REFEREE 1

Summary

Summary: This manuscript outlines simulations of spectral polarimetric radar observations for rain. The single-scattering properties are calculated using the T-matrix method for spheroids with aspect ratios determined from previous empirical relations. The spectra are then simulated using two methods for randomly generating radar signals, and the spectral ZDR and backscatter differential phase are computed from these signals and compared to observations. The simulated power spectra are fit using gamma PSD parameters and a parameter for the wind speed variability due to turbulence. The general shapes of the simulated polarimetric spectra are similar to the measurements; the magnitudes show substantial differences.

General comments: This manuscript provides some interesting insight into using the spectral polarimetric radar measurements to better understand rain microphysics. However, there are some issues with this study that need to be addressed before it is acceptable for publication.

The first issue I have with this study is that the fitting of the PSD parameters and the air motion variability parameter (σ_t) are only done with respect to the spectral power. Therefore, the PSD parameters controlling the width of the particle spectrum may be compensated by the σ_t to best fit the spectrum. As such, the assumed σ_t may deviate substantially from the σ_t associated with the measurements, introducing errors into the comparisons with the spectral polarimetric variables. To address this issue, the authors may want to show the sensitivity of the spectral polarimetric variables to σ_t and the PSD parameters. Additionally, showing the range of PSD parameters and values of σ_t that have similar RMSE during the fitting process would clarify how well constrained these parameters are.

Excluding the effects of noise and spectral averaging, the primary physical factors influencing the spectral polarimetric variables are the axis ratio–diameter relationship, the canting angle distribution, and variability in air motion, characterized by σ_t. The particle size distribution (PSD) has a comparatively minor impact on these variables. When $\sigma_t = 0$, the spectral polarimetric variables become independent of the PSD. In fitting the Doppler power spectrum, the PSD parameters that influence spectral width can be offset by variations in σ_t to optimize the spectral fit. Consequently, rather than fitting the entire Doppler spectrum, we focus on its upper portion (above a threshold of -8 dBZ/ms^{-1}), which emphasizes the resonance notches—whether sharp or smoothed—providing a more robust indication of the magnitude of σ_t. This is illustrated in the following figures (1-3).

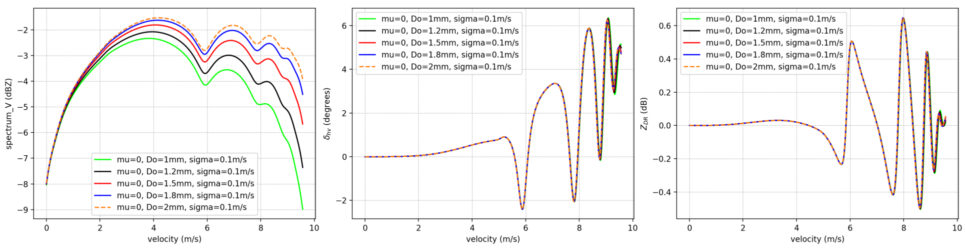

Figure 1: Different Do

Similarly, the authors mention that the spheroid shape may not adequately represent the scattering of natural raindrops due to processes such as drop oscillations. However, a variety of spheroids with the same fall speed but different aspect ratios could better represent this process and provide evidence as

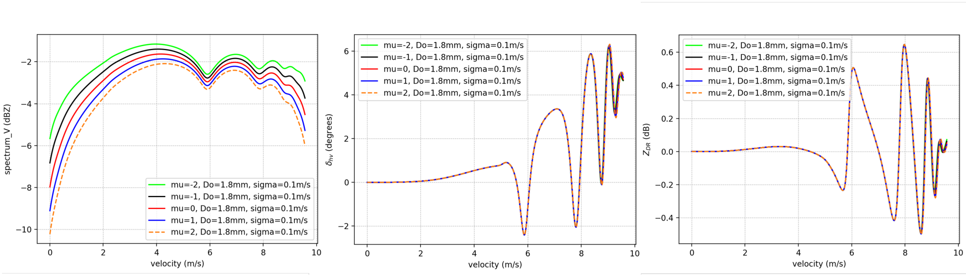

Figure 2: Different mu

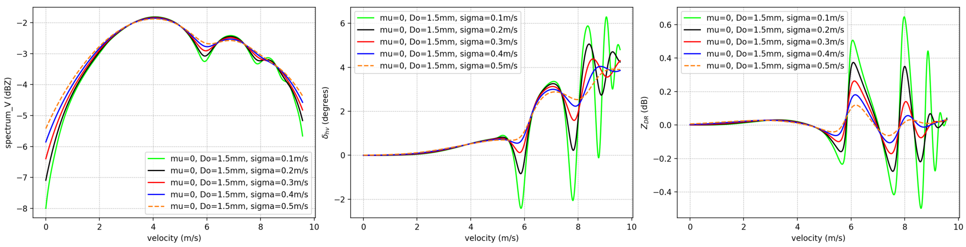

Figure 3: Different sigma

to whether the assumption of fixed aspect ratios for a given particle size is responsible for the poor comparisons between the simulated and measured spectral Z_{DR}. Randomly sampling aspect ratios for particles of the same fall speed would help demonstrate whether the broadening of the spectral polarimetric variables due to aspect ratio variability produces simulated spectra that are more consistent with the measurements.

We thank the reviewer for this valuable suggestion. By comparing simulated and observed spectral polarimetric variables at W-band, this study has demonstrated overall agreement, while also highlighting specific discrepancies. As such, it represents an initial step toward improving the simulation of spectral polarimetric variables at W-band. Future work will focus on investigating the potential causes of these discrepancies (this comment, next comment,....). One possible factor to explore is the assumption of a fixed aspect ratio for a given particle size.

Finally, there should be more discussion of simulating spectral polarimetric variables for radars with different transmission and reception strategies. For instance, fully polarimetric radars that transmit horizontal, receive horizontal and vertical, transmit vertical, and receive horizontal and vertical are processed differently than simultaneous transmit/receive radars. These differences could also explain some of the discrepancy between the observed and simulated spectral polarimetric variables. It is unclear what the transmission and reception strategy is for the radar observations presented in the manuscript. This information needs to be included to better understand how faithfully the method for simulating the spectral radar variables emulates the processing algorithm of the radar.

The polarimetric data acquisition will be mentioned at the beginning of section 3:
"The cloud radar measurements were obtained using a RPG Frequency Modulated Continuous Wave (FMCW) Dual Polarization W-band Cloud Doppler Radar, operating at 94 GHz in a simultaneous transmission - simultaneous reception (STSR) mode."

Specific Comments

• Lines 24-25: Vertically pointing radar are also able to do this. Please add that radars in slant polarization mode can take advantage of polarimetric measurements.

The text will be modified accordingly: "This configuration has the critical advantage that particles with different sizes are separated in the spectral domain (because they have different sedimentation velocities), which allows to disentangle the contributions of different particle types. While vertically pointing radars can also achieve this separation, radars in slant polarization mode additionally exploit polarimetric measurements."

• Line 39: Do you mean vertically profiling here? Please clarify.

No, we don't mean "vertical profiling". We wrote "slant or horizontal profiling" because meaningful polarimetric variables are obtained at low/intermediate elevation angles. However, there is an exception for the linear depolarization ratio, which can be used for applications involving vertical profiling.

• Lines 50-52: "Describing the methodology to compute spectral polarimetric variables" doesn't really address a science question. Based on the previous line and my impression of the study, a stronger goal might be to explore how different assumptions impact the simulated spectral polarimetric variables.

The text will be modified to "Goal of this study is to explore how different assumptions that are related to atmospheric conditions (turbulence) and white and stochastic noise of a real radar spectrum, impact the simulated spectral polarimetric variables.The second objective is to present a novel comparison between simulated and observed data."
This text will be placed at the end of the introduction before the description of the paper structure.

• Lines 57-58: The T-matrix method can simulate the scattering properties of arbitrary shaped particles (as long as the numerical integration converges; Wriedt 2002). However, these codes are not widely available and are much less efficient. Please change this sentence accordingly.

The text will be modified to "However, raindrops generally change due to oscillations, which cause departure from rotationally symmetric shape. The T-matrix method can, in principle, simulate scattering from non-rotationally symmetric particles (given numerical convergence; Wriedt 2002), but such implementations are computationally demanding and not widely available. As a result, most T-matrix applications rely on the assumption of rotationally symmetric particles."

• Lines 74-75: Does equation (1) come from one of these studies specifically? Please clarify.

This will be specified.
"In the following, Eq. (1) is employed to describe the raindrop axis ratio. For small raindrops, the axis ratio follows the parameterization by Keenan et al. (2001), while for larger drops, the formulation of Beard and Chuang (1987) is applied."

• Line 144: Please add some reference(s) for these equations.

We have cited Altas et al., (1973) where the relationship between drop diameters and corresponding terminal velocities is described, and the relevant curves are shown in Figure 5.

• Line 157: Where does this equation come from? Please address.

A reference will be added.

• Line 158: Shouldn't this denominator be in terms of d v_los instead of d v_t? What if the horizontal wind is large compared to the fall velocities or the radar has an elevation angle near 0? If this equation is an approximation, please indicate under what conditions it is valid.

For clarification, we will add the following sentence:
"Eq. (8) is formulated for elevation angles θ_{el} significantly greater than zero, without accounting for the contribution of turbulence."

• Line 178: It is a bit unclear why these two methods for calculating the spectra are being discussed. Are they the only two such methods? Please add some brief discussion on this point at the end of the previous section.

A section 2.2.5, Rationale for simulation based on IQ, will be added in the revised manuscript.

• Lines 240-241: What is the transmission and reception strategy of this radar? Can it measure retrieved co-polar signals independently?

We will mention in the text that the radar operates in a simultaneous transmission - simultaneous reception (STSR) mode.

• Line 257: I think the "e" is missing from the subscript on the elevation angle symbol.

We will change to θ_{el}.

• Line 264: Please be more specific about the degree of turbulence during this case and the following case. Are these cases on the extreme ends of the turbulence that might be observed during these such events?

No, these cases are not on the extreme ends of the observed turbulence. Therefore, the titles of the subsections will be changed:
3.1 Case Study 1: Moderate turbulence conditions
3.2 Case Study 2: Light turbulence conditions

• Lines 278-279: How were they adjusted? According to the measured values of the smallest particles? Please clarify.

Yes, the corrections were determined by measuring the offset observed for the smallest particles, which are assumed to be spherical. The sZ_{DR} and $s\delta_{HV}$ values were adjusted such that the smallest particle measurements align with 0 dB and 0°, respectively.

• 7: What does the gray shading on the plot represent? Please add this information to the figure caption.

We will add the following sentence in the text relating to Fig. 8:
"The spectral polarimetric variables are analyzed outside the gray-shaded regions, where the Doppler spectral power exceeds -8 dBZ/ms^{-1}, to ensure a sufficiently high signal-to-noise ratio."