U.S. ARMY RESEARCH, DEVELOPMENT AND ENGINEERING COMMAND

DIGITAL RADAR TECHNOLOGY FOR AIR AND MISSILE DEFENSE

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AMD RADAR MODERNIZATION CHALLENGES

Images source: internet (unclassified)

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

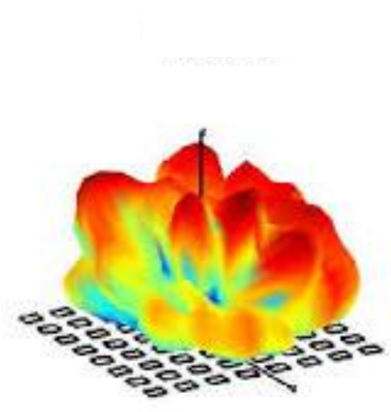
DIGITAL COMMON ARCHITECTURE SOLUTION

Digital Radar can be an Open Architecture Modular Solution

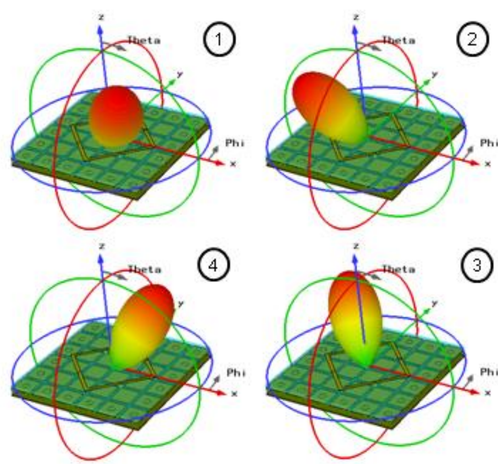
- Small, scalable, lightweight form factor ➡ **freedom of movement, mobile radar**
- Repairs and upgrades propagate across platforms ➡ **sustainment of operations**
- Networking between radar platforms ➡ **situational understanding, wide area security**
  - Common architectures mean tri-service sharing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

Individual Control of ESA at the Element Level ➡ In-situ Calibration

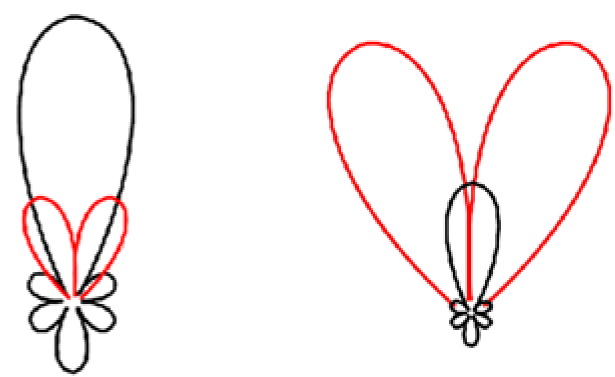
- Continuous calibration ensures continuous optimal performance
- Adaptable to emerging threats and changing operational environment



Uncalibrated Radar



Calibrated Radar ➡



Beam Shaping to Defeat DRFM/Jamming

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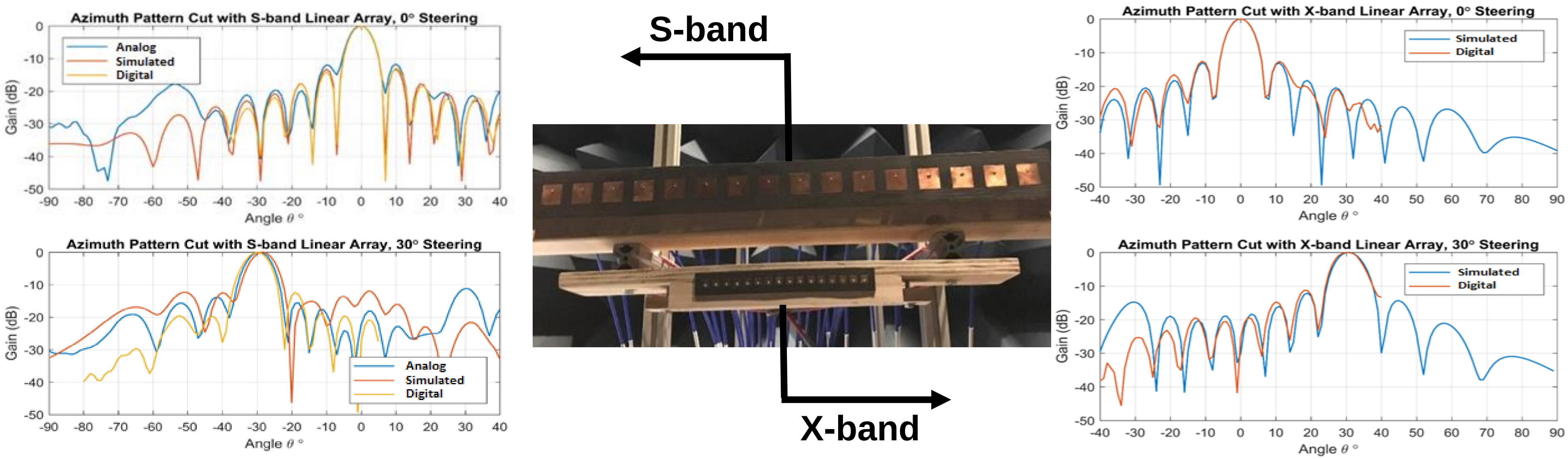
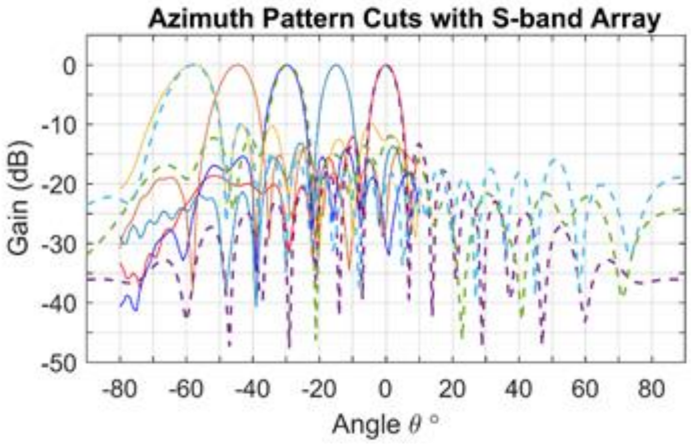
BEAMFORMING AND BEAM STEERING

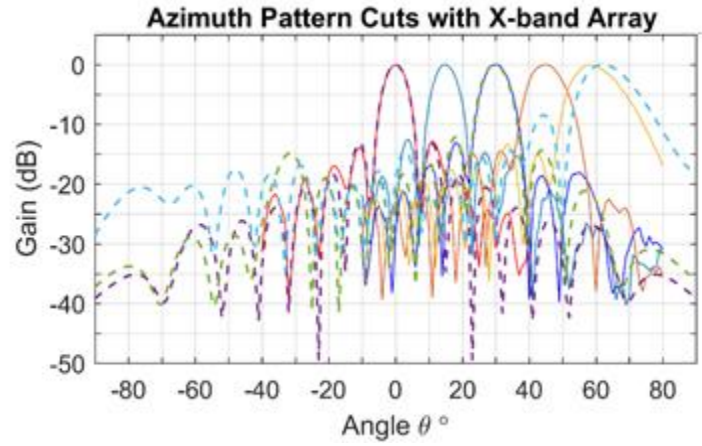


Compared analog vs. digital beamforming and beam steering for two frequency bands:

- 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 BEAMFORMING & BEAM STEERING



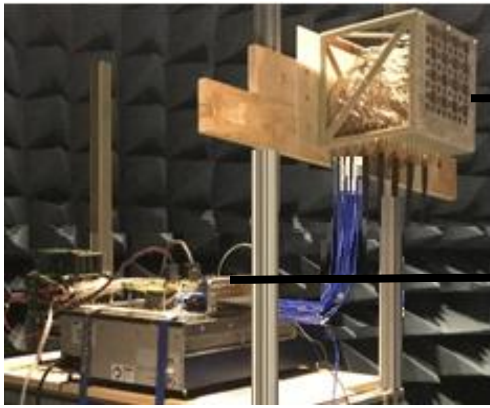


Multiple simultaneous beams at S- and X-band:

- 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

Digital Module Demonstrates Re-configurability to support Multiple Radar Systems

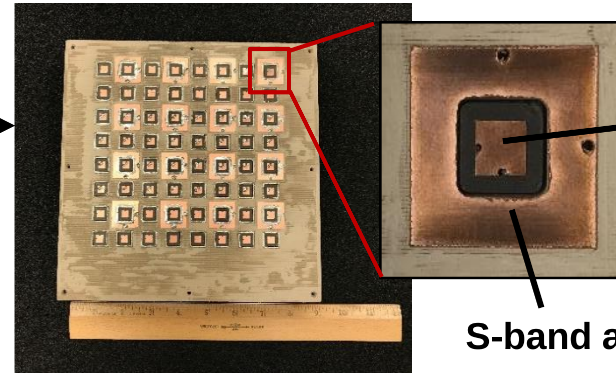
ARL DUAL-BAND PROTOTYPE



S- and X-band ESA*

Fully Digital Radar

2 Radars 1 Platform



X-band antenna

S-band antenna

*patent pending

ARL Demonstrates shared Radar Frequencies with a Single Antenna:

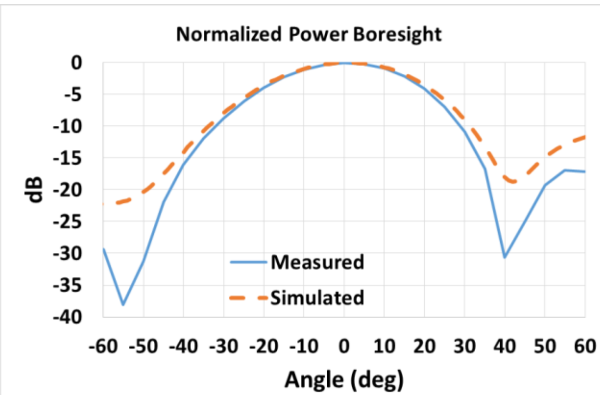
- Dual-band antenna (S- & X-band), in the same aperture
- Dual-polarization (V- & H-) flexibility for ground-based radar
- **Similar scaled array performance as currently fielded CTA and AMD radars**
  - **Return loss: -10 dB or better, gain 37 - 40 dB, 3.0° beam width**
- Simultaneous operation of digital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

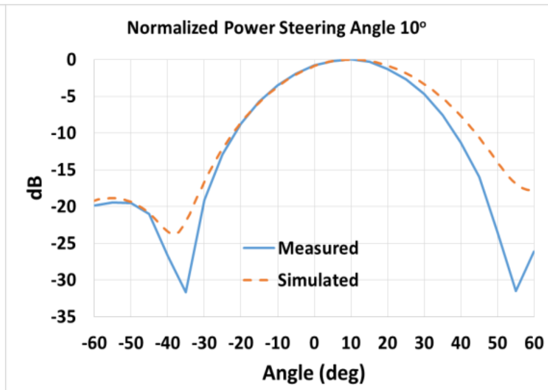
ARL has Demonstrated Dual-Band Functionality for Multi-mission Radar

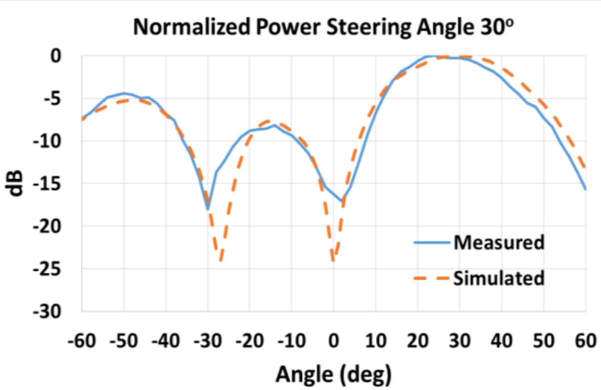
S- AND X-BAND IN ONE ANTENNA

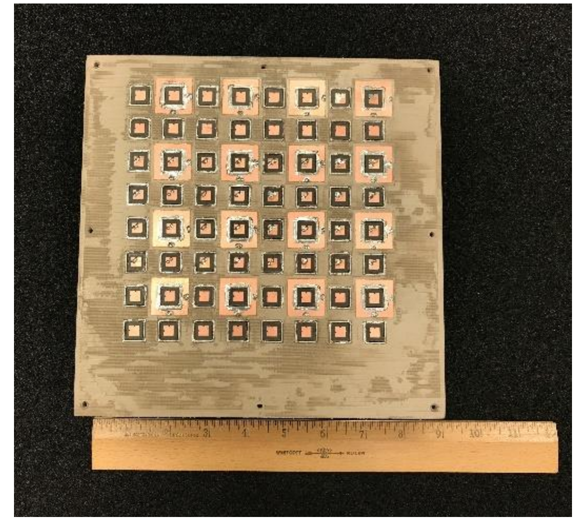
Demonstrated capability at 3.56 GHz and 10.3 GHz:

- Digital transceiver module excites dual-band antenna
- Both V- and H-pol data
- Multiple steering angles (0° to +/- 30°)
- Observed pattern cuts match simulations









S- and X-band ESA*

*patent pending

Dual Band and Dual Polarization Functionality in a Common Digital Architecture

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

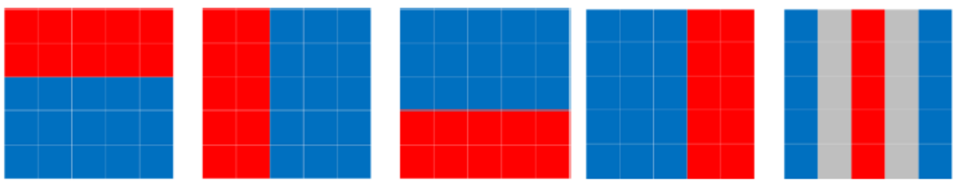
Calibration:

- **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

FUTURE WORK

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



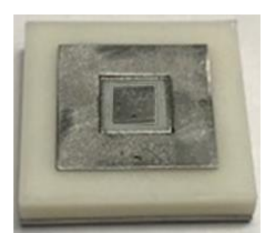
Nearest Neighbor Technique → Array elements act as transmitters to calibrate to their nearest neighbors in place over an over the air transmitter

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

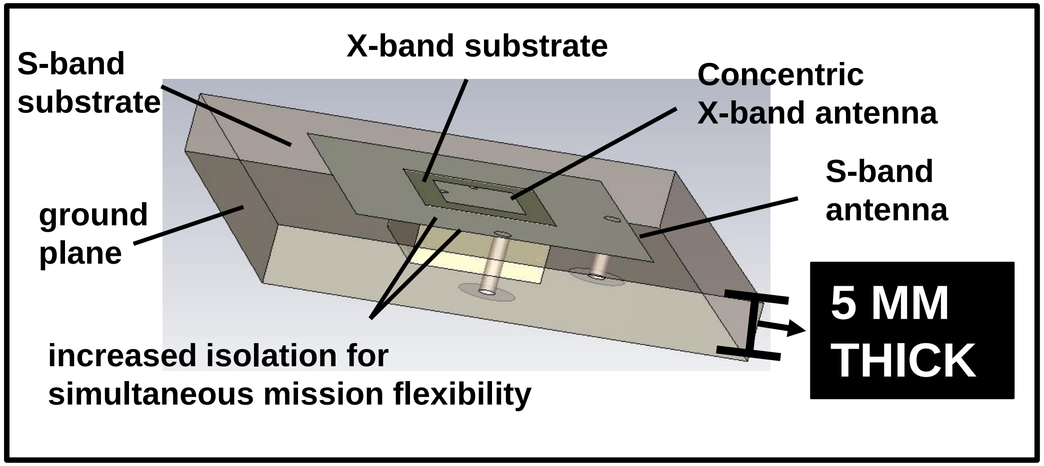
Integrated multi-mission capabilities lead to complex antenna designs

Complex hybrid material 3D printed antenna prototypes

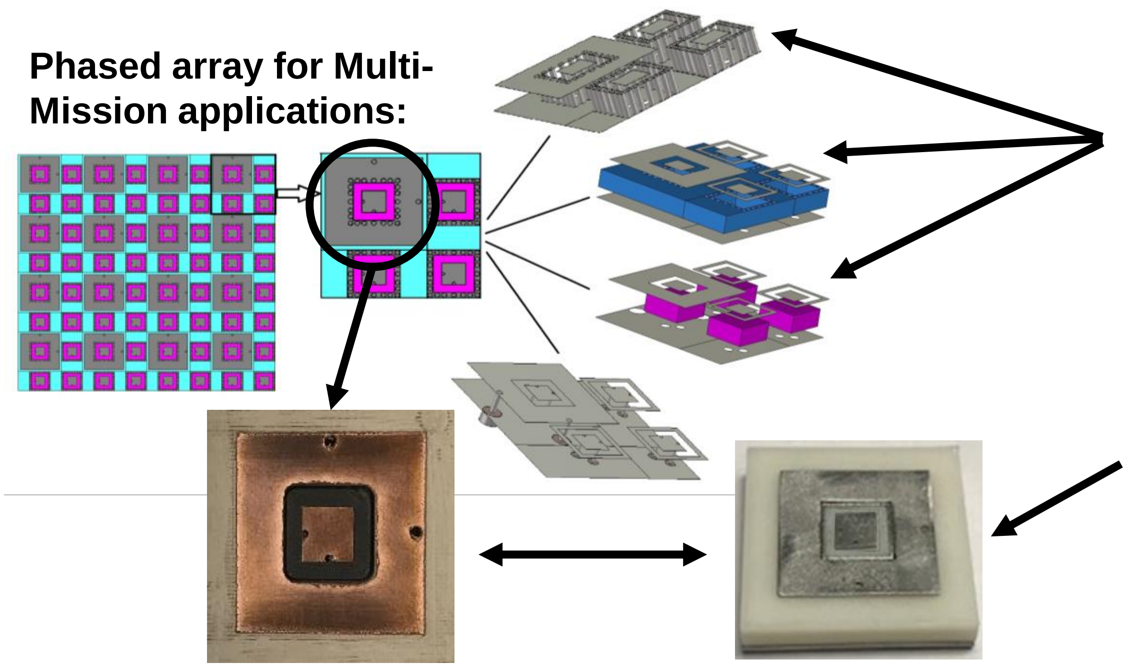


Backup Slides

3D PRINTED ANTENNA DESIGN



Phased array for Multi-Mission applications:



Non-traditional antennas:

- Simultaneous Multi-Mission capabilities
- Frequency and polarization agility
- Thin, lightweight, planar

Integrated, multi-mission capabilities lead to complex designs:

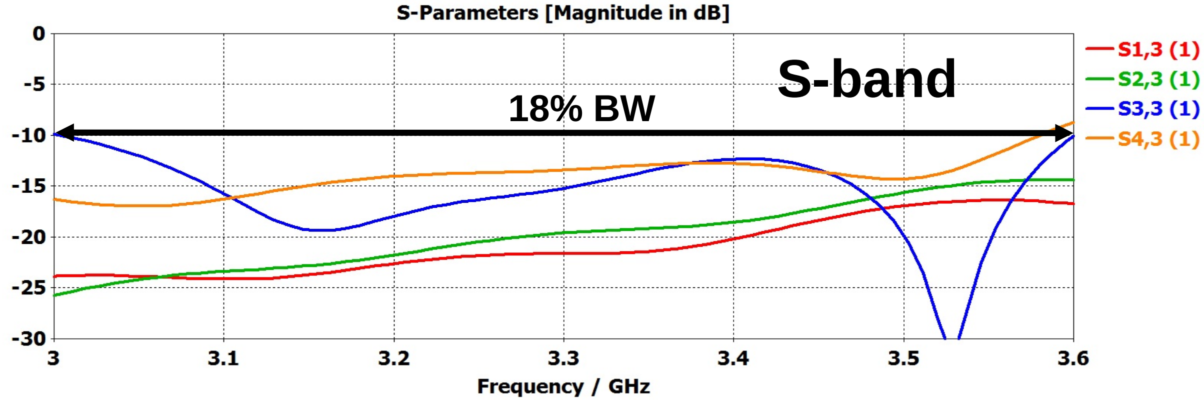
- Multiple substrates & conductive layers
- Complex geometry: concentric radiators, multiple feeds
- High cost, low volume, long lead times with traditional manufacturing

Additive Manufacturing for RF:

- ARL developing non-traditional, materials-driven approaches to manufacturing

DUAL LAYER ANTENNA GEOMETRY

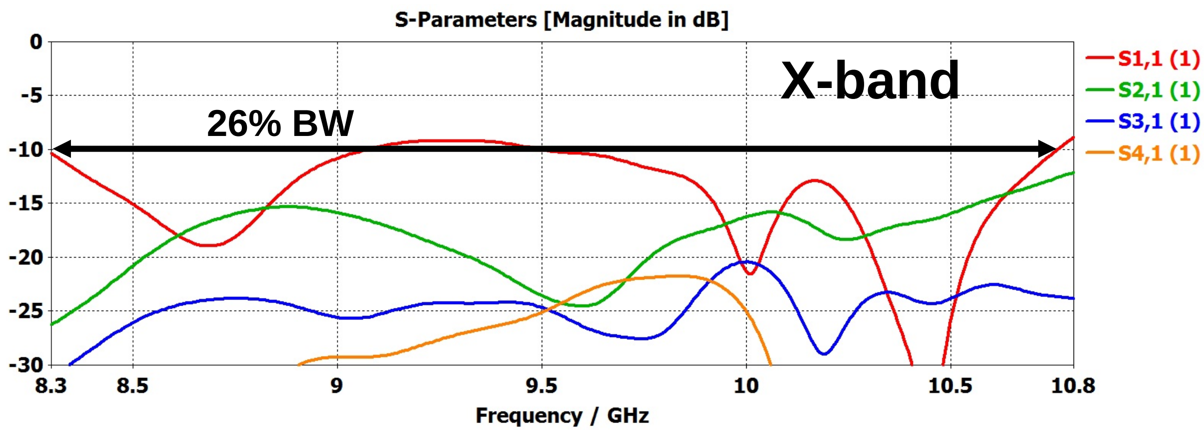
Transparent 3D View



Solid Side View

Top Duroid layer

Bottom Rogers 3006 layer



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