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Geoscientific Instrumentation Methods and Data Systems
Discussions
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Interactive comment on "The next generation airborne polarimetric Doppler weather radar" *by* J. Vivekanandan et al.

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Anonymous Referee #3 Received and published: 29 April 2014

Summary: This paper presents a science and engineering design for the next generation airborne precipitation radar to replace the aging ELDORA. The design of the APAR is excellent and well considered, and the instrument is greatly needed in the atmospheric sciences community. The manuscript does a good job of explaining the design and trade-offs involved with an airborne radar platform, and the difficulties in obtaining the required Doppler and polarimetric data quality. A few of the trade-offs and comparisons with ELDORA could be made more explicit, but the manuscript is generally well-written. I recommend only a few minor revisions prior to publication in

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Dear Referee, Thank you for your time and comments. We have revised the manuscript based on your comments. The revisions are as follows.

General Comments:

1. The trade-offs involved in determining the spatial resolution could use some clarification. For a stationary PAR e-scan the effective angular beamwidth can be essentially the same as the antenna beamwidth, but for APAR there is a trade-off between the number of samples, effective beamwidth, and the along-track resolution due to platform motion. In the conclusions you state that APAR would improve the spatial resolution by a factor of two, but this point is somewhat lost in the technical discussion. It seems that a 200 m along-track would give 10 samples (at 35% overlap), which would require 10 dB SNR for the same data quality. It would be useful to state the beam overlap used in ELDORA for comparison in the effective beamwidth, and state specifically how the spatial (presumably along-track) resolution is improved by a factor of two and whether that involves a loss of velocity quality (but improved attenuation at C-band).

A. The factor of two improvement in along-track spatial resolution is due to flexibility of scanning smaller sector in the case of APAR whereas the ELDORA's mechanical scan always scans the complete 3600 scan. APAR scans about 1000 sector with a single beam that alternates between two fixed positions. The ELDORA scans 3600 sector using two beams. Thus the APAR collects the required samples approximately in 0.5 [∼100*2/ 360] time of the ELDORA measurement time. The faster collection of measurements by the APAR directly improves the along-track resolution by a factor of two. It should be noted the APAR's beam multiplexing capability helps to reduce errors in radar measurements while providing improved spatial resolution.

2. It would be good to either combine Figs. 4 & 10, and 5 & 11 for easier comparison, or to take the best single curves (pulse compression and 1 m/s curves) from 4 & 5 to overlay on 10 & 11. This would highlight the advantage in sensitivity, but also the

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trade-off in number of samples required at C-band. Making Tables 1 & 2 equivalent would also help with the comparison. A. Sensitivities of the ELDORA and the APAR for 4 W module with pulse compression are shown in the same figure. Requirements of number of independent samples as a function of signal-to-noise ratio for ELDORA and APAR are combined as per the reviewer's suggestion in Figure 1 and 2.

Table 1 and 2 have been merged to a single table as Table 1

3. Eye-eyewall interactions are indeed a valuable target for this radar, and strong mesovortices along the inside edge of the eyewall are believed to have scales on the order of 500 - 1500 m, which would require _200 m resolution to nominally resolve at the 4-6 dx scale. This radar may be our best hope for resolving these features. The "structures of the hurricane eye" may still be a difficult target for APAR in the clear dry air above the low-level inversion however. Another important aspect of the weather motivation is the microphysics of hurricanes and severe weather. Aircraft typically do not fly in the critical mixed-phase region in these systems, so the polarimetric measurements may provide valuable new data in this region.

A. We agree with the reviewer's comments.

4. The trade-off in spatial resolution for LDR is not entirely clear. This variable will have half the spatial resolution of the other polarimetric variables, or does the scan strategy mitigate this in some way? Please clarify. It may also be good to note the science limitations with LDR only going down to -22 dB.

A. In the ATAR architecture the dwell time required for estimating polarization variables, namely, ZDR and LDR are same. Since the ATAR has only a single receiver, polarization measurements requires twice the amount of time compared to reflectivity only measurement. Requirement of twice the amount of time reduces spatial resolution. Since polarization measurements will be acquired only over a restricted range of scan angles from boresight of the fore beam, the reduction in spatial resolution is not significant.

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The following sentence has been added: The minimum LDR of -22 dB will delineate regions of liquid, ice and mixed phase but discrimination between various types of ice crystals and detection of cloud ice will be compromised.

Minor comments: Abstract L6: suggest "(PAR) has demonstrated" A. The sentence has been revised as per reviewer's suggestion.

Abstract: Consider mentioning that APAR will meet or exceed the capabilities of ELDORA, not just move to C-band.

A. The following sentence has been added to the abstract: Preliminary design specifications suggest the proposed APAR will meet or exceed ELDORA's current sensitivity, spatial resolution and Doppler measurement accuracies of ELDORA and also it will acquire dual-polarization measurements.

p3, L3 and Fig. 1 caption: The terms 'inner' and 'outer' rainbands have different meanings than the current context, and typically refer to rainbands in the inner core and at large radii, respectively. In this context the word 'eyewall' should be used for both inner and outer features. Secondly, the data is not 'masked' in the inner eyewall, but the reflectivity is significantly attenuated suggesting the eyewall is weaker than it was.

A. The figure caption and description of the figure have been changed as per reviewer's suggestion.

p5 L5: should be "other than an"

A. The sentence has been corrected.

p11 L9: The NSF radar workshop also endorsed a need for airborne radar like APAR, though the enthusiasm is difficult to judge from the report (BAMS, Bluestein et al. 2014).

A. Agreed

p11 L24: Missing period.

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A. The punctuation has been added.

p12 L11: It might be good to mention the asymmetry is due to the wings and tail.

A. The following sentence was added: As shown in Fig.2 the location of the side-looking radars with regard to wings and tail causes asymmetry in aft and fore azimuth angles of the beams.

p13 L28: suggest comma to separate clauses: ‘X-band, and X-band cumulative’

A. The sentence has been corrected.

p15 L12: It won’t affect precipitation echoes, but would affect clear-air and cloudy echoes near the aircraft. This is a fair trade-off though to have better sensitivity at longer range.

A. Agreed.

p16 L16: You may want to reference Fig. 10 here or combine them as suggested above.

A. The combined figure was referenced as follows: Comparison of independent samples as a function of SNR between the APAR and ELDORA are shown in Sect. 7.

p21 L11: “Optimal” and “currently available” are not really the same. I would suggest “best”.

A. The sentence has been corrected.

p21 L21: Remove extra comma

p23 L6: Although it is mentioned in the summary it may be good to mention here that you can do staggered PRT with APAR too.

A. The following sentence has been added: The APAR will also allow to use staggered PRF for extending the Doppler Nyquist interval.

Figure 3: The black beams are just the middle ones, or do they have some other significance? Please note these in the legend or caption.

A. The black colored beams are positions of dual-Doppler scans. The legend has been revised.

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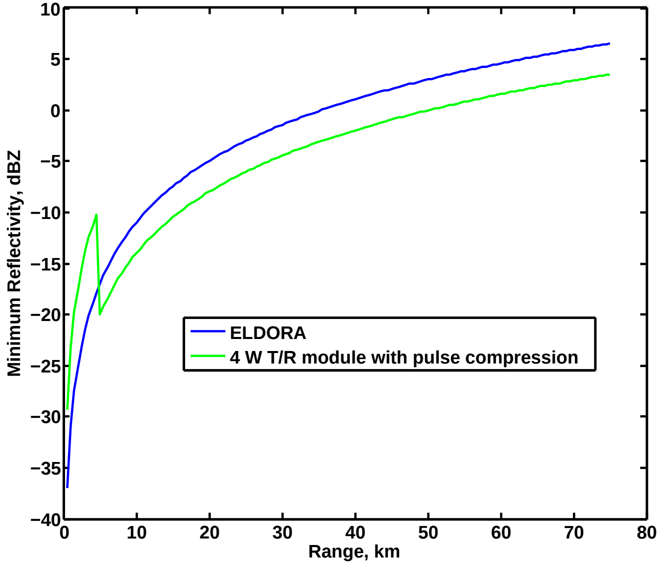

Fig. 1.

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Figure 1. Sensitivities of the ELDORA and the APAR for $ W T/R module with pulse compression are shown as a function of range.

Fig. 2.

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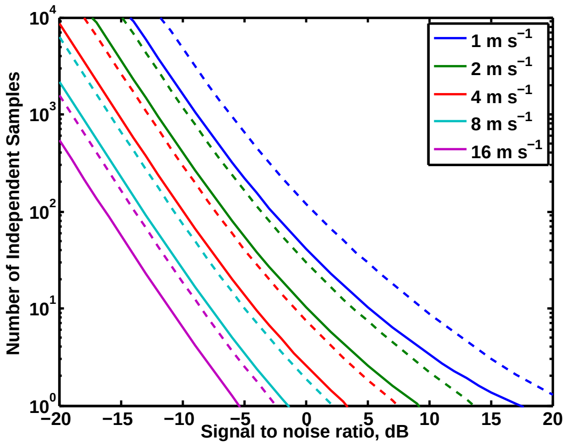
10^4
10^3
10^2
10^1
10^0
−20
−15
−10
−5
0
5
10
15
20
Number of Independent Samples
Signal to noise ratio, dB
1 m s−1
2 m s−1
4 m s−1
8 m s−1
16 m s−1

Fig. 3.

Figure 2. Requirement of number of independent samples as a function of signal-to-noise ratio for various mean velocity measurement accuracies are shown. Spectrum width is assumed 1 m s^{-1} and PRF is 2000 and transmit frequency is X-band. The dashed lines show corresponding values for the C-band i.e. APAR. Higher numbers of independent samples are required at C-band than at X-band for a specified mean velocity measurement accuracy and signal-to-noise ratio.

Fig. 4.

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Table 1: Technical Specifications of APAR and ELDORA

Parameter	APAR	ELDORA
Frequency	5.4 GHz	9.3 – 9.8 GHz
Wavelength	5.55 cm	3.2 cm
Element spacing along parallel and perpendicular to fuselage	2.78 cm, 2.78 cm	n/a
Number of Elements along parallel and perpendicular to fuselage	56, 64 (3584 elements)	n/a
Line Replacement Unit Size (LRU)	8x8 (64 elements)	n/a
Number of LRU's per PAR	7x8 (56 LRU's)	n/a
Antenna Beamwidth: (Elev, Azim) in Transmit mode (Uniform aperture illumination)	θ_0: 1.8°, 1.6° θ_{45}: 2.1°, 1.8°	2.0°, 1.8° n/a
Antenna Beamwidth : (Elev, Azim) in Reception mode (Taylor aperture illumination)	θ_0: 1.9°, 2.2° θ_{45}: 2.2°, 2.5°	2.0°, 1.8° n/a
Antenna Gain: Transmit Receive	40 dB (Uniform) 39 dB (Taylor taper)	39 dB 39 dB
Polarization	H, V Linear	H only
Peak Transmit Power	~14 kW (4W/TR)	35-40 kW
Range Resolution	150 m	150 m
Minimum Along Track Sweep Spacing	130 m	300 m
Radar Angular Resolution	~0.3 km @ 10km	~0.3 km @ 10km
Minimum Detectable Signal (at 10km)	-14 dBZ	-11 dBZ

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Fig. 5.

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