Dear Editor,

We have thoroughly revised the manuscript entitled "*Improving Simulations of Zeeman Absorption Spectrum for Hyperspectral Microwave Sounding Applications"* (ID: egusphere-2026-152) in accordance with the reviewers' comments, and we present the key revisions and responses below.

Reviewer 1 raised several points, to which we have responded point by point, and we made the following revisions in the revised manuscript:

Point 1: The reviewer identified a logical gap in the Introduction where the comparison between infrared and microwave sensors was unclear. We rewrote this paragraph to clarify that infrared and microwave sensors are complementary rather than substitutive, with microwave sensors uniquely capable of all-weather and high-altitude observations.

Point 2: The reviewer noted that Section 2 lacked original contributions and that references to oxygen absorption models were incomplete. We supplemented the references to include Liebe (1981) and Liebe et al. (1992) in Section 2.1, as these works established the foundational MPM framework and provided updated laboratory measurements of the 60-GHz oxygen band.

Point 3: The reviewer requested a clearer definition of the cumulative product matrix **P** and questioned the 2×2 dimensionality of the transmittance matrix. We provided a clearer definition of **P**, which is accumulated layer by layer starting from the top of the atmosphere following Rosenkranz and Staelin (1988). We also explained that the 2×2 formulation is physically equivalent to the 4×4 Stokes vector approach, as the four Stokes parameters (I, Q, U, V) can be fully recovered from the 2×2 brightness temperature matrix via Eqs. (8) and (9) in the manuscript, and is sufficient for the nadir-viewing geometry considered in this study.

Point 4: The reviewer noted that Section 3 lacked an introduction to the input parameters or profiles used as backgrounds. We added a description at the beginning of Section 3.1 specifying that the simulations use the 84-layer ECMWF profile dataset developed by Peter Rayer (Met Office) as input, with geomagnetic field parameters obtained from IGRF-13 (Alken et al., 2021).

Point 5: The reviewer pointed out that no units were given for the parameters in Eq. (12). We added units for all parameters: NEDT (K), BW (MHz), receiver equivalent noise temperature (K), antenna temperature (K), and integration time (s).

Point 6: The reviewer requested clearer explanations of how integration time is set for SSMIS and HMAS. We clarified that for SSMIS, the integration times (25.2 ms for channels 19-23 and 12.6 ms for channel 24) are fixed hardware parameters determined by the radiometer design. For HMAS, the extended integration time of approximately 44.3

ms can be achieved through software averaging, which is within the allowable range of satellite scan periods. We also explained that HMAS is designed as a cross-track scanning instrument, which inherently allows for a longer integration time per field of view compared to the conical scanning configuration used by SSMIS.

Reviewer 2 has General Comment on Contributions: The reviewer correctly noted that the inclusion of Larsson (2019) Zeeman coefficients in the RS-LBL model was already implemented in the 2024 version and is not our original contribution. We have revised the manuscript to avoid any implication that this is our contribution. Our specific contributions are now clearly stated: (1) systematic comparison of simulation differences between Hund's case (b) and Larsson (2019) implementations across multiple oxygen absorption lines under varying magnetic field conditions; (2) comprehensive three-parameter cyclic analysis (Be, θ, frequency shift) to characterize detection altitude under realistic geomagnetic conditions; and (3) HMAS channel design with validation through weighting function comparisons, brightness temperature simulations, and temperature profile retrieval experiments.

General Comment on HMAS Validation: The reviewer noted that the original manuscript lacked sufficient quantitative validation for the HMAS channel design. To address this, we added a new Section 4.4 presenting temperature profile retrieval experiments using an improved back propagation (BP) neural network with dual residual blocks and squeeze-and-excitation (SE) attention mechanism. The retrieval results show that HMAS achieves an RMSE of 7.652±0.389 K, an MAE of 4.911±0.282 K, and an R^2 of 0.915±0.010, compared to SSMIS channels 19-24 which yield an RMSE of 7.858±0.314 K, an MAE of 5.107±0.208 K, and an R^2 of 0.910±0.010. Daily mean statistics from January to December 2024 demonstrate that HMAS consistently outperforms SSMIS across all evaluation metrics.

Issues with Subsection 2.1: The reviewer found the original text unnecessarily convoluted, with unused symbols and unclear references. We substantially reorganized this subsection: removed unused symbols (ΔJ, ΔM, π component, σ± component), clarified the physical description of the Zeeman splitting effect focusing only on core concepts (g-factor, energy perturbation) that are directly used in subsequent analysis, replaced the vague reference "Please refer to (Larsson et al., 2019)" with a clear statement that the derivation and calculated values for individual N and J states are provided by Larsson et al. (2019), and added explicit sentences linking the theoretical discussion to quantitative results in Section 3.

Point-by-point issues: (1) Deleted “Please refer to (Larsson et al., 2019)” as suggested; (2) Deleted “In mathematics”; (3) Added y-axis unit (K) to Figure 1; (4) Revised the concluding paragraph beginning with “Since”; (5) Added complete temperature profile retrieval experiments in Section 4.4; (6) Cited the RS-LBL code following the format recommended by its author in the Introduction.

Summary of Major Revisions to this Manuscript

Abstract: Fully rewritten to reflect the added retrieval experiments and HMAS validation results, removing the implication that the Larsson (2019) coefficient update is our original contribution.

Introduction: Revised the comparison between infrared and microwave sensors to clarify their complementarity (addressing RC1 Point 1). Updated the description of the RS-LBL model to clarify that all simulations use the 2024 version with Larsson (2019) coefficients, and cited the code following the recommended format (addressing RC2 General Comment and Point 6).

Section 2.1 (Zeeman Splitting Coefficient → Zeeman Splitting Effect): Substantially reorganized and simplified. Removed unused symbols (ΔJ, ΔM, π component, σ± component). Replaced vague reference with clear statement of Larsson (2019) contributions. Added explicit sentences linking theory to application: “Consequently, it introduces systematic biases for oxygen absorption lines with low rotational quantum numbers (J_N < 10), which are precisely the lines most sensitive to upper atmospheric temperature” and “As demonstrated by Dong et al. (2026), the updated coefficients effectively reduce simulation biases in upper atmospheric sounding channels.” Supplemented references with Liebe (1981) and Liebe et al. (1992) (addressing Reviewer2 Issues and Reviewer1 Point 2).

Section 2.3 (Radiative Transfer Transmittance Solution): Added clearer definition of cumulative product matrix **P**, accumulated layer by layer starting from the top of the atmosphere (addressing Reviewer1 Point 3).

Section 3.1 (Microwave LBL Model Simulations → Model Simulation Differences and Magnetic Field Dependence): Added description of input parameters and profiles at the beginning of the section (addressing Reviewer1 Point 4). Reorganized content to reference Dong et al. (2026) for detailed analysis, removing the implication that the Stokes vector comparison is a new contribution.

Figure 1: Added y-axis unit (K) (addressing Reviewer2 Point 3).

Section 4.2 (HMAS Passband Distribution): Added detailed explanation of integration time settings for both SSMIS (fixed hardware parameters) and HMAS (achievable through software averaging, cross-track scanning configuration) (addressing Reviewer1 Point 6).

Section 4.4 (new): Added temperature profile retrieval experiments comparing HMAS and SSMIS using an improved BP neural network with dual residual blocks and SE attention mechanism, including quantitative comparison metrics (RMSE, MAE, R^2) and daily mean statistics (addressing Reviewer2 General Comment and Point 5).

Section 5 (Conclusions): Fully rewritten to reflect the new retrieval experiments and HMAS validation, with quantitative comparison metrics reported.

Eq. (12): Added units for all parameters (addressing Reviewer1 Point 5).

This work has not been published in part or in full elsewhere, nor is it under consideration for publication by any other journal. All authors have approved this revised submission, and no conflicts of interest exist.

We look forward to your decision on the manuscript's final disposition.

Sincerely yours,

Changjiao Dong