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Atmospheric Measurement Techniques Discussions

Interactive comment on "Insights into wind turbine reflectivity and RCS and their variability using X-band weather radar observations" *by* Martin Lainer et al.

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My overall statement: I find this paper very valuable, since it develops in a comprehensive form the deviation of a single WT's RCS from a a measured dBZ gained from a precipitation radar. Special care is taken to set up a measurement to isolate the radar return from specific wind turbines. Much work is invested to present a meaningful statistical analysis.

Remark on nearly all Figures: The tics and axis names are to small, and some important marks in the diagrams are also too small. This makes some figures quite unreadable.

Detailed comments referring to paragraphs:

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Abstract (Paragraph 1) and Introduction (i.e. Par. 45):

The radar in use is a "precipitation radar". Please use at least once this term.

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Par. 30:

"RCS is an optimal variable to estimate the effect of a wind turbine on the performance of a radar system, in fact existing numerical models for estimating the back-scattering efficiency of wind turbines rely on this quantity."

According to [1] ("scattering cross-section:") the incident field is assumed to be planar over the extent of the target. This is in principle not the case for objects on the ground and causes some restrictions.

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70:

I am missing a hint or a justification why the radar pulse width was selected 0.5μs but no other values. Is there a technical restriction? Same for PRF.

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125:

"... co-polar correlation coefficient are represented on 2019-03-24."

Are these coeffecients in use later when developing eq. (7) using eq. (3) ? (3) is defined for circular polarization.

"During the fixed-pointing scans, the antenna of the radar was not moving and always pointing to the same wind turbine"

Fig. 2 too small, unreadable

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150:

"The wind turbine clutter is clearly visible at the range from 7.7 to 8.6km as high ZH, HV and low ZDR and all three turbines can be distinguished from other ground clutter signals"

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165:

"In the following part of the paper, all the horizontal reflectivity ZH measurements and retrieved RCS data ..."

See restrictions of RCS mentioned above and discuss the applicability.

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175:

eq. (1) is simply a form of the radar equation and should be referred to as it is.

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185:

"Accounting for the actual distribution of power within the beam generated by a circular parabolic antenna, a correction factor of 1/(2 Âů ln2) was introduced by Probert-Jones (1962):"

The development of the later eq.(7) has some uncertainties, i.e. the usage of eq. (3) which applies to circular polarization. Please mention that and discuss what the restrictions may be applying linear polarization.

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195:

"The Rayleigh approximation of the backscattering cross section of a single water drop d can be expressed as ..." Is there a reference to literature?

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215:

"The statistical overviews in Figs. 5 and 6 show the maximum (1st row), median (2nd row) of ZH and the maximum retrieved RCS (3rd row) for all three wind turbines."

So equation (7) is used for that representation, please make a note.

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250:

"Figure 7 shows the variability of the location and intensity of the RCS maxima. The farther apart the blue and black histograms are, the higher is the variability of the distribution of the maxima."

Please explain this in more detail.

In Figure 7, both curves represent RCS values according x-axis. However, the legend says "Pmax" and "RCSmax", which is confusing. Please correct or clarify.

"The blue histograms are calculated at a fixed position (as listed in Table 13)"

Mistake: Table 13 ?? –> Table 3

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265:

From the 2020 measurement, it may be interested to zoom much deeper into time to see the fluctuation across a short period, i.e. within some seconds in contrast to the long-term diagram as of Fig. 8.

Figure 9: "dBZ" and "dBsm" refer to absolute values. If the meaning is a variation, i.e. for a bin, always use "dB" alone without reference!

Same mistake as in line 265 "about 4dBsm higher". There are maybe more of these in the entire text. In line 285 however, it's correct: "... bin width of 0.5dB".

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280:

"From the polar plots in Fig. 9(a, c) we see that the relative orientation of the turbine/nacelle is insensitive to the maximum values, evident by the round and not too much disturbed distributions"

Is this correct for a) _and_ c) ? For a) I agree. I think for the median values (red) this is correct for a) and b) depicting the dBZ. Is the averaging time always the 10 min as of Fig. 8 ? In sub-figures c) and d) the difference of medium RCS across the two positions "radial 90/270°" and "tangential 0/180°" is lower than I would expect.

Could that be validated from other sources/measurements for X-Band (references)? I have seen many RCS simulations for WTs in C band that claimed differences >20dB. From own measurements close to reflecting WTs we got differences of >30dB with rotor planes in frontal (0°) and side (i.e. 90°) view [2]. However, there is obviuosly a difference from the radar's point of view. It observes the target over a larger distance that includes terrain effects.

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290:

"Future work should take also into account numerical simulations ..." Yes, that might be interesting. I have not seen many in the X band. However, methods like MoM or even MLFMM might not be suitable due to the huge number of triangles to work with. Asymptotic methods l(like PO, GO), however, might neglect some eletromagnetic

(near) field effetcs.

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300:

"For example on 2020-03-12 or 2020-03-22 blade pitch angles of WT1 were aligned at roughly 90° over hours..."

In Fig. 10 it would be helpful alos to have an additional curve that simultaneously shows the orientation across the time axis.

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345:

Why is the relative yaw angle Psi normalized, and the other angles are not?

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410:

Ground radars in X (or K) band are used in aviation only as SMR (surface movement radars) or for the pecision approach radar (PAR). Unfortunately, for surveillance or air defense radars in S band, the actual antenna beam widths are much too large to discriminate single WTs at a far distance. Those measurement results, obtained from a similiar measurement campaign, would be really interesting.

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425:

"... the computational requirements are huge..."

Yes, and be aware of the electroagnetic solvers methods and their limitations (mentioned above).

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430:

"Thus dedicated measurement campaigns with e.g. mobile radars offer another approach to assess wind turbine reflectivity and RCS in a broad range of real environmental scenarios"

Yes, this is necessary. As an example, We did that for C band precipitation radar [2].

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[1] IEEE Std 211-1997: IEEE Standard Definitions of Terms for Radio Wave Propagation. https://ieeexplore.ieee.org/servlet/opac?punumber=5697

[2] J. Bredemeyer, K. Schubert et.al.: "Comparison of principles for measuring the reflectivity values from wind turbines", International Radar Symposium - IRS 2019, Ulm, Germany

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