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Interactive comment on "Rapid and accurate polarimetric radar measurements of ice crystal fabric orientation at the Western Antarctic Ice Sheet (WAIS) Divide deep ice core site" *by* Tun Jan Young et al.

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General comments

The authors present a quad-polarimetric radar measurement at WAIS Divide. The dataset is interesting in its innovative nature as well as in the quality of the derived results. The method follows in direct succession to earlier works developed by Shuji Fujita and Tom Jordan among others. While previous measurements required

a manual rotation of the antenna system in small steps in order to measure the azimuthal variation associated with the birefringence signature, the quad-polarimetric measurement allows for signal at arbitrary azimuths to be deduced from just four antenna orientations. The results are validated by comparison to ice core data.

The overall presentation is detailed and rigorous. Some improvements may be made by giving a clearer structure to the results and discussion sections (see later specific comments). As a non-expert on glaciological radar measurements, the theory and methods section was challenging but the provided references proofed to be very helpful. For the paper to stand on its own some more context/details may be added (see specific comments). Some more discussion may also be added to section 5.3 (Methods comparisons and limitations). It currently gives a fair comparison between radar and ice core / sonic measurements but is short on the specific limitations and assumptions involved in generating data for arbitrary azimuth angles using the quad-polarimetric data.

Specific comments

- The readability of the results section would be greatly improved by structuring it in sub-sections, as is also done for the other sections. A possible structure could be:
  - 4.1 Experimental results from WAIS (up to line 224)
  - 4.2 Modelling the observed data (lines 224-255)
  - 4.3 Fabric asymmetry estimation (lines 255 ff)
- The meaning of the pad factor mentioned in line 193 is unclear.

- The details and reliability of the firn correction as introduced in line 198 are unclear. It is mentioned that this correction amplifies the estimated $E_2 - E_1$ values in the shallow ice and surprisingly large fabric asymmetries are then measured in that depth range. Thus the firn correction merits more attention (and maybe test without the correction) during the discussion (line 265 and 305) may be warranted.

- In line 196 it may be worth mentioning that the Jordan et al. (2019) prescription to evaluate $d\phi_{hhvv}/dz$ is not actually based on the phase plot itself but on the real and imaginary components of the coherence as given in equation 7b.

- The reasons for and consequences of switching from an FIR filter to the method described in l.197ff remain unclear.

- The anisotropy parameter β seems to be missing a unit (dB?) in the caption of Figure 3.

- For depth greater than 1200 m (and to a lesser extent around 600 m) the derived $E_2 - E_1$ values become rather unstable. While this is commented on and partially reflected in larger error bars, a population of outliers with small fabric asymmetries as well as small error bars is a bit worrying. It may be beneficial to show a plot of the coherence magnitude. Given vanishing magnitudes, the phase becomes unconstrained leading to erratic $d\phi_{hhvv}/dz$ values. In the deepest region the phase in Figure 2.e is more unstable as a function of depth than expected from the model calculation.

- The sentence "The birefringence of an individual crystal and its COF are related to the bulk ..." in line 97 reads a bit odd as a COF only applies to an ensemble of crystals. Maybe change to something like "the birefringence of individual crystals and their COF".

- The term "depth step" in line 124 is a bit technical. Something like "depth where a reflection occurs" would be clearer to the reader.

- The meaning and relevance of the rotation matrix R as introduced in line 133 is unclear. To my understanding, it represents the rotation of the COF principle axis *of each traversed ice layer* with respect to a reference system defined by the antennas.

- It is mentioned that s_{vh} and s_{vh} should be identical given an ideal measurement. Has the difference between these two orientations been studied and the potential impact quantified?

- The COF orientation of each depth layer is resolved "by tracing the azimuthal minima in the cross-polarized power anomaly". While this may be a good approximation for this measurement, I wonder if this technique is generally applicable in the presence of strongly varying COF orientations. Assuming, for example, a constant angle of 20° in the top 500 m and a constant angle of 60° below, my understanding is that the minimum in the cross-polarized power anomaly would only slowly migrate towards 60° below 500 m as the bulk propagation is initially still dominated by the conditions above. One essentially measures the average COF orientation up to the scattering depth. But there may be a misunderstanding on my part here. A comment would be appreciated.

- As noted in the general comments section 5.3 would benefit from a discussion of the specific limitations and assumptions involved in generating data for arbitrary azimuth angles using the quad-polarimetric data.

- Section 5.1 paragraph 2 (lines 281-288) seems better suited in section 4.1 (results, modeling), here a Figure similar to Figure 5 in the Fujita 2006 paper may also be illustrative, showing that birefringence results in nodes in the power anomalies while anisotropic scattering results in a band structure, the spacing of which is a function of the scattering strength.

Technical comments

- The link for the Mott, H. (2006) reference appears to be dead.
- In line 156, spectra so should be plural as are the amplitudes.
- In the title of subsection 5.1 it would be more consistent to refer to "anisotropic scattering" instead of the more ambiguous "anisotropy"