Bias of the polarimetric variables on the Ten Panel Demonstrator (TPD) of a phased array weather radar

*Djordje Mirkovic[1,2], Dusan S Zrnic[2]

1. CIMMS (OU), 2. NSSL (NOAA)

Patterns of phased array antennas can be measured in the far field and near field. Both require special arrangements including access to an antenna range or sophisticated mechanisms for mounting probes in front of the antenna. Furthermore, measurements in all pointing directions would be extremely time consuming. Note, that for each pointing direction two copolar and two cross-polar patterns need to be measured. Therefore, in practice such measurements are made at select directions like broadside, few in principal planes and few out of principal planes. If the results meet expectations, it can be assumed that they will be satisfactory at other pointing directions.

Computational Electromagnetics (CEM) can supplement the physical measurements and/or yield physical insights without the need to make changes on the antenna. Furthermore, CEM tools can accurately model both, copolar and cross-polar properties of radar antennas (Mirkovic 2018). Based on the CEM simulations biases in the polarimetric variables caused by the antenna can be determined.

At broadside, the cross-pol pattern within the main lobe has four symmetric lobes with opposite phases. In the principal planes, this changes to two symmetrical lobes, while out of principal planes cross-pol pattern has an insufficiently isolated peak within the main copolar lobe (Fig. 1). Determining this bias out of principal planes is the gist of the calibration efforts (i.e., for low cross-pol isolation phase coding may be necessary).

The orientation of electric fields due to geometrical coupling (Zrnic et al. 2011) and cross-polar radiation is offset from desired horizontal or vertical direction. At each of the beam directions the field components, in general, generate elliptical polarization from either of the excited ports. Knowing the components and their phase difference, we calculate the tilt of the polarization ellipse ϕ in case of vertically oriented panel as:

$$\zeta = 1/2 * \arctan((2F_{hv}F_{vv}/(F_{vv}^2+F_{hv}^2)\cos(angle(F_{vv})-angle(F_{hv})), \quad (1a)$$

where ϕ, F_{hv}, F_{vv} depend on the pointing direction ($\theta_{0,}$ ϕ_0)and F_{hv}, F_{vv} are the voltage (one way) maxima of the radiation patterns for horizontal polarization. Similarly the polarization ellipse tilt γ for vertical polarization is:

$$\xi = 1/2 * \arctan((2F_{vh}F_{hh})/(F_{hh}^2+F_{vh}^2)\cos(angle(F_{hh})-angle(F_{vh})). \quad (1b)$$

The radiating element in the Ten Panel Demonstrator (TPD) radar, we simulated, is a balance fed stacked patch. This patch can be approximated with two magnetic dipoles radiating in desired polarization (radiating slots) and a set of four opposite magnetic radiators causing cross-pol radiation (“non-radiating” slots). The cross-polar pattern changes with the scanning angle. Determining contribution from each slot enables us to determine the best theoretically achievable antenna performance, and quantify the bias caused by the field departure from intended direction. This can be done as the departure angle from intended polarization can be calculated (Zrnic et al. 2017).

Fig. 1 –Radiation pattern of the Ten Panel Demonstrator Polarimetric Phased Array radar at broadside with four symmetric cross-pol lobes of opposite phase (up), 35^{o} away from broadside in azimuth (horizontal principal plane) with two symmetric cross-polar lobes of opposite phase (middle), and 28^{o} in azimuth and 14^{o} in elevation away from broadside with single cross-pol lobe within the main copolar lobe with only 24 dB peak to peak isolation (bottom).

References

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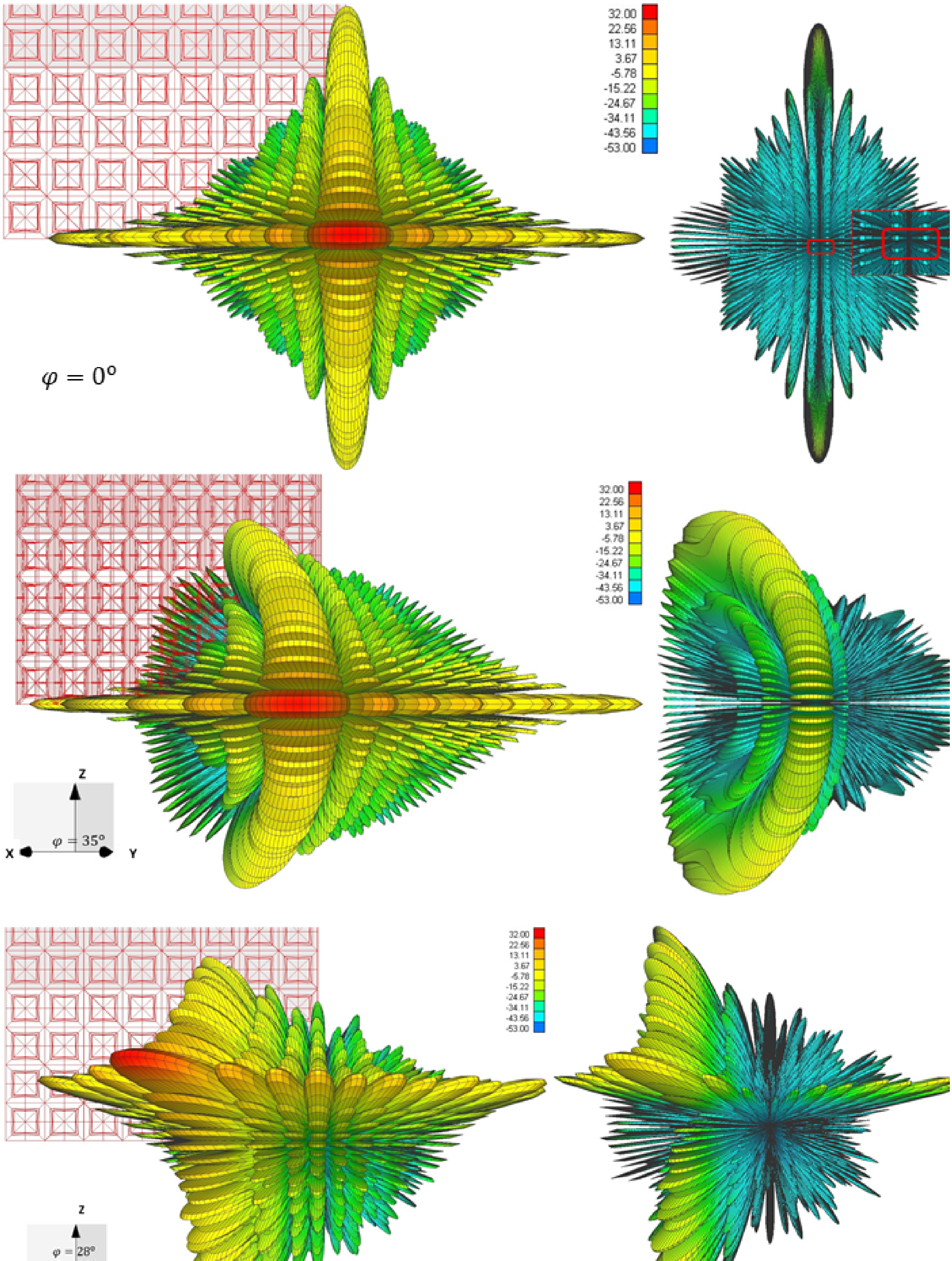
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22.56
13.11
3.67
-5.78
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32.00
22.56
13.11
3.67
-5.78
-15.22
-24.67
-34.11
-43.56
-53.00
Z
φ = 35°
X
Y
32.00
22.56
13.11
3.67
-5.78
-15.22
-24.67
-34.11
-43.56
-53.00
Z
φ = 28°
θ = 14°
X
Y