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Atmospheric Measurement Techniques Discussions

Interactive comment on "Performance of high-resolution X-band weather radar networks – the PATTERN example" *by* K. Lengfeld et al.

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Revision of the paper Performance of high-resolution X-band weather radar networks – the PATTERN example by K. Lengfeld, M. Clemens, H. Münster, and F. Ament

Reviewer Comment: The manuscript offers the opportunity to understand the benefits and drawbacks of a network of X band radars in Germany, which is composed by single systems that have the advantage to be compact, easily managed and in principle low cost. For this reasons I think that the subject presented by the Authors deserves the proper attention. However, in my opinion, the results presented are not adequately supported by a rigorous description of the methodology used. In addition, the two concepts of "high resolution" and "low cost", highlighted by the Authors, seem to me

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Interactive Discussion

Discussion Paper

misleading or not covered at all. For the above-mentioned reasons I would suggest rejecting the paper but I strongly encourage the Authors to resubmit it again following the reviewer's suggestions.

Authors' Reply: We appreciate the comments and thank the reviewer for the helpful suggestions to enhance the quality of the manuscript. We agree that more detailed description of the applied methods is needed and that the advantages of the proposed X-band radar network need to be stated more clearly. We believe that all concerns of the review can be resolved by the major revisions which are outlined in detail below. The revised manuscript will describe the algorithms and methods applied for calibration, clutter detection and the comparison to large scale C-band radar in more detail. The concepts of high resolution and low cost will be discussed more distinctly. We will highlight the use of high temporal resolution and the multiple radar coverage for clutter detection. A long-term comparison between X- and C- band radar systems has to our knowledge not been published before. Therefore, we believe that after the indicated revision, the manuscript will provide novel and relevant contributions to the science community.

Reviewer Comment: 1. Resolution Abstract line 5-10. "The spatial and temporal resolution is 1° and 30 s" but in table 1 the beam width is 2.8° and the range resolution is 60 m. This means that at 20 km we have thin slices of approximately 60 m long x 1000 m wide x 1000 high. In section 2, line 5-10, an "oversampling" procedure is applied to "achieve an angular resolution of 1°". Is not explained the meaning of the oversampling performed by the Authors. I assume that the Authors just averaged the received samples in 1° interval for 30 s. Actually, this does not lead to an increase of the angular (only in azimuth) resolution. One way to do that is apply a deconvolution technique that is based on the oversampling of range gates plus an inversion strategy. I strongly suggest the Authors to check one of the references below to properly address this important issue.

Authors' Reply: We thank the reviewer for his valuable comments on our paper. We

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agree that the text should be corrected. The angular resolution of the radar is 2.8° (according to its antenna beam width). The received signals/reflectivities are averaged over a sequence of transmitted pulses within an angular range of 1°. As the radar is transmitting with a pulse repetition frequency of 800 Hz and the antenna is continuously rotating with an angular velocity of 24 rounds per minute. Therefore, the average is based on about 67 pulses per angular range of 1° and averaging interval of 30 s (5-6 pulses per sweep). We agree that in this context the term "oversampling" is not correct and should be removed.

Reviewer Comment: 2. Costs The paper highlights the concept of "Low cost" with respect to more performing systems. This is too generic statement. A detailed analysis of costs including maintance and probability of failure should be addresses. While it appears reasonable a lower cost for one miniradar, it less intuitive the lower cost for a network of miniradars as those described by the Authors.

Authors' Reply: The reviewer is right. The paper should highlight the concept of "low cost" in more detail as it is denoted as one of the major differences comparing to "more performing systems". We will make some changes in the paper taking this aspect into account. We will make clear that the network operating in the PATTERN area was designed as research deployment. It addresses issues regarding radar network algorithms (clutter removal, attenuation correction ...) as well as combining measurements of different types of radars (C-band and X-band as well as the vertical pointing K-band radar). In this sense, the network consists of more radar devices, X-band radars and MRRs, than necessary for operational rain estimation in local areas. In operational use it is possible to apply common adjustment procedures using ground-based precipitation observations by gauges, disdrometers etc. However, we think that vertical profiling instruments, like MRRs, provide an opportunity to compare directly observed reflectivity within a common volume. Here one additional MRR and rain gauge in the area covered by all four radars would be sufficient to run the network and obtain reliable precipitation data.

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However, comparing acquisition price of the “low-cost” X-band radar system of about 60.000 Euros with the conventional X-band radar, it costs less than one tenth. This price includes the radar with pc and the tower/container construction (see figure 2b in the paper). The network is operational for three years and operated continuously despite a change of engines.

The overall price of the network depends on the kind of application and the area to be observed. In complementation to larger scale radars, such as C-band, one or two X-band radars would be sufficient. Nevertheless, the network based algorithms used in the PATTERN network are designed for at least three X-band radars.

Reviewer Comment: 3. Clutter Removal The clutter removal chain seems to perform very well in the cases showed by the Authors. This is an interesting subject. However, the description of the clutter removal modules is too generic. The thresholds used in the various algorithms seem to be subjectively fixed. An explanation of their derivations would benefit the reader.

Authors’ Reply: We agree with the reviewer and will provide much more details on the determination of thresholds for the clutter detection in the revised manuscript. The thresholds are based on several case studies. They are chosen to optimize the balance between computing time and clutter detection.

Reviewer Comment: 4. Calibration a) Reflectivity form MRR is used for calibrating that at X band. Here my main concerns are about the methodology of comparisons between the two sources. MRR is probably working at 24 GHz (please confirm it) while X band radar is working at $\sim$ 10 GHz. I guess that the two frequency bands experiments different resonant effects when observing rain precipitation. Thus, I am wondering if a better comparison should include a proper frequency scaling to make the two reflectivity comparable each other before proceeding with the calibration.

Authors’ Reply: The reviewer rightly assumes that the MRR is working at 24 GHz while the X-band radar performs at a frequency about 10 GHz. Therefore, received signals

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of the MRR are transformed to drop size distributions (DSDs) using single particle backscattering cross sections that are calculated with Mie theory (using the code of Morrison and Cross, 1974). To allow comparisons between MRRs and weather radars, the reflectivity Z is derived from the MRR DSDs using Rayleigh approximation (Peters et al., 2005). For the X-band radar, scattering is assumed to appear mainly as Rayleigh scattering which is a good approximation for light and moderate rainfall. For high rain rates, it is difficult to completely separate the non-Rayleigh scattering effect from the rain attenuation. In this rain intensity range, attenuation by liquid water is of the same order or outweighs non-Rayleigh scattering effects. The good agreement between X- and C-band systems (Fig. 12 in our manuscript) is also found by Barbieri et al. (2014). This confirms the applicability of the Rayleigh approximation for X-band radars.

- Barbieri, S., Piciotti, E., Montopoli, M., Di Fabio, S., Lidori, R., Marzano, F., Kalogiros, J., Anagnostou, M., and L. Baldini, 2014: Intercomparison of dual-polarization X-band mini-radar performances with reference radar systems at X and C band in Rome supersite, Proc. of ERAD 2014, Garmisch-Partenkirchen, Germany.

- Morrison, J. A., and M. J. Cross, 1974: Scattering of a plane electromagnetic wave by axisymmetric raindrops. Bell Syst. Tech. J., 53, 955-1019.

- Peters, G., Fischer, B., Münster, H., Clemens, M., and A. Wagner, 2005: Profiles of Raindrop Size Distributions as Retrieved by Microrain Radars. J. Appl. Meteor., 44, 1930-1949.

Reviewer Comment: b) Another aspect that is not mentioned in the paper is how the Authors have dealt with the different resolution and viewing geometry of MRR and X-band radar. More than one MRR range gate is within a single X-band radar range gate. Which is the MRR range gate chosen by the Authors to make the comparison? Do they apply some averages?

Authors' Reply: In the discussion manuscript we used the MRR range centered in the X-band radar beam at the corresponding distance and azimuth gate. We agree that a

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weighted average over all MRR ranges within the beam would be more accurate and will include this in the revised manuscript. However, we do not expect a significant change in the calibration constants, because the mean received power of the X-band radar comes from the center of the beam. We attached a case study comparing both calibration procedures for August 2013. Both are very similar concerning bias, RMSE and correlation coefficient.

Minor Comments

RC: Abstract lines 20 – 25. The phrase is misleading. Considering only a standard deviation of 3 dB is not the only parameter indicating an improvement spatial resolution.

AR: We will make the improvement in spatial resolution clearer in the abstract by adding also results from the long-term comparison between X- and C-band systems and the rain coverage (Fig. 13a) within a C-band range gate.

RC: pag. 8236, lines 25. In my knowledge, there exists a third approach. Doppler, dual pol. X band miniradar: Look at: http://www.pa.op.dlr.de/erad2014/programme/ExtendedAbstracts/223_Barbieri.pdf

AR: These systems are technically based on the same type of radar as the ones used in the PATTERN network with low peak power of 25 kW, but they perform dual polarization measurements and can scan on different elevation angles. We will include the X-band miniradars in our list.

RC: pag. 8237, line 19. Change “approvements” into “improvements”.

AR: Done

RC: pag. 8240, line 31. At this point of the reading is not clear what Fig 3a should explain.

AR: We agree with the reviewer and will add a description of the raw reflectivity field as received from the radar in Fig. 3a.

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RC: pag. 8243, eq (2) Why this formula is calculated only in range direction?

AR: The formula is calculated in range direction only according to Hubbert et al. (2009) in order to optimize computing time.

- Hubbert, J.C., Dixon, M., and S.M. Ellis, 2009: Weather radar ground clutter. Part II: Real-time identification and filtering. J. Atmos. Ocean. Tech., 26, 1181-1197

RC: pag. 8244, line 20 – 23. At this point of the reading SPK method seems working best.

AR: Maybe the colors of the bars in Fig 4 are misleading. SPK is shown in pink, the violet bars refer to the network filter. We will use more distinct colors in the revised manuscript.

RC: pag. 8245, line 11. Are the other clutter algorithms compared on the same overlapping areas.

AR: All single radar based clutter filters operate in the same areas. Only the network based clutter filter is only used in the overlapping.

RC: pag 8246, eq.5. How dBRMRR is obtained in detail?

AR: According to dBZ dBR is calculated as follows: dBR = 10.*log(RR)

RC: pag 8246, eq.7. Is it "(dBZX-dBZMRR)" or (dBZMRR- dBZX)?

AR: We use dBZX-dBZMRR.

RC: pag. 8246 eq 8. How is the value of "δC"?

AR: The calibration error δC is $\pm$1dB.

RC: pag 8247, line 19, Do you have a statistic of A(r) for your radars?

AR: Not yet.

RC: pag. 8268, fig 11. I would change the title on the right panel b.

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AR: We will change the title of the figure 11 (right panel) to “C-Band Radar Hamburg (DWD)” in the revised manuscript.

Interactive comment on Atmos. Meas. Tech. Discuss., 7, 8233, 2014.

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Interactive Comment

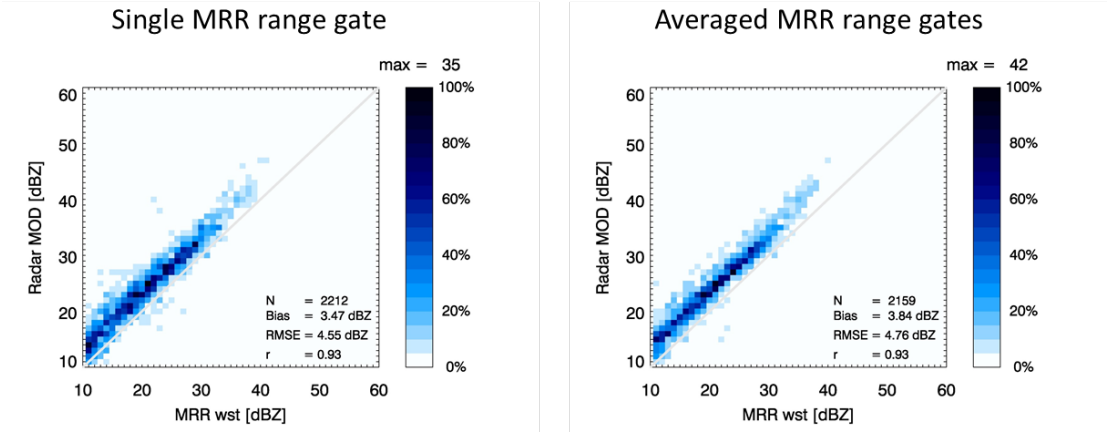

Fig. 1. Calibration

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