

# AIRBORNE PHASED ARRAY RADAR (APAR)

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## I. Introduction

Airborne radar systems have been used successfully to study air motion and microphysical characteristics in storms where ground-based radars are ineffective. Studies of tropical convection, lake-effect snow, and hurricane eye walls, and rain bands are examples of atmospheric phenomena studied by the Electra Doppler Radar (ELDORA) system. Retirement of Naval Research Lab P-3 aircraft beginning 2013 effectively terminates future deployment of ELDORA in the current configuration. Continuation of airborne radar capabilities necessitated NCAR's Earth Observing Laboratory to investigate possible development of active electronic scanned phased array radar mounted on the fuselage of the NSF/NCAR C-130 turboprop aircraft. Electronic scanning capability offers more accurate and higher temporal resolution meteorological observations in a shorter dwell time when compared to a mechanically scanned beam. Recent advances in monolithic microwave integrated circuits in the commercial manufacturing area show potential for building robust phased array radar. This poster describes preliminary design concept, development timeline and cost.

## II. Background

Due to the large surface area of the C-130 fuselage, the radar system can be either C- or X-band. Sensitivity of the X-band radar system is about 5 dB better than C-band in the absence of any significant attenuation due to precipitation. Signal attenuation at X-band is about a factor of five to seven times larger. As a result, an X-band radar fails to penetrate a heavier precipitation region when compared to C-band radar. Figure 1 shows ELDORA X-band radar's limitation for detecting inner rainband as a result of attenuation.

EOL is in the process of developing automatic data quality control of ELDORA data and estimating real-time dual-Doppler winds. This package will be adopted for an e-scan system. One of the significant enhancements to the proposed airborne radar is polarization capability for estimating precipitation and cloud microphysics. A number of simulation studies suggest high quality polarimetric measurements could be collected over limited scan coverage.

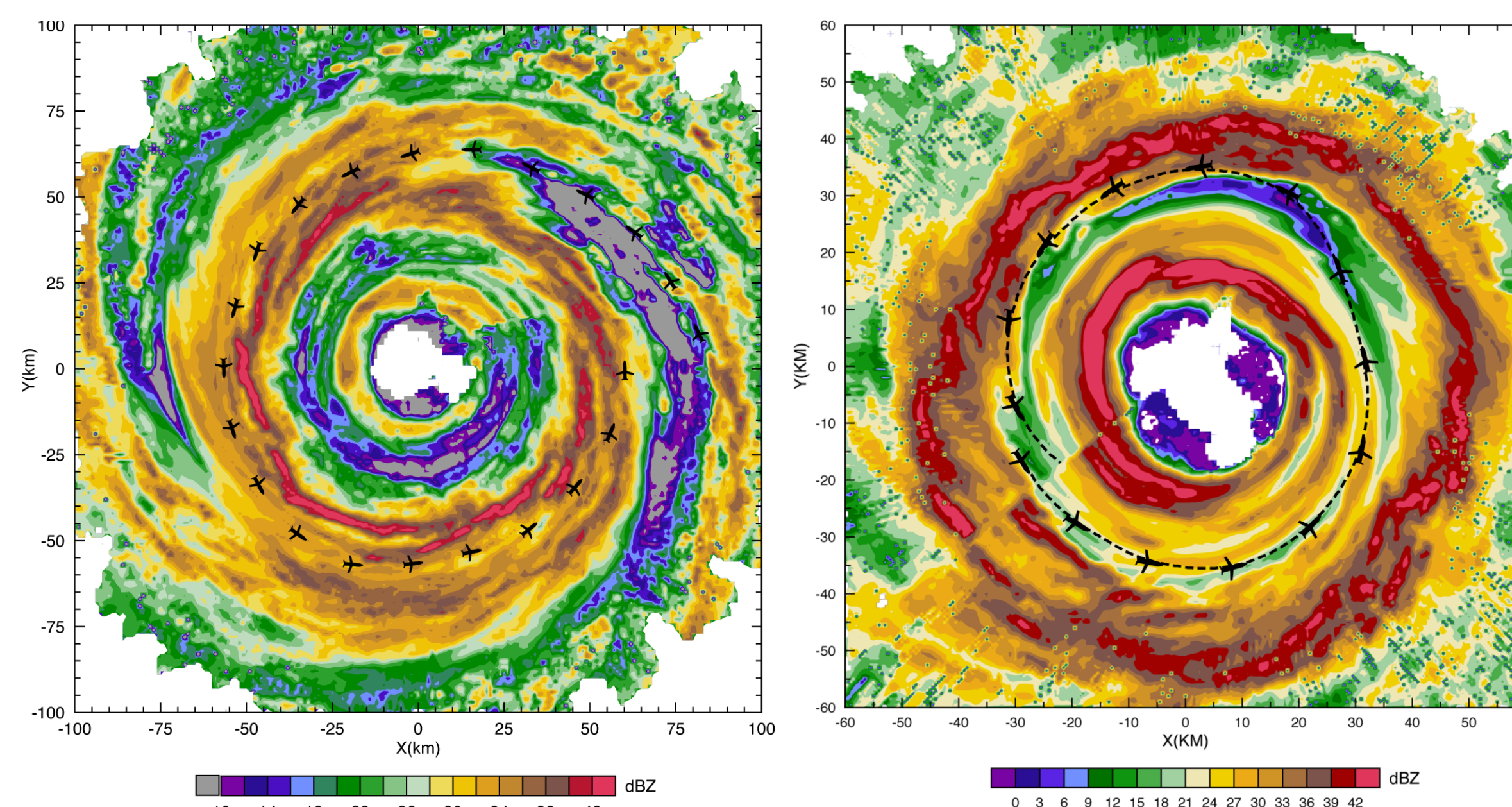


Fig. 1. Hurricane Rita Reflectivity from ELDORA at 2 km MSL, 22 September 2005. Attenuation at X-band limited detection of inner rainband.

## Comparison Between ELDORA and the Proposed C-band Phased Array radar

- Mechanically scanned – inflexible, least reliable part of radar**
  - Operates at X band – subject to large attenuation**
  - Transmits high peak power at low duty cycle – single point failure, lifetime < 10,000 hrs**
  - Fixed antenna beamwidth and gain**
  - Limited to single polarization**
  - Calibration is straightforward**
- Electronically scanned – fast, flexible, reliable**
  - Operates at C band – less effected by attenuation**
  - Transmits moderate peak power at moderate duty cycle – fault tolerant, lifetime > 40,000 hrs**
  - Antenna beamwidth and gain varies with scan angle**
  - Doppler and dual-polarization measurements ( $Z_{DR}$ ,  $K_{DP}$ , LDR,  $\rho_{HV}$ )**
  - Calibration is complex**

## III. Airborne Phased Array Radar (APAR) Concept

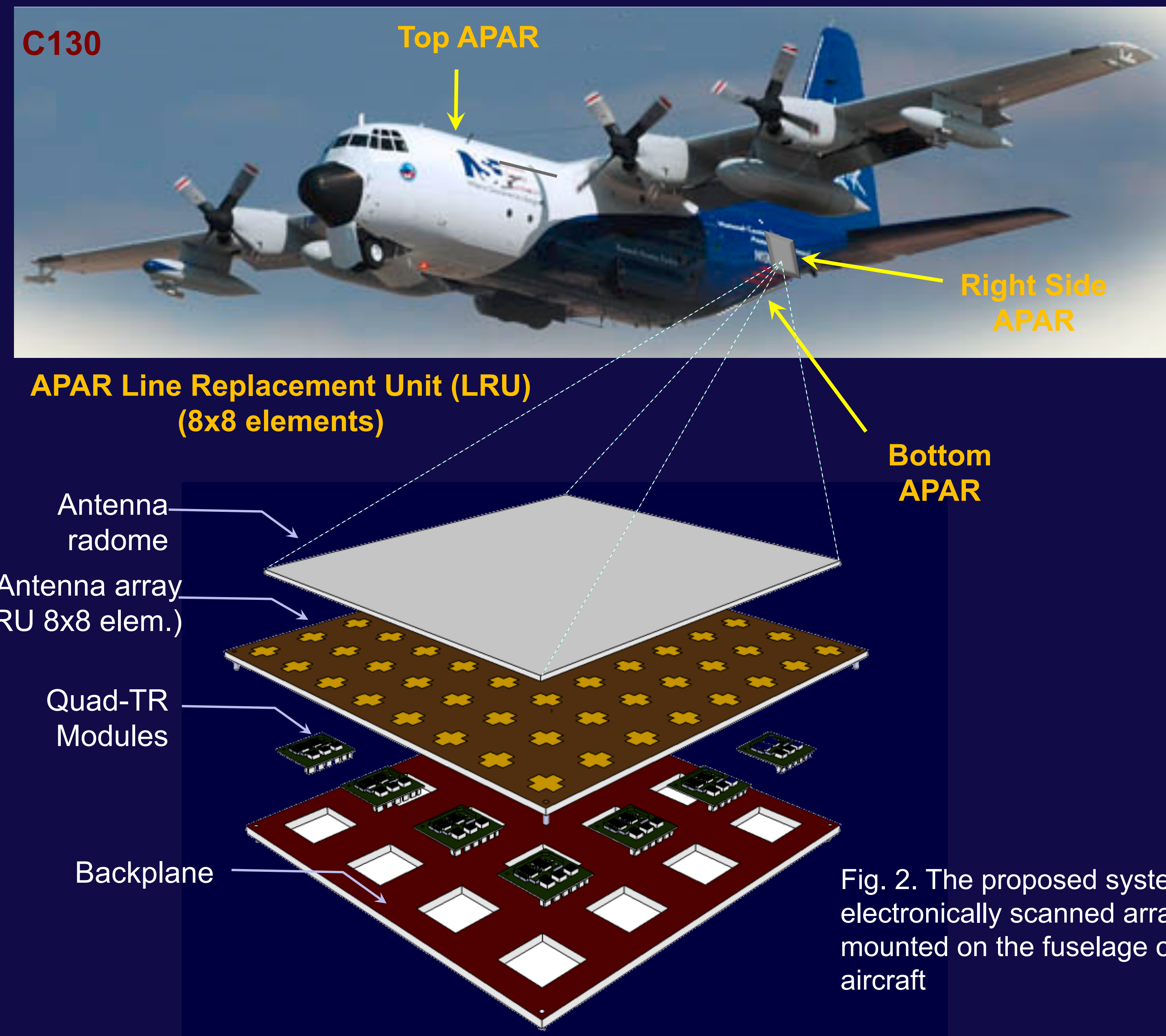


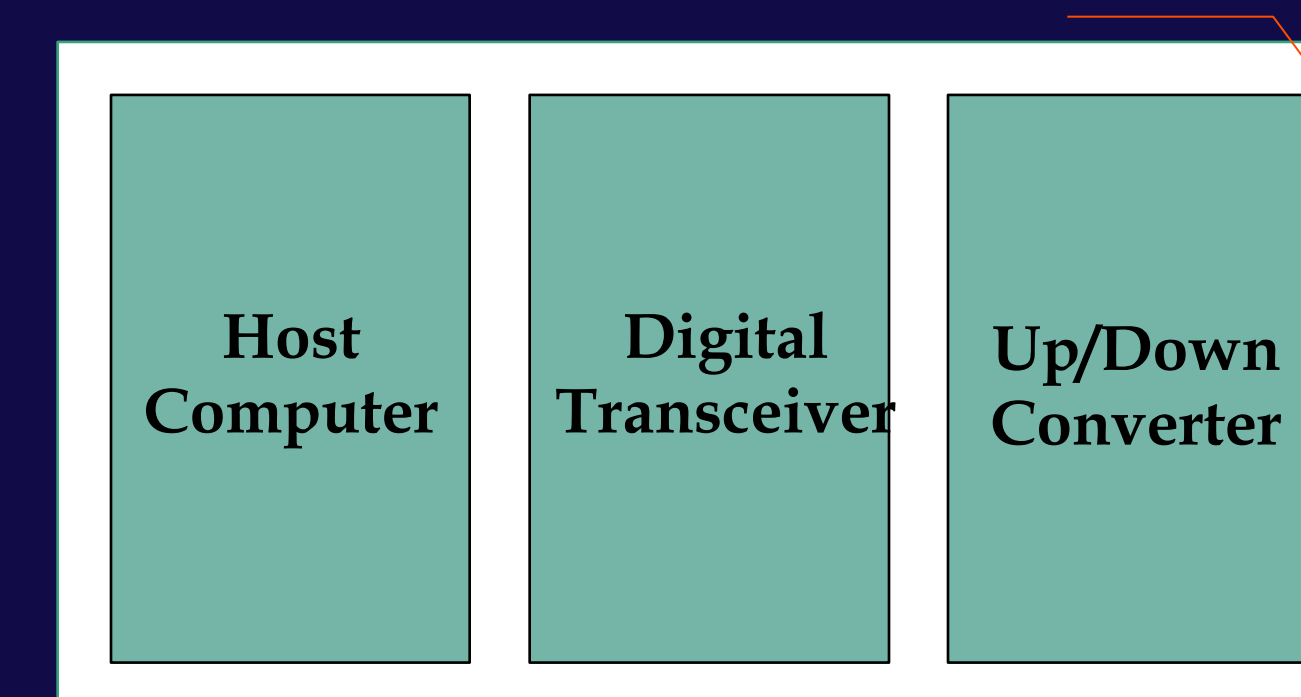
Fig. 2. The proposed system consists of four, C-band active electronically scanned array antennas (AESAs) strategically mounted on the fuselage of the NSF/NCAR C130 turboprop aircraft

### APAR Technical Characteristics

Parameter	Specification
Frequency	5.4 GHz
Wavelength	5.55 cm
Element spacing (0.5 lambda)	2.78 cm
Number of Elements (#Nx, #Ny)	56, 64 (3584)
#LRUx, #LRUy	7, 8
Tx Beamwidth (Uniform)	$\theta_0$ : 1.8°, 1.6° $\theta_{45}$ : 2.1°, 1.8°
Rx Beamwidth (Taylor -25dB, n=4)	$\theta_0$ : 1.9°, 2.2° $\theta_{45}$ : 2.2°, 2.5°
Tx Gain	40dB
Rx Gain	39dB
Xpol isolation (ATSR)	<-25dB
Spatial Resolution at 10 km	~350m
Tx Power (4W per TR mod.)	14.3kW
Sensitivity @10km (include attenuation at 10 mm h <sup>-1</sup> )	-12dBZ

- Array antenna front-end
- Array TR-modules
- Array antenna back-plane
- Radar back-end

### LRU (8x8) ASP PAR project



- Radar back-end**
- UP/DOWN converter
  - Digital Transceiver
  - Host Computer
  - Waveform design
  - Data processing

## APAR Architecture

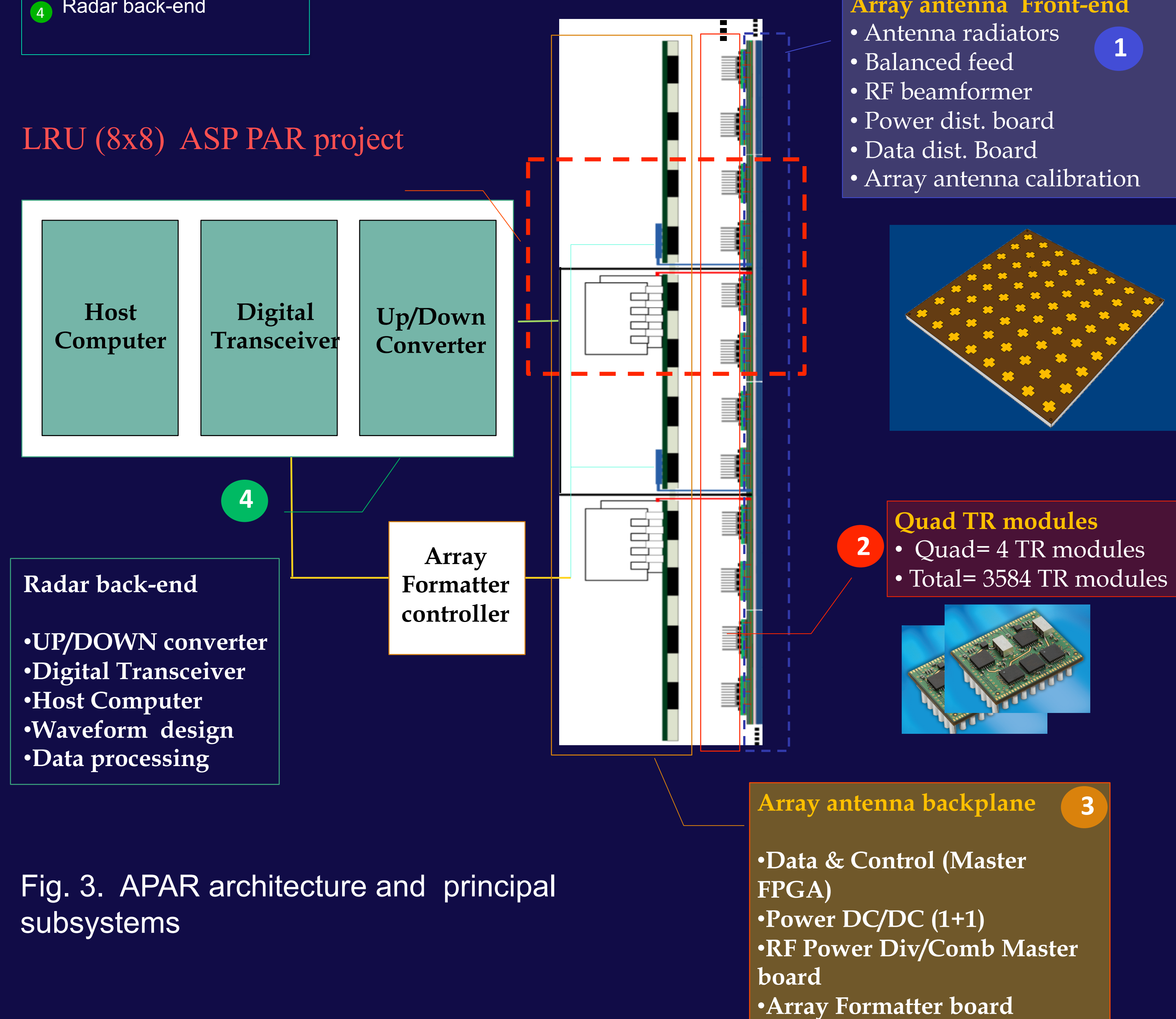


Fig. 3. APAR architecture and principal subsystems

## IV. APAR Transmit and receive (TR) module and micro strip patch antenna

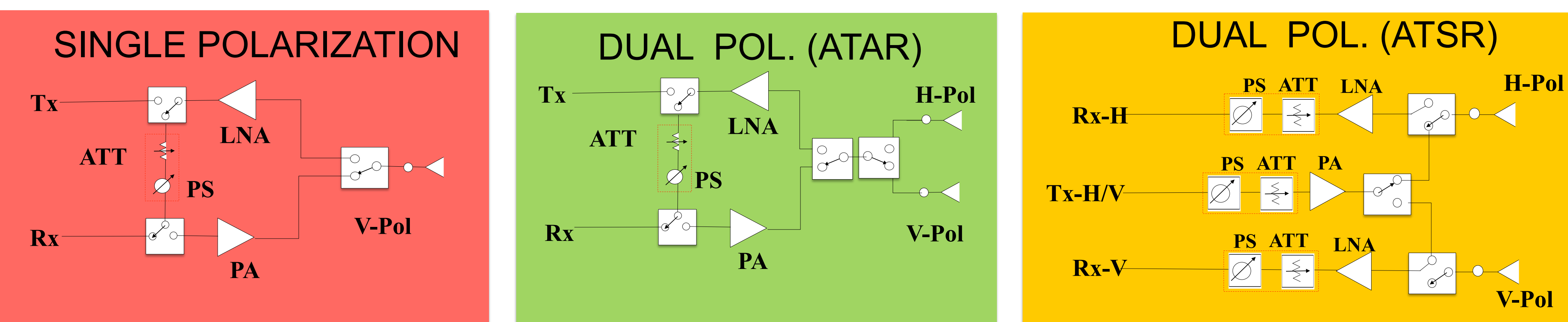


Fig. 4. TR-Module architecture options for APAR: a) Single Polarization, b) dual-polarization for alternate transmit and alternate receive (ATAR) and, c) dual-polarization alternate transmit and simultaneous receive (ATSR)

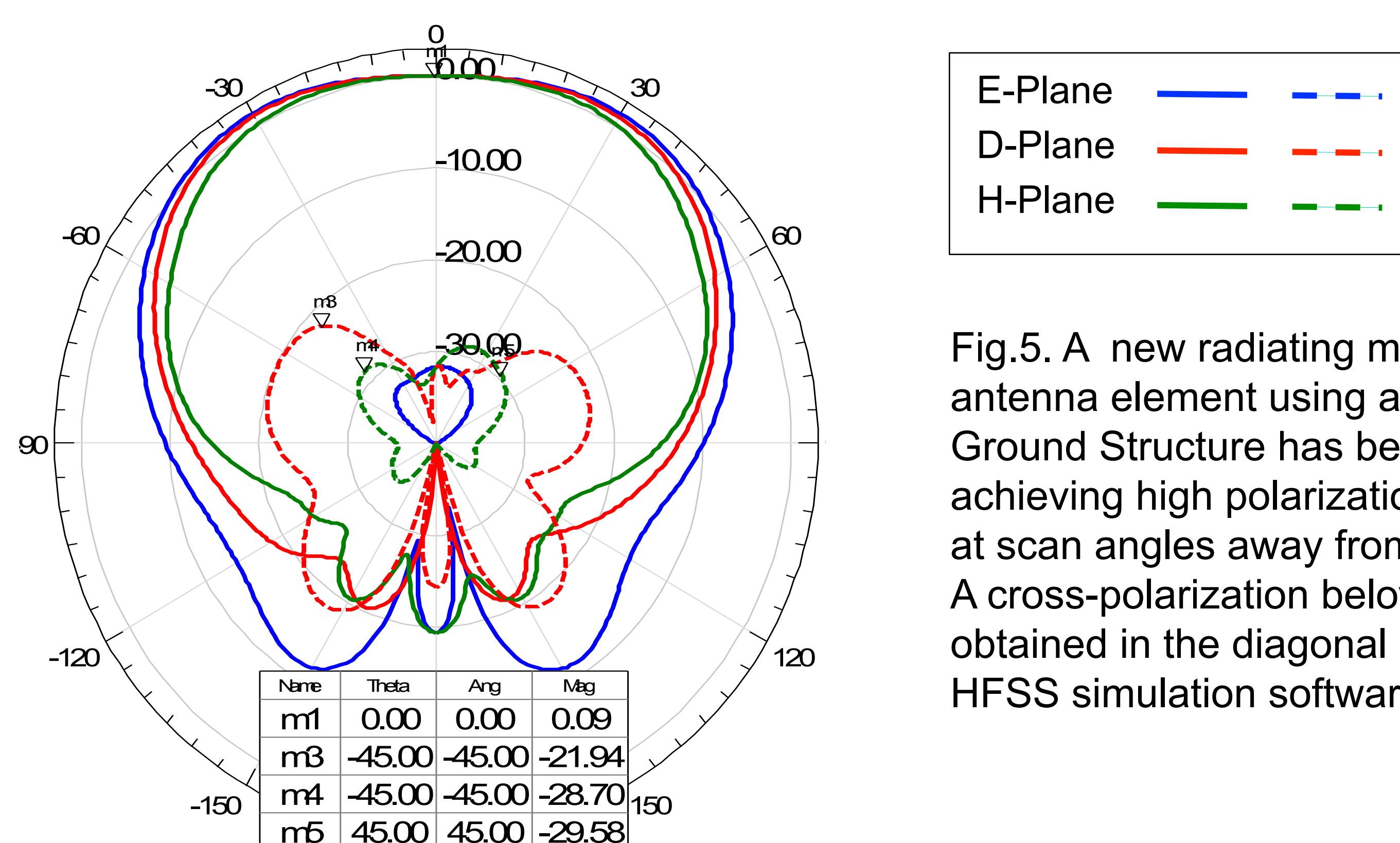
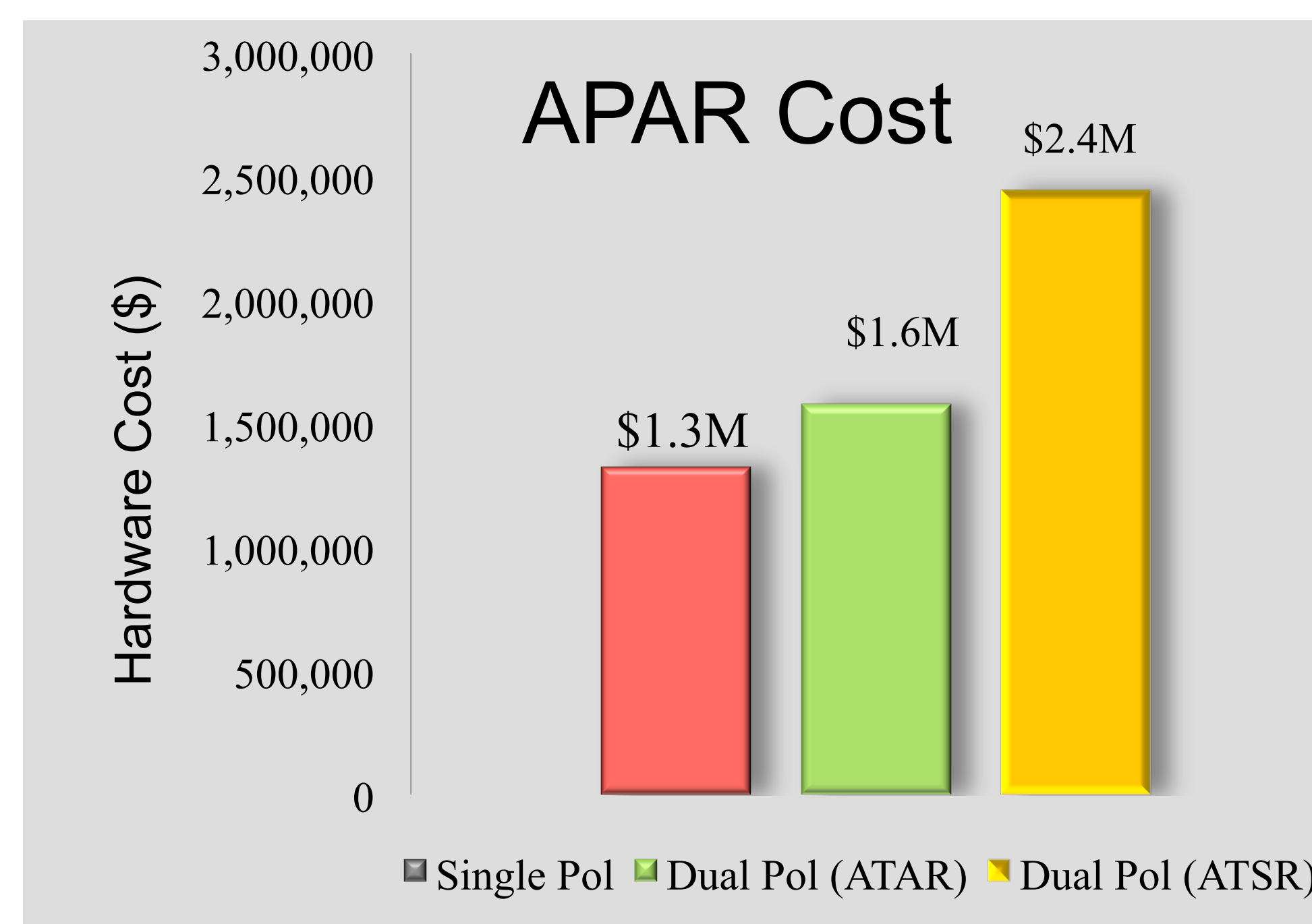
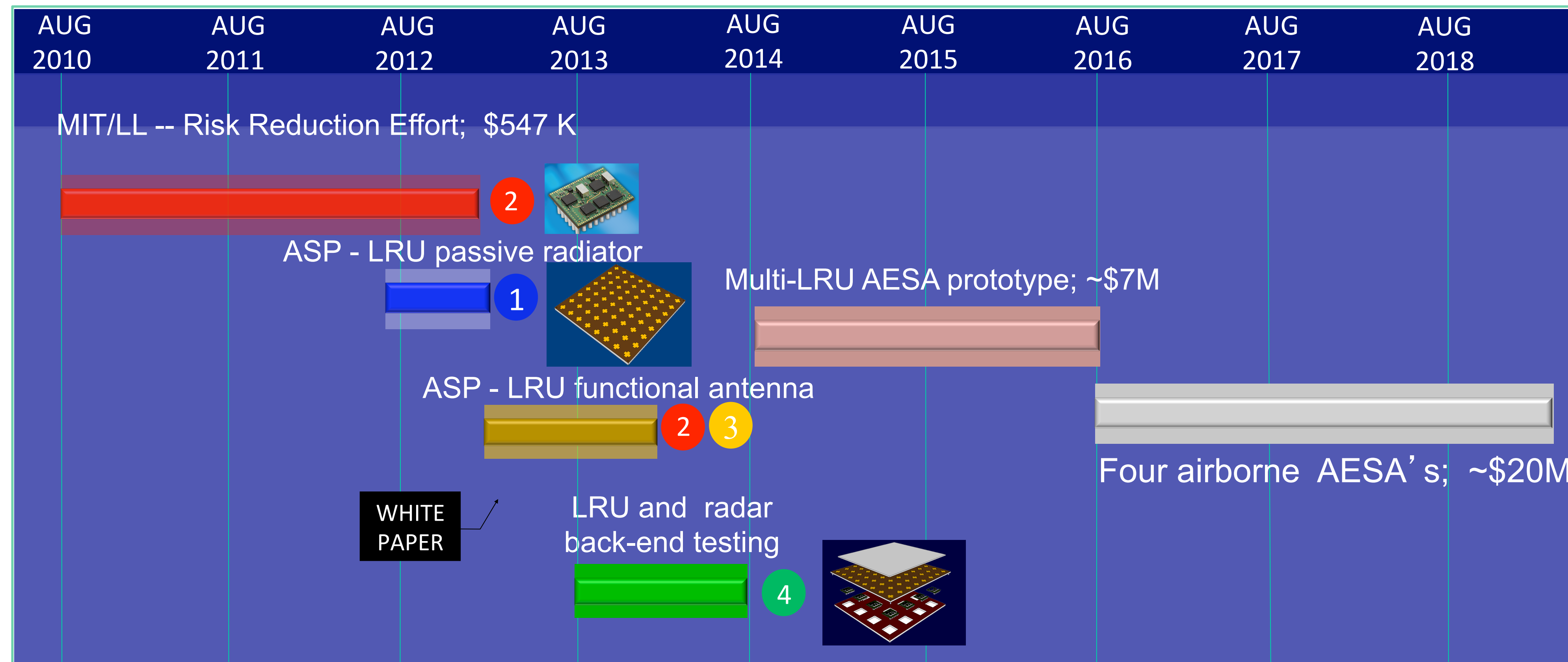


Fig.5. A new radiating micro strip patch antenna element using a Defected Ground Structure has been designed for achieving high polarization performance at scan angles away from boresight. A cross-polarization below -25dB is obtained in the diagonal plane using HFSS simulation software

Fig. 6. APAR hardware cost as function of polarization capability

## V. APAR Development timeline and hardware cost estimate



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