Airborne Polarimetric Doppler Phased Array Weather Radar: Modularity and Scalability Features

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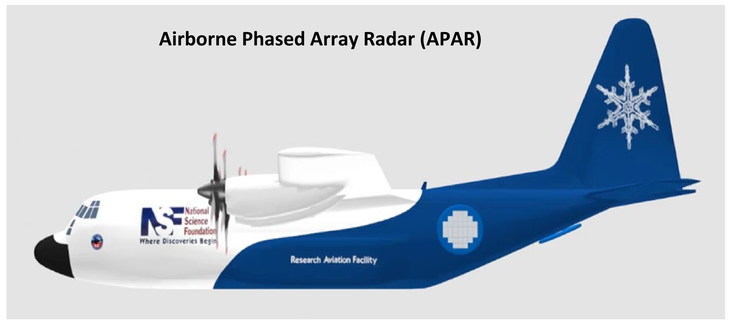
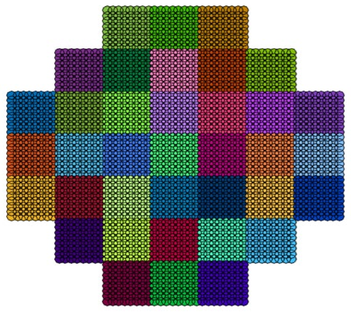
I. Introduction

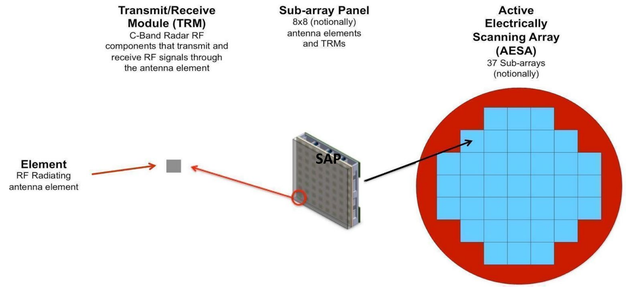
The National Center for Atmospheric Research is the process of developing and testing the Airborne Phased Array Radar (APAR) system. APAR will be the first rapid-scanning dual-Doppler and dual-polarization C-band radar on an airborne platform with the flexibility to target and follow specific features that can derive unprecedented kinematic (3-D winds) and microphysical (e.g., particle type [ice or water], shapes, and liquid/ice water contents) details within the interior of clouds. The APAR consists of four removable, dual-polarized, C-band active electronically scanned arrays (AESA) strategically located on the NSF/NCAR C-130. Two AESAs will be mounted on both sides of the fuselage ("side AESA"), the third will be mounted on the top of the fuselage ("top AESA"), and the fourth on the cargo door ("cargo door AESA"). APAR's AESA is based on a hybrid analog-digital beamforming architecture.

II. APAR Technical Specifications





37 replaceable subarray panels (SAPs) comprising AESA fit within 1.8 m diameter circle. Each SAP is made of 8 x 8 T/R modules.

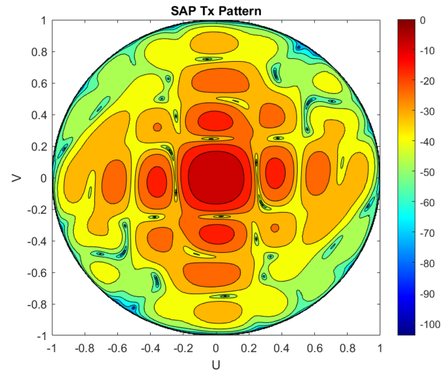


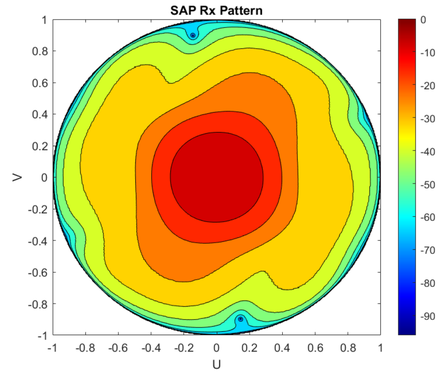
APAR Key Technical Features

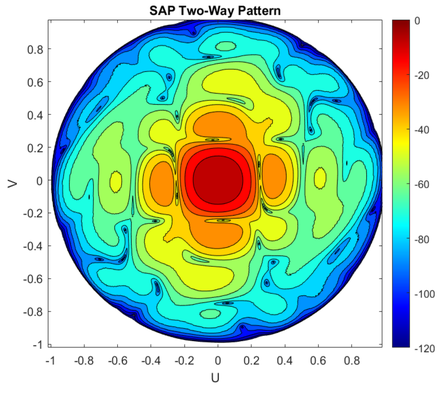
- Four Active Electronic Scanning Arrays (AESA)
  - Each AESA is composed of 2368 transmit and receive modules (TRM)
- AESA is 1.77 m diameter
  - 2.20 beamwidth
  - Sample volume: 150 m X 395 m X 380 m
- Dual-Doppler mode (6 moments)
- and dual-pol (16 moments)
  - - 11 dBZ sensitivity at 10 km.
  - Maximum range: 75 km
  - Duration of a dual-Doppler scan ~ 1 sec
  - Radar observations data rate 48 GB/hr for all four panels
  - Scientific product data rate 24 GB/hr

III. Beamwidth and Gain

- Half-power beamwidth q3dB= 0.88 λ/D
- Linear array of N elements with λ/2 spacing: q3dB= 1020/N
- Planar array of N X N elements λ/2 spacing: q3dB= 1020/N
- Gain (G) varies with the scan angle (q) away from boresight
- G(q) = G(bore sight) * Cos(q)
- G(bore sight) = gain of individual element * array gain



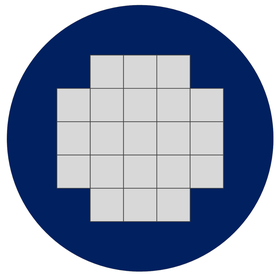


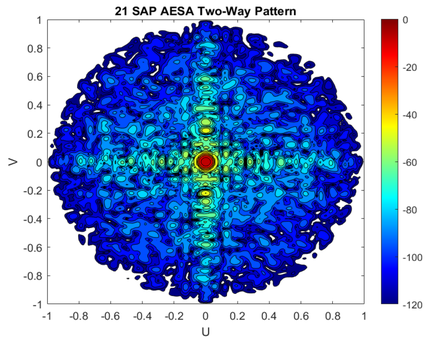


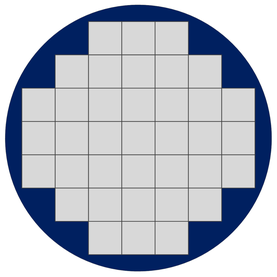
APAR Aperture Characteristics

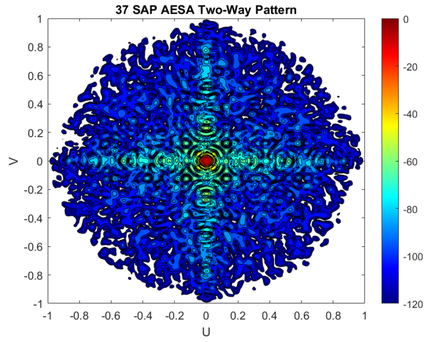
	SAP	AESA - 21	AESA-37
Gain Tx	22.4 dBi	33.8 dBi	36.9 dBi
Gain Rx	20.9 dBi	34.7 dBi	37.6 dBi
Beamwidth Tx	14.6°	2.9°	2.2°
Beamwidth Rx	18.4°	3.4°	2.4°
Taper Tx	None	Taylor (nbar=3,SLL =-16)	Taylor (nbar=3,SLL =-16)
Taper Rx	Taylor (nbar=5,SLL =-20)	Taylor (nbar=6,SLL =-31)	Taylor (nbar=6,SLL =-31)
MDS @ 10 km	13.1 dBZ	-8.4 dBZ	-12.9 dBZ
PSL	-24 dB	-41.4 dB	-41.7 dB

IV. Radiation Pattern Characteristics

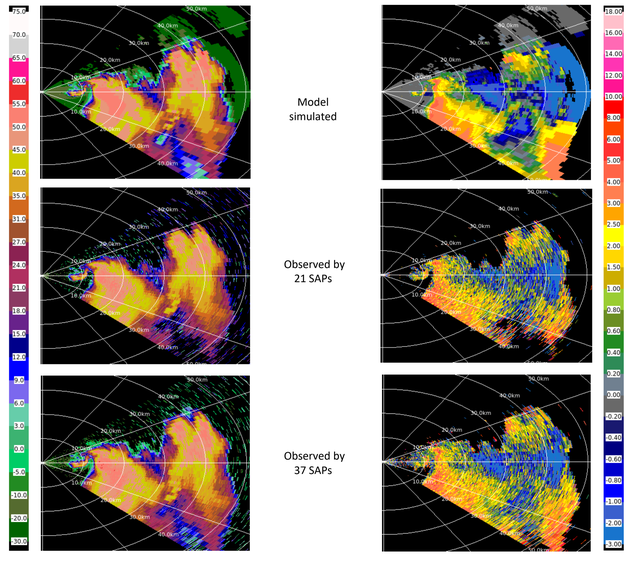








V. APAR Digital Twin Simulated Reflectivity and Differential Reflectivity



VI. Summary

- Full-size phased array radar (PAR) is constructed using scalable architecture in a modular approach.
- Modularity and scalability offer flexibility in realizing full-size PAR of desired technical specifications at a reduced cost and servicing PAR consisting of thousands of elements.
- A single array panel consisting of a grid of transmit and receive module modules is arranged in a tiled fashion in an active electronic scanning array (AESA). Tiles are identical, and the components are etched on a printed circuit board (PCB).
- The layout of AESA determines the gain and beamwidth of PAR and hence spatial and temporal resolutions of radar observation.

References

- J. Vivekanandan, and E. Loew, "Airborne polarimetric Doppler weather radar: trade-offs between various engineering specifications," Geosci. Instrum. Method. Data Syst., vol. 7, pp.21-37, Jan. 2018 https://doi.org/10.5194/gi-7-21-2018, 2018.
- Adam Karboski, Jothiram Vivekanandan, Christopher Burghart and Turing Eret, 2022: Airborne Polarimetric Doppler Phased Array Weather Radar: Digital Twin of the Active Electronically Scanned Array. *IEEE International Symposium on Phased Array Systems and Technology, Boston.*

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