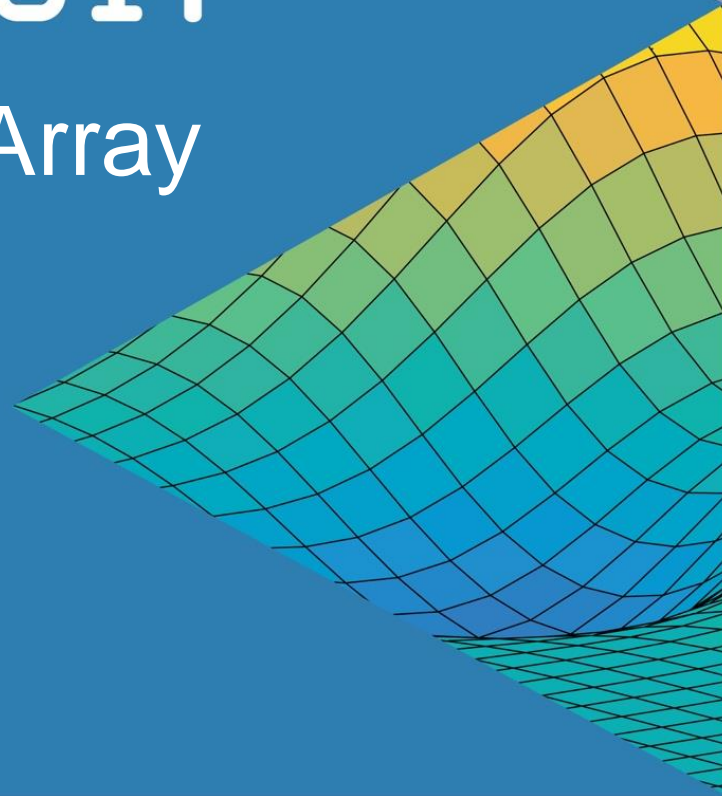# MATLAB EXPO 2017

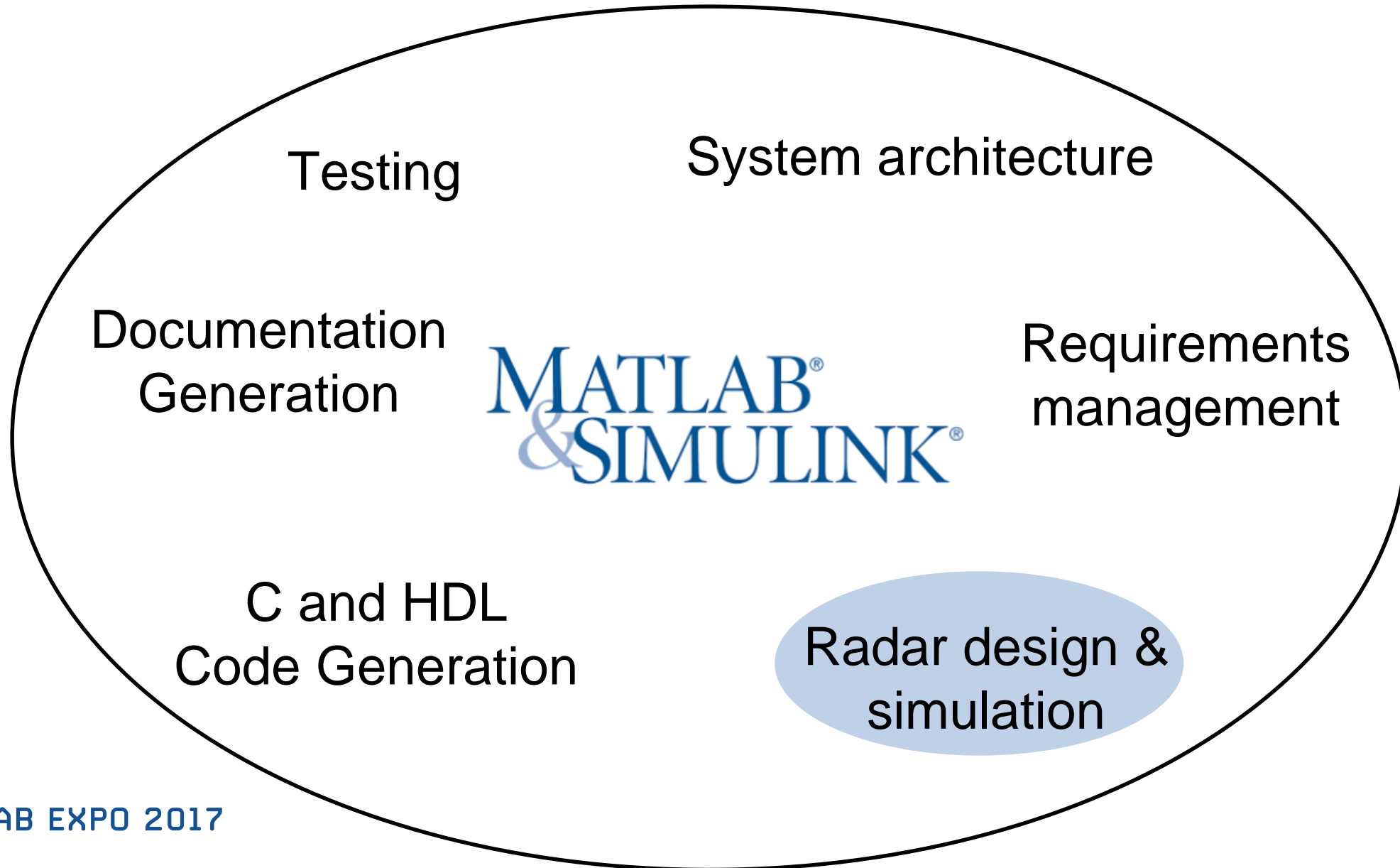# System Design for Phased Array Radars

Rick Gentile
Product Manager
Signal Processing and Communications

Trends in AESA Radar Systems

- Phased Array technology is pervasive

- Array structures are complex – conformal arrays are required

- Predicting system performance most valuable early in the project

- Requirements for robust operations in the presence of interference

- Wideband applications are expanding rapidly

- Multi-function, multi-domain systems are complex (radar, EW, comms)

Full Coverage of Radar Design Process

Testing

System architecture

Documentation
Generation

MATLAB & SIMULINK®

Requirements
management

C and HDL
Code Generation

Radar design &
simulation

Radar System Design: From Antenna to Algorithms

Antenna, Antenna arrays
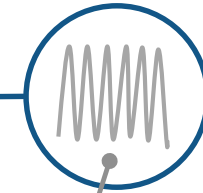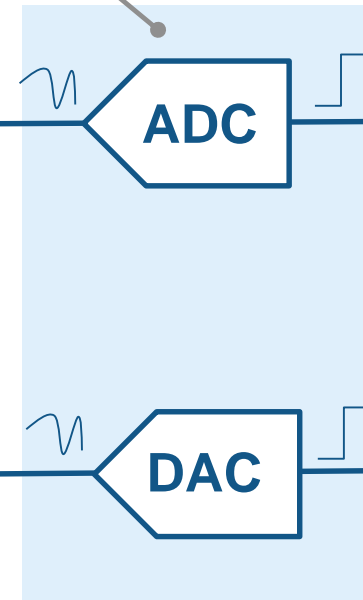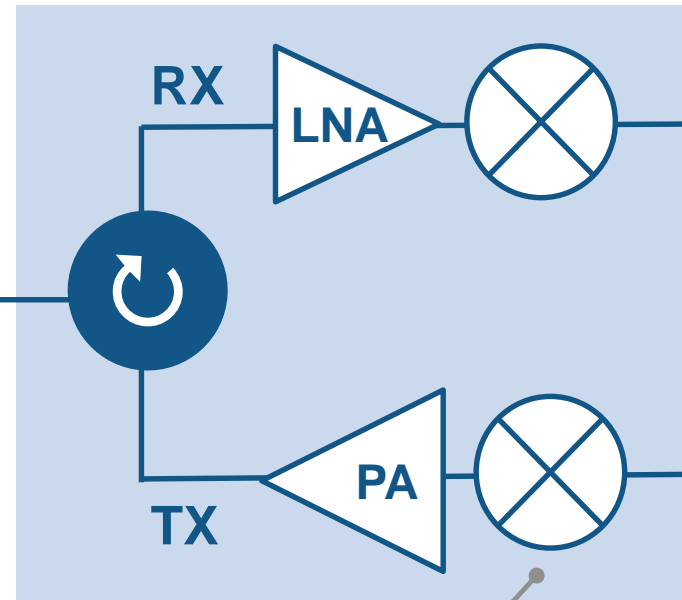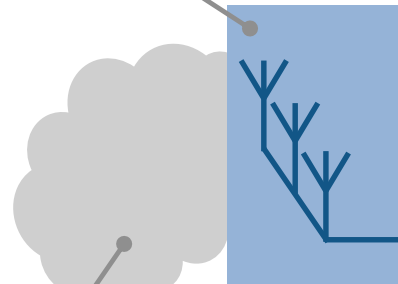*type of element, # elements, configuration*

- **Antenna Toolbox**
- **Phased Array System Toolbox**

Mixed-Signal
Continuous & discrete time

- **Simulink**
- **DSP System Toolbox**
- **Control System Toolbox**

Algorithms
beamforming, beamsteering, MIMO

- **Phased Array System Toolbox**
- **Communications System Toolbox**
- **DSP System Toolbox**

RX
LNA

ADC

Signal Processing

TX
PA

DAC

- **Communications System Toolbox**
- **Phased Array System Toolbox**

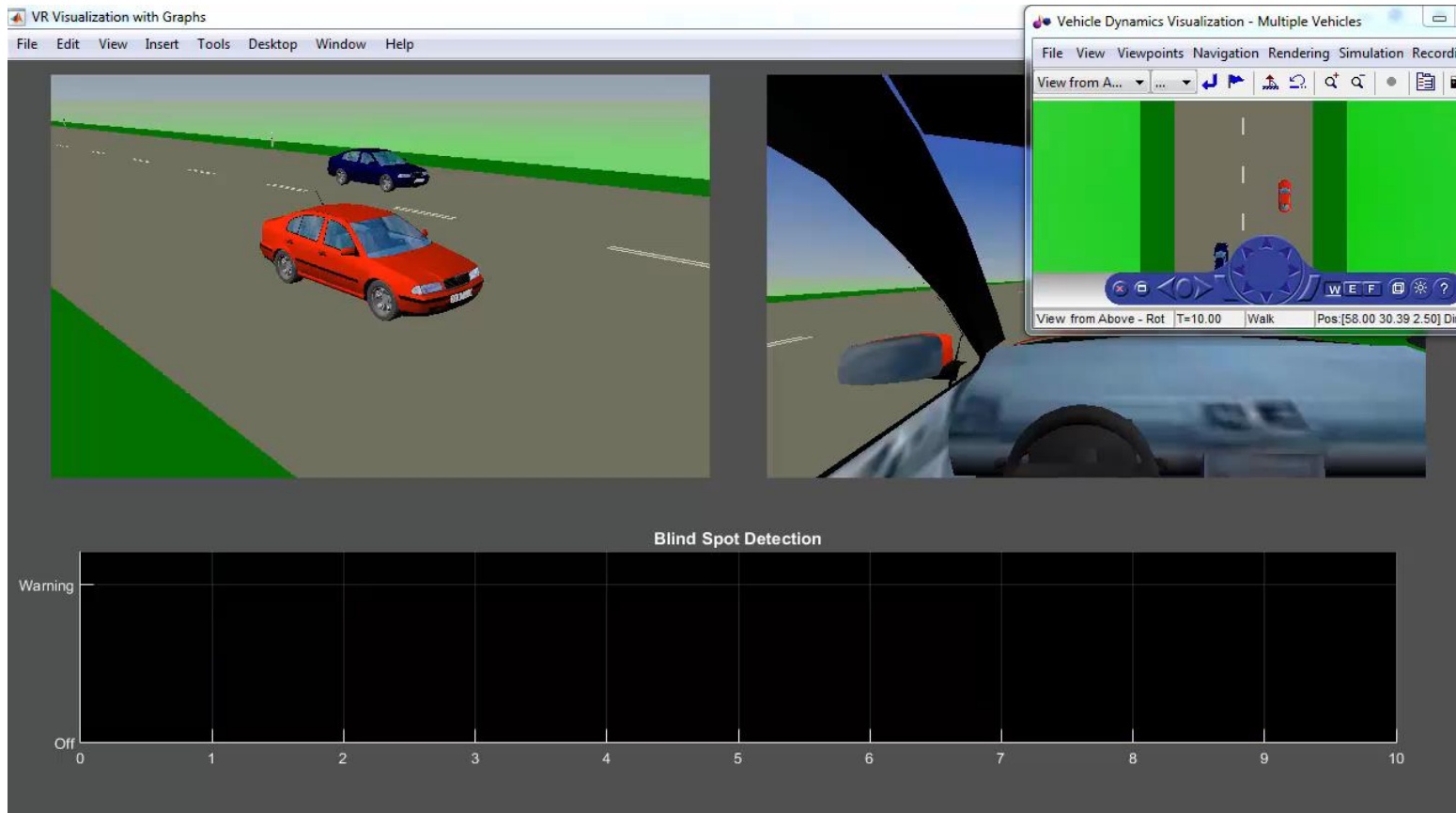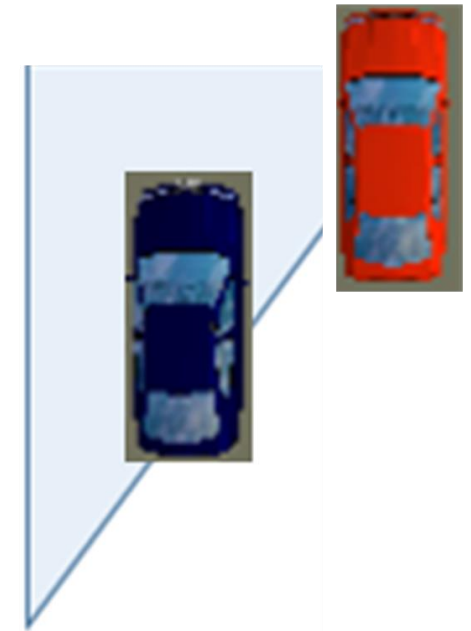**Channel -** *interference, clutter, noise*

- **RF Blockset**
- **RF Toolbox**

- **Phased Array System Toolbox**
- **Signal Processing Toolbox**
- **SimEvents**
- **Instrument Control Toolbox**

RF Impairments
frequency dependency, non-linearity, noise, mismatches

Waveforms & Resource Scheduling
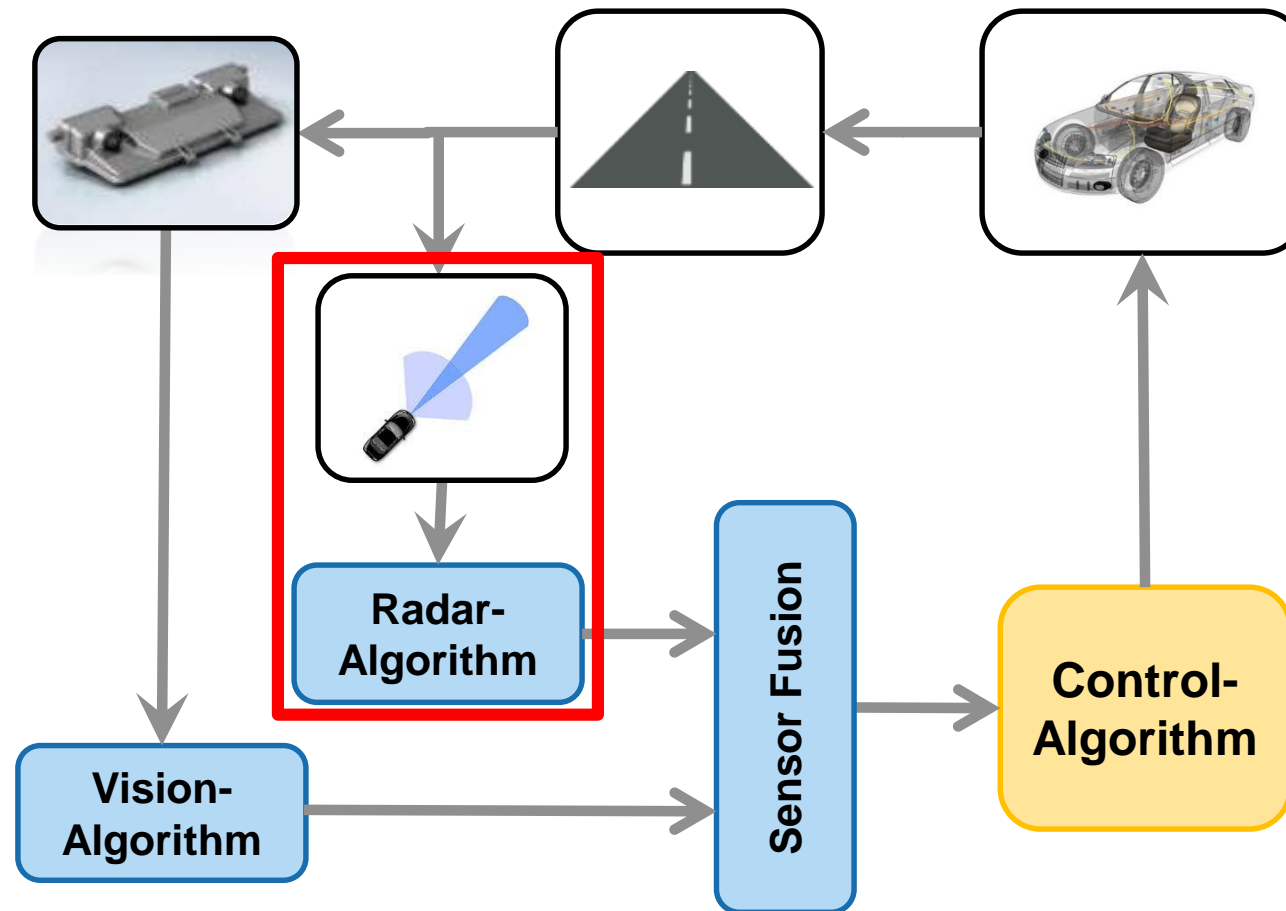
Automotive Radar Modeling

- How can we use a radar to see this region of interest?

- What kinds of parameters can we determine from a model?
  - Detection
 - Angle of arrival
  - Distance
  - Direction

Modeling ADAS Features in Simulink

Integrate <u>sensing</u> (radar, vision, etc…) and <u>control</u> algorithms

Multifunction Space-Time Adaptive Processing (STAP) Radar Model
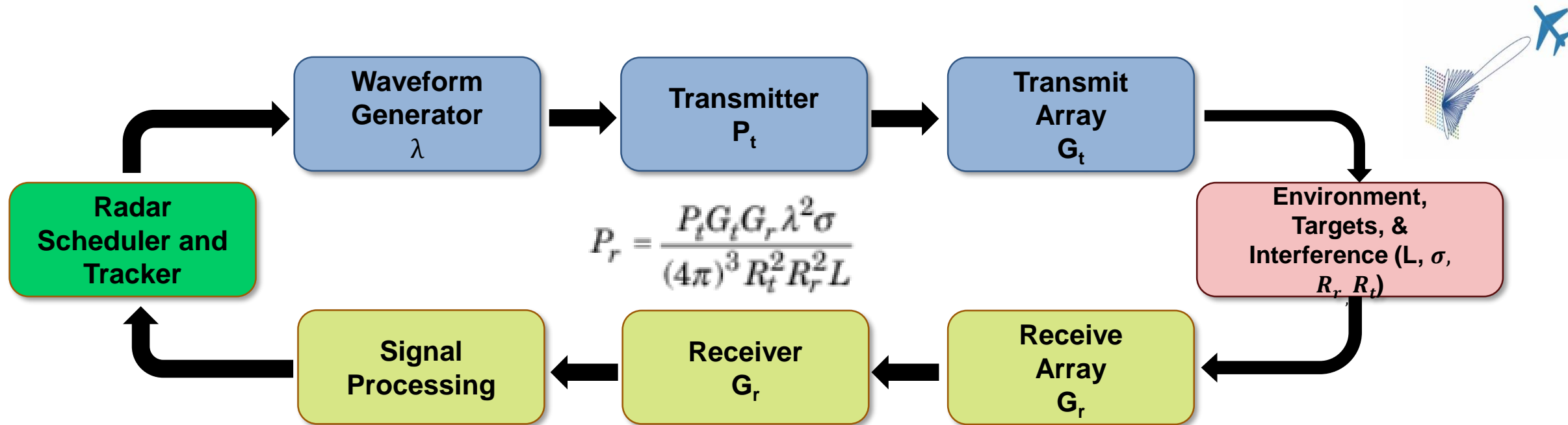
- What is needed to model radar systems?
  - Phased array antenna
  - Receiver/Transmitter
  - Propagation channel
  - Target(s)
  - Interference
  - Clutter
  - Signal processing algorithms
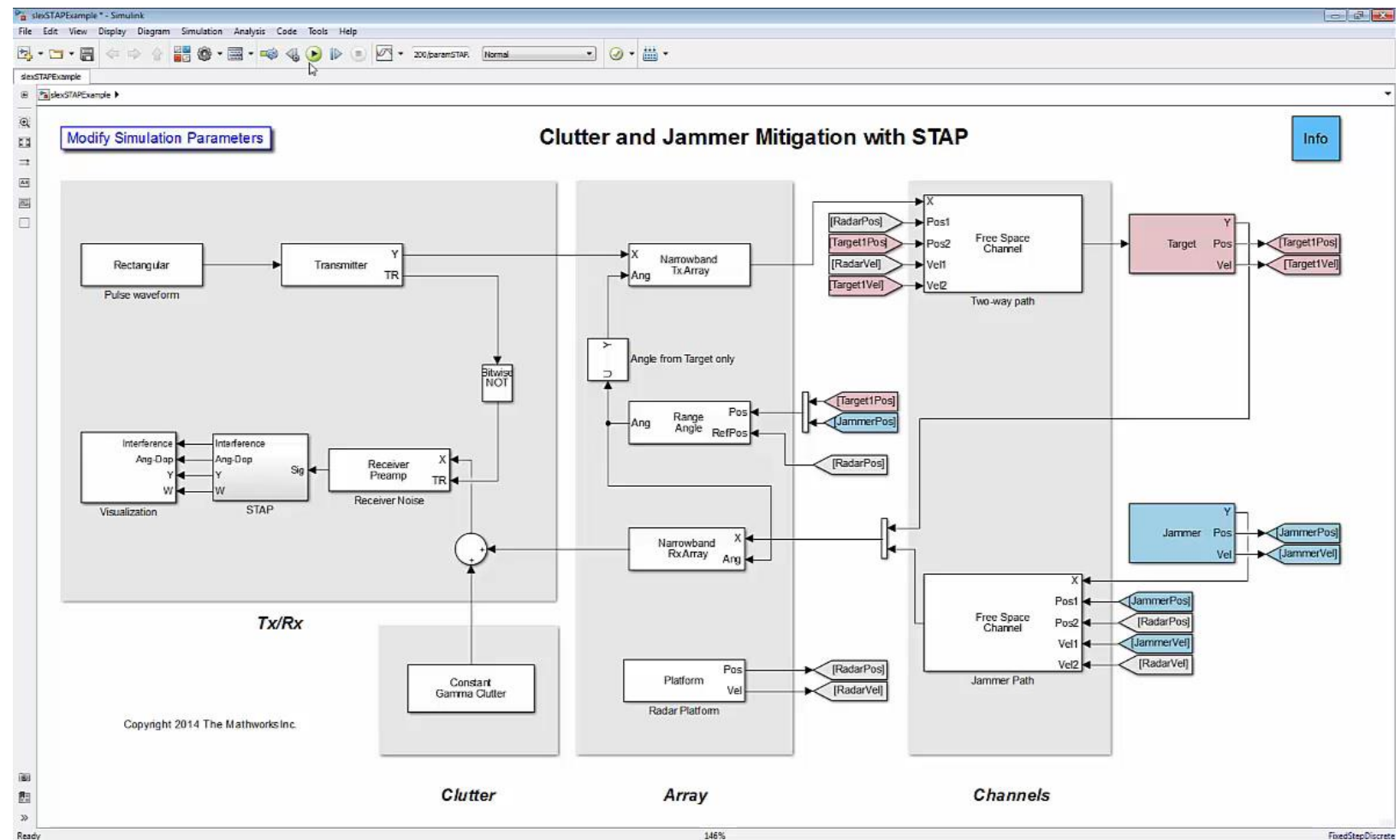
Objectives for MathWorks Radar Simulation Architecture

- Extensible modeling tools for phased array radar design
  - Reduce risk of complex system development
  - Signal level simulation to ensure understanding before system is designed and built

- Multi-domain system modeling for radar systems
  - RF, signal processing, data processing, etc.

- Path to higher fidelity and customization
  - Model should match closely with end system

- Live specification for model-based design
  - Encourage re-use through project phases and across projects
 - Provide early model of system to your customers

Simulation Framework Overview

Waveform Generator λ → Transmitter P_t → Transmit Array G_t → Environment, Targets, & Interference (L, σ, R_r, R_t) → Receive Array G_r → Receiver G_r → Signal Processing → Radar Scheduler and Tracker → Waveform Generator

$$P_r = \frac{P_t G_t G_r \lambda^2 \sigma}{(4\pi)^3 R_t^2 R_r^2 L}$$

- Functions for calculations and analysis
- Apps for common workflows
- Parameterized components for system modeling
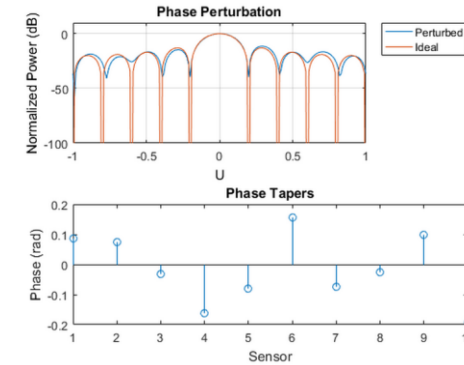- Code generation for deployment
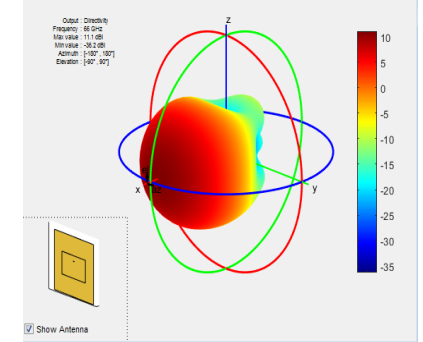
Array Modeling

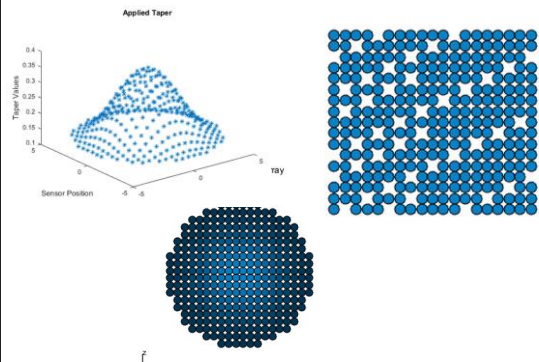Design an array
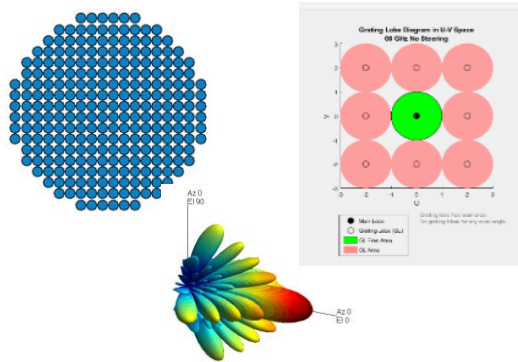
Design subarrays
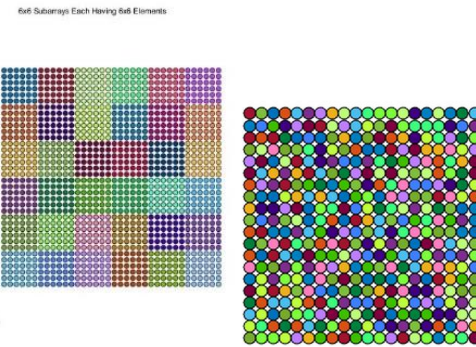
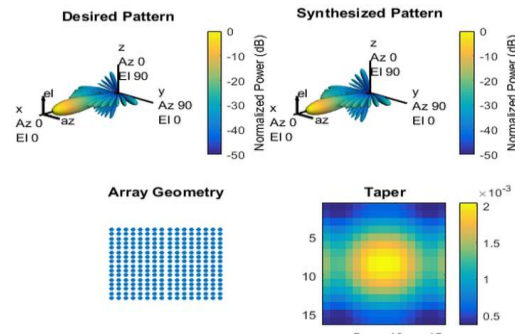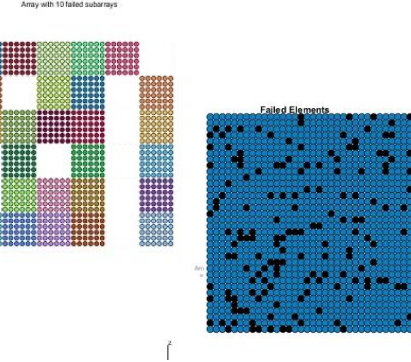
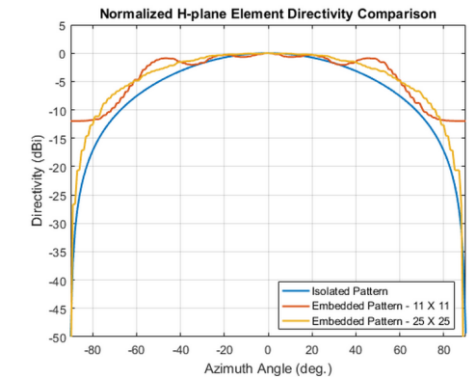Model imperfections

Import antenna patterns

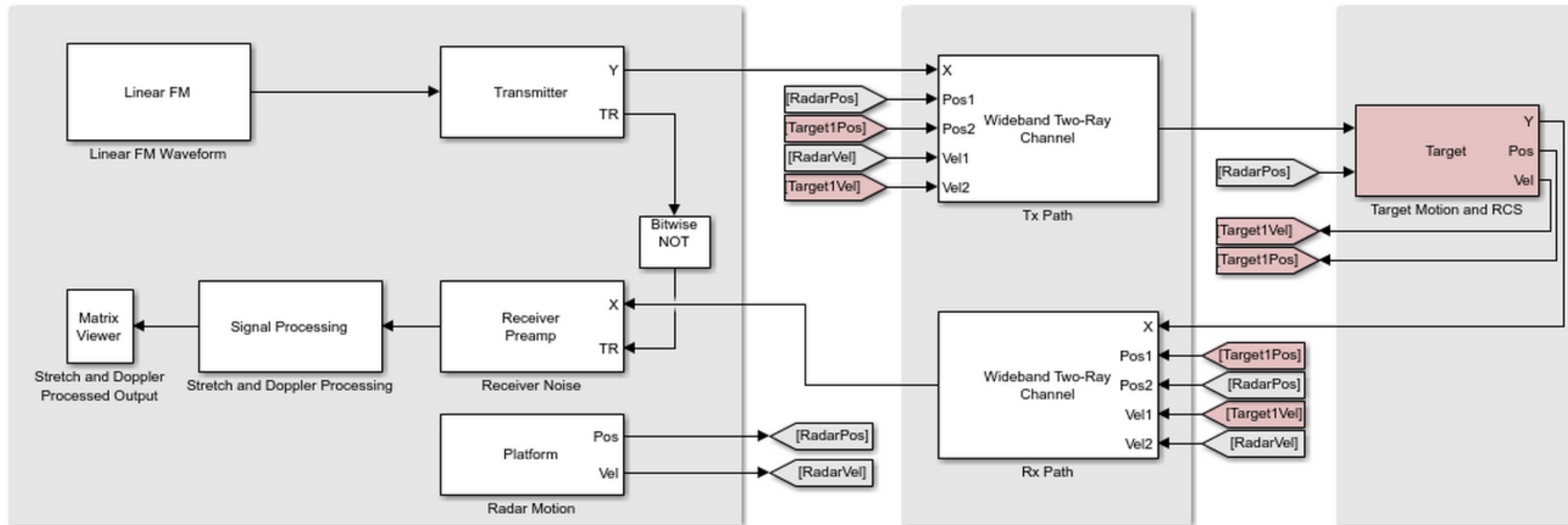Taper/thin arrays

Synthesize arrays

Model failures

Model mutual coupling

Similar capabilities for other radar components

System Level Validation

Wideband Radar with One Target in a Separable Multipath Environment

MATLAB EXPO 2017

11

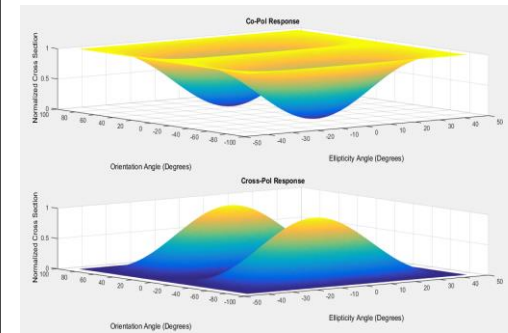# Supporting Capabilities for Radar Systems
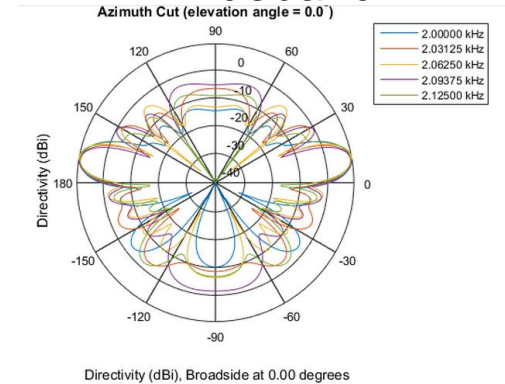
Data cube processing
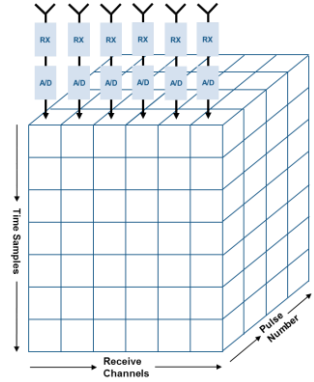
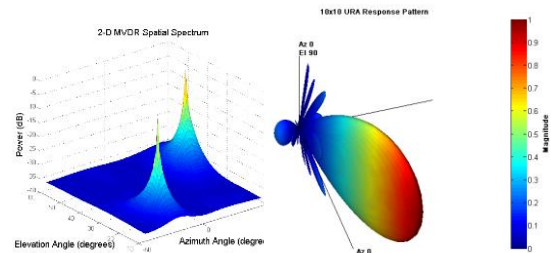## Scenario visualization
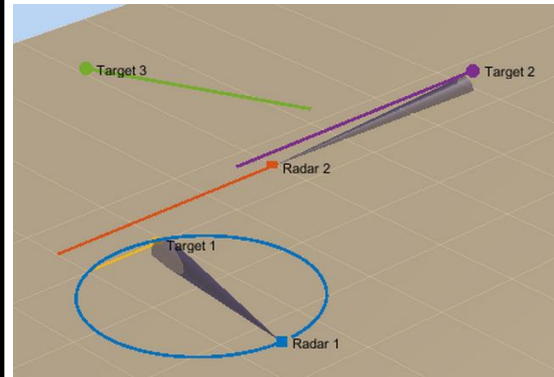
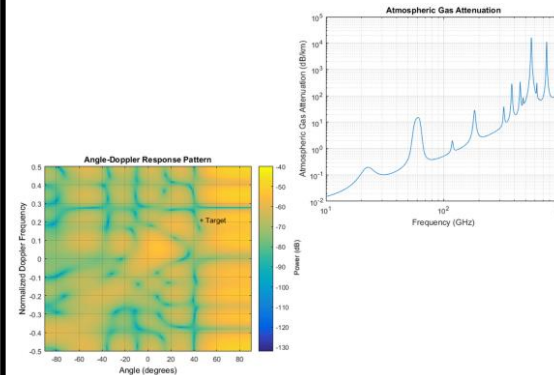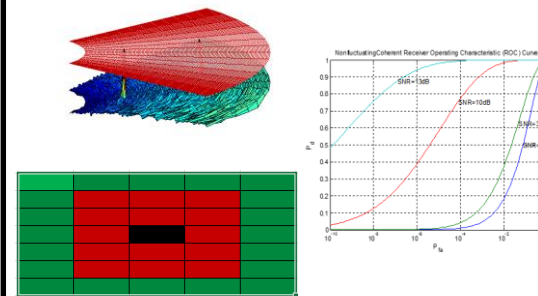## Polarization

Wideband

Spatial signal processing

Environment

CFAR

Code generation

Path to Higher Fidelity

- Extend model fidelity over project evolution

Antenna element	Target model	Propagation model	RF signal chain
Ideal elements	Point target	Free space	Baseband
EM solver with mutual coupling	Synthesized backscatter (angle & frequency)	Line of sight atmospheric effects	RF components
Measured pattern import	Measured return (angle & frequency)	Multipath, terrain and ducting effects	Multi-domain simulation

- Simple interface to replace off-the-shelf components with custom ones

Case Studies: Staggered PRF Radar

Dynamic PRF/Waveform selection based radar detections

Closed loop between radar model and scheduler
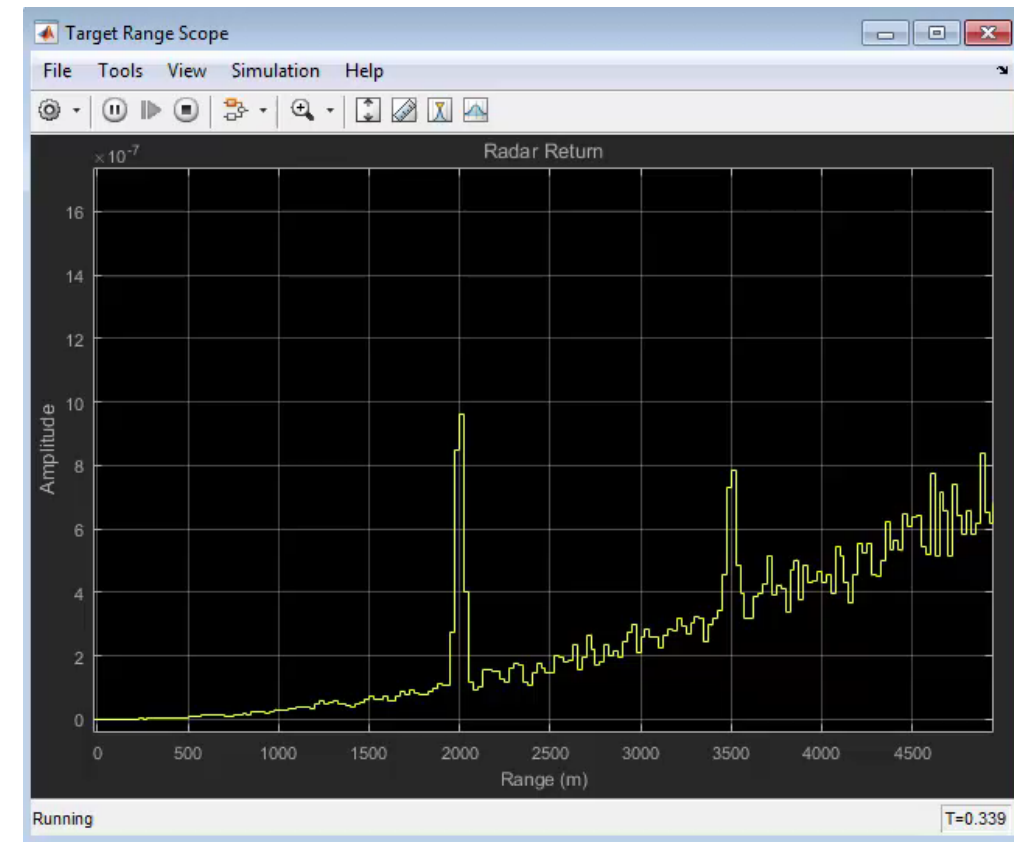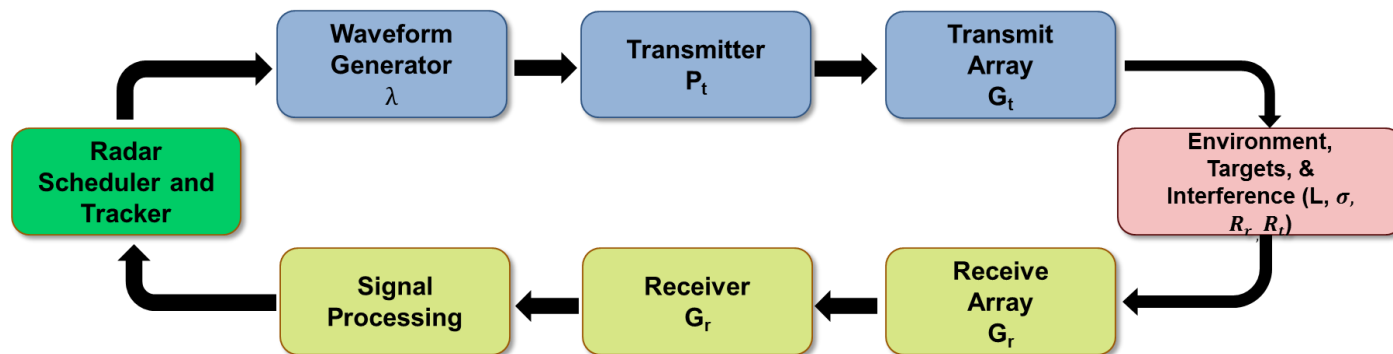
Case Studies: Modeling a Radar Scheduler

Dynamic & static events

Case Studies: Model-Based Design of an MTI Radar

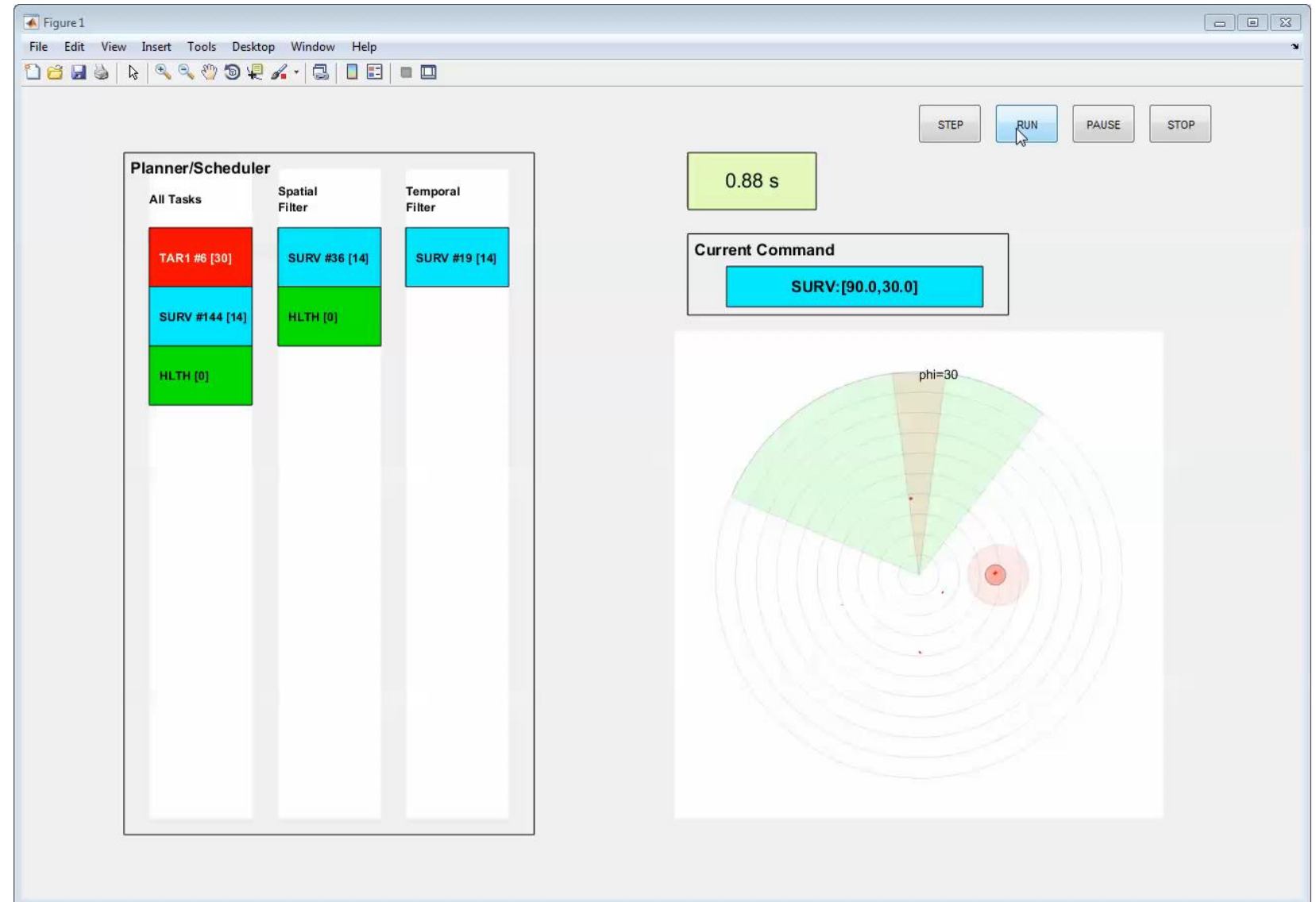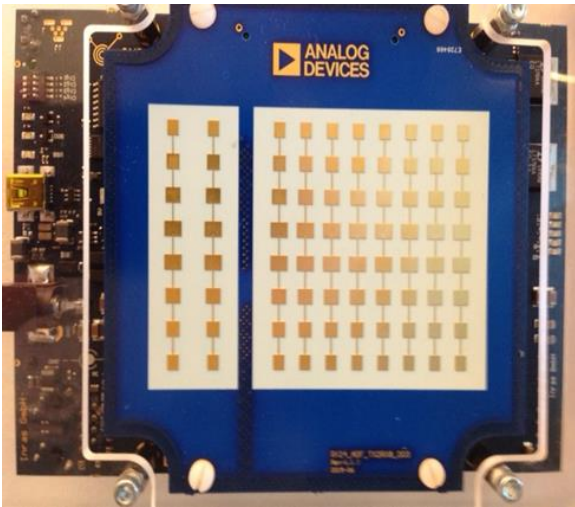Develop and test with synthesized data

Verification with measured data

8 channel Rx array
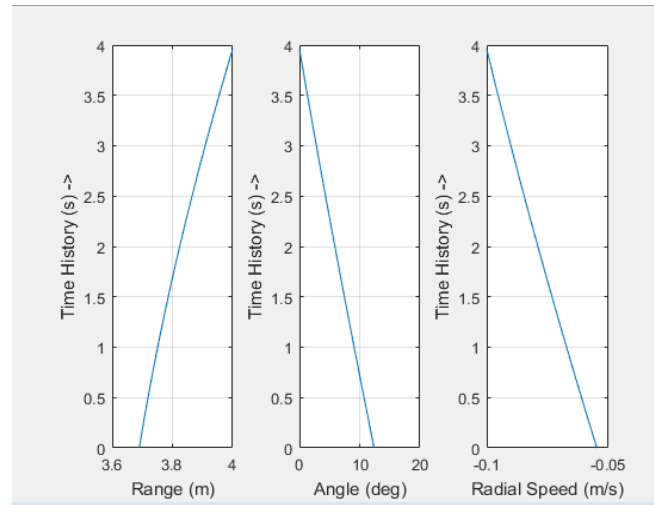
Range   Angle   Radar

Workflow

- Model-based simulation for algorithm development and validation
  - Scenario synthesis
  - Detection thresholds, CFAR, Beamforming, DOA

- Moving Target Indication
  - Pulse canceller

- Range-Doppler processing

- Antenna effects
  - Mutual coupling
  - Model fidelity

Simulated Target Scenario

Initial phase

MTI Radar Model

Live Target Scenario

Subsequent phase
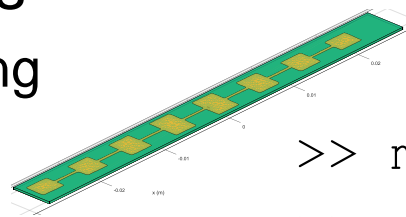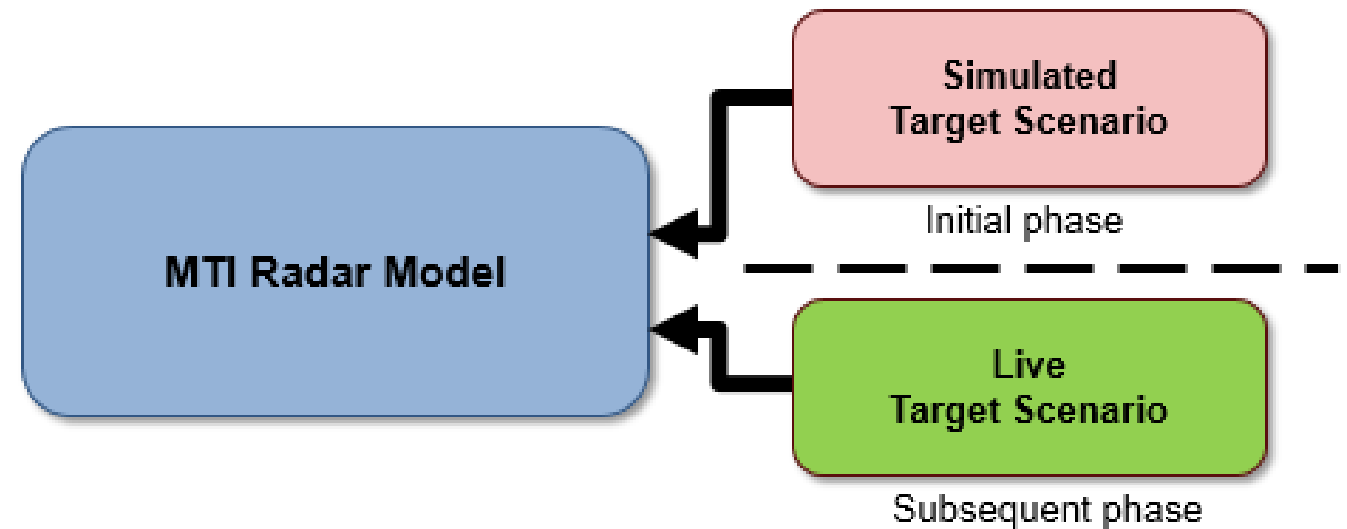
```
>> myURA = phased.URA;
>> myURA.Element = customAntenna;
```

Output: Gain
Frequency: 24 GHz
Max value: 13.7 dBi
Min value: -27 dBi
Azimuth: [-180° , 180°]
Elevation: [-90° , 90°]
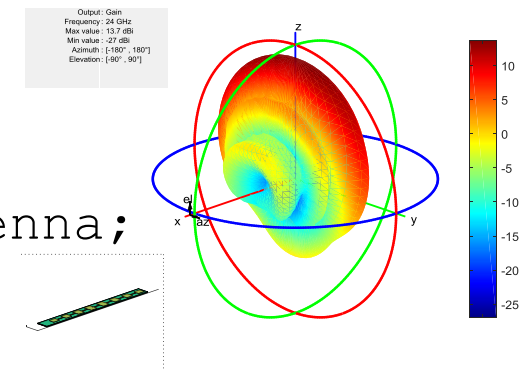
Summary

- Building phased array radar systems is easier with MathWorks tools
  - Phased Array System Toolbox
  - Antenna Toolbox
  - RF Blockset

- Many examples to get started with

- Thank you for attending and please visit our demo station

Explore these examples and more online:
mathworks.com/phased-array-examples

- *Antenna Array Analysis with Custom Radiation Pattern*
- *Array Pattern Synthesis*
- *Mutual Coupling in Large Arrays*
- *Space-Time Adaptive Processing*
- *Designing a Monostatic Pulse Radar*
- *Ground Clutter Mitigation with MTI Radar*
- *Simulating a Bistatic Polarimetric Radar*

Radar System Design: *mathworks.com/radar*

What You Can Do to Learn More

Phased Array System Toolbox

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Trial software | Contact sales

Design and simulate phased array signal processing systems

Phased Array System Toolbox™ provides algorithms and apps for the design, simulation, and analysis of sensor array systems in radar, sonar, wireless communications, and medical imaging applications. The system toolbox includes pulsed and continuous waveforms and signal processing algorithms for beamforming, matched filtering, direction of arrival (DOA) estimation, and target detection. It also includes models for transmitters and receivers, propagation, targets, jammers, and clutter.

The system toolbox lets you model the dynamics of ground-based, airborne, or ship-borne multifunction radar systems with moving

Phased Array System Toolbox Overview

▶ Watch video