# Update of a Low-Profile C-band Active Array Antenna for a Polarimetric Imaging Radar System

J. Salazar, *Senior Member, IEEE,* J. Ortiz, *Student, IEEE,* J. Diaz, *Student, IEEE,* J. Ortiz, *Student, IEEE,* N. Aboserwal, *Member, IEEE,* C. Fulton, *Senior Member, IEEE,* T. Yu, M. Yeary *Fellow, IEEE,* and R. Palmer *Fellow, IEEE*

***Abstract*—This paper describes a concept of a low-profile C-band active array antenna for a Polarimetric Atmospheric Imaging Radar (PAIR) radar system. Emphasis on the antenna design and scanning performance of finite array of 8x8 elements is presented.**

***Index Terms*—Active array antenna, CMOS core chip, GaN front end chip, dual-polarized phased array radar.**

## I. Introduction

RRAPID scanning radars for weather observation has significantly increased during the last decade among scientist and radar community. Fast scanning update radars (less than 1 minute) are desirable for monitoring tornado evolution and providing better weather forecast observations [1]. With these agile capabilities, PAR offers multibeam features applicable to diverse applications such as air traffic control and weather observation with a single radar platform.

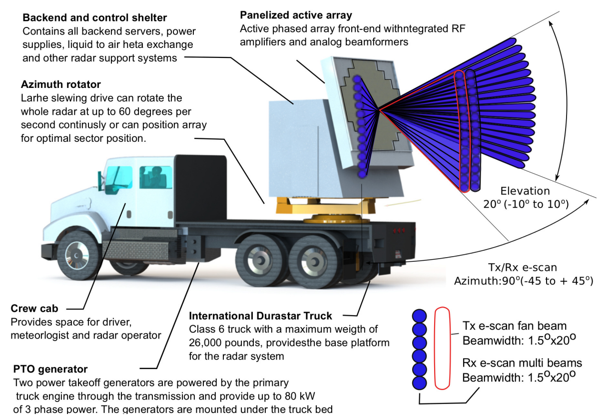


Fig. 1: Mobile C-band Polarimetric Atmospheric Imaging Radar (PAIR) system concept

The University of Oklahoma (OU) has a long history of severe local storms research and field program activities using mobile radars, and has pushed the limits of technology to further the science [2]. In 2015, OU was awarded a five-year project by the National Science Foundation (NSF) to design, fabricate, and commission a next generation mobile polarimetric phased-array radar. Based largely on promising results already obtained by the Atmospheric Imaging Radar (AIR) [3], and experience gained from the development of an all-digital polarimetric phased array radar in the Advanced Radar Research Center (ARRC) [2], [4], [5], this new Polarimetric Atmospheric Imaging Radar (PAIR) will be capable of the high spatial resolution afforded by a mobile system, with unprecedented temporal resolution using an imaging technique.

## II. PAIR front-end antenna array

The PAIR radar system is a mobile, C-band, dual-polarized, 1D imaging radar system capable of electronic scanning in azimuth. As illustrated in the Fig. 1 PAIR, a spoiled antenna beam of 20° in elevation and 1.5° in azimuth (denoted by red lines) is transmitted with simultaneous horizontally and vertically polarized waves. In reception, the 64 elements in each row will be arranged to perform as a sub-array, each of which has an independent up-down converter (UDC) and customized digital receiver to produce I/Q signals. Finally, an advanced cluster computing system will be exploited to aggregate and process the dual-polarimetric I/Q data from the 64 sub-arrays (double for H- and V-polarizations). After standard DBF processing, a flexible number of beams can be formed with regular beamwidth of $1.5^\circ \times 1.5^\circ$ (denoted by blue circles). In both reception and transmission, the spoiled beam and simultaneous multiple beams in elevation can be steered electronically in azimuth or mechanically using the rotary table. A total transmit power of 41 KW can be transmitted using all elements in the array. In this project, a phase-method synthesis approach will be used to produce the vertical fan beam of $20^\circ \times 1.5^\circ$, while maximizing the transmitted power.

The Fig. 2 shows a high-level block diagram of the proposed antenna front-end system. The RF electronics, up-down converters, and digital receivers will be integrated into a single panel enclosed by a protective, flat radome. The full array will be made up of 64 flat modular tile line replacement units (T-LRU), each containing $8 \times 8$ elements arranged in a square lattice. Special effort in the design of the aperture antenna to achieve a co-polar beam match ($<7$ %) and cross-polarization isolation (better that -35 dB) is needed in order to satisfy the polarization requirements for simultaneous transmit and receive (STSR) mode without prohibitively large corrections through calibration [4]–[6]. The T/R modules will be placed in

J. Salazar, J. Diaz, J. Ortiz, N. Aboserwal, C. Fulton, T.Yu, M. Yeary and R. Palmer are with the Advanced Radar Research Center and the Department of Electrical and Computer Engineering, The University of Oklahoma, Norman, OK, 73019 USA.

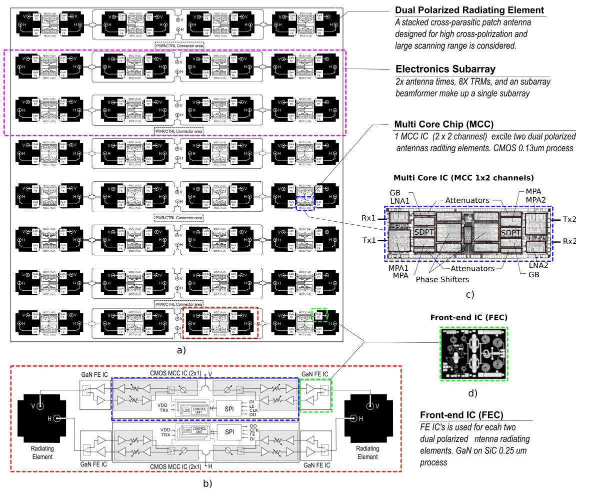


Fig. 2: PAIR front-end architecture. a) Antenna panel array of 8x8 elements b) Electronic unit cell c) Multicore (MCC) IC and d) Front-end chip (FEC).

the back of the radiating antenna element (tile configuration, see Fig. 3), and a analog beamforming network will interconnect all of the active elements in the array. Previously, the performance of a C-band radiating element and LRU array of 8×8 elements that satisfies these polarimetric requirements was developed [4]–[7]. The T/R modules, as shown in Fig. 3, is designed to operate in STSR mode, but will also support alternate transmit and simultaneous receive (ATSR) mode, where polarization accuracy requirements may be relaxed. This architecture will make use of two customized IC's a multicore chip (MCC), and a front-end chip (FEC).

To satisfy high cross-polarization isolation better than -40 dB, a bandwidth of 18% and e-scanning range of $\pm 50°$, the radiating antenna is designed based on a parasitic cross-patch with aperture-coupled feed network. Two air cavities are used to minimize the losses and potential excitation of surfaces waves in the antenna substrates (Roger 4350B). An aperture is located on a ground plane that separates both vertical and horizontal polarization. The radiating element geometry and cross-sectional view of this mechanism using stacked patches are shown in Fig. 3(a,b). The 3(b,c) illustrate the predicted gain loss and active reflection coefficient based on numerical simulation of an antenna array unit cell and Floquet analysis in Ansys HFSS. In order to reduce the radiation that comes from the slot, a feeding network based on striplines with a backing ground plane is used for one of the polarizations. Fig. 3(d,e) illustrate the patterns array patterns (co- and cross-polarization) of an 8x8 elements array. It is shown that isolation levels below -48 dB are possible in the element while the scanned cross-polarization can be maintained below -40 dB.

## III. Conclusion

This paper presents an overview of a fully polarimetric imaging radar system being developed by the University of Oklahoma. Preliminary results of the proposed antenna array demonstrated the feasibility of a low-cos, low profile high performance dual-polarized e-scanning array.

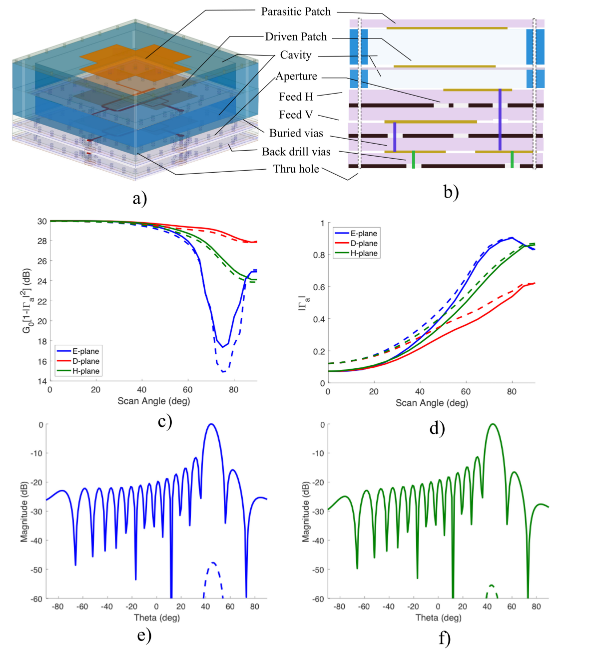


Fig. 3: Antenna geometry (a, b), predicted scanning performance of the array based on a infinite array approach (c, d). Simulated antenna patters scanned at 45° of a finite antenna array of 8x8 elements (e,f).

## Acknowledgement

The technical development of the PAIR is led by the ARRC engineering team. In particular, M. McCord is the technical lead with support from R. Kelley, J. Meier and other members of the ARRC.

## References

[1] D. S. Zrnic, J. F. Kimpel, D. E. Forsyth, a. Shapiro, G. Crain, R. Ferek, J. Heimmer, W. Benner, T. J. McNellis, and R. J. Vogt, "Agile-beam phased array radar for weather observations," *Bulletin of the American Meteorological Society*, vol. 88, no. 11, pp. 1753–1766, 2007.

[2] C. Fulton, T. Y. Yu, J. Salazar, and R. Palmer, "Updates on next-generation array-based weather radar developments at the University of Oklahoma," in *2017 IEEE International Conference on Microwaves, Antennas, Communications and Electronic Systems (COMCAS)*, Nov 2017, pp. 1–4.

[3] B. Isom, R. Palmer, R. Kelley, J. Meier, D. Bodine, M. Yeary, B.-L. Cheong, Y. Zhang, T.-Y. Yu, and M. I. Biggerstaff, "The atmospheric imaging radar: Simultaneous volumetric observations using a phased array weather radar," *Journal of Atmospheric and Oceanic Technology*, vol. 30, no. 4, pp. 655–675, 2013.

[4] J. D. Diaz, J. L. Salazar, J. A. Ortiz, C. Fulton, N. Aboserwal, R. Kelley, and R. Palmer, "A dual-polarized cross-stacked patch antenna with wide-angle and low cross-polarization for fully digital multifunction phased array radars," *IEEE International Symposium on Phased Array Systems and Technology*, pp. 6–9, 2017.

[5] J. A. Ortiz, J. Diaz, N. Aboserwal, J. L. Salazar, L. Jeon, S. Sim, and J. Chun, "Ultra-compact universal polarization X-band unit cell for high-performance active phased array radar," *IEEE International Symposium on Phased Array Systems and Technology*, pp. 10–14, 2017.

[6] J. Salazar, N. Aboserwal, J. Diaz, J. Ortiz, and C. Fulton, "Edge Diffraction Impact onthe Cross-Polarization Performance of Active Phased Array Antennas," *Fifth International Symposiym on Phased Array Systems and Technology*, pp. 1–5, 2016.

[7] J. L. Salazar, R. H. Medina, and E. Loew, "T / R Modules for Active Phased Array Radars," vol. 3, no. 1, pp. 1125–1133.