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A Comparison of Planar and Cylindrical Configurations of Polarimetric Phased Array Radar for Weather Observation

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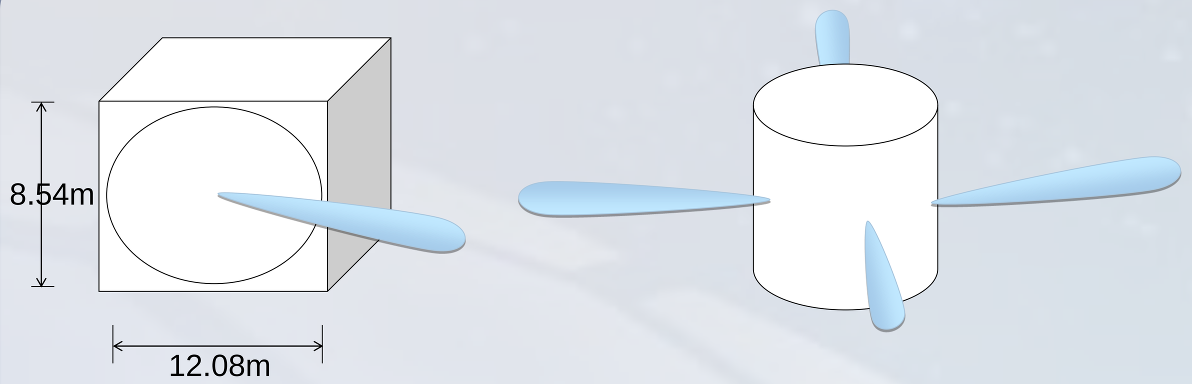
Abstract

Planar and cylindrical arrays are candidate antennas for future polarimetric phased array weather radars. A planar phased array is a matured technology and easy to fabricate but it has issues of polarization coupling and when the beam steers off broadside and scan-dependent beam characteristics (Zhang et al. 2009; Doviak et al. 2011). A cylindrical phased array has polarization orthogonality and can make azimuth scan invariant measurements (Zhang et al. 2011; Lei et al. 2011). Each of them has their own advantages and disadvantages.

To make un-biased polarimetric measurements, the radar systems need to be calibrated for each beam steering position. Two possible calibration procedures (Zhang et al. 2009; Zrnić et al. 2011; Lei et al. 2012) :i) projection/correction matrix method and ii) polarimetric variable calibration are examined. The correction matrix method adjusts amplitude and phase of each element for the H and V polarization, whereas the polarimetric variable calibration corrects the polarimetric estimates such as Z_{DR} and ρ_{hv}.

Planar and Cylindrical Polarimetric Phased Array Radar(PPAR) comparisons

	Planar PPAR	Cylindrical PPAR
Advantages	1) A lot of experience in design and fabrication 2) Extensive analysis algorithms available such as FFT	1) Scan-invariant polarimetric radar measurements 2) Polarization purity 3) Flexibility to choose the number of beams for fast data update and multi-functionality 4) High efficiency of utilizing radiation power. 5) A nature configuration for weather and aircraft surveillance
Dis-advantages	1) Large geometrically induced cross-polar field 2) Scan-dependent beam characteristics, scan loss 3) Extensive polarimetric calibration needed	1) lack of experience 2) synchronization of all the elements to form multiple beams



Beam matching comparisons when planar PPAR points at, $(\theta,\phi)=(70^o,45^o)$ and cylindrical PPAR points at, $(\theta,\phi)=(70^o,0^o)$

For uniform excitations

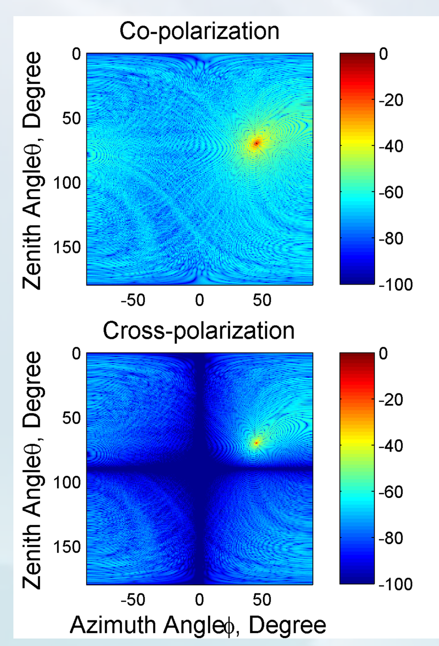


Fig. 1. planar PPAR co & cross-polar patterns

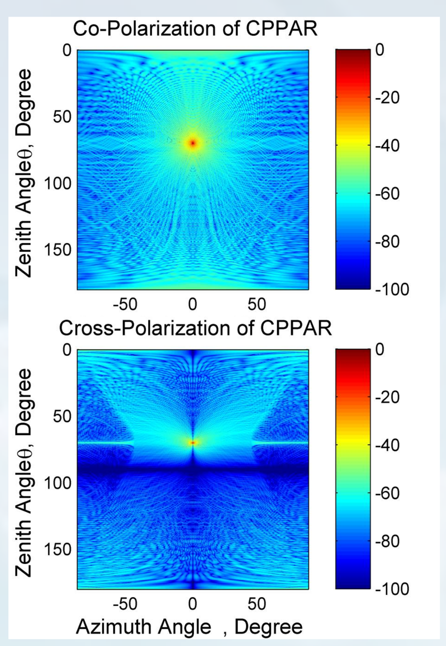


Fig. 2. cylindrical PPAR co & cross-polar patterns

For tapered excitations

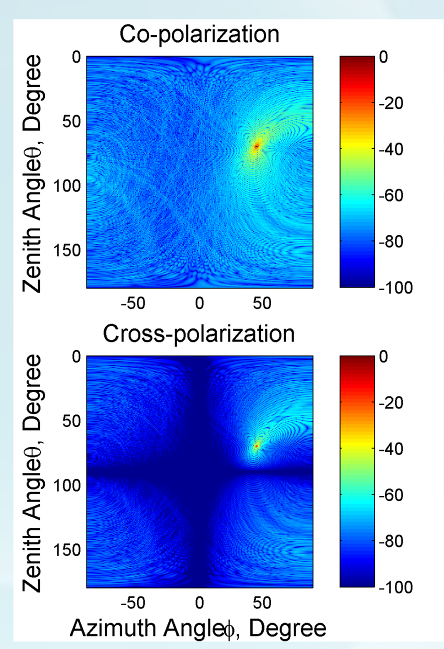


Fig. 3. planar PPAR co & cross-polar patterns

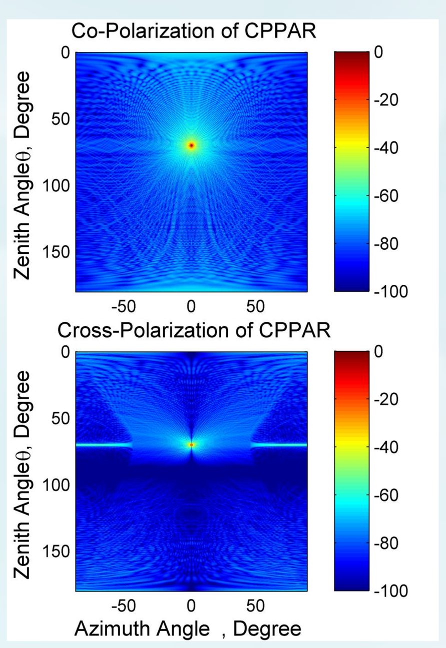


Fig. 4. cylindrical PPAR co & cross-polar patterns

The pattern comparison shows that the cylindrical array has much lower cross-polar pattern peak than the planar array, which allows more accurate measurement of weather radar parameters.

Projection/Correction matrix Method

To transmit and receive pure horizontal or vertical waves, the amplitudes in the transmitter and receiver chains behind antenna elements need to be adjusted

1) Adjustment of Planar Polarimetric Phased Array Radar

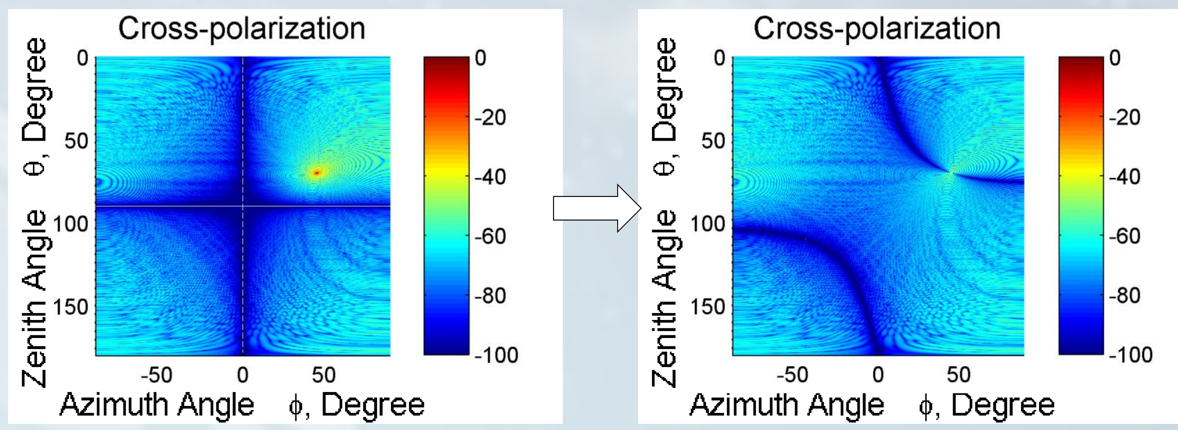


Fig. 5. Before adjustment After adjustment

After adjustment, the cross-polarization is much lower and there is a null at boresight direction.

2) Adjustment of Cylindrical Polarimetric Phased Array Radar

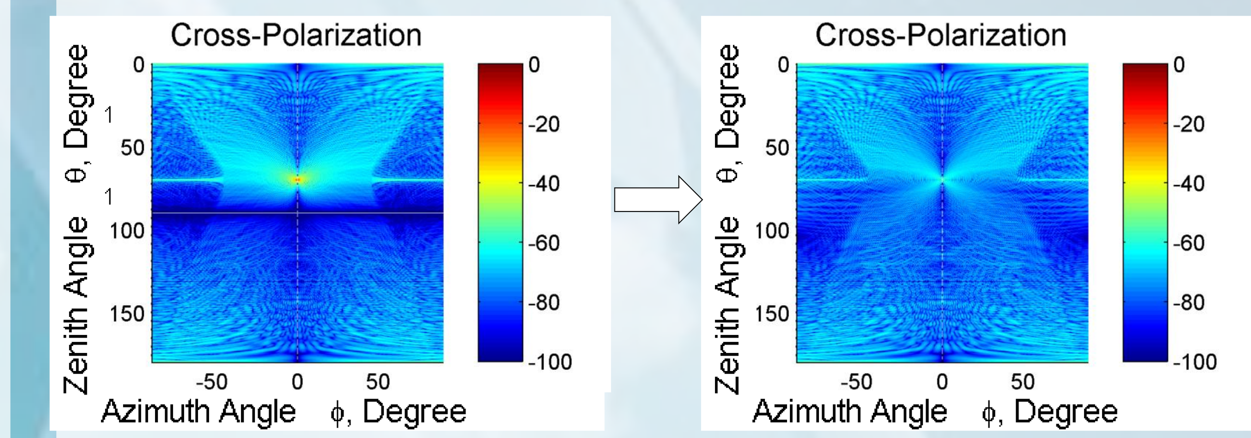


Fig. 6. Before adjustment After adjustment

Cross-polarization of cylindrical PPAR can also be corrected at the main beam direction. However, because cross-pol pattern is good enough for weather applications, the correction is sometime unnecessary.

Polarimetric variable calibration

This method is to directly calculate the bias of polarimetric radar parameters which can then be used to restore the estimated polarimetric parameters to their true values by subtracting the bias.

The bias of polarimetric radar variables is calculated through the integrations of simulated antenna patterns. Bias of Z_{DR} and ρ_{hv} of planar PPAR and cylindrical PPAR is compared in the following figures.

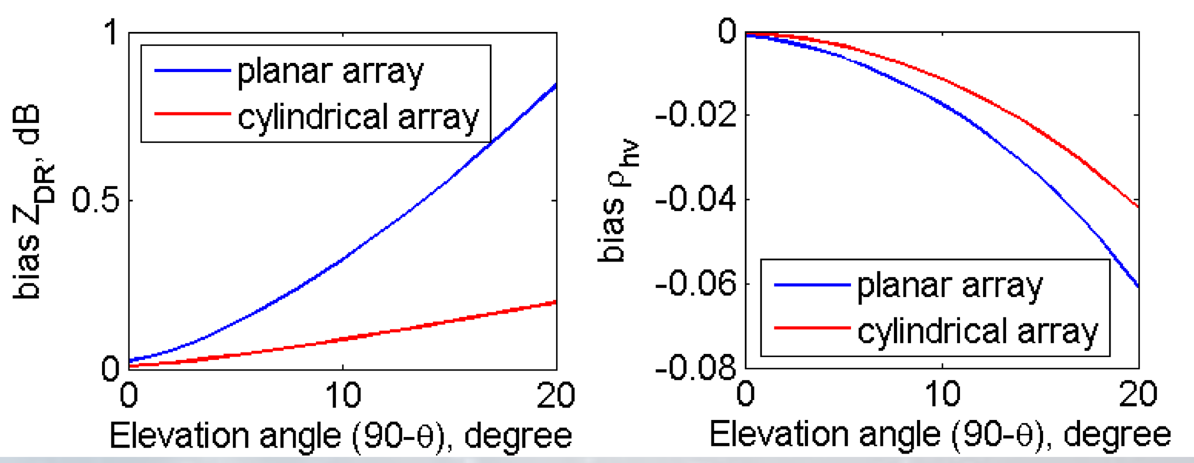


Fig. 7. Z_{DR} and ρ_{hv} biases for STSR mode, Parameters used for the calculations are $Z_{DR}=1dB$, $\rho_{hv}=0.97$ and $\phi_{DP}=0^o$

It is shown that, the cylindrical PPAR causes less bias to polarimetric radar variables than the planar PPAR.

Conclusions

The planar array has high geometrically introduced cross-polar field along boresight while the cylindrical array does not have this cross-polar field along the boresight. Bias associate with this cross-polar field can be corrected by adjusting the amplitudes in the transmitter and receiver chains behind antenna elements or correcting the bias to the radar parameters.

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