. Though POLARIS is a fully polarimetric system, only HH and VV polarized data were acquired simultaneously in this case. Consequently, polarization synthesis cannot be applied in order to verify the principal axes of the birefringence like in [2]. Data were acquired from two flight tracks, one perpendicular the ice divide and one parallel to the ice divide. For the HH data the transmit and receive polarizations are parallel to the flight track, while these polarizations are perpendicular to the flight track for the VV data. Consequently, at the cross-over the HH data from one flight track are expected to be similar to the VV data from the other flight track and vice versa.

Firstly, the polarization dependence of the POLARIS data is visualized by computing the relative range derivative of the multi-looked amplitude data. In practice the sample-to-sample difference of the amplitude is computed and divided by the (averaged) amplitude at the same range. This way, the internal ice layers are enhanced (via high-pass filtering) and the range attenuation is suppressed (assuming an exponentially attenuated signal).

Secondly, the complex VV-HH cross-correlation coefficient, or coherence, is computed. The magnitude of this coherence is a measure of the similarity of the HH and VV data. (Differences in the local amplitude and phase variations reduce the coherence amplitude.) The phase of the coherence is a measure of the difference between the electrical two-way propagation path followed by the HH and the VV signals. For an isotropic media the coherence phase is zero, provided the radar is properly calibrated. However, in case of birefringence, the same physical propagation path corresponds to two different *electrical* path lengths at the two polarizations. In absence of birefringence, the effective phase center of the resolution cells may be located at different depths if the reflection of the internal layers is polarization dependent, so also this mechanism may contribute to the coherence phase.

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[1] The POLARIS development and the data acquisition is supported by the European Space Agency.

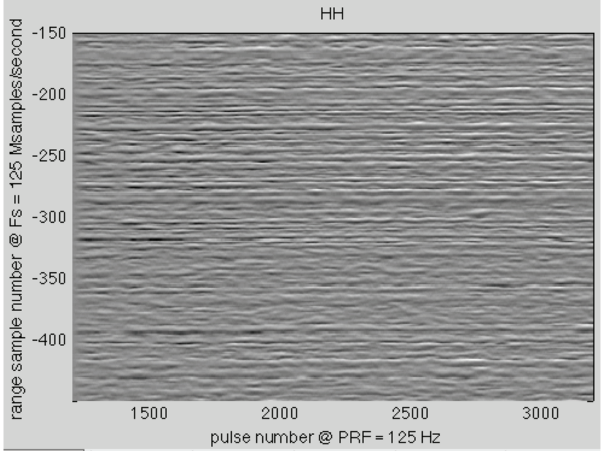

Figure 1. Internal ice layers (relative range derivative)

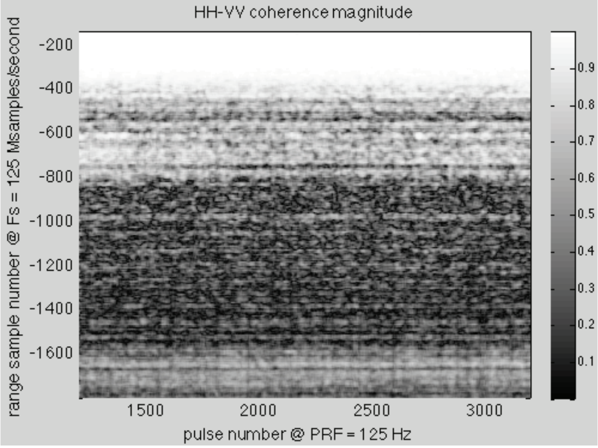

Figure 2. HH-VV coherence magnitude.

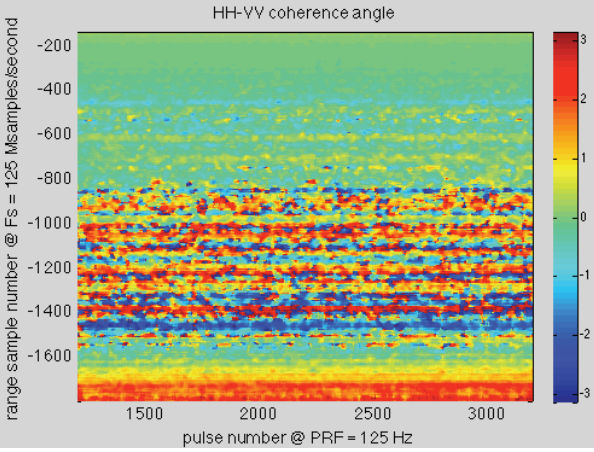

Figure 3. HH-VV coherence phase.

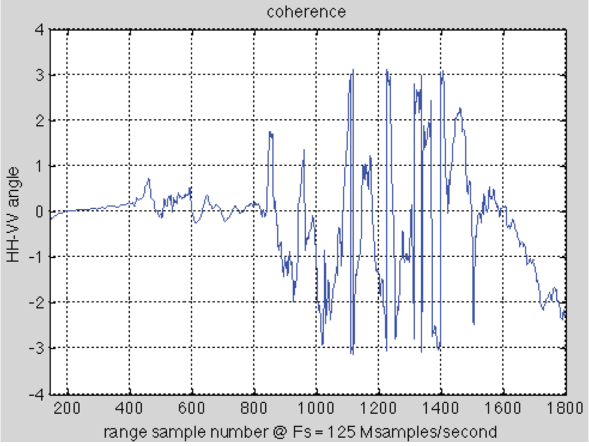

Figure 4. HH-VV phase profile (along-track average).

4. RESULTS

Near the ice surface (range sample 140-320), the internal ice layers look the same, and the complex VV-HH coherence has unity magnitude and a phase near 0°, as shown in Figures 1-4. Further down (sample 470-860), the HH and VV signals differ considerably, and the coherence magnitude has a characteristic profile (the maxima and minima appear at the same range within an area of at least 7 km). Below this region (sample 860-1420) the coherence magnitude is very low and the coherence phase correspondingly noisy. Finally, in the lowest part of this shallow acquisition window (sample 1420-1800) the coherence magnitude increases somewhat, while for the east-west track the VV-HH phase decreases linearly with the depth. For the north-south track the VV-HH phase *increases* linearly, as expected for symmetry reasons.

The similarity of the HH and VV signals near the surface is to be expected since no COF has developed as the ice has not yet been noticeably stretched. Presumably, the coherence phase in the lowest part of the data acquisition window is resulting from birefringence, and the linear curve corresponds to a constant difference in the speed of light at HH and VV polarizations. The observation in the middle region cannot be attributed birefringence. However, a low coherence magnitude and layer-to-layer variations of the phase would result if the reflectivity of the layers were polarization dependent [3].

5. REFERENCES

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[3] S. Fujita, T. Matsuoka, T. Ishida, K. Matsuoka, S. Mae, "A summary of the complex dielectric permittivity of ice in the megahertz range and its applications for radar sounding of polar ice sheets", *Physics of ice core records*, pp. 185-212, 2000.