12B.2 What's new at the NATIONAL WEATHER RADAR TESTBED (PHASED-ARRAY)

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1. INTRODUCTION

A very different type of weather radar is being tested in Norman, Oklahoma at the National Severe Storms Laboratory. The technology being evaluated is a phased array antenna that provides electronic steering of the radar beam (Zrnic, 2007). As a result of the partnership between the National Oceanic and Atmospheric Administration's National Severe Storms Laboratory, the United States Navy's Office of Naval Research, Lockheed Martin Corporation, the University of Oklahoma's Electrical and Computing Engineering Department and School of Meteorology, the Oklahoma State Regents for Higher Education, the Tri-Agencies' (Department of Commerce, Defense and Transportation) Radar Operations Center, the Federal Aviation Administration's Technical Center and Basic Commerce and Industries, Inc, the National Weather Radar Testbed (NWRT) has been testing the concepts of a multi-function radar system since 2003.

The system continues to demonstrate the advantages of agile beam weather and aircraft surveillance radar (Forsyth, 2009 & Forsyth, 2010). In this paper, we will describe the present status and future plans for the NWRT and provide examples of the latest results of our testing of the phased array technology.

2. CURRENT STATUS

This past year, we have continued to work on adding adaptive range oversampling (Curtis, 2011) and additional automatic calibration routines. Our preliminary tests with oversampling produced a reduced scan time by a factor of 2 with improved data quality (See Figure 1). We also continued our work on adaptive scanning by enhancing the capabilities of ADAPTS (Heinselman, 2010) by adding elevation prioritized scanning and the ability to modify scanning strategies and change acquisition parameters "on the fly". We also started work on an Automatic schedule based scanning function. This will allow different storms to be scanned with different settings and update rates. The scheduler plans the best sequence of tasks to meet requested performance, thus optimizing the utilization of the radar resources.

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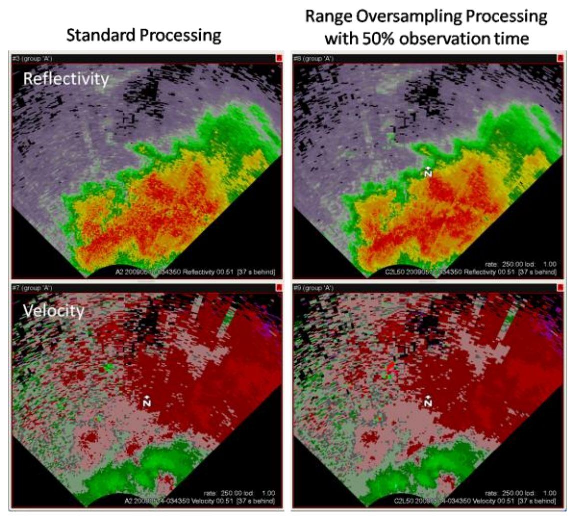

Figure 1. Range Oversampling (Right) compared to Standard Processing (Left). Range Oversampling took half the time to collect the same quality data with the NWRT Phased Array Radar.

NetCDF was added as a new data format. We continued to improve our Radar User Interface (RUI) to support new features (Figure 2) and we added an additional processor to the Digital Signal Processor (a dual-quad core machine as the 5th node on the cluster) to support the real-time oversampling algorithm (Torres, 2011).

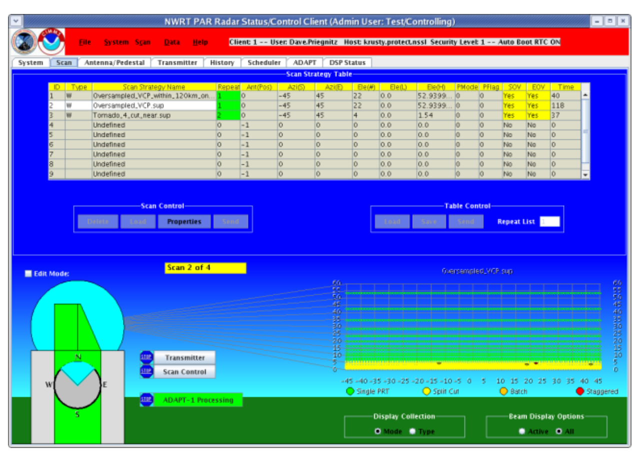

Figure 2. User Interface upgrades to handle adaptive scan strategies and adjusting strategies "on-the-fly".

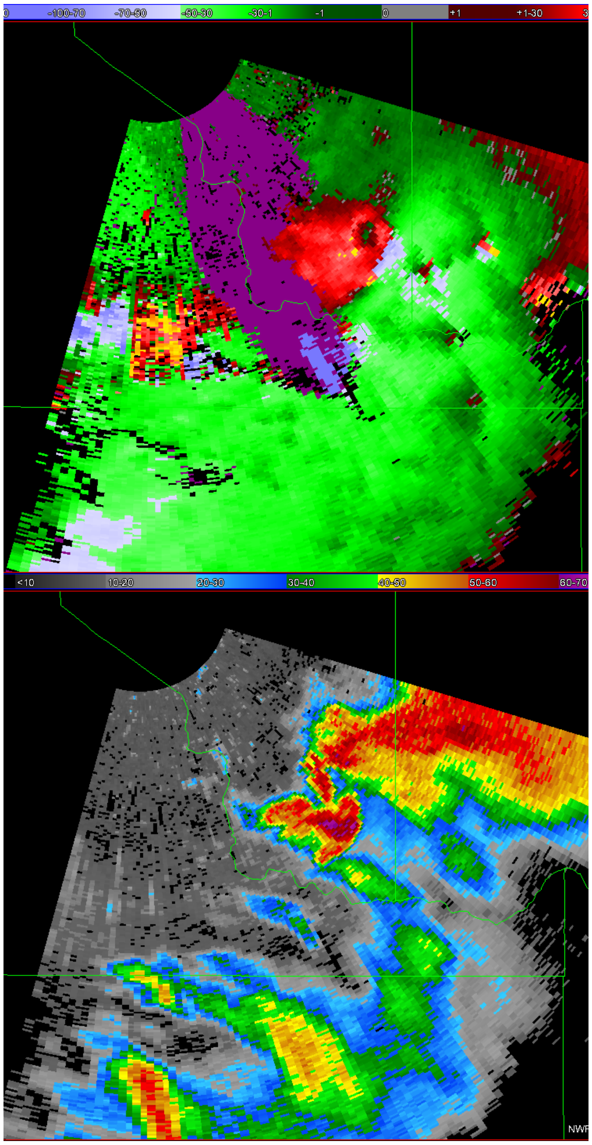

Figure 3. NWRT Reflectivity (bottom) and Velocity (top) on May 10, 2010 for a tornadic storm.

With these new improvements, a new set of experiments were executed for the spring 2010 that included the Phased Array Radar Innovative Sensing Experiment (PARISE) (Heinselman, 2011) and we supported VORTEX-2 during their second year of data collection. The NWRT captured the tornado that formed just to the south of the National Weather Center on May 10, 2010 (See Figure 3.) Work also continued on using PAR data for model initialization.

Work continued with Basic Commerce Industries on designing a dual-polarized panel. The panel design has been completed and its antenna pattern is very promising.

The hardware for the Multi-Channel receiver suite obtained by a National Science Foundation (NSF) funded proposal to OU was integrated into the NWRT (Yeary, 2011) and it continued to be tested. This subsystem is capable of recording real-time returns from the conventional sum beam signals coherently with a set of difference and auxiliary channel returns. These recorded data will be used to develop tracking, adaptive beamforming and clutter cancelling techniques (See Figure 4).

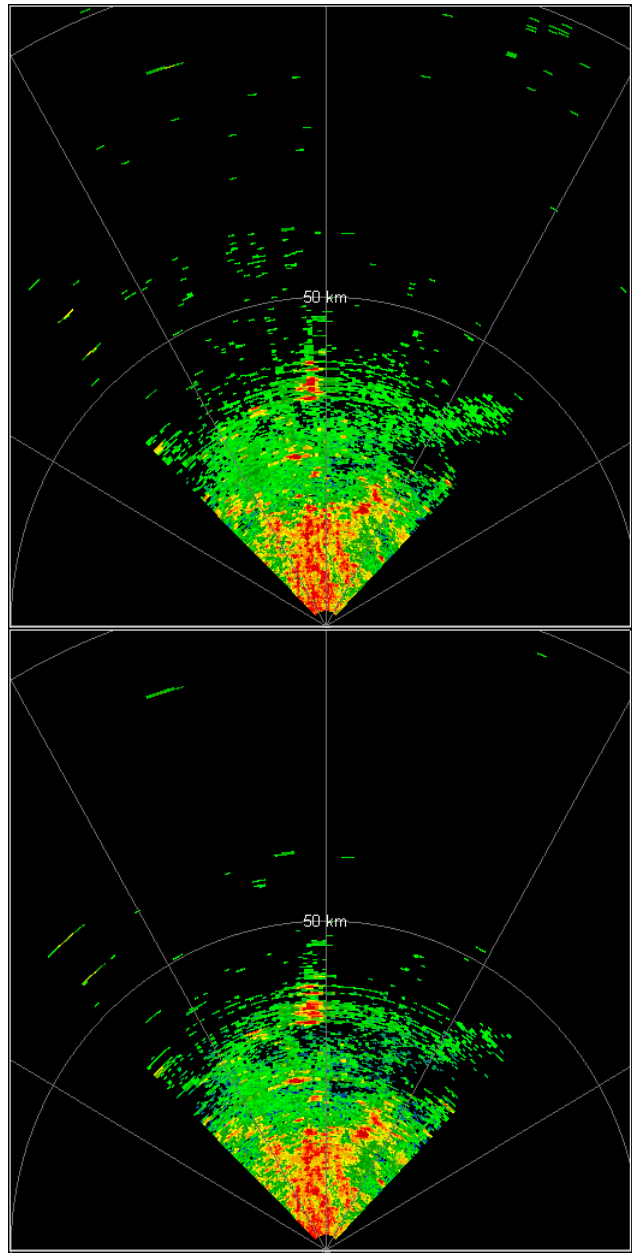

Figure 4. NWRT Multichannel Receiver data for the SUM (Top) and Delta Azimuth (Bottom) Channels looking at ground clutter return.

3. DATA COLLECTION (JAN 2010 – DEC 2010)

Date	Collection Type	Moment Archived	IQ	Weather / Comments
1/28/10	Ice Storm	400M	19G	
3/08/10	Thunderstorms	2.4G	156G	Possible TVS
4/02/10	Severe Thunderstorms	1.1G	49G	TVS/Hail
4/06/10	Severe Thunderstorms	1.7G	84G	Hail/Velocity Couplet/ Squall line
4/22/10	Severe Thunderstorms	3.8G	162G	Distant TVS
5/10/10	Severe Thunderstorms	7.2G	161G	Hail/Strong winds/TVS
5/11/10	Severe Thunderstorms	6.6G	144G	Hail/ Distant TVS
5/12/10	Severe Thunderstorms	16G	348G	TVS/Hail
5/14/10	Severe Thunderstorms	766M	16G	
5/16/10	Severe Thunderstorms	5.8G	124G	Hail/Rotation
5/19/10	Severe Thunderstorms	7.5G	201G	TVS/ Vortex-II
5/26/10	Thunderstorms	1.5G	32G	
5/30/10	Severe Thunderstorms	9.8G	225G	Microburst/ Divergence
6/14/10	Thunderstorms	4.6G	103G	Heavy Rain
7/07/10	Thunderstorms	4.6G	108G	Heavy Rain/ Flooding/ Kessler
7/08/10	Thunderstorms	4.6G	105G	Heavy Rain/ Flooding/ Kessler
7/11/10	Storms	4.7G	112G	
9/08/10	Tropical Storm	13G	339G	Hermine over Kessler farm
10/11/10	Thunderstorms	4.9G	105G	Video Disdrometer Testing
10/22/10	Thunderstorms	9.9G	212G	Video Disdrometer Testing

Table 1. Summary of Data Collection for 2009. Moment data (Reflectivity, Mean Velocity, and Spectrum Width). I/Q data are raw data collected before moments are calculated. (G = giga-bytes, M = Mega-bytes, TVS = Tornadic Vortex Signature)

4. RESEARCH PROGRESS and PLANS

Data Collection has continued on targets of opportunities with over 16 terabytes of data including 10+ terabytes of I&Q data being archived for research purposes. The archive now contains:

Supercells	24 -11 Tornadic
MCS	25 - 2 Tornadic, 4 severe winds
Pulse	22 - Microbursts, weak and strong
Scattered	15

An example of another first for the NWRT was capturing a tornadic supercell within 40 Km containing a mesocyclone and vortices within 20 Km. We were also able to perform a dual-Doppler analysis using the PAR and KTLX data. This case showed amplification of the vertical vorticity associated with the tornado occurred during the occlusion phase along the axis of convergence (Heinselman, 2010).

Additional work for the 2011 spring program will include working with operational meteorologists to execute data collection strategies to 1) develop a set of optimized sampling procedures for wind and tornado-producing storms and 2) develop a data base of existing and future visualization techniques to aid warning decision making with rapid update data.

Most of the effort in the Digital Signal Processor (DSP) area will continue to be involved with porting the scanning control from the Real Time Controller (RTC) to the DSP in order to implement even more advanced scanning strategies, to maximize flexibility and to reduce the RTC computational requirements. This will facilitate the development of automated algorithms to control the scanning strategies. We are also looking at an automated method for optimizing scanning strategies based on the range of the storm from the radar.

We will continue to work with BCI and Lockheed-Martin on the development of a dual-polarization panel and anticipate building a panel this coming year. In addition, we will continue to follow and support the efforts by Lincoln Laboratory to test their dual-polarization panel (effort funded by the FAA).

5. ACKNOWLEDGMENTS

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6. REFERENCES

Curtis, C. D. and S. M. Torres, 2011: Efficient range oversampling processing on the National Weather Radar Testbed. Preprints, 27th *International Conf. on Interactive Information Processing Systems for Meteor., Oceanography, and Hydrology*, Seattle, WA, Amer. Meteor. Soc., 13B.6.

Forsyth, D. E., J. F. Kimpel, D. S. Zrnic, R. Ferek, J. F. Heimmer, T. McNellis, J. E. Crain, A. M. Shapiro, R. J. Vogt and W. Benner, 2010: Progress Report on The National Weather Radar Testbed (Phased-Array) - Preprints, 26th *International Conf. on Interactive Information Processing Systems for Meteor., Oceanography, and Hydrology*, Atlanta, GA, Amer. Meteor. Soc., 14B.1.

Forsyth, D. E., J. F. Kimpel, D. S. Zrnic, R. Ferek, J. F. Heimmer, T. McNellis, J. E. Crain, A. M. Shapiro, R. J. Vogt and W. Benner, 2009: What's new at the National Weather Radar Testbed (Phased-Array). Preprints, *34th Conference on Radar Meteorology, Williamsburg, VA,* Amer. Meteor. Soc., 8A.1.

Heinselman, P. L., C. L. Ziegler, and L. R. Lemon, 2010: Single- and dual-Doppler analyses of a tornadic supercell sampled by NWRT PAR and WSR-88D. Preprints, 25th *Conference on Severe Local Storms,* Denver, CO, Amer. Meteor. Soc., 7A.4.

Heinselman, P. L., S. M. Torres, R. Adams, C. D. Curtis, E. Forren, I.R. Ivic, D. Priegnitz, J. Thompson, and D. A. Warde 2010: Exploiting NWRT PAR capabilities to improve temporal data resolution. Preprints, 26th *International Conf. on Interactive Information Processing Systems for Meteor., Oceanography, and Hydrology*, Atlanta, GA, Amer. Meteor. Soc., 15B.2.

Torres, S. M., R. Adams, C. Curtis, E. Forren, I. Ivic, D. Priegnitz, J. Thompson, and D. Warde, 2011: Software and signal processing upgrades for the National Weather Radar Testbed phased-array radar. Preprints, 27th *International Conf. on Interactive Information Processing Systems for Meteor., Oceanography, and Hydrology*, Seattle, WA, Amer. Meteor. Soc, 12B.3.

Yeary, M. R., J. E. Crain, A. Zahrai, J. Meier, I. R. Ivic, C. Curtis, R. Kelley, Y. Zhang, R. D. Palmer, T. Y. Yu, G. Zhang, R. J. Doviak, Q. Xu, P. B. Chilson, and M. Xue, 2011: A status report on the integration and test of the new multi-channel receiver at the National Weather Radar Testbed. Preprints, 27th *International Conf. on Interactive Information Processing Systems for Meteor., Oceanography, and Hydrology*, Seattle, WA, Amer. Meteor. Soc.,12B.5.

Zrnic, D. S.**,** J. F. Kimpel**,** D. F. Forsyth**,** A. Shapiro, G. Crain, R. Ferek, J. Heimmer, W. Benner, T. J. McNellis, 2007: Agile beam phased array radar for weather observations. *Bulletin of the American Meteorological Society*, **88**, 1753-1766.