An X-Band Phased Array Weather Radar Testbed

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Introduction

Phased array radar technology has great potential in meteorology and is attracting a growing interest. For example, it could enable more rapid scanning of weather phenomenon than traditional reflector radars. However, such phased array systems should also support dual-polarization. Dual-polarimetric weather measurements provide superior hydrometeor identification and are now being adopted by many weather radar networks.

Unlike reflector antennas, phased array scans produce polarization biases when scanning off boresight. The biases are due to the polarization of the radiating elements differing from the horizontal and vertical polarization of the overall beam. While these biases are small, when making measurements of differential reflectivity (Z_{DR}) or the copolar cross-correlation coefficient (ρ_{hv}) they become problematic. In the ideal case, the biases can be described mathematically and corrected for in processing collected data. However, this process has not yet been thoroughly tested using real weather measurements.

Research Objectives

The University of Massachusetts Microwave Remote Sensing Laboratory (MIRSL) proposes to study the behaviors and limitations of an X-band dual-polarization phased-array radar using the prototype Low Power Radar (LPR) system. The following outlines our specific research objectives:

1. Characterize the performance of a dual-polarization phased-array radar through laboratory measurement and by direct comparison to a co-located mechanically-scanned reference radar.

2. Develop and assess the effectiveness of correction schemes to mitigate impacts of imperfect calibration and polarization distortions unique to phased-array antennas.

3. Expose the LPR to the meteorological community by enabling access for experiments and through collaboration with meteorologists in fixed and (possibly) mobile field studies.

Upon conclusion of this project, through systematic comparison with a co-located and synchronized mechanically-scanned radar, we will have validated the observations of a polarimetric planar phased array. As a result, we will have a much clearer picture of their capabilities and limitations for weather applications.

Project Description

The testbed will consist of an 2D phased array radar as well as another radar using a mechanically-scanned parabolic reflector antenna. Both radars will be dual-polarized and operate at X-band, with a frequency separation of around 200 MHz. Ultimately the two radars will be co-located and operated simultaneously. This will be achieved by mounted both radars onto the Orchard Hill radar tower in Amherst (Figure 2).

The phased array, known as the Low Power Radar (LPR) consists of 2560 dual-polarized antenna elements divided into 20 tiles of 128 element each. Single tiles may be mounted in a test rig so that individual element patters may be measured more easily (Figure 3). The mechanically-scanned radar, called the MA-1 radar, uses a magnetron transmitter and a single downconversion receiver. System parameters for both radars can be seen in Table 1.

Initial work will include detailed characterization of the LPR through laboratory and weather measurements. In addition, simulation will be created and refined to predict polarization biases and the effectiveness of correction algorithms. Once both radars are fully functional and characterized, they will be co-located on the tower and weather data will be accumulated. Correction schemes can then be applied and correlations determined between both radars as well as the simulations. A significant challenge will be in comparison between the two radar systems. While the two radars operate at similar frequencies with similar sensitivities and beamwidths, the radars employ differing polarization schemes (ATAR vs. STSR). These issues will be addressed and discussed as part of this project.

References

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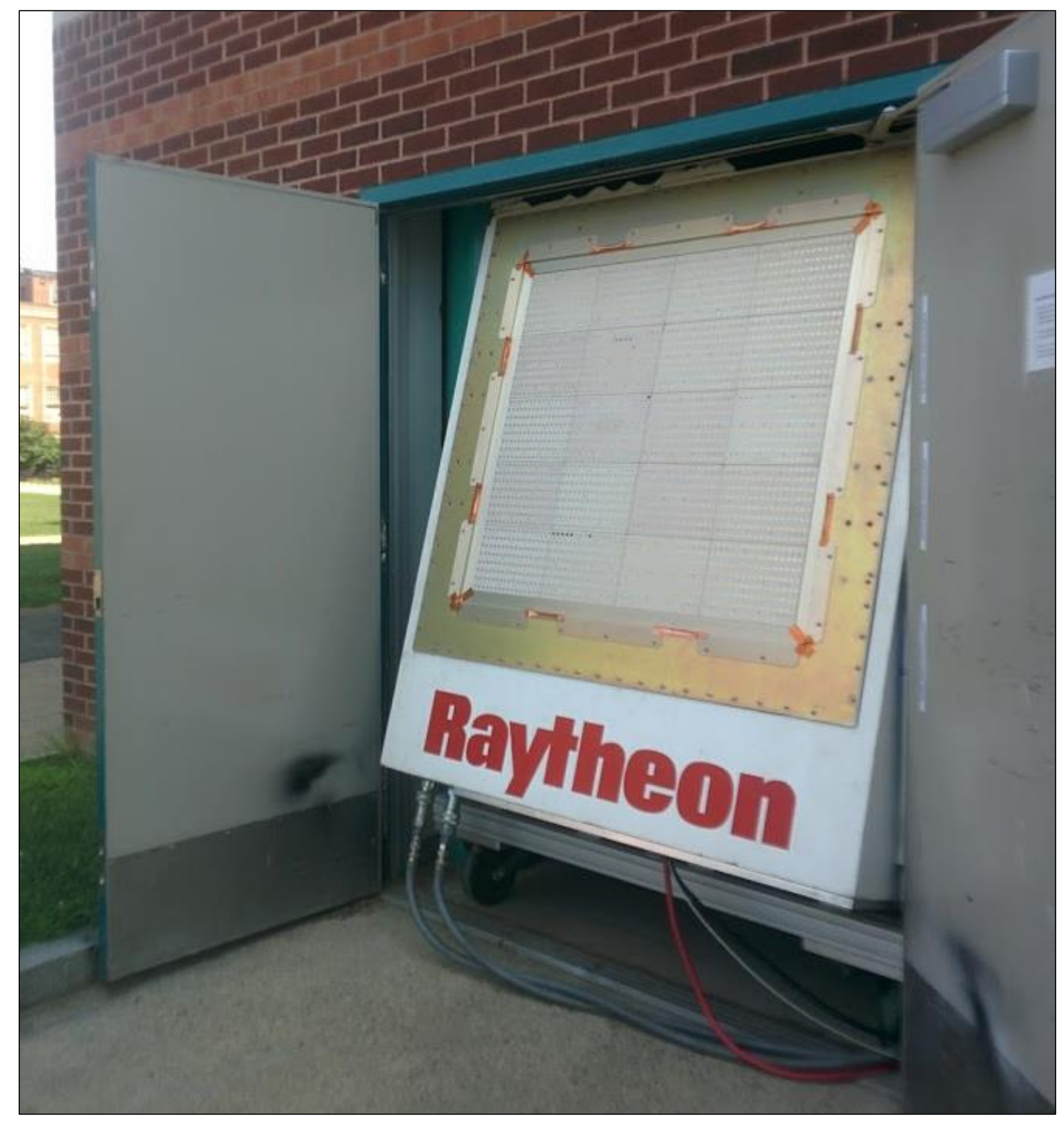

Figure 1: Photo of the X-band dual-polarization Low Power Radar (LPR)

Table 1: Radar System Characteristics

Parameter	LPR	MA-1
Center frequency	9.6 GHz	9.41 GHz
Peak/average power	125/23 W	25 kW
Bandwidth	< 6 MHz	5 MHz
Polarization	Dual H/V (ATAR)	Dual H/V (STSR)
Beamwidth	1.9º Az, 2.1º El	1.25º
Scan range	±45 Az, 0-30 El	±180 Az, 0-90 El
Range resolution	60 m	30-150 m
Waveforms	Pulse, NLFM, LFM	Pulse
Sequences	Single/dual PRF	Single/dual PRT

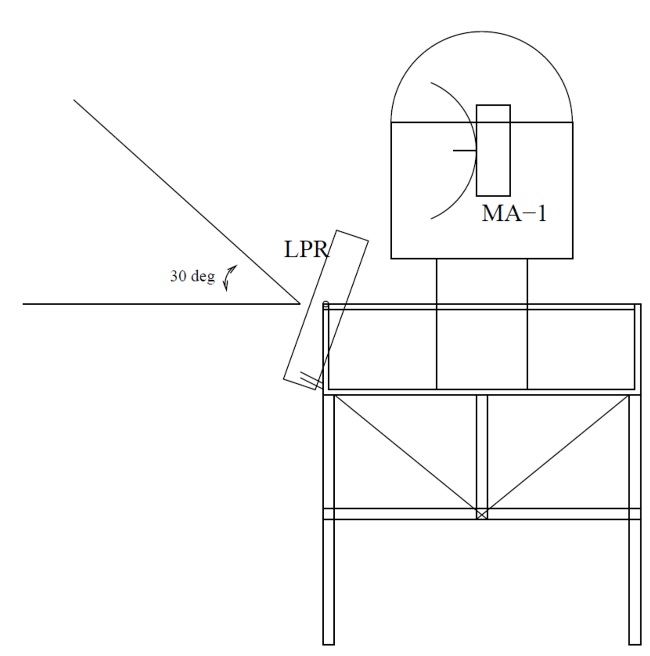

Figure 2: Sketch of combined installation of LPR and MA-1 radars

Figure 3: Single Tile Testing Rig for the LPR

Preliminary Simulations

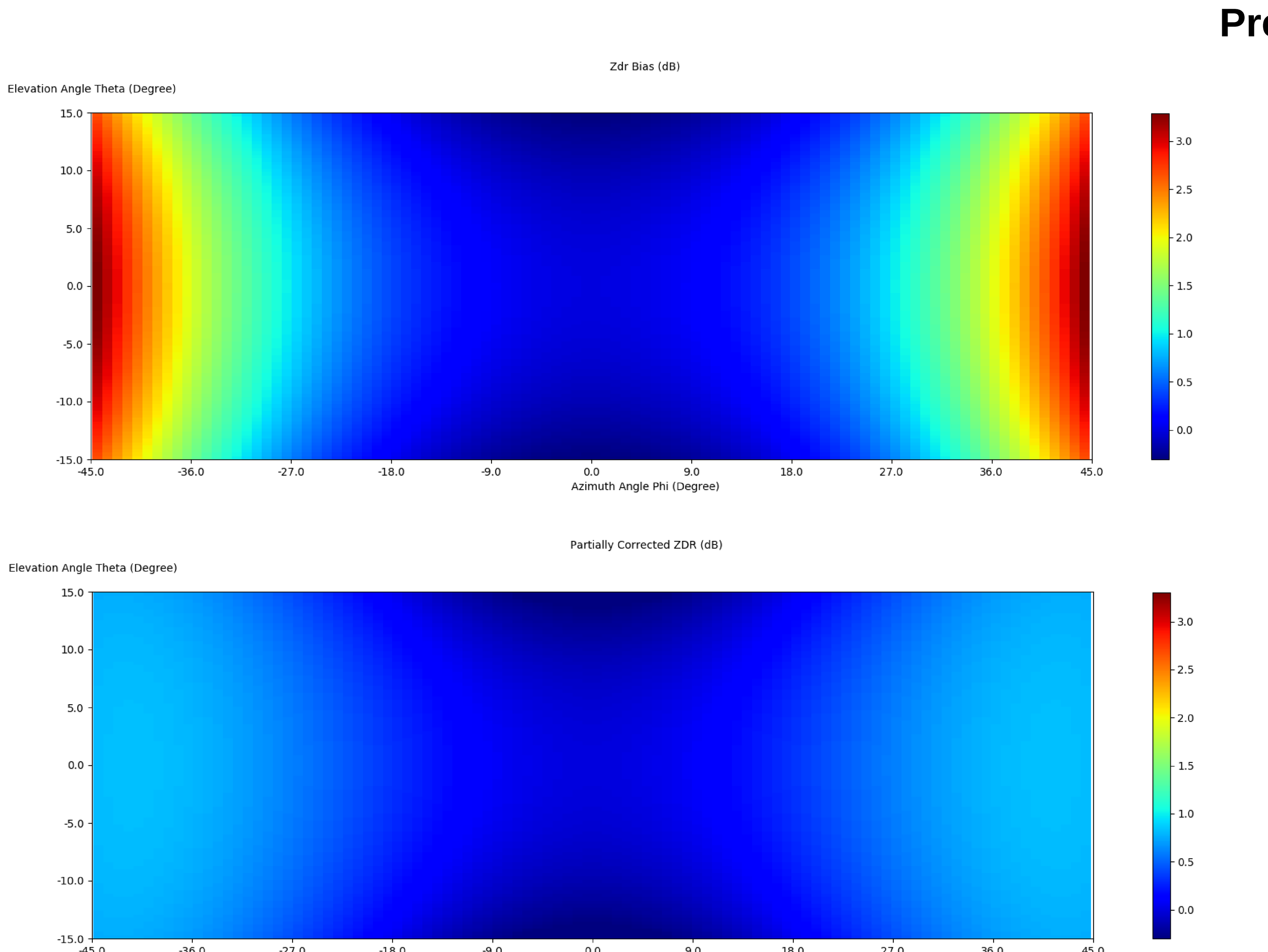

Figure 4: Top: Predicted Z_{DR} bias for X-band dual-polarization patch element over the scan range of the LPR assuming Z'_{DR} = 1. Bottom: Predicted Z_{DR} bias after $\cos(\phi)^4/\sin(\theta)^4$ element pattern compensation.

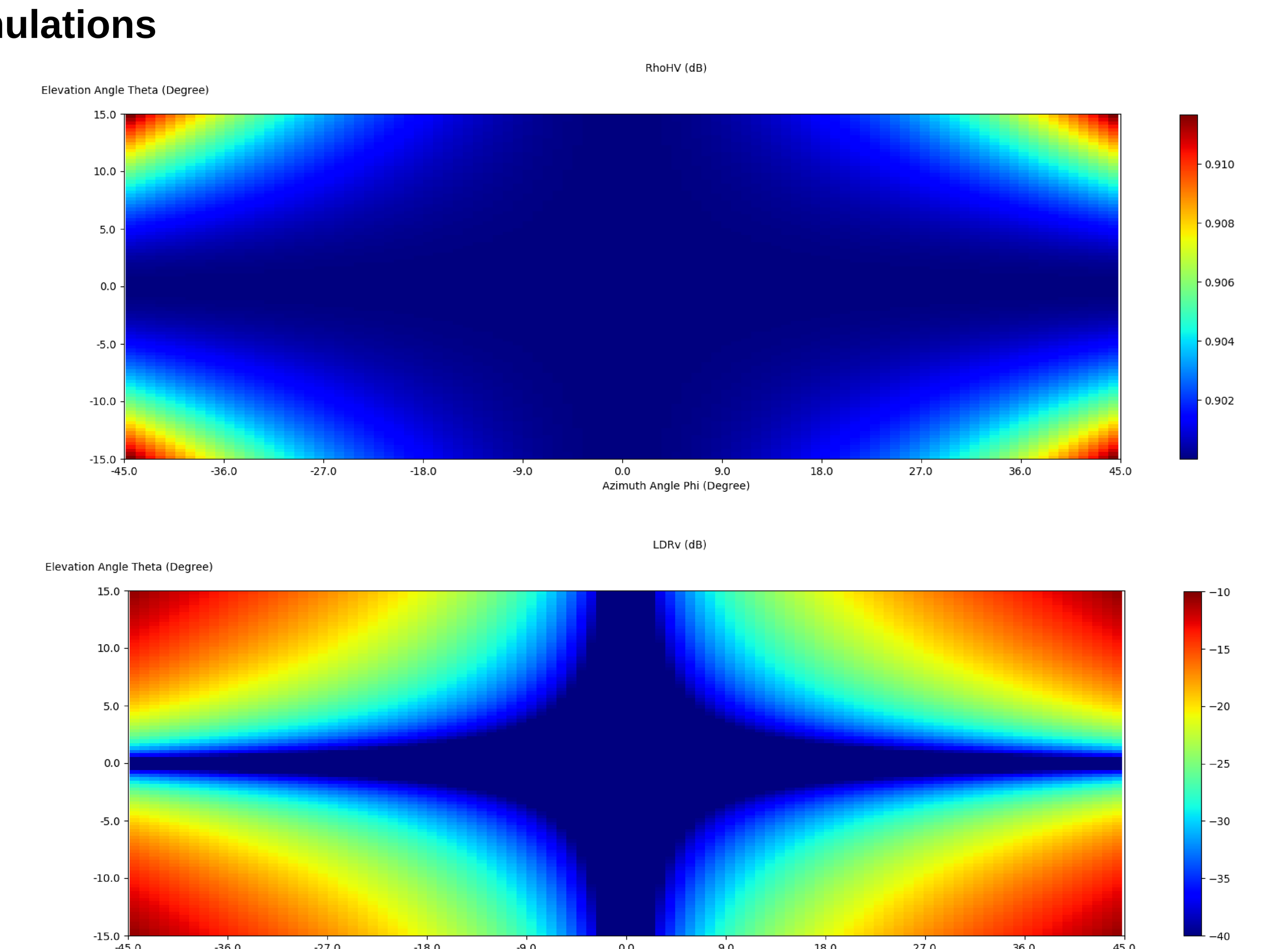

Figure 5: Top: Predicted Rho_{hv} bias (Rho_{hv} nominal = 0.9) for the X-band dual-polarization patch element over the scan range of the LDR. Bottom: Predicted LDR for X-band dual-polarization patch element.

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