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Geoscientific Instrumentation Methods and Data Systems Discussions

Interactive comment on "Airborne polarimetric Doppler weather radar: Trade-offs between various engineering specifications" *by* Jothiram Vivekanandan and Eric Loew

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Review of GI-2017-45: Airborne polarimetric Doppler weather radar: Trade-offs between various engineering specifications Authors: Jothiram Vivekanandan, and Eric Loew

Summary: This paper presents a very ambitious project of airborne polarimetric Doppler radar, as a follow on of the previous ELDORA/ASTRAIA radar developed in the 90's between NCAR and CNRS. I approve the main definition features of the project: - C-130 as the aircraft carrier, - Phased array antenna for the radar technology, - Polarisation diversity capability. Very good paper. I have nevertheless some questions or

comments.

Reply to Reviewer #1

Dear Reviewer,

Thank you for your time and comments toward helping us improve the manuscript. We have revised the manuscript based on your comments. The revisions made to the manuscript are as follows.

Table 1- and Figure 6: I understand that the choice of the radar frequency, C band (instead of X band for ELDORA/ASTRAIA) is dictated by the concern of avoiding situation of total extinction of the radar signal in severe weather. However, I am wondering if this choice is not too much penalizing in antenna performance -angular resolution and side lobes.

A: The C-band is chosen for achieving similar angular resolution as in the ELDORA and also for keeping the cost of the radar system lower. Since in the airborne research community, the ELDORA's measurement is considered to be the standard, the desired goal for the proposed APAR is to meet the current sensitivity of the ELDORA. On the C-130 maximum, allowable antenna aperture size is 1.93 m (76"). It will produce a narrower beamwidth at X-band, but it would require four times the number of T/R elements and consequently would be more expensive.

Table 1: I do not understand how you can achieve a 3 dB beam resolution (one-way) of 2.2âŮę with a 38" diameter antenna at C band. A reflector antenna with good sidelobes (<-30 dB), respects a relation like : 3dB_beam_res $\approx$ 65 λ/D (1). - With this relation, your 3 dB beam aperture should be 3.7âŮę. Can you improve the performance predicted by rel. (1) simply because you may control much more easily the antenna illumination with phase array technique? If yes, it's worth mentioning.

A: Sorry for the confusion about antenna size. On the C-130 maximum, the allowable aperture is an ellipse of 1.93 m (76") major diameter and 1.78 m (70") minor diameter.

The specification of antenna size in Table 1 has been changed to diameter.

Fig.6, the first sidelobe is at -15 to – 17 dB, which may be quite penalizing from airborne where part of the exploration is made at negative elevation where you must address the problem of the surface clutter. It's the reason why -30dB side lobes were specified for the ELDORA/ASTRAIA antenna.

Did you check (by simulation?) that your antenna sidelobes are compatible with your objective of detecting -10dBZ within 400m of surface at 5 km range?

A: Fig. 6 shows a uniformly illuminated pattern, where no amplitude tapering is done. This yields the most antenna gain, narrowest beamwidth, and highest sidelobe levels. The intent of this figure is to compare the relative characteristics (sidelobe and mainlobe) of the antenna apertures being considered for APAR, namely elliptical, circular and square. Unlike traditional antennas, active electronically scanned antennas (AESAs), have inherent flexibility to alter the antenna pattern by adjusting both phase and amplitude at each antenna element. Typically, the antenna patterns are not symmetrical on transmit and receive. Fig. 7. illustrates the two-way, combined antenna patterns the solid red line shows that -50 dB two-way peak sidelobes are achievable using a combination of amplitude weighting on transmit (15 dB Taylor) and on receive (-30 dB Taylor). Randomizing the active elements on transmit while applying amplitude weighting on receive has been shown to further reduce the first sidelobe level to <- 55 dB. Another approach is to effectively null the near in sidelobes which intersect the ground. Both these approaches are still topics of ongoing research. Based on recent simulations, the circular aperture having -50 dB two-way peak sidelobes does not meet the objective of detecting -10 dBZ within 400m of a surface at 5 km range. In fact, this objective pushes the current capabilities of most conventional antennas and very definitely AESA antennas.

Section 4: Polarimetric measurement configuration Your discussion about ATSR (alternate transmit and simultaneous receive) and STSR (Simultaneous transmit and si-

multaneous receive) is interesting. Today in operational, most radars use the STSR mode, since the ATSR mode requires a high-power polarization switch, a component very expensive and unreliable. A big potential interest of the phased array is that it opens the possibility of using very naturally the ATSR mode, which authorized the possibility to measure LDR (impossible with STSR). However, I totally disagree with the argument of the author to discard STSR on the argument that with this mode the "isolation" between H and V should be 44dB. How this "isolation" is defined? Is it the usual crosspolar level? In that case, that would mean the impossibility of STSR methodology since no antenna holds this performance. Meanwhile hundreds of operational polarimetric radars provide satisfactory data (including ZDR) worldwide. In fact, the criteria for appropriate measurement of ZDR with STSR is the same as the one for LDR. It is based of the same ICPR cited by the authors in their formula (1). Simply, It is less stringent with STSR to measure ZDR than with ATSR to measure LDR. I figured out that to measure LDR down to – 27 dB with ATSR, ICPR should be below -33 dB (as recommended by Bringi and Chandraseckar, 2001), while to measure ZDR with 0,2 dB bias with STSR, ICPR should be below -23 dB (In the extreme case where ZDR$\approx$ -10dB (due to differential attenuation). I think it would be wise within this project to maintain the capability of the system to operate polarimetric measurements both with ATSR and STSR methodologies. Jacques Testud, October 16 th, 2017

A: We agree with the reviewer's comments. The requirement of -44 dB isolation for the STSR mode is based on the worst-case scenario where the differential propagation phase varies up to 1500. The following sentences about the cross polarization isolation requirement have been added to section 4:

"Cross-polarization isolation requirement is less stringent for estimating unbiased Z and ZDR in the ATSR mode than in the STSR mode. Cross polarization isolation depends on ICPR of the radiating elements, cross-polar system phase (phase difference between co and cross-channel) and the differential propagation phase of the precipitation medium in the STSR mode. Assuming the system phase characteristic is known, ICPR

< -23 dB is required for estimating ZDR with less than 0.2 dB bias (Wang and Chandrasekar 2006). In ATSR mode ICPR < -20 dB is satisfactory for estimating ZDR with less than 0.2 dB bias. However, for ICPR better than -33 dB is required for measuring intrinsic LDR of -27 dB (Bringi and Chandraseckar, 2001)."

References

Bringi, V. N., and Chandrasekar, 2001: Polarimetric Doppler weather radar. Cambridge University press.

Wang, Y., and V. Chandrasekar, 2006: Polarization isolation requirements for linear dual-polarization weather radar in simultaneous transmission mode of operation. IEEE Trans. Geosci. Remote Sensing, 44, 2019-2028.

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