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Atmospheric Measurement Techniques Discussions

Interactive comment on "Ground-based Multichannel Microwave Radiometer Antenna Pattern Measurement using Solar Observations" *by* Lianfa Lei et al.

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Thank you very much for your letter and suggestion.

The comments are all valuable and very helpful for revising and improving our paper. We have studied comments carefully, and have made corrections and modification which we hope meet with approval. We have been trying our best to improve the manuscript. Please see the revised version of the manuscript for detail. The following is the one to one correspondence to the comments.

1. Comment: The method is not novel, nor is the application novel. A potential novelty

needs to be elaborated in detail and the benefit for MWR measurements have to be highlighted.

Response: Thanks for your suggestion, may be the former version didn't describe the innovative points prominently. We have noticed that several researchers in literature used the sun to measure weather radar antenna pattern, but our study is to accurately measure the antenna pattern of MWR with a simplified method. We apply this method to measure the MWR pattern.

As most observations for meteorology are done in the zenith direction, relatively large beamwidths are acceptable. However, this becomes important when viewing at low elevation angles during the period for Tipping curve calibrations. The antenna pattern and pointing error are important influential factors for Tipping curve calibration uncertainties (Han and Westwater, 2000 "Analysis and improvement of tipping calibration for ground-based microwave radiometers"). When Tipping curve calibration is enabled, the radiometer performs a scan from zenith to 20° elevation, the calibration uncertainties increase by increasing beamwidth. If not corrected, this can introduce a bias to the Tipping curve calibrations (Radiometrics MP3000 Microwave Radiometer Performance Assessment. Technical Report –TR29. Version 1.0). In order to improve the observation and Tipping method calibration accuracy of MWR, the antenna pattern of MWR must be accurately measured on site any time necessary. The purpose of this study is to present a simplified solar method so that the method can be applied operationally in the future. On the other hand, we need to check whether the performance of an antenna in field operation complies with the design specification. Furthermore, in case the antenna is very large or the final assembly occurs at the installation site, the traditional method is extremely difficult. Especially the chamber method cannot be used to measure the antenna pattern of a radiometer in field operation. Therefore, we suggest to use the solar method in our study in order to improve the accuracy of a ground-based MWR observation by automatically checking the pointing accuracy together with alignment correction. And this paper presents the solar method to determine the MWR antenna pattern and to calibrate antenna pointing of MWR networks operating in the field.

The description above about the motivation for applications of MWR has been added to the manuscript. Please see Lines 39 - 57 on Pages 1 - 2 of the revised version.

2. Comment: Technical detail of the MWR model are missing: antenna size, frequencies in K- and V-band, number of receivers

Response: I am very sorry for our negligence of the system performance of the MWR. We have added the following into the revised version.

The antenna system of MWR contains parabolic reflector (Size:320.5×186.3mm, focal length:180mm), beam splitter and compactness a corrugated feedhorn. Parabolic reflector can focus the beam and be used to scan the beams in elevation. Corrugated feedhorn offers a wide bandwidth, low cross polarization level, low sidelobe level and a rotationally symmetric beam. The MWR have two receivers (K- and V-receiver), many channels to observe atmospheric radiation intensity in K-band (22-30GHz) and V-band (51-59GHz), the frequency of observation are 22.235, 22.5, 23.035, 23.835, 25.0, 26.235, 28.0, 30.0, 51.25, 51.76, 52.28, 52.8, 53.34, 53.85, 54.4, 54.94, 55.5, 56.02, 56.66, 57.29, 57.96, 58.8 GHz.

The description above about the motivation for applications of MWR has been added to the manuscript. Please see Pages 2 - 4 of the revised version.

3. Comment: Equations for sun azimuth and elevation are not necessary since they don't describe the necessary information as long as the declination is not given.

Response: Thanks for your suggestion. I have revised this manuscript according to the suggestions.

4. Comment: Too many details in the sections about "model of atmospheric TB" and "model of the antenna power pattern". Why is the opacity of the atmosphere relevant for this study? Minor remarks.

Response: Thanks for your suggestion, I have revised this manuscript. We have described briefly in the sections about "model of atmospheric TB" and "model of the antenna power pattern".

In order to calculate the TB increment of the solar radiation arriving at the antenna without atmospheric attenuation, we must calculate the opacity of the atmosphere in real time. For antenna elevation angles different, the slantwise attenuation is proportional to the ratio of the zenith attenuation for horizontally homogeneous sky conditions.

5. Comment: English grammar and spelling need to be checked. There are many recurrences of statements.

Response: I have carefully corrected them.

6. Comment: The DOI links in the references have wrong syntax: should be https://doi.org/ or doi: instead of https://doi:

Response: The DOI links in the references have been corrected in the manuscript.

7. Comment: Line 38-39: check English grammar

Response: The grammar errors have been checked and corrected.

8. Comment: Line 44: Laura et al., 2017 is missing in references

Response: The missing reference has been checked and corrected.

9. Comment: Lines 48-50: check English grammar

Response: The grammar errors have been checked and corrected.

10. Comment: Lines 51 - 71: several recurrences of statements

Response: I have re-written this part according to the suggestions.

11. Comment: Figure 2 is not necessary, this is not a paper about calibration

Response: I have removed Figure 2.

12. Comment: Figure 3 is not necessary, the solid angle of the sun and estimated solid angle of the antenna give sufficient information to the reader

Response: I have re-written and improved this part according to the suggestions.

13. Comment: Line 140:" only solar emission" What else?

Response: Solar emission and atmospheric emission.

14. Comment: "solid" instead of "sold"

Response: The spelling error has been checked and corrected.

15. Comment: Figure 4: different date as in Figure 5. How can this be related to each other? Not relevant for this manuscript

Response: I have corrected this part according to the suggestions.

16. Comment: Lines 170 - 175: very difficult to understand. How can the antenna be fixed (line 174) during a sun scan (line 174)?

Response: I have re-written this part according to the suggestions. The MWR contains a high-precision elevation and azimuth stepping motor. The antenna pointing angle is sent to the antenna servo control system so that the antenna beam can scanning the sun.

Please see Lines 90 - 102 of the revised version.

17. Comment: Line 173: smaller than 10°

Response: I have corrected this error.

18. Comment: Lines 182-187: I do not understand the context

Response: I have re-written this part. Because of the directional characteristics of the antenna, the TB increment observed is proportional to the ratio of the solar solid angle to the antenna solid angle.

19. Comment: Line 189: Holleman et al.,2010

Response: The missing reference has been corrected.

20. Comment: Line 196: Remove, this has been written very often now

Response: I have removed this part.

21. Comment: Lines 217 - 219: what is the calibration angle? Is it 0 in azimuth and 0 in elevation? Response: It is 0.12° in azimuth and 0.3° in elevation. These data have been added to the revised version of the manuscript.

22. Comment: Figure 7: what are the markers, what are the lines?

Response: I have added the description. The markers are for the observed data and the lines are for fitting of the Gaussian function.

23. Comment: Line 237: what is the H-plane and E-plane in this context? Solar radiation is not polarized

Response: The solar radiation is not polarized but the antenna is. In the case of the linearly polarized antenna, the H-plane is the plane containing the magnetic field vector and the direction of maximum radiation. The E-plane is the plane containing the electric field vector and the direction of maximum radiation. For a vertically polarized antenna, the H-plane usually coincides with the horizontal/azimuth plane. For a horizontally polarized antenna, the H-plane usually coincides with the vertical/elevation plane.

24. Comment: Line 254: what is D?

Response: It is the antenna gain. I have corrected this error.

25. Comment: Line 262 Holleman et al., 2010

Response: The missing reference has been corrected.

26. Comment: calculated

Response: The spelling error has been corrected.

27. Comment: Table 2: it would be necessary to have more than one measurement series to get statistical relevant accuracy of the antenna parameters

Response: I have revised this part according to the suggestions.

28. Comment: Line 297: Why should one use a MWR to observe the radiation of the sun? What will be the context? What will be the difference to the current manuscript?

Response: In this paper, we measured the antenna pattern of the MWR by observing the sun. We hope to observe the variation of solar microwave radiation through long-term observation by the MWR in the future in order to study the effect of the earth's orbital eccentricity on incident solar flux.

Thanks again for your kindly comments and suggestions.

All the best,

LEI Lianfa

On behalf of all the authors

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