3.3
Element-Level Digital Array for Multifunction Phased Array Radar (dMPAR)

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Multifunction Phased Array Radar (MPAR)

Current Aircraft and Weather Radars

Terminal Area Aircraft

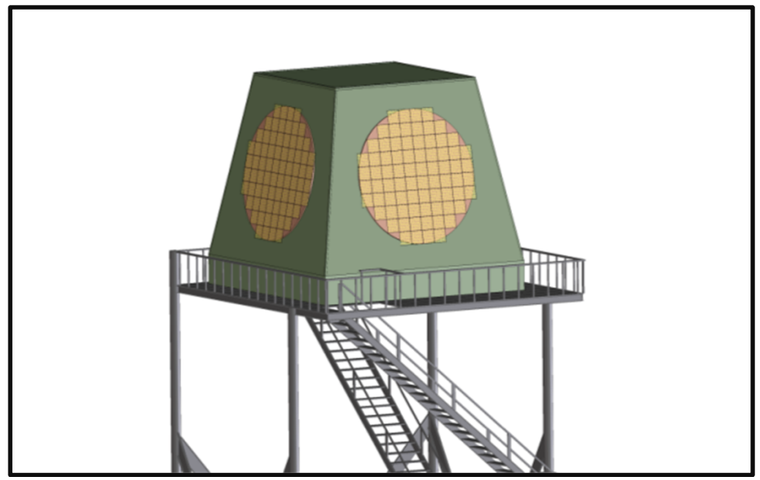
Long Range Aircraft

Long Range Weather

Terminal Area Weather

- **9 Radar System Designs**
- **Rotating Dish Technology**
- **Many Nearing End-of-Life**

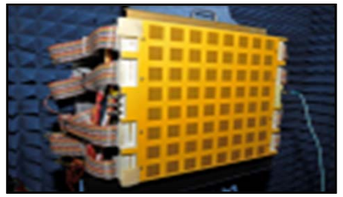
Multifunction Phased Array Radar



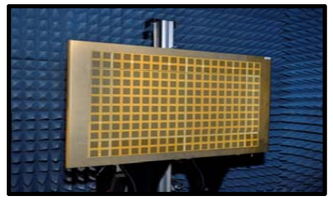
- **Lower Life Cycle Cost**
  - **Reduced radar count from over 600 to 400**
  - **Reduced O&M (no moving parts)**
  - **Streamlined training and sparing infrastructure**
- **Increased performance benefits**
  - **Adaptive Scan Strategies**
  - **Faster update rates**

MPAR Development Timeline

2007-11:
First Panel

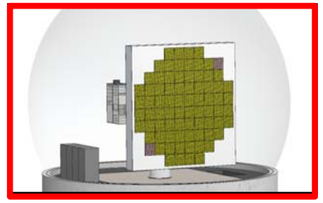


2012-13:
2 Panels



2014-15:
10 Panel Demo

2015-18:
76 Panel Advanced Technology Demo (ATD)



ATD Antenna Testing
July 2017 – May 2018

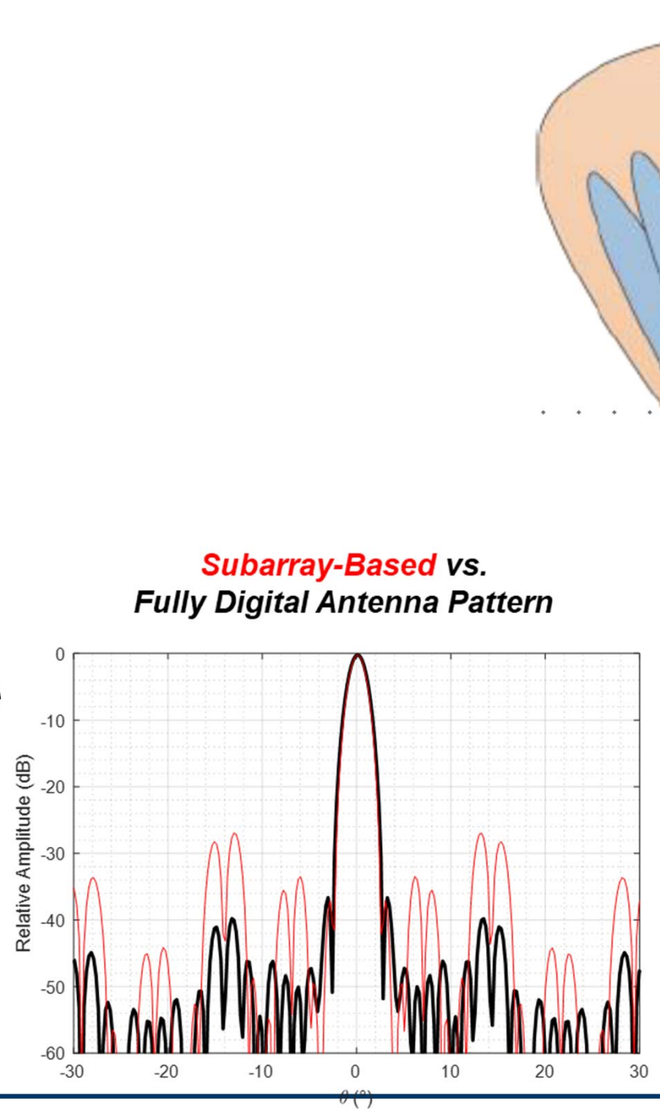
ATD Installation
National Weather Radar Testbed (NWRT),
Norman, OK, July 2018

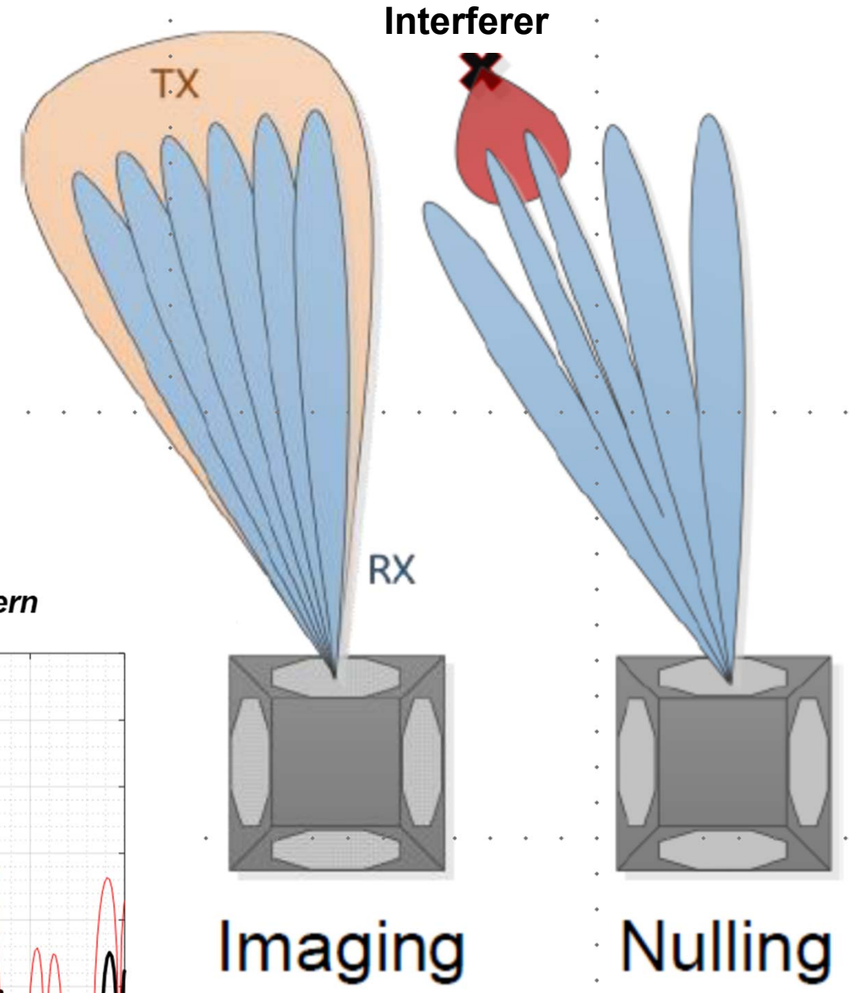
Element Level Digital for MPAR

- MPAR effort focused on the development of low cost phased array panels that would enable the application of phased array technology for the civilian National Airspace applications of aircraft surveillance and weather forecasting
- Concurrent with that work, significant strides in technology have been made
  - RF semiconductors >> Gallium Nitride (GaN) high power amplifiers (HPA)
  - RF mixed signal integrated circuits >> RF System on a Chip (RFSoC)
  - High speed, high density RF connectors
  - 3D printing in metals and plastics
- Element level digital phased array panels enabled by
  - Commercial technologies
  - S-band operation, radiator lattice ~ 2”
  - ATD development experience with design for cost

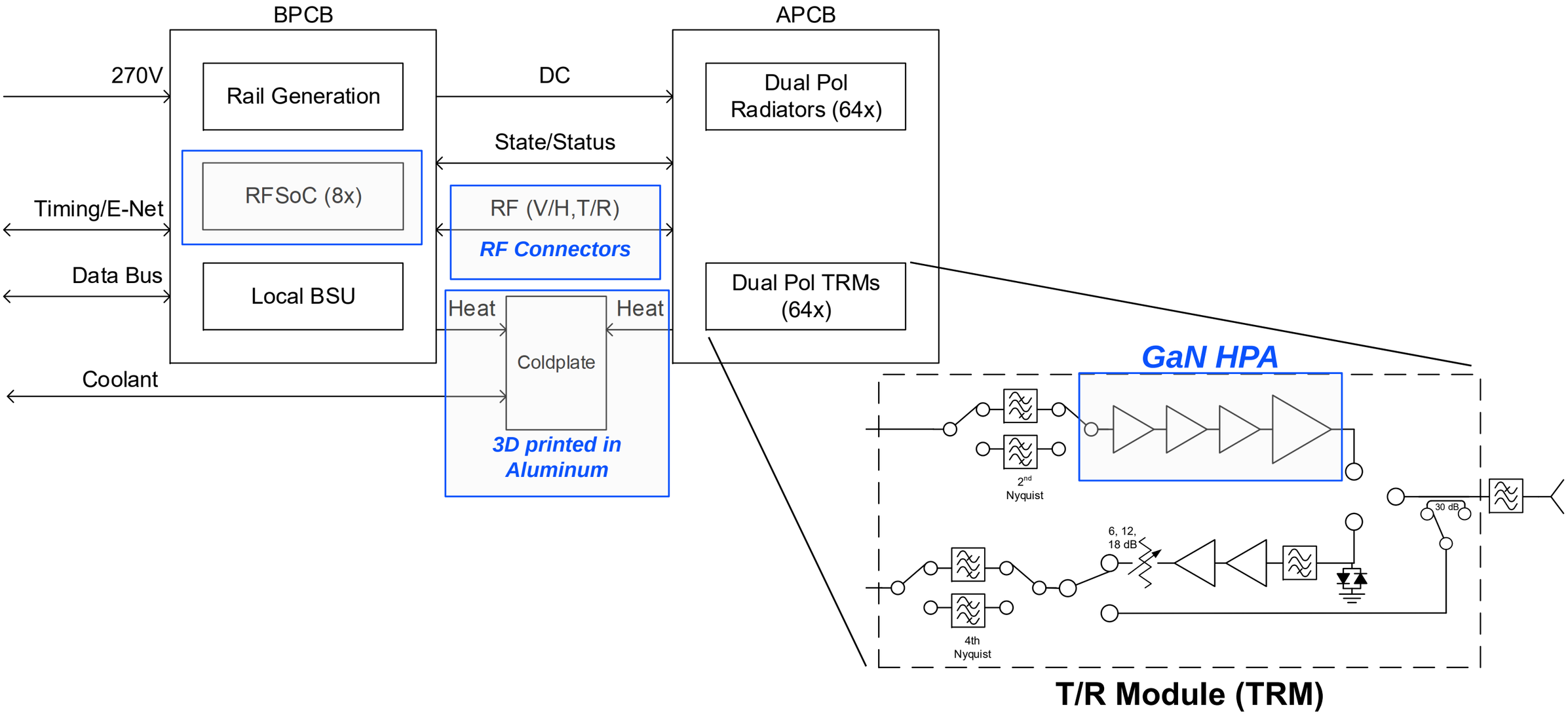
Element Level Digital Beamforming Motivation

- **Flexible, site adaptable beam set**
- **Enhanced calibration and bias correction capabilities**
  - **Mutual coupling based approaches**
  - **Improved cross-pol isolation**
- **Eliminates antenna pattern spurs, systematic error lobes, caused by subarray architectures**
- **Much improved linear dynamic range**
  - **Input compression level, 30+ dB**

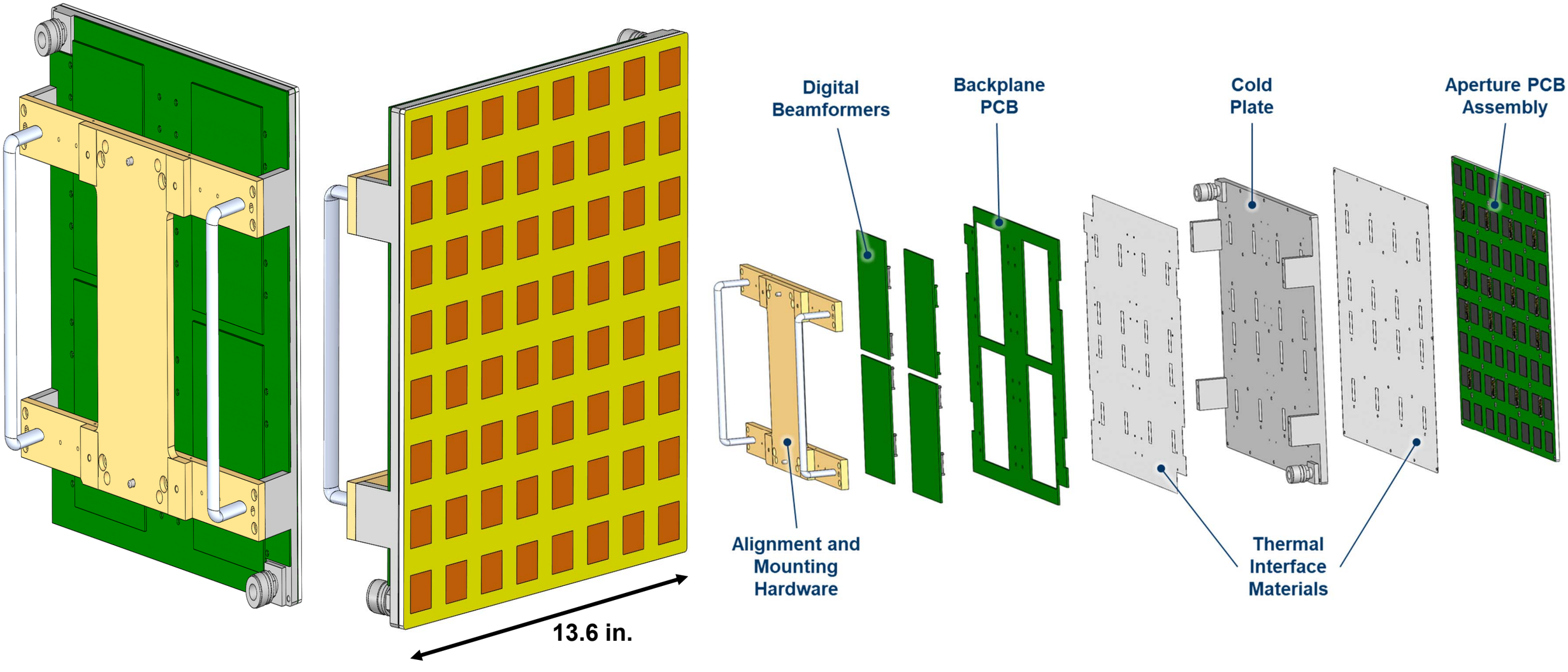




Panel Block Diagram



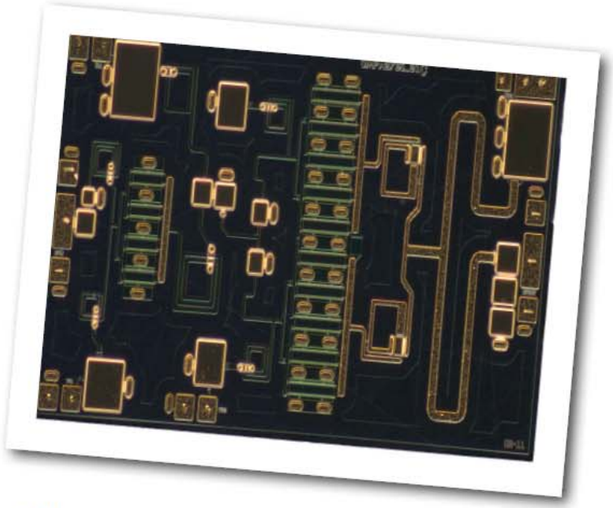
Panel Assembly Model



GaN HPA

CMPA2735030D

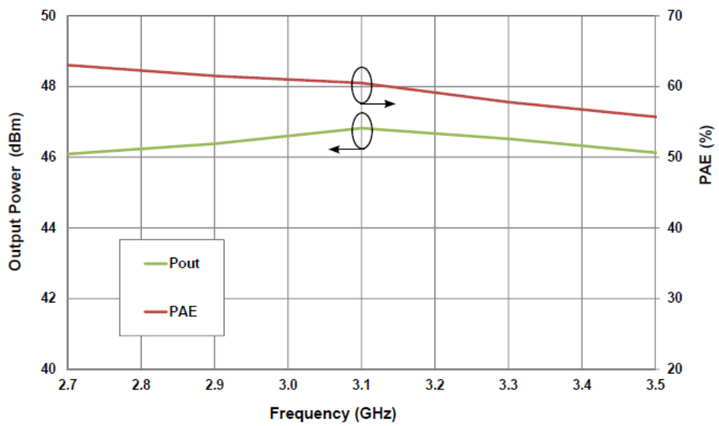
30 W, 2.7 - 3.5 GHz, GaN MMIC, Power Amplifier



Cree's CMPA2735030D is a gallium nitride (GaN) High Electron Mobility Transistor (HEMT) based monolithic microwave integrated circuit (MMIC). GaN has superior properties compared to silicon or gallium arsenide, including higher breakdown voltage, higher saturated electron drift velocity and higher thermal conductivity. GaN HEMTs also offer greater power density and wider bandwidths compared to Si and GaAs transistors. This MMIC contains a two-stage reactively matched amplifier design approach enabling very wide bandwidths to be achieved.

- **Cree Wolfspeed die**
- **Extremely robust**
- **60% power added efficiency**

Figure 2. - Output Power and PAE vs Frequency of CMPA2735030D
V_{DD} = 50 V, I_{DQ} = 0.135 A, Pulse Width 500 us, Duty Cycle = 10%, P_{IN} =18 dBm

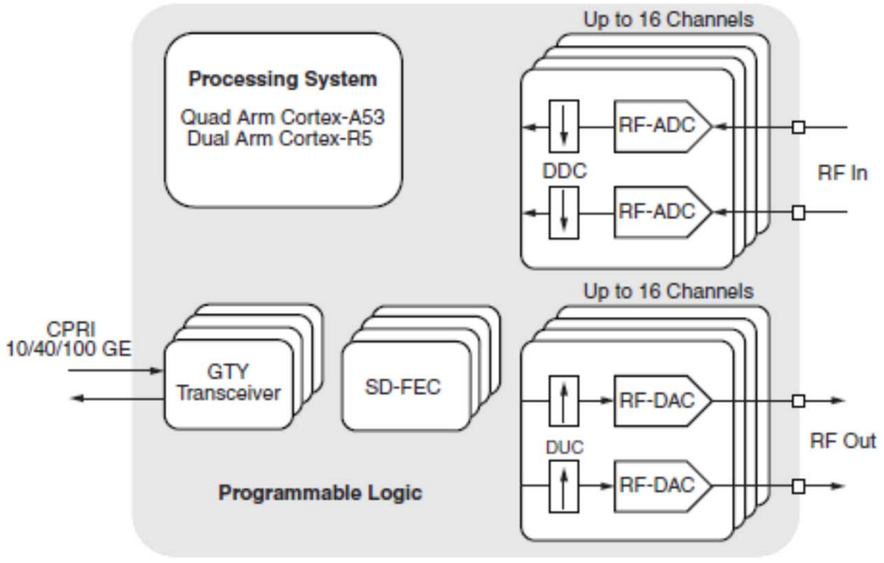


Xilinx RF System on a Chip (RFSoC)

- **Xilinx RFSoC is a key enabling technology**
- **Integrates 16x ADCs and 16x DACs, into a single monolithic IC**
  - **12-bit 2.058 GSPS ADC**
  - **14-bit 6.554 GSPS DAC**
  - **Built-in decimation**
- **16x 32 Gb/s serial transceivers provide substantial off chip data bandwidth**
- **Fits into a 42.5x42.5 mm package**
- **8x RFSoCs capable of handling processing for a single panel of elements**

XILINX®

ZYNQ® RFSoC

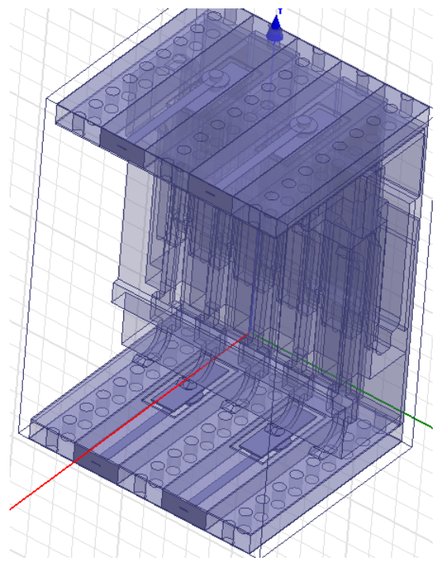


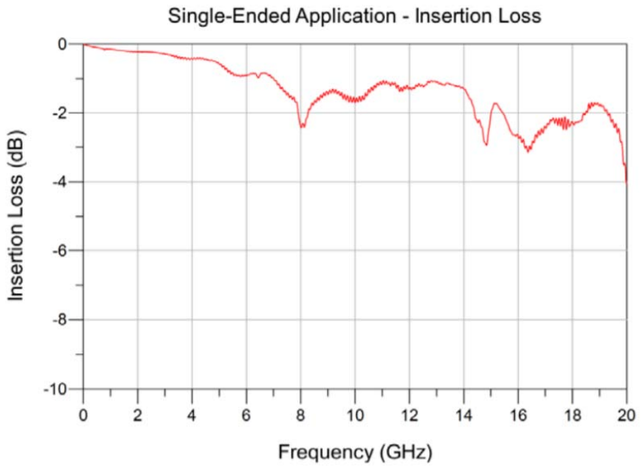
*Images curtesy of Xilinx.com and Xilinx DS889

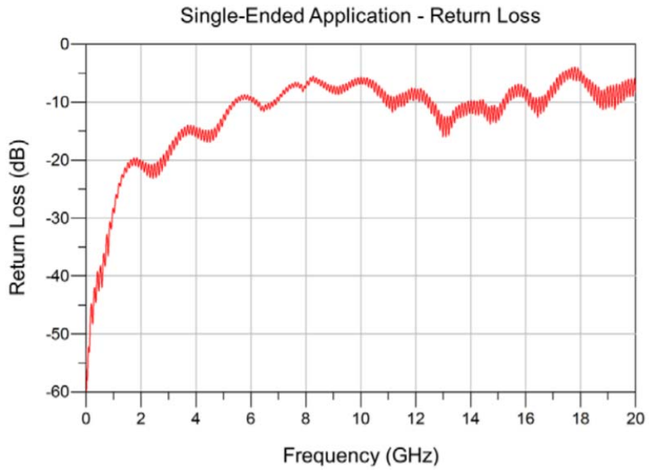
Low Cost RF Connector

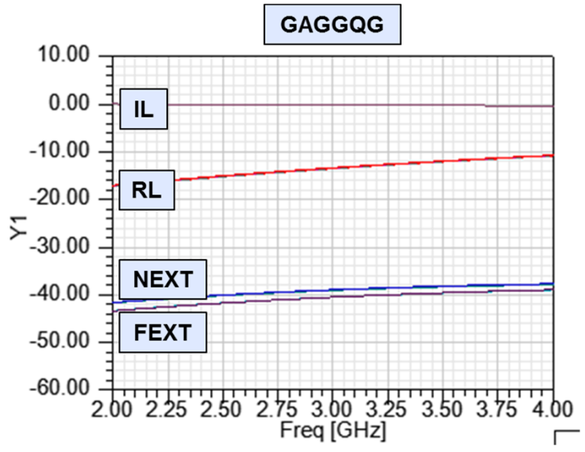
- **Samtec high density Q-Rate connectors show good performance up to 6GHz+ with integrated ground plane**
- **Simulations show 40dB isolation**
- **More isolation possible with extra pin separation**

Quantity	Cost Ea
1-999	$7.67
1000-9999	$6.16
10000+	$5.25









Executive Summary

- **Fully digital phased arrays can provide considerable performance advantages over analog counterparts**
  - **Excellent beam quality, low 2-way sidelobes and high cross-pol isolation, improved dynamic range, advanced calibration techniques, beam adaptivity to scene**
- **Requires overcoming some key challenges**
  - **Data throughput, bandwidth and processing requirements increase with array size**
  - **Necessitates advances in processing algorithms (parallelism) to reduce complexity**
- **Recent advances in commercial systems provide enabling technologies for dMPAR**
- **Large body of knowledge resulting from successful deployment of MPAR-ATD lays groundwork for dMPAR development**
  - **Panel development expertise, calibration methodology, cost reduction techniques, signal processing algorithms, etc.**
- **Partnering with industry and academic sources to leverage existing expertise in digital and analog phased array technology**

Rockwell Collins

Digital Hardware Expertise

MACOM

Microelectronics Design and Manufacturing Expertise

The University of Oklahoma ARRC Advanced Radar Research Center

Signal Processing Expertise