2008 Real-time Phased Array Radar Experiment

A Guide for Forecasters

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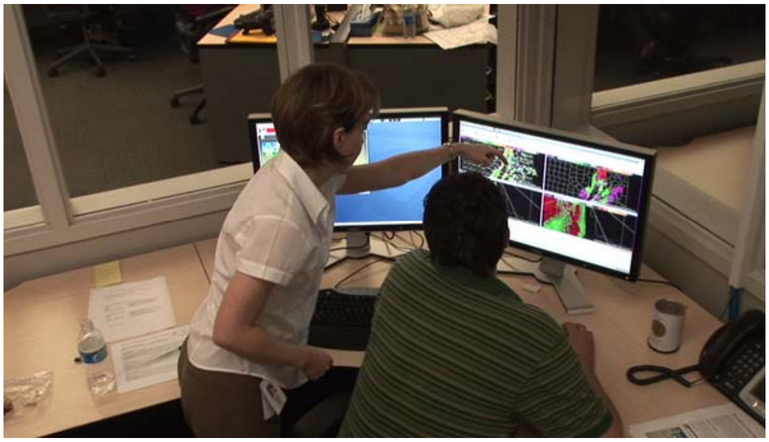

1. Introduction

Since the WSR-88D is approaching its 20-year life span, the time is right to explore replacement technologies. The rapid-scan, multi-function capabilities of phased array radar (PAR) make this technology an attractive option that is under consideration (Weber et al. 2007; Zrnić et al. 2007). The National Weather Radar Testbed Phased Array Radar (NWRT PAR) located in Norman, Oklahoma, samples storms from a 9.38-cm, single-faced, PAR antenna. The PAR supports adaptable scanning strategies and volumetrically scans storms in time scales of seconds instead of several minutes (Zrnic et al. 2007). Such high-temporal sampling provides unprecedented opportunity to improve understanding of rapidly evolving weather phenomena (Heinselman et al. 2008) and to investigate the potential benefits of PAR to forecast operations.

The primary objective of the 2008 PAR Hazardous Weather Testbed Spring Program is to have forecasters like you evaluate the operational utility of this experimental technology during real-time operational warning situations. When storms are located in central Oklahoma, you will be asked to perform real-time radar analysis of storms and issue severe weather warnings using the Warning Decision Support System – Integrated Information (WDSS-II; Lakshman et al. 2007). During operations, you will work with a research meteorologist who will run the PAR and be your PAR information resource. After operations, you will be asked to fill out a survey (Appendix A) designed to attain your evaluation of:

- strengths and limitations of PAR data in your analysis of severe storms,
- how characteristics of PAR scanning strategies affect your understanding of severe storms,
- how using PAR data to make warning decisions impacts your warning decision-making, and
- how PAR data may be of benefit to your operational responsibilities and to the public.

Your evaluation of the potential operational utility of PAR is crucial to determine its suitability as a replacement technology for the WSR-88D. To help you prepare for this task, the next section describes characteristics and capabilities of the NWRT PAR and the experiment's scanning strategies. More information about the NWRT PAR is available in the online module (http://www.nssl.noaa.gov/projects/pardemo). This module explains how the NWRT PAR works, compares the functionality of the NWRT PAR to the WSR-88D, and provides comparative animations of the evolution of severe storms sampled by the PAR and WSR-88D. Zrnić et al. (2007) give an overview of weather surveillance capabilities of the PAR and Heinselman et al. (2008) provide detailed comparisons of storm evolution depicted by the NWRT PAR and the Twin Lakes WSR-88D (KTLX).

2. Comparison of NWRT PAR to WSR-88D

The most significant difference between the PAR and the WSR-88D is the antenna design. Zrnić et al. (2007) provide a detailed description of the PAR. The phased array antenna forms a beam electronically by controlling the phase of 4,352 transmit/receive elements, whereas the WSR-88D's beam is formed from a parabolic antenna. Additionally, in a WSR-88D, the steering of the beam is accomplished mechanically, by rotating the antenna. Long volumetric updates generated by a rotating antenna can deliver spatially incongruous vertical storm structures and reduced data quality (smearing) due to antenna motion. In contrast, with a phased array antenna, steering of the beam is done electronically by fixing the beam in a set direction while data is collected along a radial, and then instantly switching the beam to a new direction.

Currently, the PAR is a single-faced phased array system which can scan a 90° sector while stationary. Hence, the PAR performs a VCP 12 scanning strategy (Brown et al. 2005) within 58 s rather than 258 s (90° sector vs 360° sector, respectively), for example. The reduction in time required for volumetric updates produces more realistic evolution of storm structures and eliminates smearing of the beam due to rotation of the antenna during data collection. An operational PAR configuration, however, would have a system containing 4 independent faces capable of scanning a complete 360° sweep. In essence, a four-faced PAR is like having four radars in one location, each scanning its own 90° sector. Another goal of an operational PAR system would be to match or exceed current operational standards.

Owing to the different antenna design, the PAR is dissimilar to the WSR-88D in several ways. First, electronic steering of the beam supports adaptable scanning of weather echo. Hence, the dwell time may be optimized to the temporal- and spatial-scale of a particular weather phenomenon and its distance from the radar. Furthermore, close to the radar (< 35 km), where conventional VCPs may undershoot storm top height, higher elevations may be easily added to a scanning strategy. Accuracy requirements for WSR-88D scanning strategies are standard deviation values of 1 dB*Z* for reflectivity and 1 m s^{-1} for velocity for specific signal-to-noise ratio and standard deviation in the estimate of spectrum width values (ROC 2007). The accuracy of reflectivity and velocity estimates in this study will match VCP 12 requirements. More information about the scanning strategies is found in section 3.

Second, the PAR was developed with vertically polarized electromagnetic waves (Fig. 1) to track military missiles and airplanes, rather than to detect weather echo. Since a raindrop becomes flatter with increasing size, the magnitude of reflectivity data diminishes compared to data collected with a horizontally polarized beam.

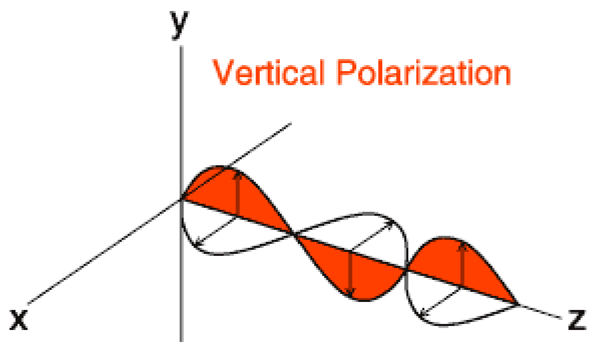

Figure 1. Illustration of a vertically polarized electromagnetic wave.

Third, the beam width varies with azimuth (Fig 2). In the direction perpendicular to the antenna face, the beam width is 1.5°, which is quite similar to the effective beam width of the WSR-88D. When the beam is 45° from the perpendicular, the beam width is 2.1°. During data collection, 1° azimuthal sampling was used to provide finer resolution of the increasingly degraded data toward the edges of the sector scan. In an operational system, the beam width would match or exceed that of the WSR-88D.

One thing to keep in mind is that the NWRT PAR is an *experimental research radar* in early stages of development. Thus, participants are forewarned to expect some hiccups during data collection and to take them in stride. To improve data quality, we have implemented software to mitigate second trip echoes and velocity ambiguities due to range folding.

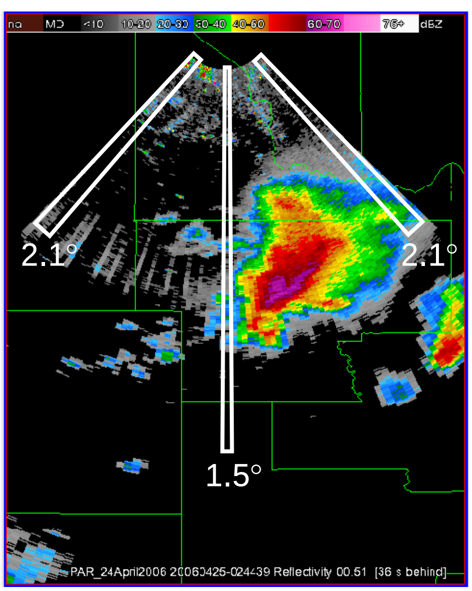

Figure 2. Illustration of variations in beam width with respect to azimuth. Notice that the beam width is most narrow (1.5°) perpendicular to the array and widens to 2.1° when the beam is at an angle of ±45° to the array.

3. Scan Strategy Characteristics

This spring two enhanced VCP 12 scan strategies will usually be run during operations (Tables 1 and 2). The enhanced VCP 12 scan strategies take advantage of the operational VCP 12's range and accuracy while improving vertical sampling based on whether storms are near or far (70-km threshold) from the radar and improving temporal sampling at low-levels by revisiting the 0.5° tilt on average every 23 seconds. The scan strategy also demonstrates the capability to volumetrically sample a 90° sector within about one minute (61 seconds); a four-faced PAR system would scan four 90° sectors (i.e., 360°) within the same period. These scan times may be cut in half by running the enhanced VCP 12 scan strategy over a 45° degree sector. The result would be ~12 second updates of the 0.5° tilt and ~30 second volumetric updates, which may be useful to warning decision-making when isolated tornadic supercells are anticipated, for example.

Table 1. Enhanced VCP 12 scan strategy for scanning storms within 70 km of the PAR. The total time (seconds) to complete a 90 degree sector may be computed by multiplying the total vertical slice time by 90 (61 seconds).

Experiment (name):	NWRT Temporal Sensitivity Study
Scanning Strategy Number	Storms out to 465km - 2 half degree cuts (Near)
Scanning Mode (RHI or PPI):	PPI
Pulse Width (short or long):	short
Sector Size:	90 degrees and 45 degrees
Azimuth Spacing:	1 degree

NOTE: PRT range is 800 to 3200 for short pulse and 800 to 2213 for long pulse

Elev	Type	PRT1	Pulses1	PRT2	Pulses2	Nyquist	Rmax1	Rmax2	Time
0.51	CS	3104	15			#DIV/0!	465.2	0.0	0.047
0.51	CD			984	40	23.82	0.0	147.5	0.039
1.50	CS	3104	15			#DIV/0!	465.2	0.0	0.047
1.50	CD			984	40	23.82	0.0	147.5	0.039
2.60	CS	2240	3			#DIV/0!	335.7	0.0	0.007
2.60	CD			984	30	23.82	0.0	147.5	0.030
3.80	CS	2240	3			#DIV/0!	335.7	0.0	0.007
3.80	CD			984	30	23.82	0.0	147.5	0.030
5.20	CS	1552	3			#DIV/0!	232.6	0.0	0.005
5.20	CD			984	30	23.82	0.0	147.5	0.030
6.80	CS	1552	3			#DIV/0!	232.6	0.0	0.005
6.80	CD			984	30	23.82	0.0	147.5	0.030
8.70	CD			912	38	25.70	0.0	136.7	0.035
0.51	CS	3104	15			#DIV/0!	465.2	0.0	0.047
0.51	CD			984	40	23.82	0.0	147.5	0.039
11.00	CD			800	44	29.30	0.0	119.9	0.035
13.80	CD			800	44	29.30		119.9	0.035
17.20	CD			800	44	29.30		119.9	0.035
21.30	CD			800	44	29.30		119.9	0.035
26.20	CD			800	44	29.30		119.9	0.035
32.00	CD			800	44	29.30		119.9	0.035
38.00	CD			800	44	29.30		119.9	0.035
					Total vertical slice time (sec)				0.68

Table 2. Enhanced VCP 12 scan strategy for scanning storms 70 km or farther from the PAR. The total time (seconds) to complete a 90 degree sector may be computed by multiplying the total vertical slice time by 90 (61 seconds).

Experiment (name):	NWRT Temporal Sensitivity Study
Scanning Strategy Number	Storms out to 465km - 2 half degree cuts (Far)
Scanning Mode (RHI or PPI):	PPI
Pulse Width (short or long):	short
Sector Size:	90 degrees and 45 degrees
Azimuth Spacing:	1 degree

NOTE: PRT range is 800 to 3200 for short pulse and 800 to 2213 for long pulse

Elev	Type	PRT1	Pulses1	PRT2	Pulses2	Nyquist	Rmax1	Rmax2	Time
0.51	CS	3104	15			#DIV/0!	465.2	0.0	0.047
0.51	CD			984	40	23.82	0.0	147.5	0.039
1.10	CS	3104	15			#DIV/0!	465.2	0.0	0.047
1.10	CD			984	40	23.82	0.0	147.5	0.039
1.70	CS	3104	3			#DIV/0!	465.2	0.0	0.009
1.70	CD			984	29	23.82	0.0	147.5	0.029
2.40	CS	2240	3			#DIV/0!	335.7	0.0	0.007
2.40	CD			984	30	23.82	0.0	147.5	0.030
3.20	CS	2240	3			#DIV/0!	335.7	0.0	0.007
3.20	CD			984	30	23.82	0.0	147.5	0.030
4.10	CS	2240	3			#DIV/0!	335.7	0.0	0.007
4.10	CD			984	30	23.82	0.0	147.5	0.030
5.10	CD	1552	3			#DIV/0!	232.6	0.0	0.005
5.10	CS			984	30	23.82	0.0	147.5	0.030
0.51	CS	3104	15			#DIV/0!	465.2	0.0	0.047
0.51	CD			984	40	23.82	0.0	147.5	0.039
6.20	CS	1552	3			#DIV/0!		0.0	0.005
6.20	CD			984	30	23.82		147.5	0.030
7.40	CS	1152	3			#DIV/0!		0.0	0.003
7.40	CD			984	30	23.82		147.5	0.030
8.70	CD			888	39	26.39		133.1	0.035
10.10	CD			848	40	27.64		127.1	0.034
11.70	CD			800	44	29.30		119.9	0.035
13.50	CD			800	44	29.30		119.9	0.035
15.50	CD			800	44	29.30		119.9	0.035
					Total vertical slice time (sec)				0.680

4. Summary

Your evaluation of PAR data during real-time operations will provide the data needed to begin building an understanding of how PAR technology may be of benefit to NWS operations. This understanding is crucial to assessing the suitability of PAR as a replacement technology for the WSR-88D network. We appreciate your contributed time and energy in helping us make this assessment.

Acknowledgments: There are many people behind the scenes who are making this PAR demonstration possible. They include the NHWT directors and the radar engineers and software developers of the Radar Research and Development Division. In particular, I'd like to thank Vicki Farmer for her help with the pardemo webpage.

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Survey for NWS Weather Assessment and Decision-Making with PAR Data

Please complete questions 1–9 on the following pages for each case or real-time session.

Name: ______________________________ Organization: _________________________

Title: _______________________________ Year Forecasting Experience: ___________

Date & Time of Event Reviewed: ____

1. For storms in which you analyzed any of the following features, please respond to the questions in the table.

Feature	What were the strengths or weaknesses of PAR data	Did the PAR help to identify this feature better than KTLX?
Supercell		
Squall line		
Bow Echo		
Microburst		
Updrafts/Downdrafts		
Divergence/Convergence		

Feature	What were the strengths or weaknesses of PAR data	Did the PAR help to identify this feature better than KTLX?
Hail and Precipitation		
RFD		
WER/BWER		
Shear		
TVS		
Mesoscale Rotation (e.g., MCV)		

2) Rate the suitability of the following visual presentation type(s) to your data interpretation and decision-making.

PPI	Low ① ② ③ ④ ⑤ ⑥ ⑦ High
CAPPI	Low ① ② ③ ④ ⑤ ⑥ ⑦ High
Vertical cross section	Low ① ② ③ ④ ⑤ ⑥ ⑦ High
Animation	Low ① ② ③ ④ ⑤ ⑥ ⑦ High

What other visualization tools would have been helpful?

3. How did the following PAR scanning strategy characteristics <u>assist or impede</u> your analysis of storm features?

a. near one-minute volumetric updates?

b. 25-second updates of the 0.5° tilt?

c. Faster updates when collecting data over a 45° sector (if used)?

d. Higher vertical resolution scans when storms were relatively far from the radar (if used)?

4. We are interested in your scan strategy needs. Given the opportunity to design your own, what would your scan strategy look like, and why?

5. The following questions pertain to <u>warning decision making</u>.

a) How did PAR data impact your warning decision making?

b) Rate your confidence in making warning decisions using PAR data.

Low ① ② ③ ④ ⑤ ⑥ High

c) Rate the suitability of the PAR scan strategy(s) used to warning decision making.
Please explain.

Low ① ② ③ ④ ⑤ ⑥ High

Explanation:

d. Do you think that PAR data might help to produce more regionally specific warnings? If so, how?

e. Do you think that PAR data may help to extend warning lead times? Please explain.

6. What, if any, challenges arose during your analysis of PAR data? How might these challenges be addressed?

7. In what ways might the PAR data help you communicate with:

a. Emergency Managers and/or Spotters

b. The Media

c. General public

8. What kinds of information would you like to see from weather radar that you don't have now? How would that information make a difference?

9. What was your overall impression on the usefulness of phased array radar technology in the forecasting of severe weather phenomena *(with the understanding that the NWRT is a research radar with limited capability relative to a complete, higher resolution phased array radar)?*