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Atmospheric Measurement Techniques
Discussions

Interactive comment on "A novel approach for absolute radar calibration" *by* C. Merker et al.

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Response to interactive comments of Referee 2

The calibration method illustrated in the paper is interesting and can be of interest for dense networks of weather radars working at attenuated frequencies, although the main interest semms to be the calibration of the vertical profiler. It is not clear to me whether such method can be extended to radars with different frequencies. The concept of calibration is proven by means of simple simulations. Experimental validation, even in a preliminary form, would add more value to the paper. Moreover, to set up a specfici calibration experiment should not be too much complicated.

We thank the reviewer for the comments on the manuscript which point out important aspects of the topic, especially when it come to the application of the described

method. Responses to the raised points (including these mentioned above) can be found below.

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The setup should be considered for calibrating R_3 in the first place. This radar can be operated at any wave length, although the method becomes simpler if k_3 can be neglected (this is generally the case because of the short vertical path). The horizontal radars must of course be operated at attenuated wavelength because the method is based on attenuation. This can be any frequency provided that the attenuation from rain along the section of interest is high enough to be detected. In practice, the attenuation for X band, for example, would be approx. one order of magnitude smaller then for MRRs using K band (Atlas and Ulbrich, 1977), making it difficult to get a clear attenuation signal when measuring uncertainty is of about 2 dB. So using any device with lower frequency than K band for the horizontally oriented radars is probably not possible. Both should operate at the same frequency in order to be subject to the same attenuation.

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We agree on the importance of testing the method using real, measured data. However, even if the setup of an appropriate network looks simple, it is not trivial in detail. The network in Lindenberg was build up in order to validate the method, but the pointing of both horizontally oriented MRRs had to be improved, which was done by the end of 2014. At the same time, a rain gauge for validation against a proved method was installed next to MRR_3. The data set collected since this necessary improvement of the setup is not large enough yet to provide a satisfying amount of cases for calibration. Furthermore, the application of the method on real, measured

data would require further preprocessing (selection of suitable measurements) which still remains to be optimised. A proper analysis of the effect of the integration time on results is also required. In our opinion this would be beyond the scope of this article, focusing on the theoretical formulation, but will be done in future studies. The title of the manuscript was changed to be less confusing about that.
Changes in manuscript: Adapted title

Please see the answers to both stated main comments below.

Main comments:

a *The use of a $N(D)$ estimated by the Doppler vertical profiler is supposed to be not affected by some known effects, such as the presence of vertical winds as expressed also in the cited paper by Atlas et al. 1993. In general, profiler DSD estimates are not perfect, but this is not important. Important is to establish conditions (rain intensity, wind) in which the $N(D)$ estimate is acceptable to make calibration method to work within acceptable limit. I think to deal with this issue is important to 'proof the concept'.*
Vertical air motion is indeed one major possible source of errors when it comes to applying the method to a real data set. An error in the estimated specific attenuation yields an error of the same factor in the calibration (see eq. 7). Vertical wind effects on MRR measurements have been studied in Peters et al. 2005. Table A1 lists the impact of vertical wind on attenuation. The relative error (LEM) is nearly linear and can be approximated to 3 dB per ms^{-1} (this means specific attenuation k_3 is overestimated by a factor 2 for 1 ms^{-1} vertical wind). The remaining bias (LET) in k_3 is found to be 0.8 dB per $\mathrm{m}^2\mathrm{s}^{-2}$. However, a test using 10s vertical wind values at a height of 50 m (measurements at the Wettermast Hamburg, May and June 2014) yields a standard deviation of 0.49 ms^{-1} when considering rainfall events. This strongly reduces the possible error to about a factor 1.4 for LEM

and 0.05 dB for LET. Since convective precipitation events should not be considered for calibration anyway (strong inhomogeneities), the typical variance of vertical wind in considered cases should be even lower. Furthermore, the MRR considers a measuring volume, which also reduces fluctuations. Still, this remark is justified and certainly requires attention in future work.
Changes in manuscript: A paragraph was added to the conclusion in order to highlight the issue.

b *Effects of vertical variability of DSD within horizontally looking radar sample volumes is not taken into account. The variability detected by the vertical profiler can be real or induced by artifacts (see Tokay et al. JTECH 2009 'A Field Study of Reflectivity and Z–R Relations Using Vertically Pointing Radars and Disdrometer', where fig. 5 shows a bias of MRR reflectivity measurements at lower level that increases with height and measured reflectivity (from 35 dBZ).*
The point raised here is an important aspect for the application of the method to real, measured data. It is not discussed in the manuscript because of the focus on synthetic data. However, the major assumption made for this method is homogeneity of rain within the area of interest around R_3. For cases fulfilling this conditions (which have to be chosen carefully), vertical variability should only have a small impact. When comparing measurements of vertically and horizontally oriented devices, averaging measurements of the vertical device over all range gates within the beam both horizontal MRRs should also minimise the made error (minimum range width for MRRs is 10m).
Changes in manuscript: A paragraph was added to the conclusion in order to highlight the issue.

Interactive comment on Atmos. Meas. Tech. Discuss., 8, 1671, 2015.