“*On the calibration and monitoring of dual-polarization radar receivers operating at C-band using solar flux reference at S-band*”

Reply to referee 2 - Dr. Hidde Leijnse

Andrea Francesco Battaglia & Marco Gabella

7th August 2026

1 Referee report

This paper investigates the relation between the solar spectral irradiance at S-band to that at other bands. This is very relevant for weather radar calibration, especially for radars operating at bands other than S-band because the most widely used reference (DRAO) is at S-band. The authors propose a useful adaptation to the relation used to convert DRAO flux data to C-band flux estimates that is shown to be more accurate than the original. This adaptation is based on a thorough analysis of EOVSA spectral data of sun measurements. The authors demonstrate the usefulness of these data based on weather radar data, both in ”sun-check” and ”sun-track” modes. I also appreciate that the authors attempted to use a nearby C-band reference, and that the results led them to conclude that we need a dedicated nearby reference at C-band for proper C-band weather radar calibration. I think the paper is scientifically sound, and is on the whole well-written. It could use some clarifications in some places. These are listed below.

Specific remarks

1. Section 2.1: What happens if there is rain over the observatory? How will the attenuation caused by that rain (much more pronounced at C-band) affect the results? Or is there a correction in place?

2. Section 2.2, I suggest also introducing the Finnish ANJ radar here.

3. Fig. 2: the spectra show some very local peaks, but also some local dips. How could these be explained, and what do they tell us about the behavior of the spectrum? These excursions are much larger than the difference between S- and C-bands, so it would be good to know about their relevance.

4. Eq. (2): should the p-variable be called pC instead of pλ? This because on the right-hand side of the equation C-band is indicated.

5. In some cases the order in which things are explained could be modified. For example, when introducing the normalization constant of 141.2, it would have been more intuitive for me to have the explanation on lines 214-220 before Eq. (3) on line 210.

6. Fig. 3a: can parentheses be added for the log functions in the legend, so that the reader can see what the argument of the logarithm is?

7. lines 231-236: repetition of the value of 87.9%. Mentioning this value only once would be sufficient for me.

8. Section 5.1 is confusing to me. After reading it several times, and going back to the equations and figures to which are referred, I understood what is actually being compared. I think it would help to explain in words that Eq.(1) refers to the Tapping formula, Eq.(3) refers to the proposed formula, and that Fig. 5 refers to the relation between the Swiss weather radar and the reference. If that is more clearly stated, it is much easier to understand. In terms of what this section shows, I think it is more a proof that the assumption that the weather radar calibration did not change than that it shows the value of the new formula (I can conclude that the old one is also fine for this case).

9. line 383: "we have thought of replacing". Was the missing date replaced by the 5 March 2026 data, or did you only think of it? It's not clear from the text.

10. Section 5.3: given this explanation, it seems like the behavior depends largely on the distribution of magnetic fields. Is there information about typical distributions available that can help explain the results?

11. line 457: it now reads like "ANJ" is the abbreviation for "Albis". Please rephrase this sentence for clarity.

12. lines 473-475: consider adding something about that the processing of the reference data should be optimized in terms of integration time and scanning strategy that maximizes the Sun-to-noise ratio.

Typos that I noticed:

1. line 20: "tool" should be "tools"

2. line 25 "fluctuations" should be "fluctuation"

3. line 366: "2006" should be "2026".

4. line 385: "tof such referemce" should be "of this reference" or something similar.

5. line 412: "whhose" should be "whose"

2 Reply to referee 2

We thank referee 2 for the encouraging comments, which we appreciate very much, and the constructive feedback. In the revised version of the manuscript (to be submitted later), we have addressed all comments, as detailed below. To address the points raised by Referee 2, we highlighted our revisions directly in the manuscript using underlined orange text for ease of review (~~strikethrough red~~ indicates removed text from the previous version).

Specific remarks

1. EOVSA does not apply any correction for atmospheric attenuation. In our analysis, however, we explicitly avoided observing days characterized by heavy rain or heavy snowfall, when such effects could become significant. We also consulted directly with the PI of the EOVSA telescope, Prof. Dr. Dale Gary, who stated: "We do not attempt to make any adjustment for atmospheric attenuation. [...] We generally do not notice it [*in the analysis of solar flares*] except in heavy rain or snow."

2. We thank the referee for this comment. Since the Finnish ANJ radar data are shown and discussed in different places, we agree that it is important to address them with a dedicated paragraph in the manuscript. We have therefore added a new Sect. 2.3, where we briefly introduce the ANJ radar data.

3. This is an important remark that we did not clarify in the first version of the manuscript. We have now clarified in the figure caption that these features are due to instrumental artifacts. To ensure that the spectrum used in our analysis was free of such artifacts, we examined not only the temporally integrated spectrum (see examples in Fig. 2) but also the time profiles at the frequencies of interest (see the example in Fig. A below). Since these artifacts vary in time, they can be readily identified by the manual inspection of the 240 temporal profiles that we have performed. Figure A illustrates that, over the considered hour-long interval, the two frequencies used in the paper (2.79 GHz and 5.59 GHz) show no variations due to flares or artifacts, whereas the example frequency at 10.63 GHz exhibits drops caused by instrumental effects. We have therefore specified in Sect. 2.1 that we inspected the time profiles, and we added gray shaded areas and a dedicated sentence to the caption of Fig. 2.

4. We agree that p_C would remove any ambiguity about which frequency is being estimated; however, we chose the p_λ formulation to remain consistent with the convention adopted in Tapping (2001). We therefore adopt a compromise. In Eq. (2), where we first introduce the expression used to derive the parameter, we write it as p_λ^C and then state at the end of the paragraph that we simply denote p_λ^C as p_λ. We hope this version is clearer than the previous one.

5. To address this issue and make the formulation more intuitive, we replaced the 141.2 value in Eq. (3) with a generic normalization constant F_0, which is introduced and discussed in more detail in Eq. (4).

6. When generating the figure, we included the parentheses. Our Overleaf version of the manuscript also displays the parentheses correctly (as in Eq. (3) and Eq. (5)), so we suspect this could be a rendering issue. We have now regenerated the figure using a different method and hope the problem is now solved. We tested opening the PDF with Document Viewer in Ubuntu 24 and Adobe Acrobat in Windows 11, and the parentheses are visible in both.

7. To avoid repetition, we removed the first occurrence of this value, since the second occurrence provides more detail.

8. We agree that this can be confusing for the reader. We have now clearly specified which model each reference to the formula refers to.

9. The date was actually replaced. We therefore removed the ambiguity by removing "thought of".

10. This behavior is typically seen in microwave observations of solar flares. Although solar flares mainly occur in active regions, these regions contain sub-areas where the magnetic field can vary substantially. For example, in plages the field strength is typically 100–300 G, whereas in sunspots it often exceeds 2000 G. Depending on where the microwave emission originates (i.e., where the flare is rooted), among other factors, the microwave spectrum can show significantly different peaks (sometimes exceeding 10 GHz). In solar physics, this provides a powerful tool to infer the magnetic-field strength and its evolution during flares.

11. We acknowledge that the original sentence was confusing, and we have rephrased it. ANJ was not intended as an abbreviation of Albis; rather, it refers to all values and expressions in parentheses. We have therefore edited the bullet point and now removed the parentheses for clarity.

12. We thank the referee for this opportunity to comment on the scan strategy and integration time of future European radio telescope(s). Concerning the scan strategy, we would recommend the optimal implementation at DRAO, described in Sec. 4.1. In particular, this convincing scan strategy consists of eight steps; its choreography is described by Tapping (2013, pp. 398–399) and illustrated in Fig. 6. As for the integration time, we expect to provide a more definitive answer in the coming years, once Philipp Schmid has completed his PhD at the University of Bern under the supervision of Prof. Dr. Axel Murk. Philipp is developing an innovative prototype of a future radio telescope tailored to weather-radar calibration. We also have experience with the low-cost X-band CALLISTO radio telescope and a traditional Sun-Track scan strategy (see [23], p. 398 in Tapping, 2013). In that case, the one-hour integration time used at DRAO could be reduced. A reasonable compromise could be to adopt the DRAO scan strategy with a 30-minute integration time, thereby acquiring 5, 7, or 9 calibration reference signals per day to be delivered to the weather-radar community. In any case, we would prefer to discuss these two aspects within the framework of the EUMETNET OPERA weather-radar programme. We believe it would be premature to specify in the current manuscript the scan strategy and integration time of future European radio telescope(s); this is why we have chosen not to add dedicated text to the manuscript.

Typos

We thank the Referee also for reporting typos, which have been corrected.

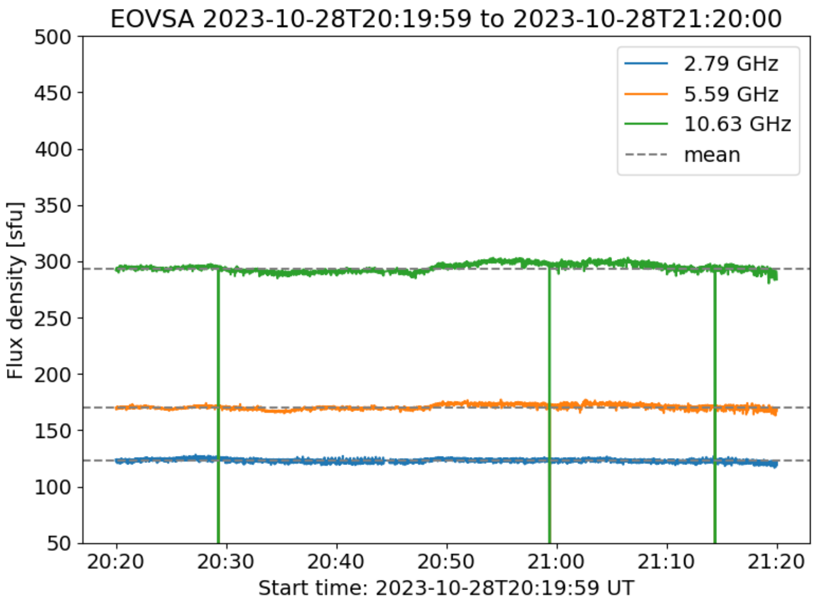

Figure A: Example EOVSA full-disk time profiles at three selected frequencies. The two frequencies of interest (2.79 GHz and 5.59 GHz) do not show variations due to flares or instrumental artifacts, and are thus considered for the analysis. As an illustrative example, the 10.63 GHz frequency band shows three short drops in flux due to instrumental artifacts.