U.S. ARMY RESEARCH, DEVELOPMENT AND ENGINEERING COMMAND

DIGITAL RADAR TECHNOLOGY FOR AIR AND MISSILE DEFENSE

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AMD RADAR MODERNIZATION
CHALLENGES

Legacy radar platforms are stove piped:
- Custom hardware, custom software, single mission
- Upgrades don’t propagate across multiple platforms
- Platforms can’t network capabilities
- Not scalable or sustainable for Army modernization priorities

Can’t adapt to dynamic environments:
- Not jamming resistant, not frequency agile
- Can’t respond to new threats without upgrades

Calibration:
- High precision in-situ calibration is essential for future success of digital radar
DIGITAL COMMON ARCHITECTURE SOLUTION

Digital Radar can be an Open Architecture Modular Solution

- Small, scalable, lightweight form factor \(\rightarrow\) **freedom of movement, mobile radar**
- Repairs and upgrades propagate across platforms \(\rightarrow\) **sustainment of operations**
- Networking between radar platforms \(\rightarrow\) **situational understanding, wide area security**
  - Common architectures mean tri-service sharing of assets and information

Individual Control of ESA at the Element Level \(\rightarrow\) **In-situ Calibration**

- Continuous calibration ensures continuous optimal performance
- Adaptable to emerging threats and changing operational environment

Uncalibrated Radar  \(\rightarrow\) Calibrated Radar  \(\rightarrow\) Beam Shaping to Defeat DRFM/Jamming
Compared analog vs. digital beamforming and beam steering for two frequency bands:

- Used 16 element linear arrays at S- and X-band
- Simulated results represent a perfectly calibrated array
- Beam steering was tested from 0° to 60° off boresight
- Digital module matches simulated results
Digital Module Demonstrates Re-configurability to support Multiple Radar Systems

Multiple simultaneous beams at S- and X-band:
- Digitally steered 4 simultaneous receive beams
- Beams steered up 0° to 60° off boresight
- Excellent agreement between measured and simulated patterns
- Coherently formed and steered beams of two separate radars
ARL DUAL-BAND PROTOTYPE

ARL Demonstrates shared Radar Frequencies with a Single Antenna:
- Dual-band antenna (S- & X-band), in the same aperture
- Dual-polarization (V- & H-) flexibility for ground-based radar
- Similar scaled array performance as currently fielded CTA and AMD radars
  - Return loss: -10 dB or better, gain 37 - 40 dB, 3.0° beam width
- Simultaneous operation of digital dual band systems at S- and X-band frequencies
- Antenna allows full beam control at both frequencies at the same time

ARL has Demonstrated Dual-Band Functionality for Multi-mission Radar
S- AND X-BAND IN ONE ANTENNA

Demonstrated capability at 3.56 GHz and 10.3 GHz:
- Digital transceiver module excites dual-band antenna
- Both V- and H-pol data
- Multiple steering angles (0° to +/- 30°)
- Observed pattern cuts match simulations
SUMMARY

Digital Radar Capabilities:

- Modular solution with a common architecture across platforms
- Formation and scanning of multiple beams, null steering, in-situ adaptability
- Propagates repairs and technology upgrades across all platforms
- Networking between radar platforms
- Small, scalable, lightweight form factor

ARL Novel Dual-band ESA:

- Combines the S- and X-band antennas into a single platform
- Simultaneous S- and X-band operation
- H- and V- polarization diversity in a thin planar structure
- Needs novel material manufacturing methods to scale design

Calibration:

- Leverage re-configurability and computational capabilities inherent to digital arrays
- High precision calibration is essential for digital array technology viable
- Need calibration techniques that are wideband and computationally efficient
- Over the air calibration not feasible in the field
Digital Calibration Algorithms:

- ESA radar functions require high element level phase accuracy
- ARL is investigating in-situ calibration algorithms using digital radar
- These algorithms will be system agnostic and adaptable

Additive Manufacturing for Antennas:

- New antennas lead to increasingly complex geometries with tight tolerances
- Traditional manufacturing techniques can’t meet these requirements
- ARL is leading research on 3D printing of antennas and RF devices
  - Develop electromagnetic materials compatible with 3D printing
  - 3D printing complex antenna designs
Backup Slides
3D PRINTED ANTENNA DESIGN

Non-traditional antennas:
- Simultaneous Multi-Mission capabilities
- Frequency and polarization agility
- Thin, lightweight, planar

Integrated, multi-mission capabilities lead to complex designs:
- Multiple substrates & conductive layers
- Complex geometry: concentric radiators, multiple feeds
- High cost, low volume, long lead times with traditional manufacturing

Additive Manufacturing for RF:
- ARL developing non-traditional, materials-driven approaches to manufacturing
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DUAL LAYER ANTENNA GEOMETRY

Transparent 3D View

Solid Side View

Top Duroid layer

Bottom Rogers 3006 layer

S-Parameters [Magnitude in dB]

18% BW

S-band

Frequency / GHz

3 3.1 3.2 3.3 3.4 3.5 3.6

26% BW

X-band

Frequency / GHz

8.3 8.5 9 9.5 10 10.5 10.8