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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 sugesstion.

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: I am missing some motivation for the study: Of course, it is always de-

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sired to characterize an instrument as well as possible. However, more motivation on why is it important to know the exact antenna patterns for ground-based microwave radiometers would be necessary to mention (e.g. temperature profiling, considering antenna patterns in radiative transfer modelling for retrieval algorithms, etc.). Response: Special thanks for this comment. The manuscript has been revised based on the following description:

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.

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We have added the antenna design description and the schematic antenna structure. The antenna system 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 many channels to observe atmospheric radiation intensity in K-band (22-30GHz) and V-band (51-59GHz). The designed beamwidth is less than 5° in K-band and 3° in V-band.

The description above the antenna of MWR has been added to the manuscript. Please see Lines 39 - 102 on Pages 1 - 4 of the revised version.

2.Comment: The sun has been used as target for antenna pattern studies before. Please make clear what your novelty is. Would it be possible to apply your method automatically to check the pointing accuracy as well as the alignment of a radiometer that is deployed in the field?

Response: Thanks a lot for guidance. We have noticed that several researchers in literature used the sun to measure weather radar antenna pattern. In this paper, our study is to accurately measure the antenna pattern of MWR with a simplified solar method. We apply this method to measure the MWR pattern and this method can be used to improve the Tipping curve calibration accuracy, automatically check and calibrate the pointing accuracy. Therefore, this method can be used for MWR antenna measurements and hopefully to monitor the antenna pattern and pointing of a radiometer in operational, field applications after installation. It is possible to apply our method automatically to check the pointing accuracy as well as the alignment of a radiometer that is deployed in the field and this is a good idea. 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.

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

3.Comment: The basics on microwave radiometry and antennas cover too much of the manuscript. Most of the information can be found in textbooks. On the other hand, the technical description of the instrument is very poor in terms of receiver technique and other components. How is elevation and azimuth scanning performed by the instrument? What are the sources of uncertainty in this regard? What is the temporal resolution of the brightness temperature measurements when performing scans?

Response: Thank you for your suggestions, I am very sorry for our negligence of the system performance of the instrument. And we have added some technical description of the instrument (receivers, schematic internal and antenna structure of MWR).

During the elevation and azimuth scanning, the antenna is moved to raster a box around the actual sun position using several PPIs, by adding a step value $\Delta\theta$ (-10°∼10°) on the elevation and azimuth of the sun in each antenna pointing angle and the observing angle are sent to the antenna servo control system so that the antenna beam can scanning the sun. This scanning can last about 30 minutes at each frequency. Since the sun is moving along the sky within this time interval, the scanning box also follows the sun. The sources of uncertainty contain atmospheric refraction, the fluctuation of solar radiation brightness temperature and the accuracy of the antenna servo control system.

The description above about the motivation for applications of MWR has been added to the manuscript. Please see Lines 65 - 102 on Pages 2 - 4 of the revised version.

4.Comment: What about the repeatability of the method? Did you perform several scans under different conditions and/or solar elevation angles (e.g. summer/winter, morning/noon)? What are your recommendations in that respect?

Response: Thanks for your suggestion, this method can be repeated and we have revised this manuscript. Scans under different solar elevations and seasons have been completed in order to study the effect of the solar elevation and season variation to the measurement of antenna pattern. Therefore, more observations and results have been added as one can see at Pages 8 - 9 of the revised manuscript. During the elevation and azimuth scanning, the sun at low elevation (<25°) should be avoided because of atmospheric refraction.

Thanks again for your kindly comments and suggestions.

All the best,

LEI Lianfa

On behalf of all the authors

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