P1.12 MULTI-PATTERNS MEASUREMENTS FOR CALIBRATION AND SIDELOBE REDUCTION ON THE NATIONAL WEATHER RADAR TESTBED

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1. INTRODUCTION

Phased array technology has attracted attention in the weather radar community. This leads to the recent development of the nation's first phased-array weather radar, called the National Weather Radar Testbed (NWRT). The NWRT is a 10-cm wavelength Doppler radar managed by the National Weather Center (NWC) (Forsyth et al. 2006). It provides opportunities to study and better utilize radar resources for weather surveillance, aviation control, and target detection/tracking. Its pulse-to-pulse beam steering capability allows accurate measurements in a shorter dwell-time, yielding faster data updates than obtained with a mechanically rotating dish (Yu et al. 2007; Zrnic et al. 2007). The NWRT has sum and difference channels that allow the study of spaced antenna interferometry for crossbeam wind measurement and sub-volume inhomogeneity/object detection (Zhang and Doviak, 2007).

One unique feature of the NWRT is its dual-scan (mechanical and electrical) capability. This capability has not been explored yet. Sidelobes of the NWRT's radiation pattern when the main lobe is electronically pointed +/- 45 degree away from broadside, are different from those when the beam is steered to broadside. An example of measured antenna patterns for the NWRT is shown in Fig. 1.

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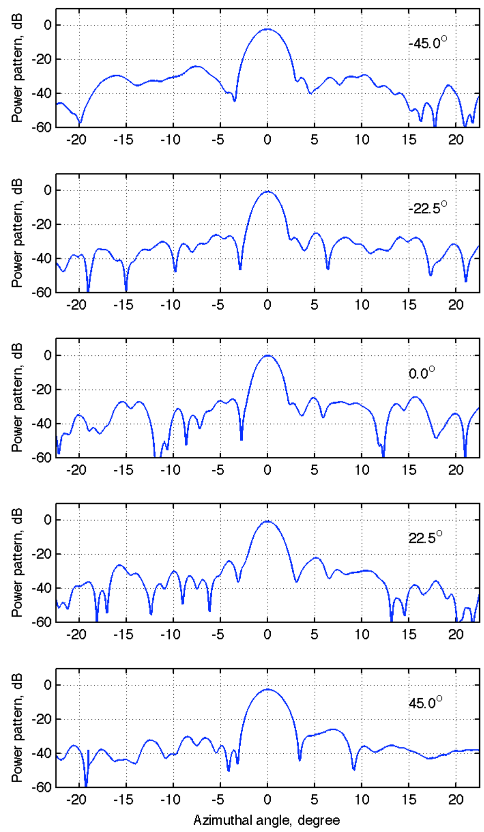

Figure 1: Comparison of the NWRT antenna patterns for electronic beam positions at broadside (0^o) and away from broadside ($\pm 22.5^o$ and $\pm 45^o$), respectively.

As the figures demonstrate, the sidelobe amplitude and phase change as the beam is electronically steered. Therefore, the interference from echoes received through sidelobes will be not as coherent as the echoes received through the mainlobe (after calibration for the different electronic steering directions relative to the broadside). In another words, echoes received through sidelobes will be noise-like when the antenna steers at different electronic directions. Thus, by jointly processing the data recorded for different electronic directions (corresponding to different antenna patterns), we should be able to distinguish the echoes received through the mainlobe and sidelobes.

In this study, we propose and describe a multi-pattern technique to reduce the effects of sidelobes, and thus to improve radar data quality. The multi-pattern technique is to electronically point to several directions (corresponding to different patterns) while mechanically scanning the antenna. Hence, several sets of radar data are collected with a one mechanical scan, and then jointly processed for a set of data with reduced sidelobes.

2. CALIBRATION

Radar equation (4.14) in Doviak & Zrnic (1993) can be extended for an elliptical beam as sketched in Fig. 2. When the beam widths are represented by θ_1 and ϕ_1 in elevation and azimuth planes, respectively, the radar equation is

$$P_r = \frac{P_t g^2 \eta c \tau \pi \theta_1 \phi_1 \lambda^2}{(4\pi)^3 r_0^2 l^2 16 \ln 2} \qquad (1)$$

and the gain can be approximated by

$$g \approx \pi^2 / \theta_1 \phi_1 . \qquad (2)$$

For the PAR, we have

$$\phi_1 = \phi_{10} / \cos\phi_e \qquad (3)$$

where ϕ_{10} is the broadside beam width and ϕ_e is the electronic beam position.

Substituting (2) into (1) and using (3), we have

$$P_r = \frac{P_t g_0^2 \eta c \tau \pi \theta_1 \phi_{10} \lambda^2}{(4\pi)^3 r_0^2 l^2 16 \ln 2} \cos\phi_e \qquad (4)$$

where g_0 is the broadside gain. This contributes a 1.5 dB power reduction when looking at 45^o from the broadside. This includes the reduced pattern peak and increased beam width for off broadside directions as seen in Fig. 1.

A $\cos\phi_e$ factor needs to be divided from both sides of Eq. (4) for PAR calibration, which can be verified through multi-pattern measurements over a uniform weather region.

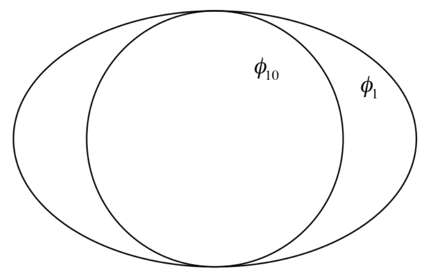

Figure 2: Sketch of antenna beamwidths for the NWRT. The inner circle represents the beam at broadside, and the outer ellipse represents that away from broadside.

3. SIDE-LOBE REDUCTION

Side-lobe reduction through multi-pattern measurements is based on the fact that the side-lobe location and magnitude are different for different E-beam position. Averaging of radar reflectivity over the set of measurements would have reduced sidelobe effect. Using PAR characteristics, the amplitude pattern is calculated as a function of both E-beam position (ϕ_e) and azimuthal angle (ϕ) $f(\phi_e,\phi)$. To have an optimal result, we maximize the difference in these patterns by defining a cost function as

$$\chi = \sum_{j=1}^{N} std\left(\left|f(\phi_{ei},\phi_j)\right|^2\right) \qquad (5)$$

where "std" stands for the standard deviation of the multi-patterns at the E-beam for all sidelobes and the summation is done over all the azimuth angles.

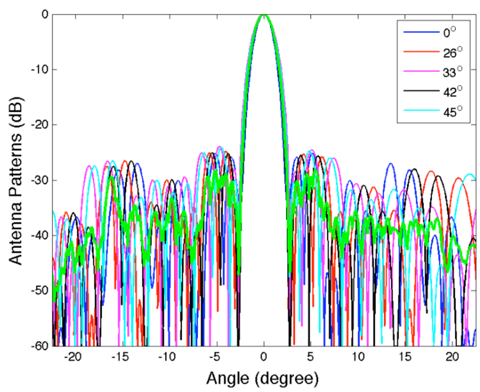

Figure 3: An optimal combination of multi-patterns for sidelobe reduction. The thick green line is the averaged pattern.

A simulation result for the NWRT is shown in Fig. 3. A case for five patterns is studied: one pattern is that of broad side and one at 45° away from the broadside, and the other three E-beams are adjustable so that their standard deviation is maximized. We found an optimal combination of the E-beams are ϕ_e= 0, 26, 33, 42, 45 degrees, respectively. Averaging these five patterns, we obtain a mean pattern shown in thick green line which has a maximal sidelobe that is 5 dB lower than the individual patterns.

4. SUMMARY

We introduced a multi-pattern method for the NWRT calibration and sidelobe reduction. Using the calculated patterns, we demonstrated an approach to find the optimal combination of E-beam positions. Preliminary results show that one-way sidelobe levels can be reduced on average by about 5dB. Potential application of the multi-pattern technique includes removing ghost images and reducing ground clutter contamination.

Acknowledgement

This work is partially supported by NOAA/NSSL under the Cooperative Agreement NA17RJ1227. Many thanks go to Lockheed Martin and NSSL's engineers

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