

The MATLAB logo graphic is a large, stylized letter 'M' composed of several overlapping triangles in shades of blue and orange. It is positioned on the left side of the image, partially overlapping the hands.

MATLAB EXPO 2018
KOREA

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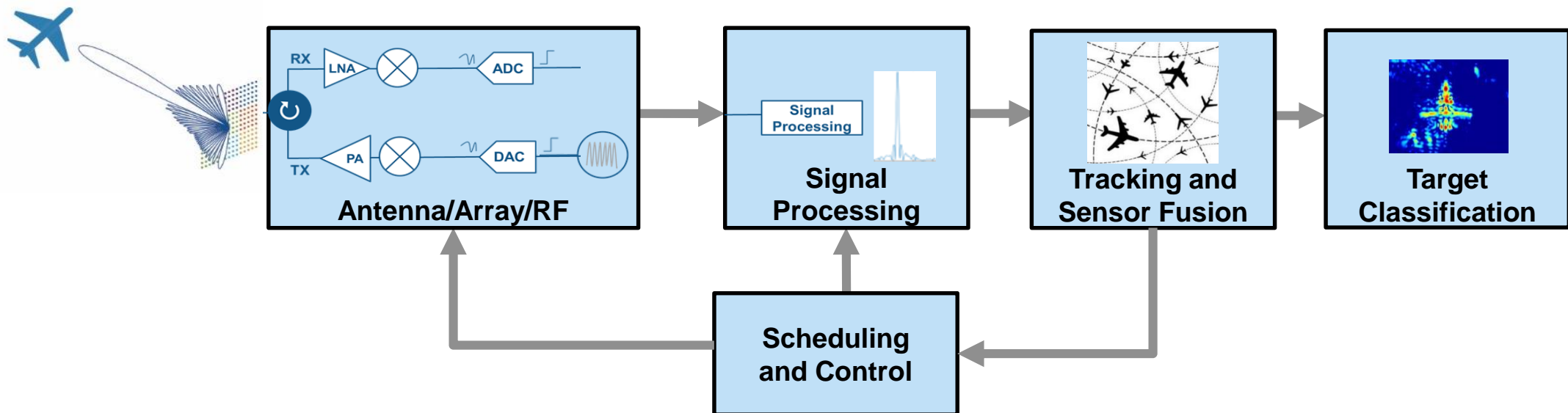
Machine Learning for Radar & EW

서기환 과장

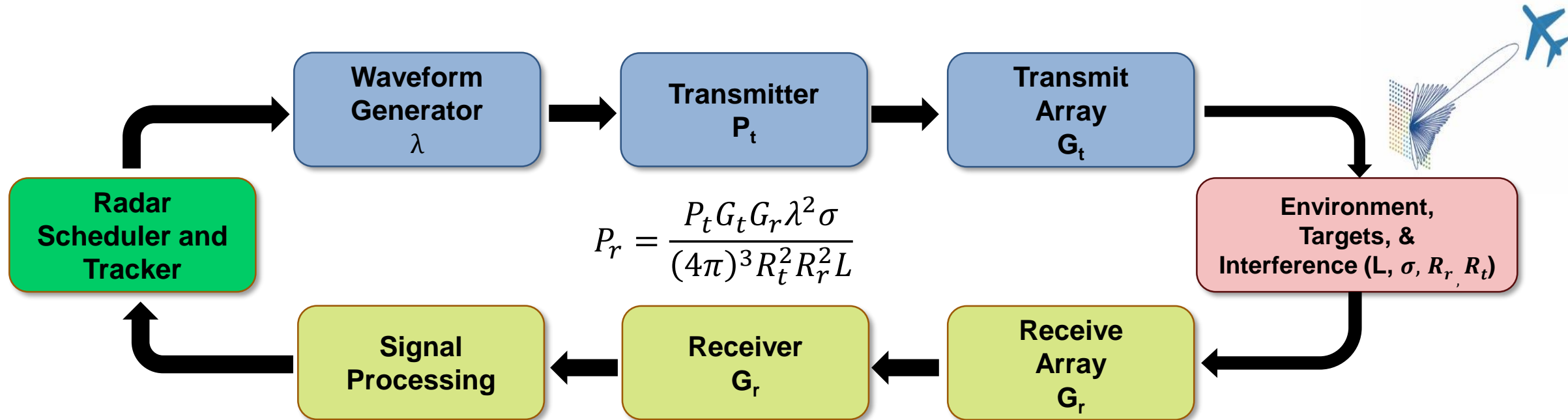


Agenda

- » Radar and EW modeling
- » Synthesizing data for Machine Learning workflows
- » Machine Learning Examples



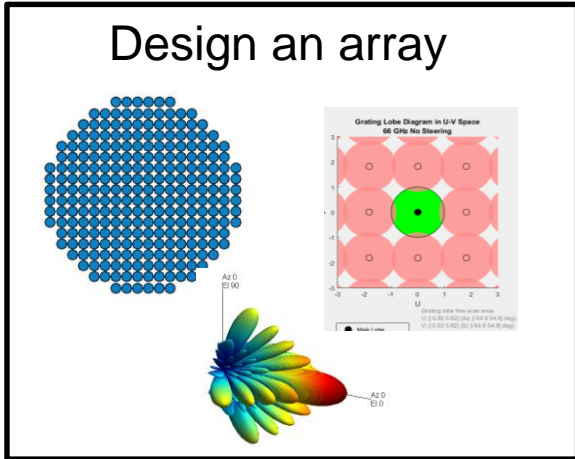
Radar and EW Simulation and Modeling Architecture



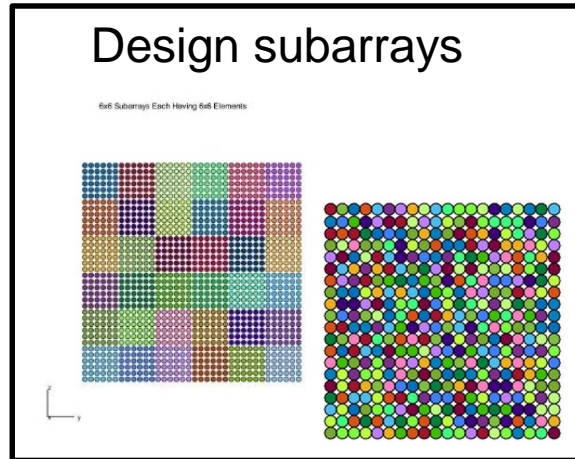
- Functions for calculations and analysis
- Apps for common workflows
- Parameterized components for system modeling
- Easy path to increased fidelity for antenna and RF design
- Code generation for deployment

Design Phased Array Antennas

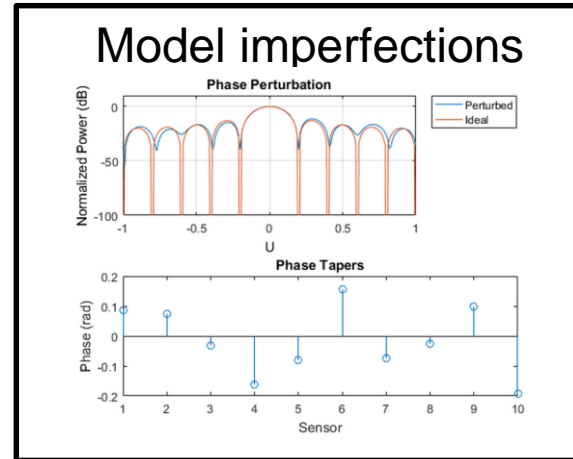
Design an array



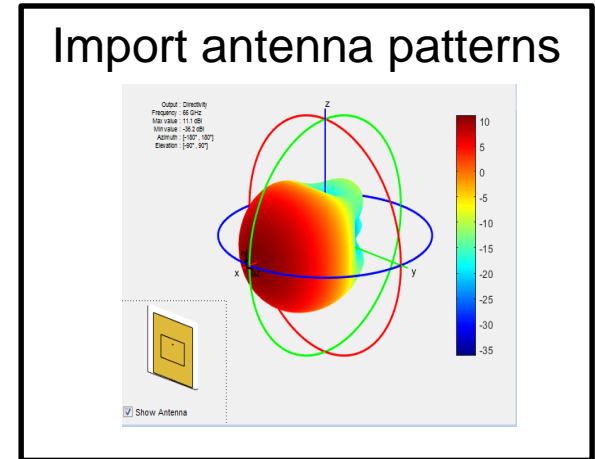
Design subarrays



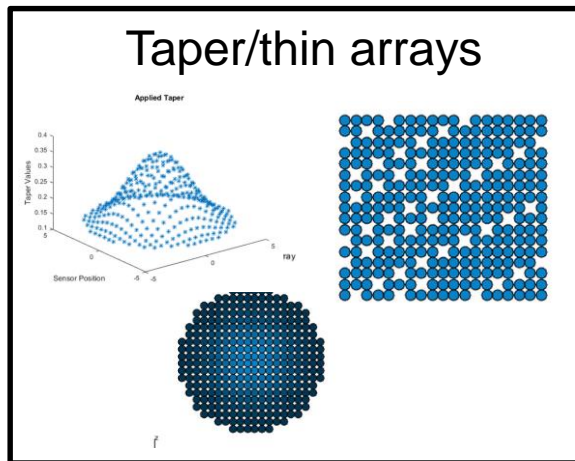
Model imperfections



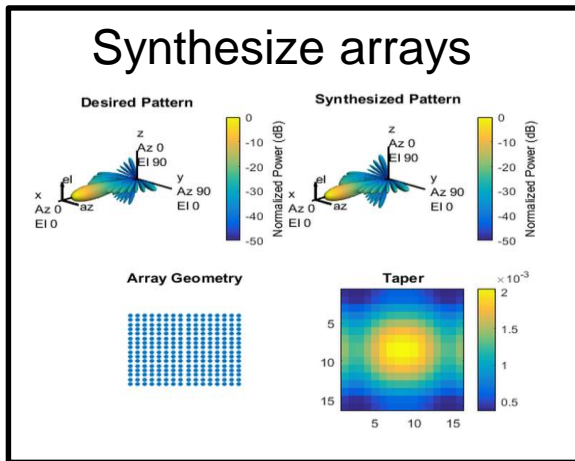
Import antenna patterns



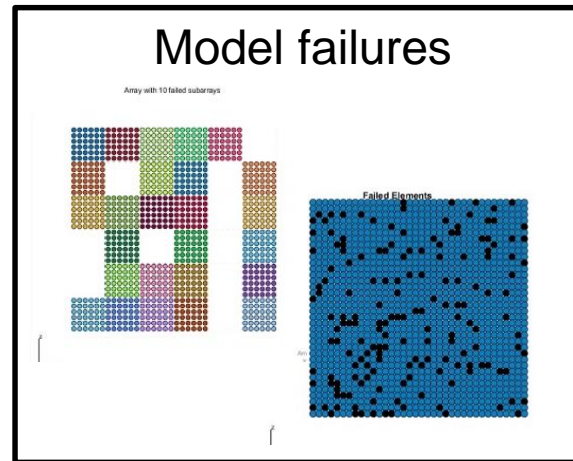
Taper/thin arrays



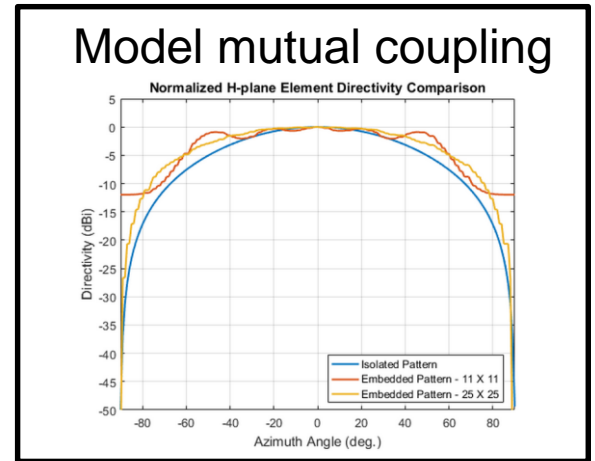
Synthesize arrays



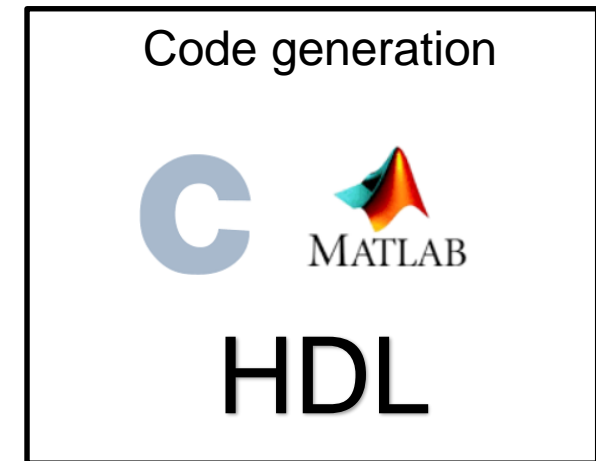
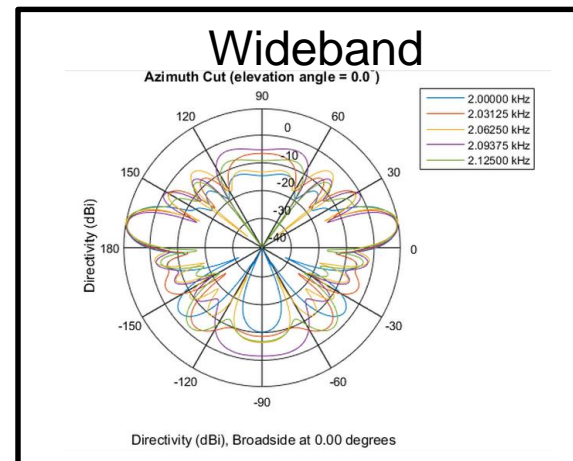
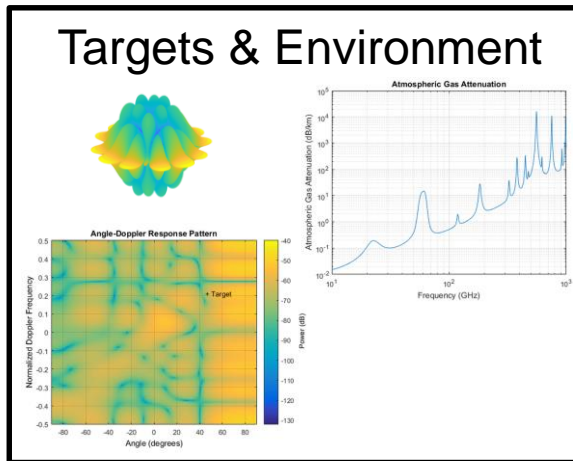
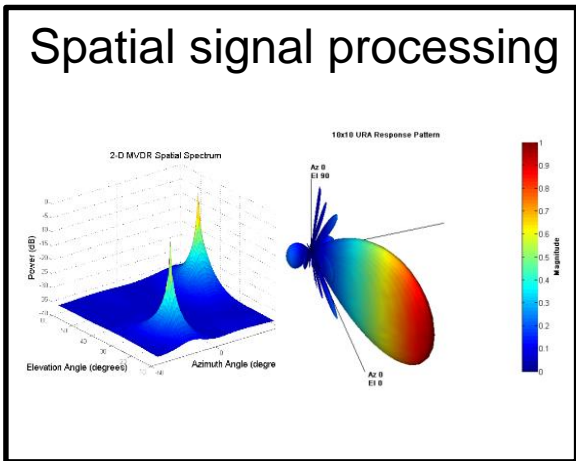
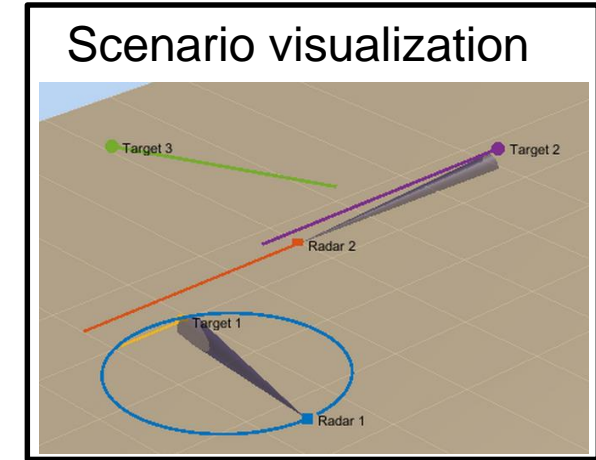
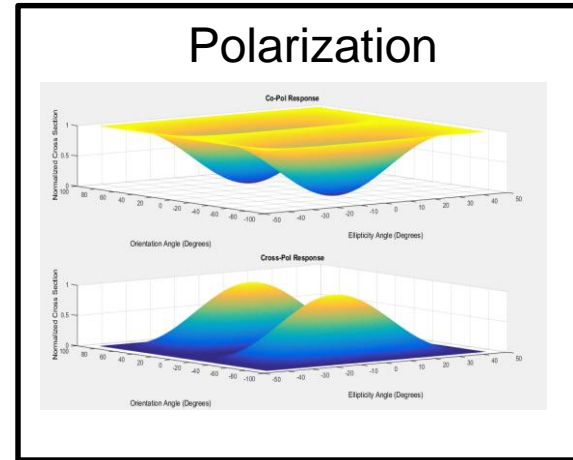
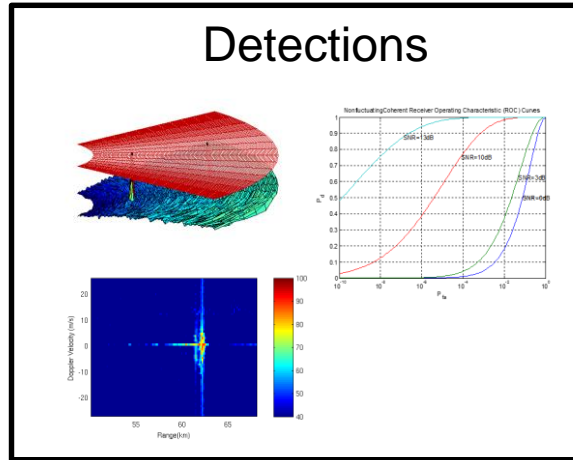
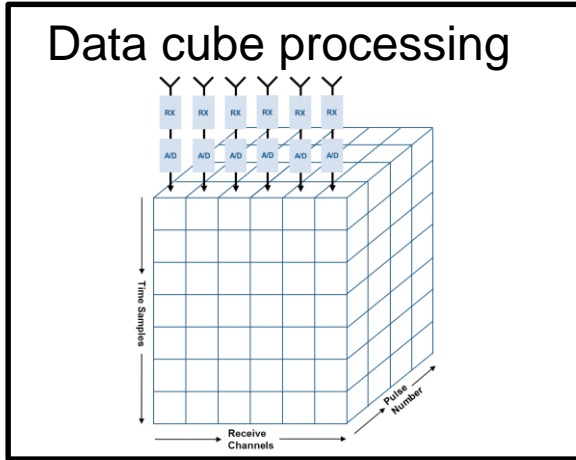
Model failures



Model mutual coupling

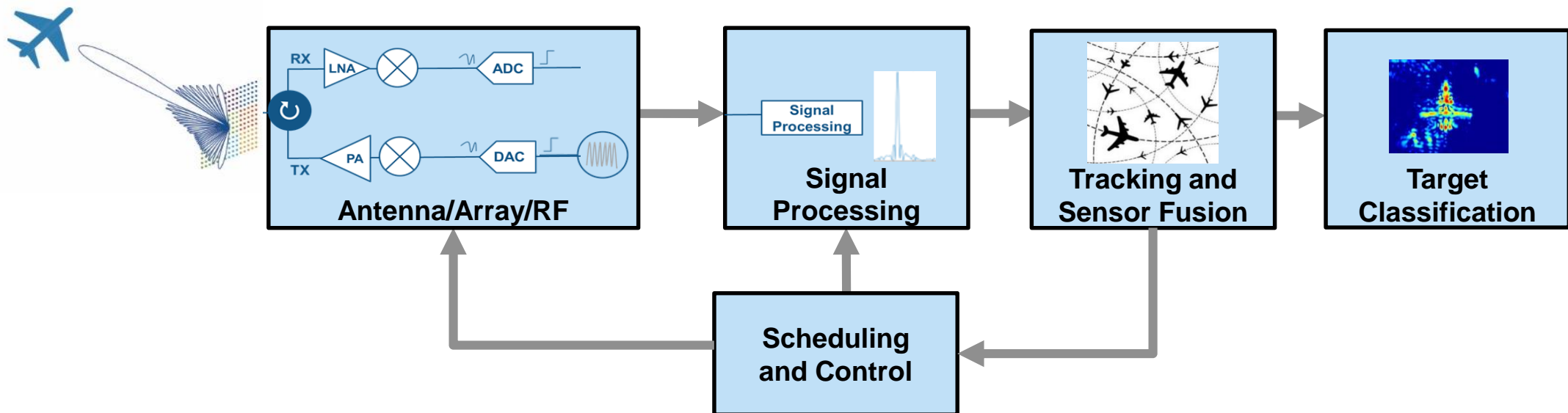


Design Radar and EW Systems



Agenda

- Radar and EW modeling
- » ▪ **Synthesizing data for Machine Learning workflows**
- Machine Learning Examples



Machine Learning Workflow

Access and Explore Data

Preprocess Data

Develop Predictive Models

Integrate Analytics with Systems

Files



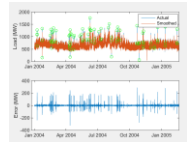
Databases



Sensors



Working with Messy Data



Data Reduction/
Transformation



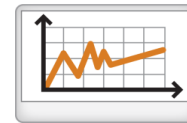
Feature Extraction



Model Creation e.g. Machine Learning



Parameter Optimization



Model Validation



Desktop Apps



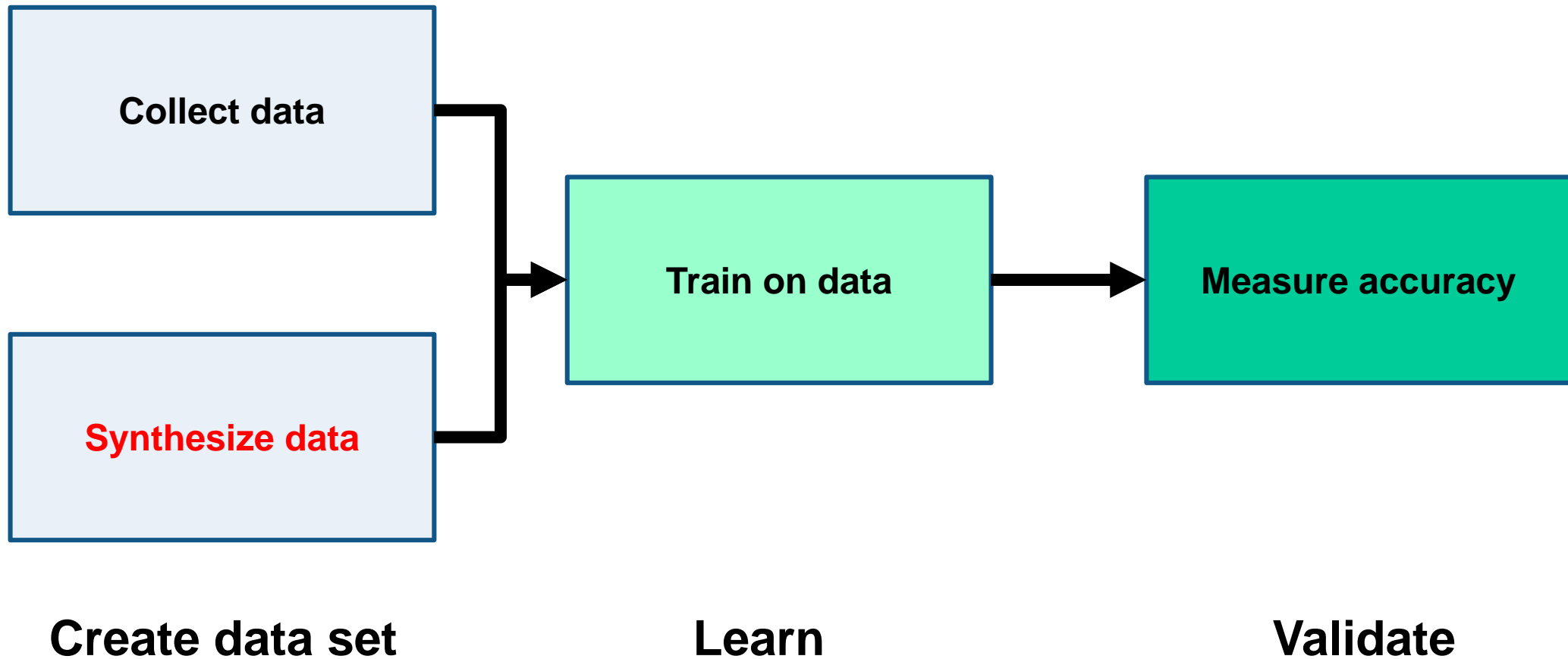
Enterprise Scale Systems

MATLAB Excel
.NET C/C++
.exe Java .dll

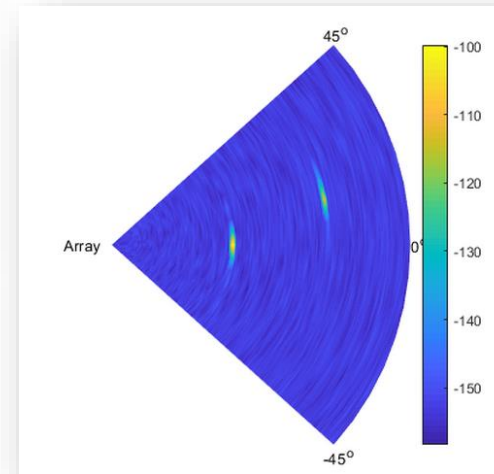
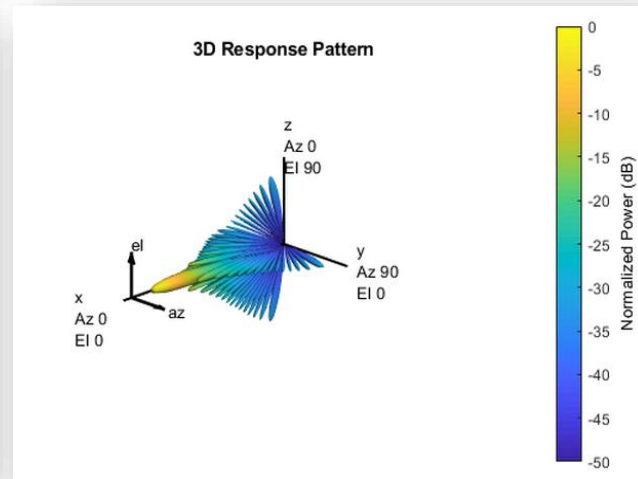
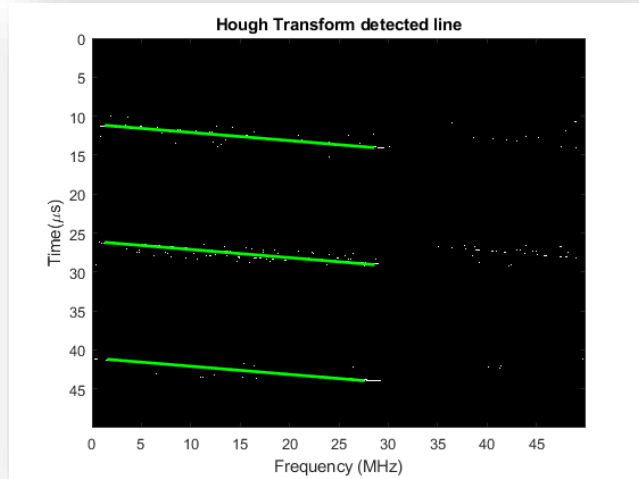
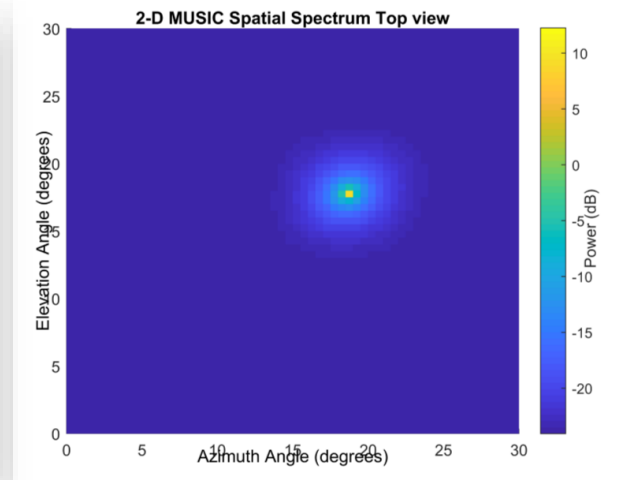
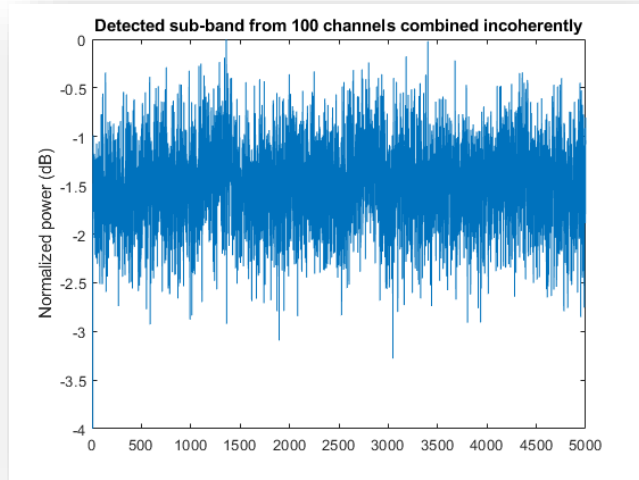
Embedded Devices and Hardware



Synthesize Radar Data for Machine Learning



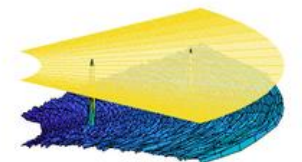
Synthesize Received Radar Signals



Signal Parameter Estimation in a Radar Warning Receiver

Modern aircraft often carry a radar warning receiver (RWR) with them. The RWR detects the radar emission and warns the

R2018a



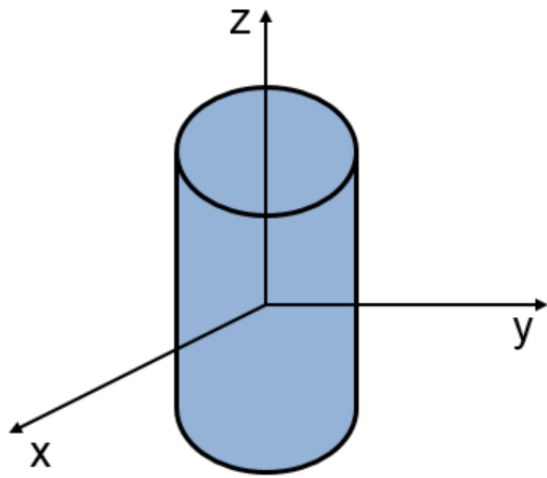
Scan Radar Using a Uniform Rectangular Array

Simulates a phased array radar that periodically scans a predefined surveillance region. A 900-element rectangular array is used in this

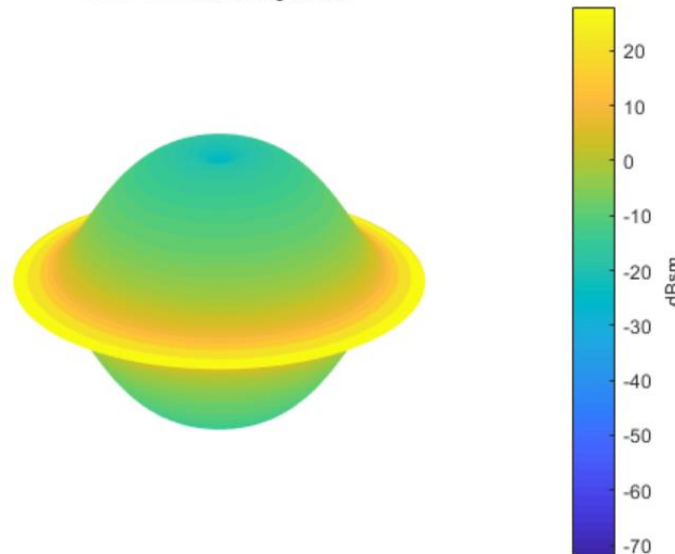
[Open Script](#)

Define a Backscatter Target with Angle and Frequency

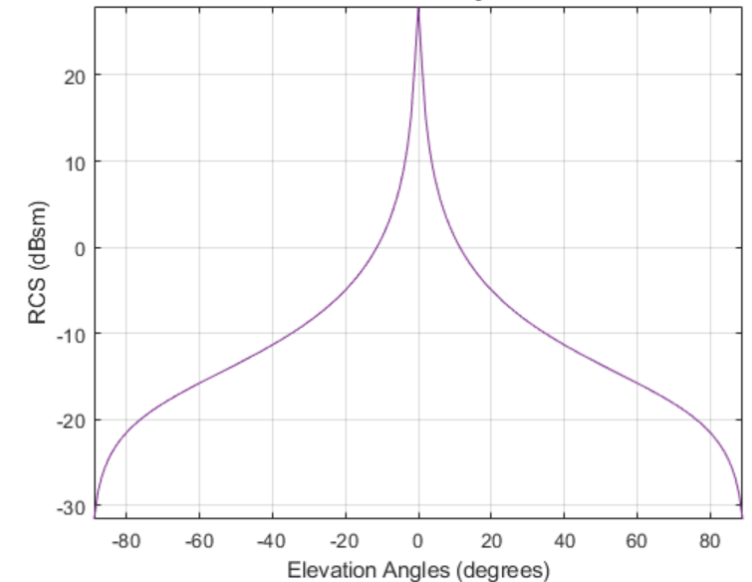
```
rsc_cyl = cylinderrcs(r1,r2,H,c,fc,az,e1);
```



RCS Pattern of Cylinder

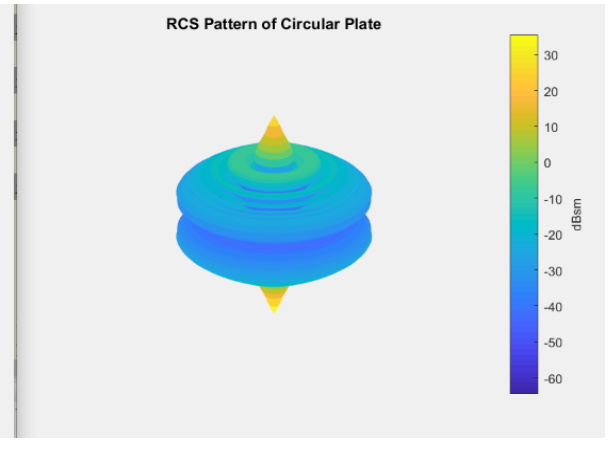
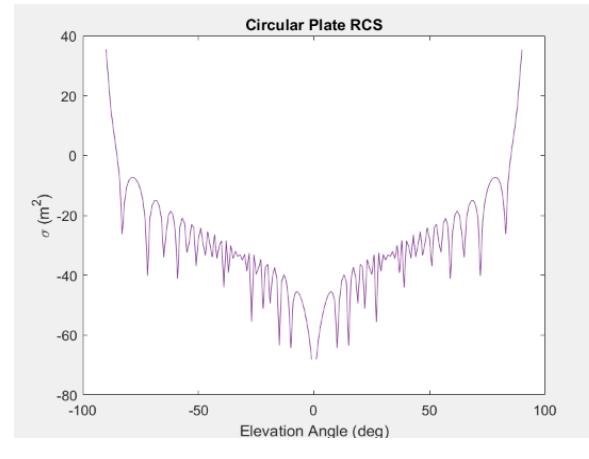
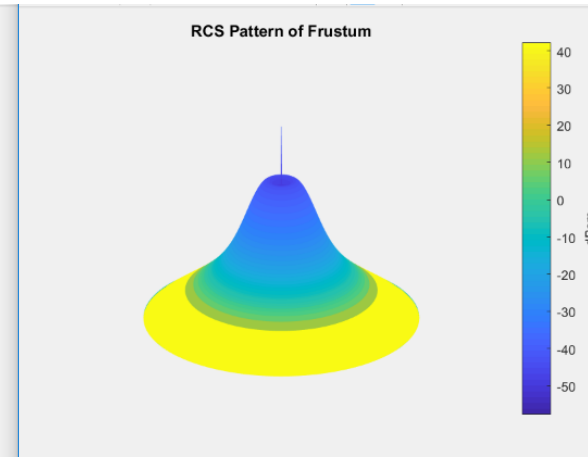
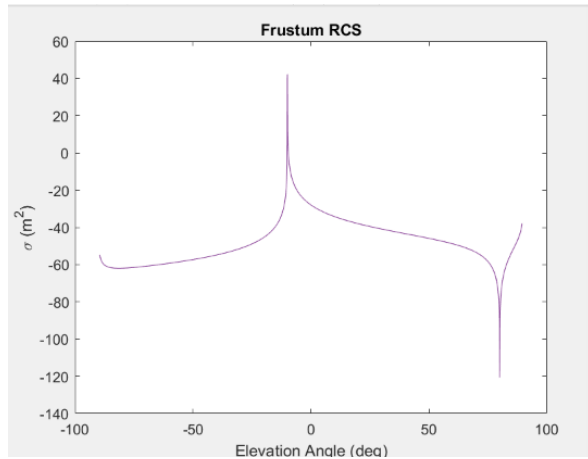
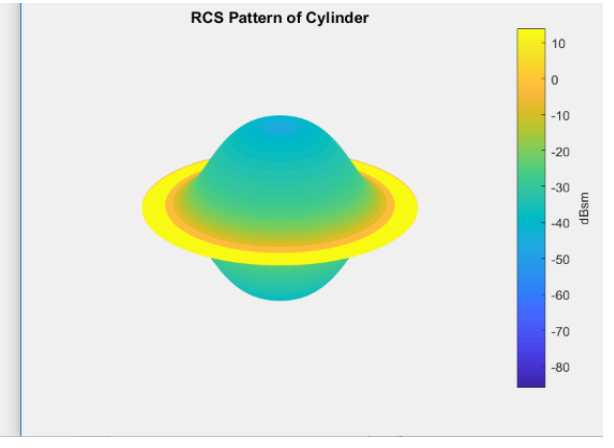
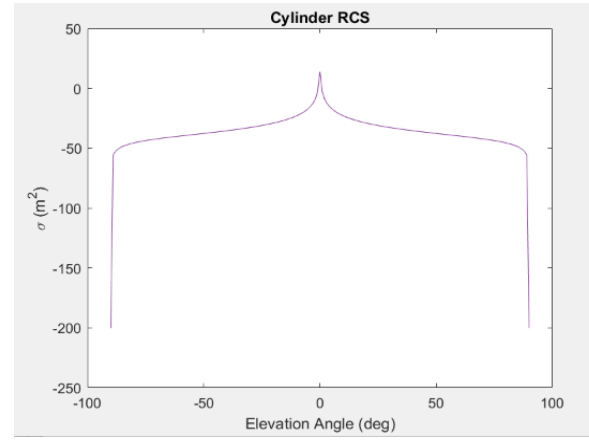
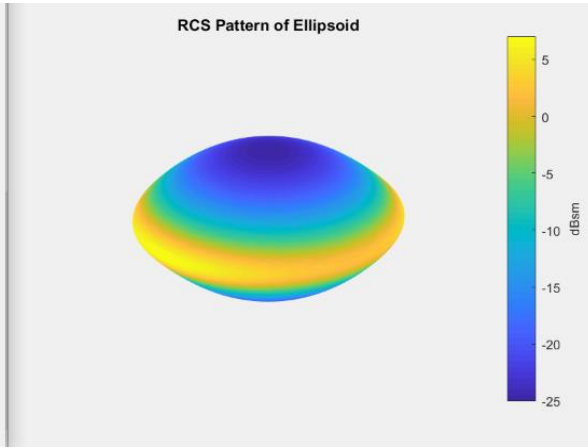
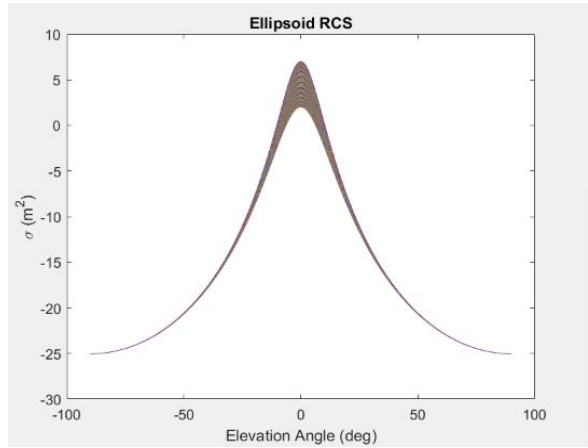


RCS Pattern for Cylinder

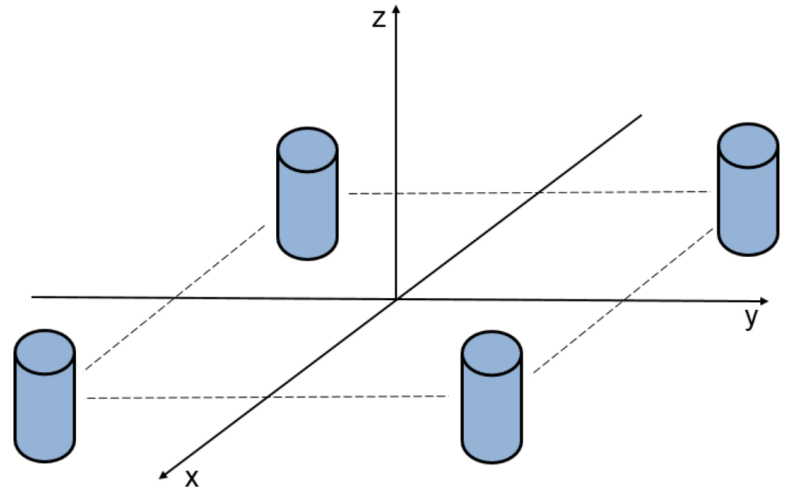


```
target = phased.WidebandBackscatterRadarTarget('Model','Nonfluctuating', ...
    'AzimuthAngles',azpattern,'ElevationAngles',elpattern,...
    'RCSPattern',rcspattern, 'OperatingFrequency',fc,'NumSubbands',32, ...
    'FrequencyVector',fvec);
```

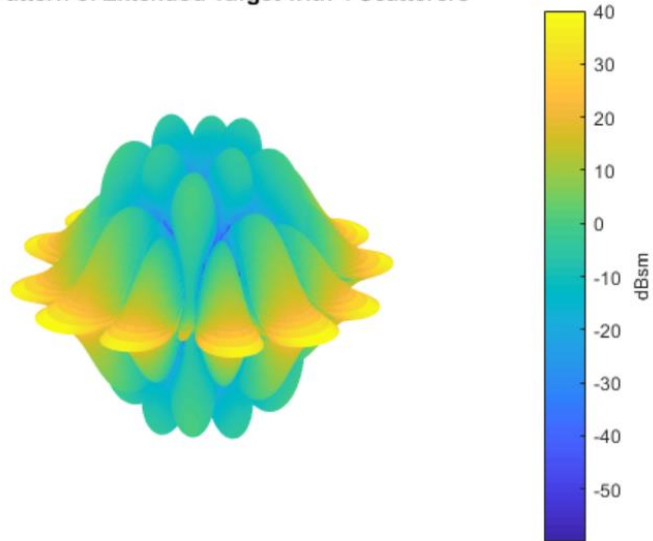
Model Basic Shapes



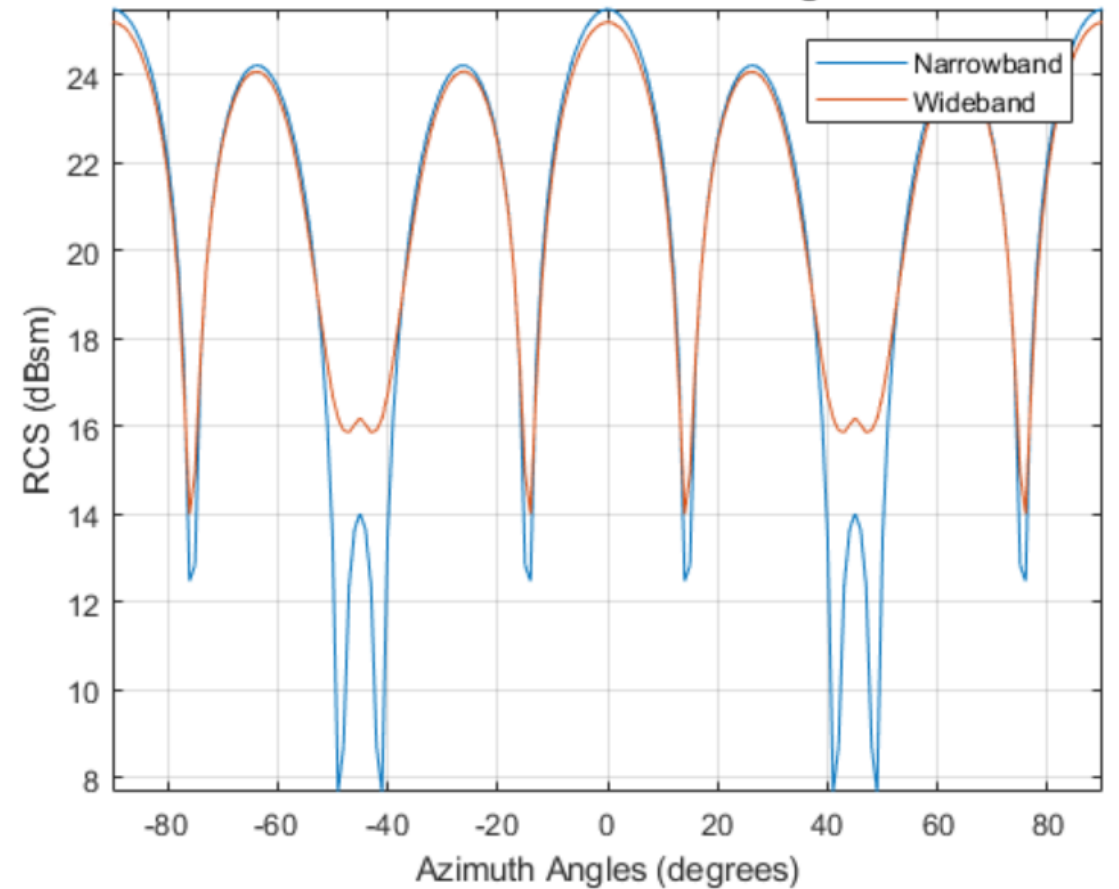
Model Extended Targets with Multiple Scatters



RCS Pattern of Extended Target with 4 Scatterers

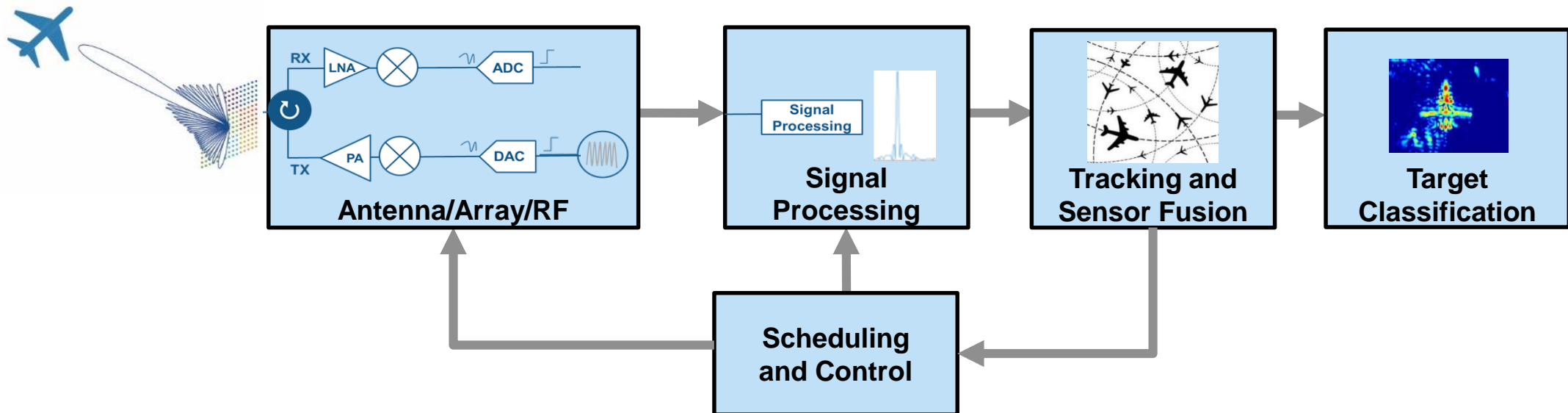


RCS Pattern at 0° Elevation for Extended Target with 4 Scatterers

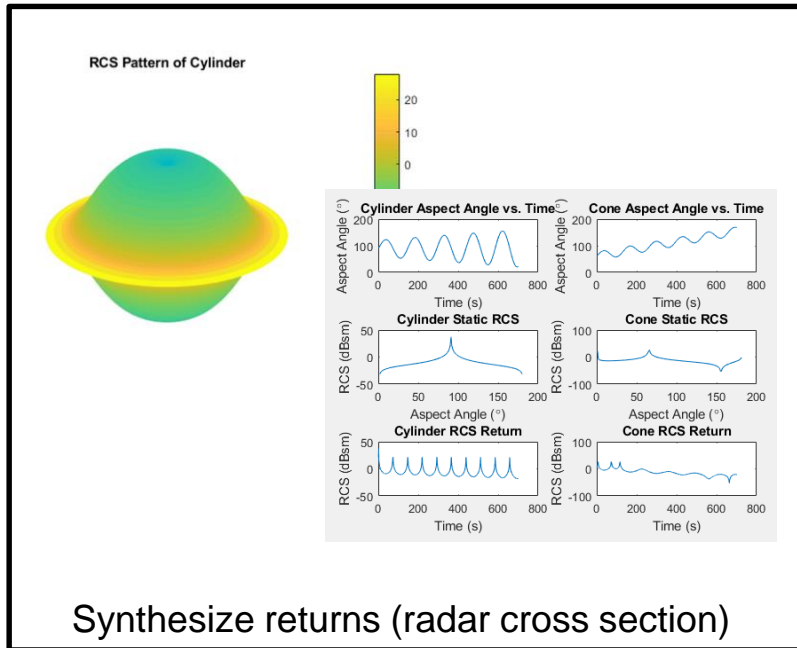


Agenda

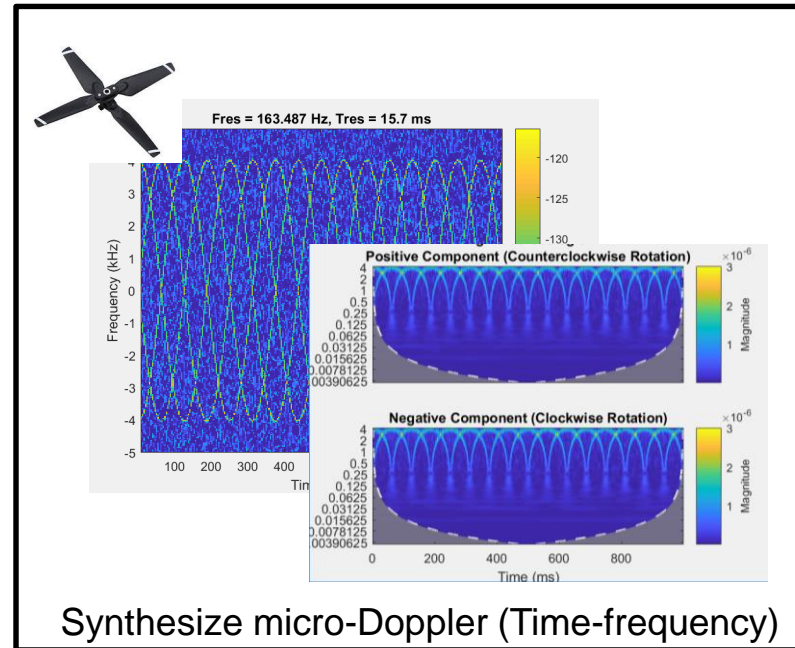
- Radar and EW modeling
- Synthesizing data for Machine Learning workflows
- » ▪ Machine Learning Examples



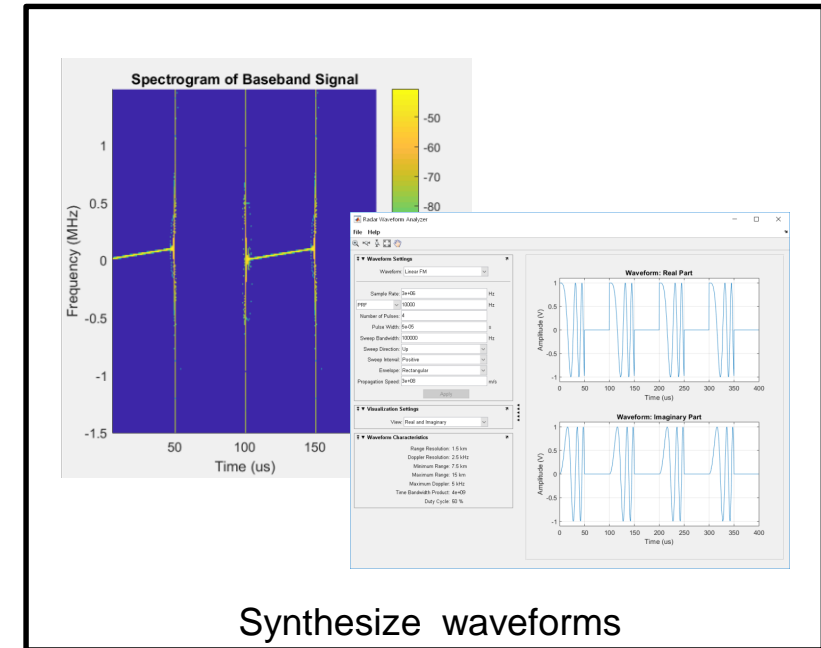
Machine Learning for Radar Examples



Synthesize returns (radar cross section)

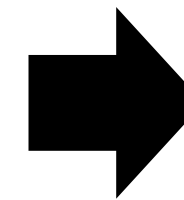
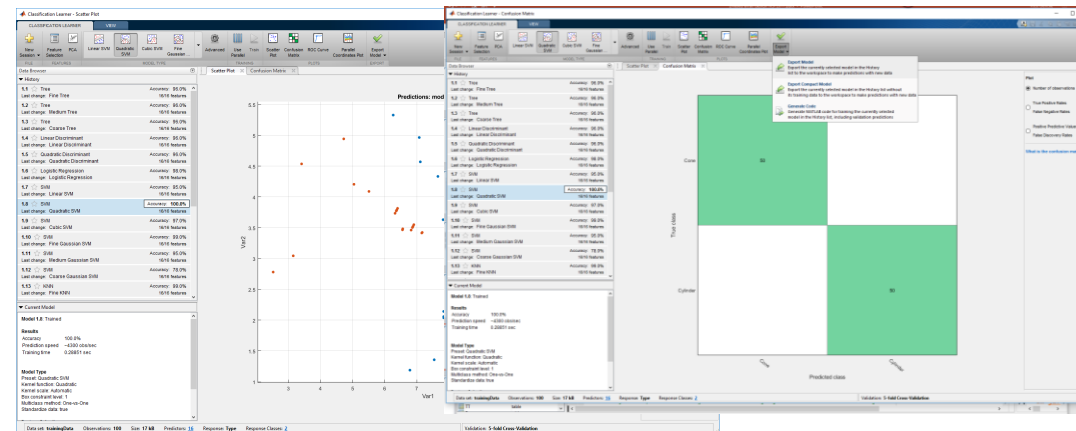
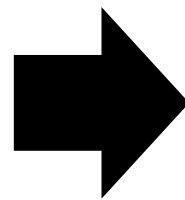


Synthesize micro-Doppler (Time-frequency)



Synthesize waveforms

Signals
Features
Time-frequency
Etc.



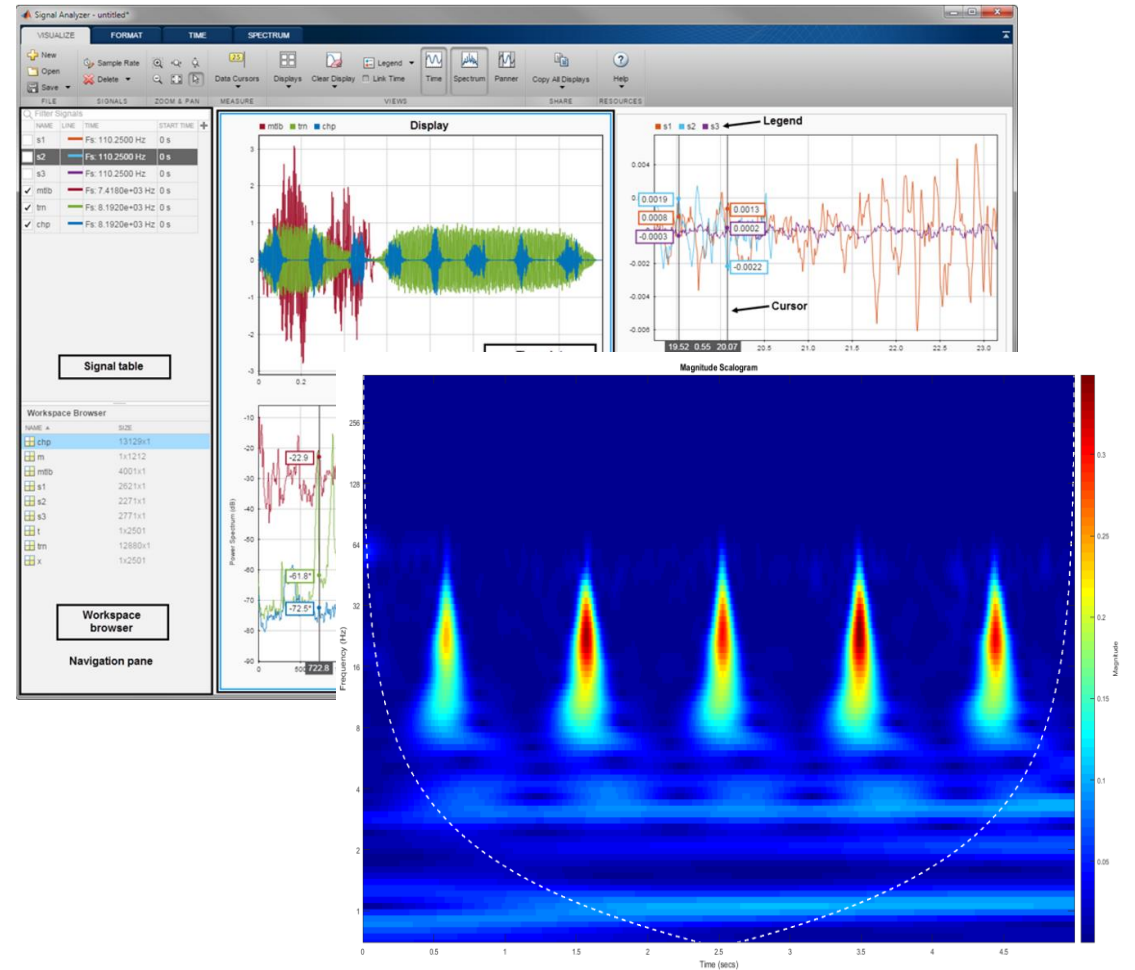
Classification

Signal Processing and Wavelets for Feature Extraction

- Signal Manipulation
 - Signal Analysis App

- Time-Frequency Analysis Capabilities
 - Short Time Fourier Transform
 - Continuous Wavelet Transform
 - Synchrosqueezing

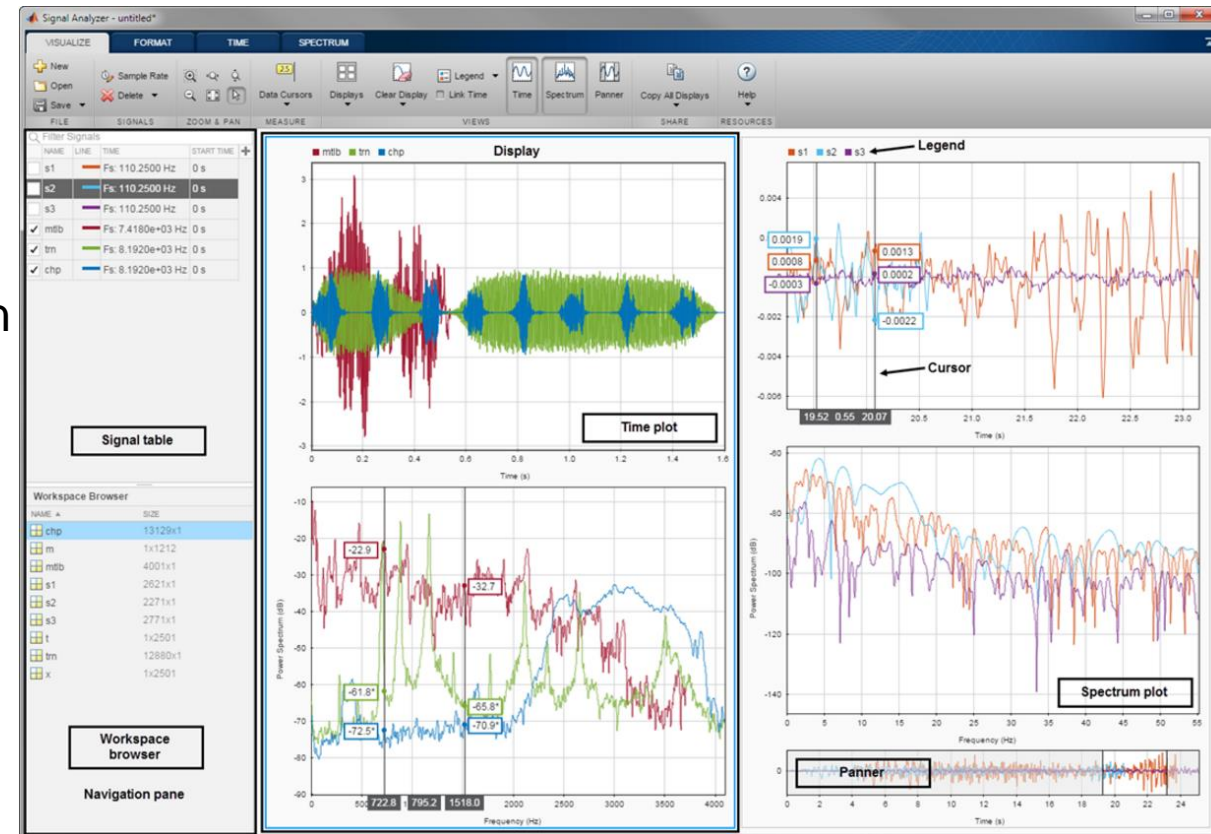
- Multiresolution Analysis Capabilities
 - Discrete Wavelet Analysis
 - Wavelet Packets



Signal Analyzer App

Analyze signals in time, frequency and time-frequency domains

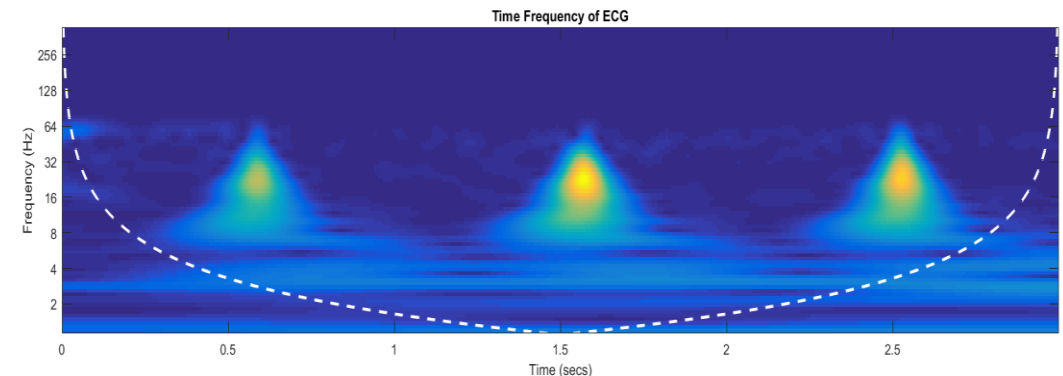
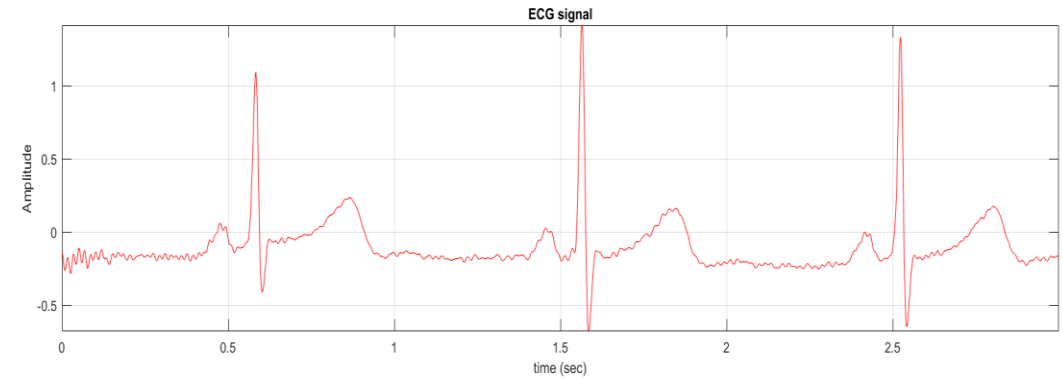
- With the Signal Analyzer you can :
 - Import multichannel signals
 - Explore signals jointly in time-frequency domain
 - Zoom and pan signals



Identifying Features in Real World Signals

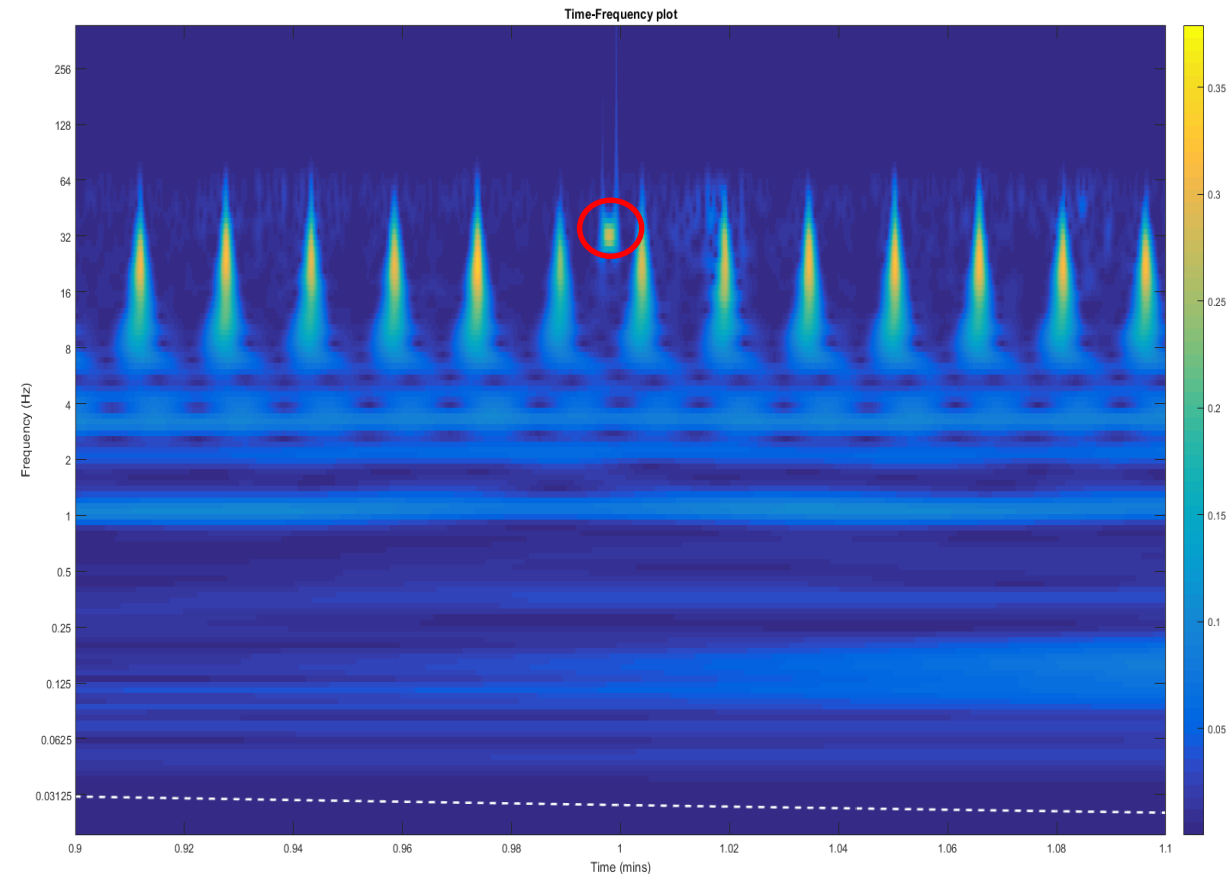
Quantify time-varying signals in frequency domain

- Characterizing signal features in spectral domain is often challenging as one needs to appropriate tools
- Accurate time-frequency measurements are possible using wavelet based time frequency analysis techniques
- Features once identified, can be extracted from signals for further processing
- In this demo, we will characterize features in EKG signals using Continuous Wavelet Transform



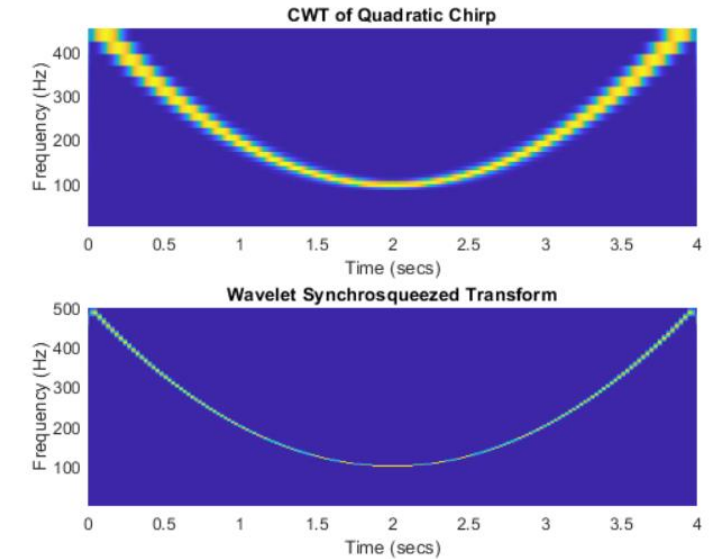
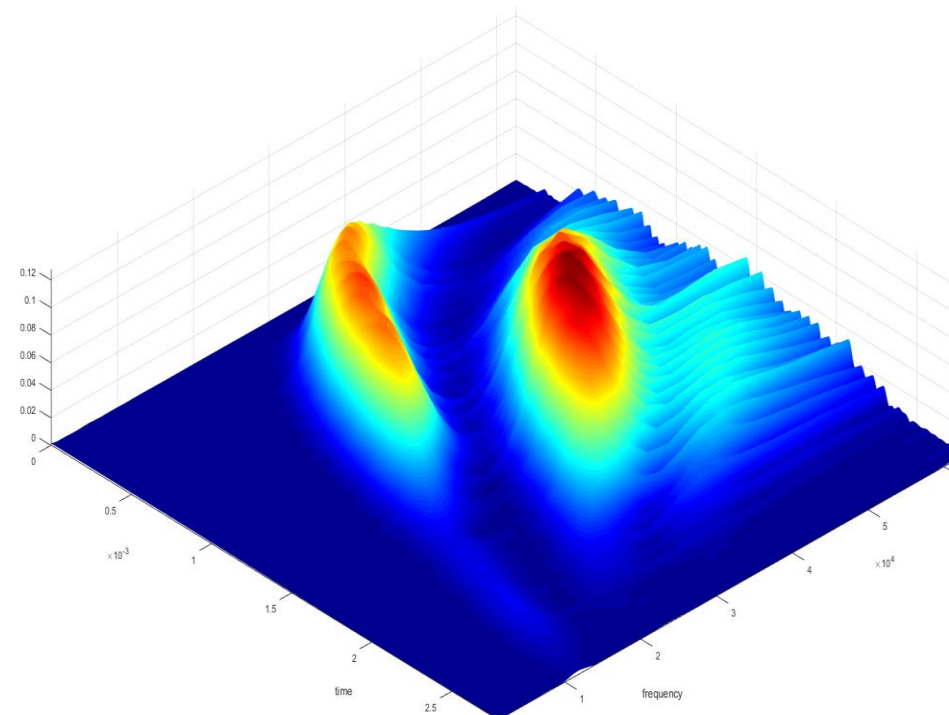
Filtering Frequency Localized Components

- Sometimes unwanted signals can get captured during signal acquisition process
- A traditional filter cannot be used if the frequency range of the interference lies within the frequency range of the signal
- Unwanted components can be localized jointly in time and frequency using wavelets and removed

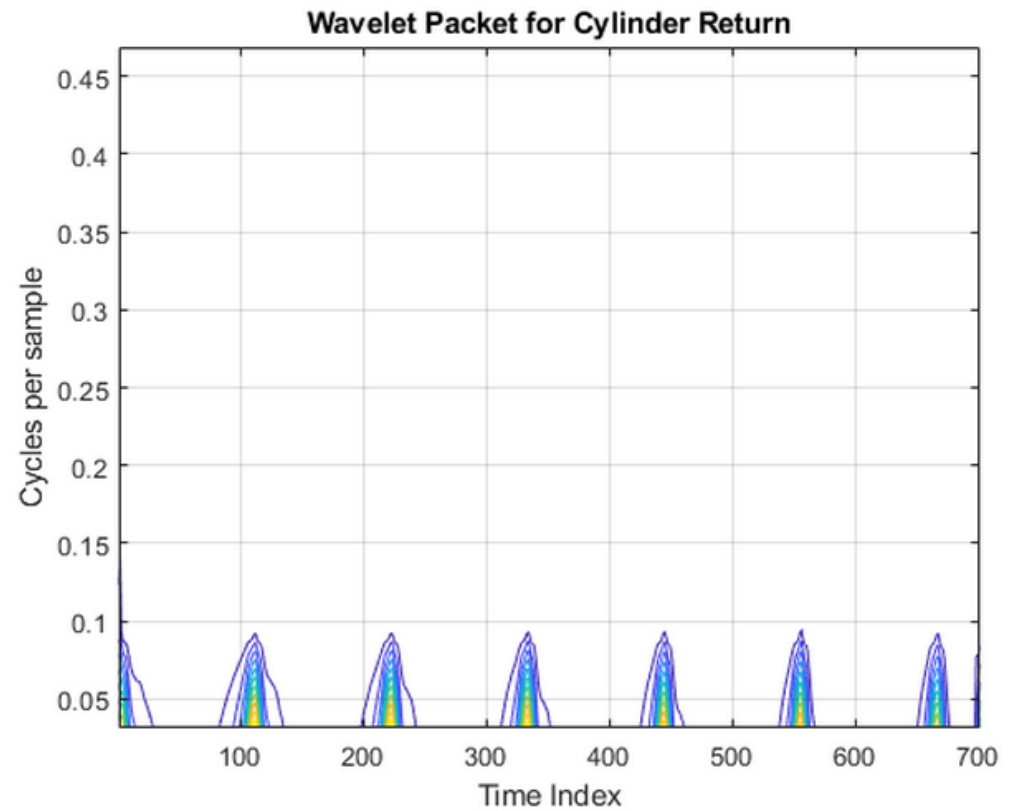
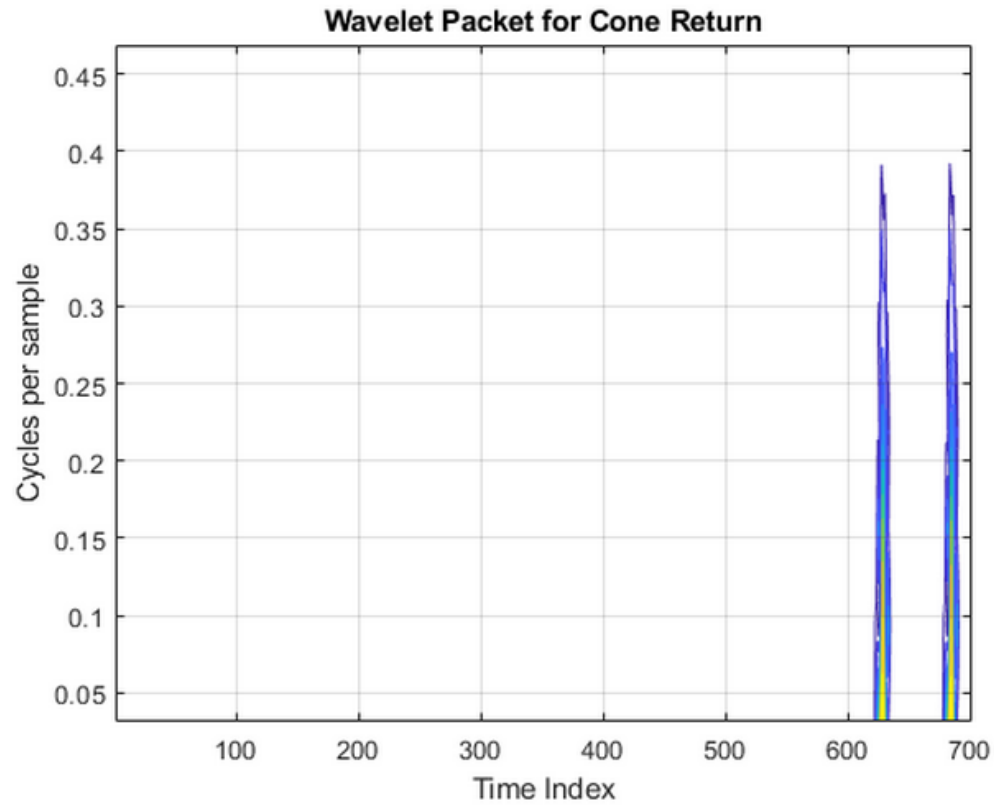


Wavelet Synchrosqueezing

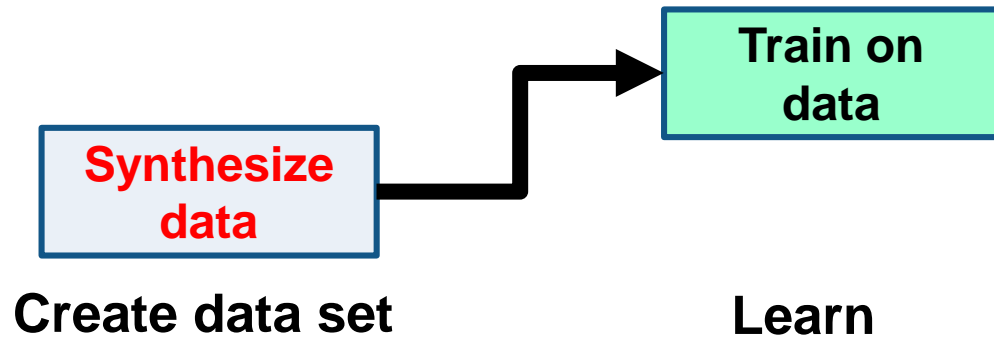
- For certain non-stationary signals, wavelet Synchrosqueezing can be used to identify and extract signal modes
- Wavelet Synchrosqueezing helps extract signal components from localized regions of time frequency plane



Example 1: Radar Echoes from Cylinder and Cone

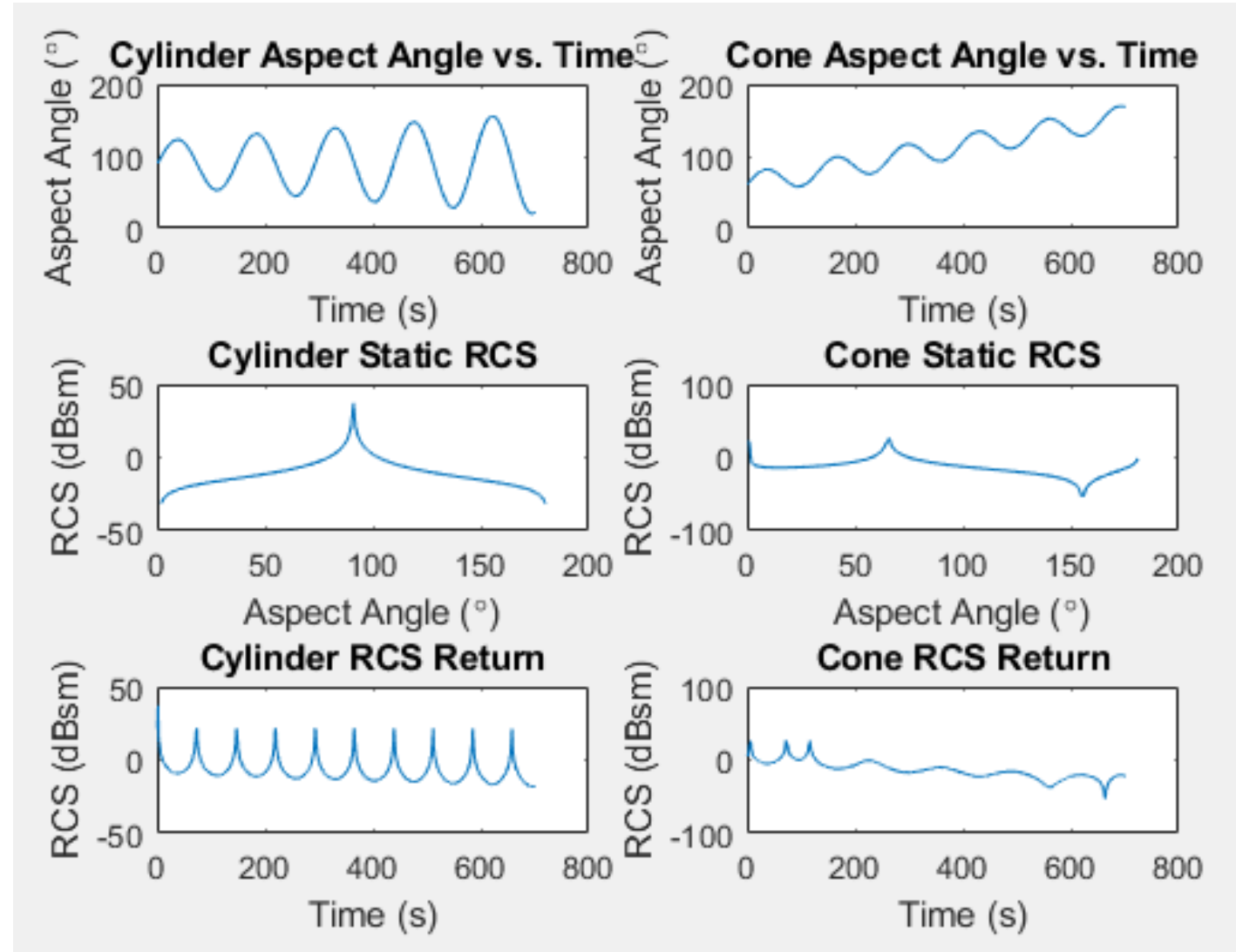


Generate law radar data from models

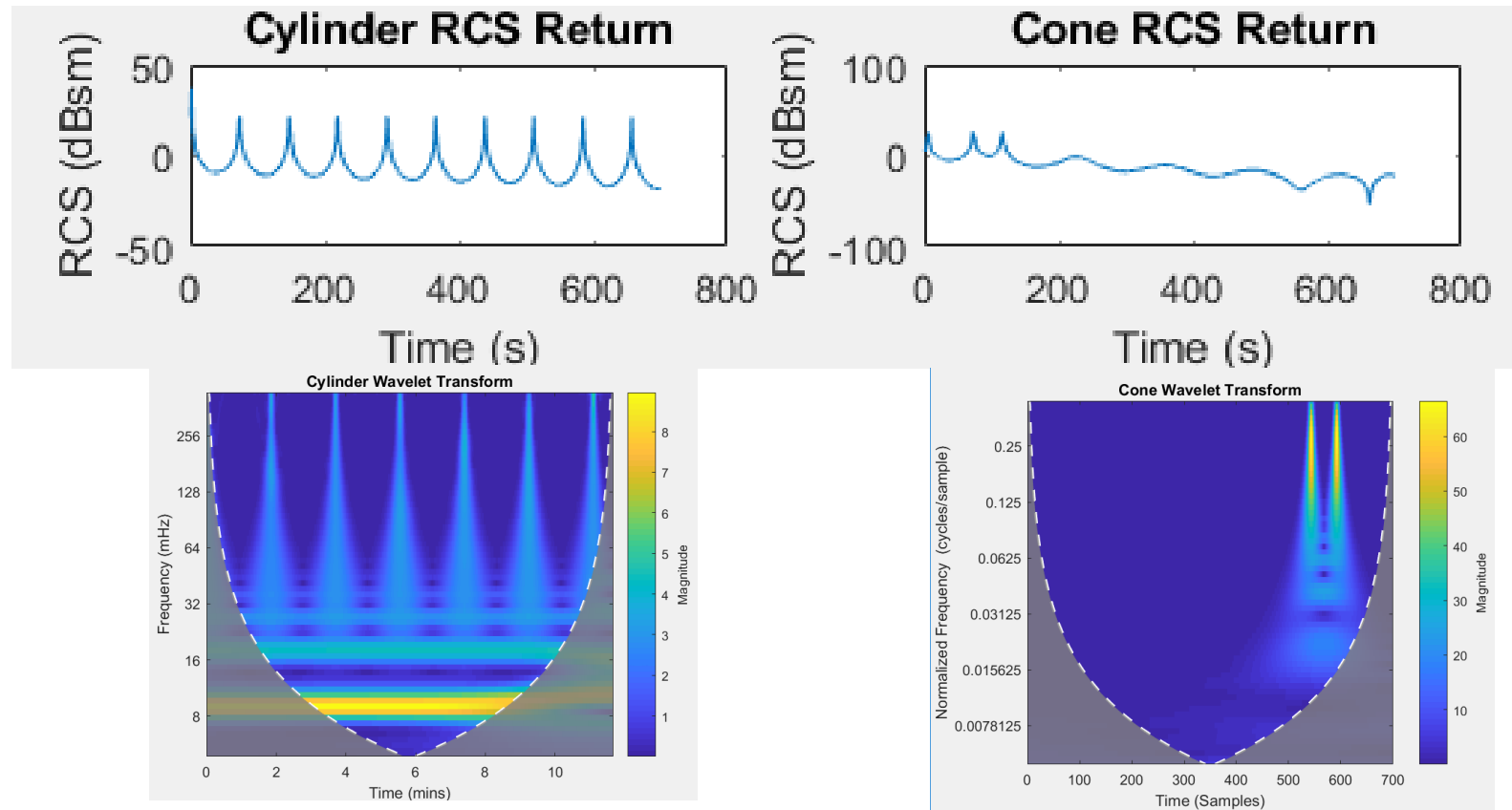


Randomize parameters

Generate many data sets



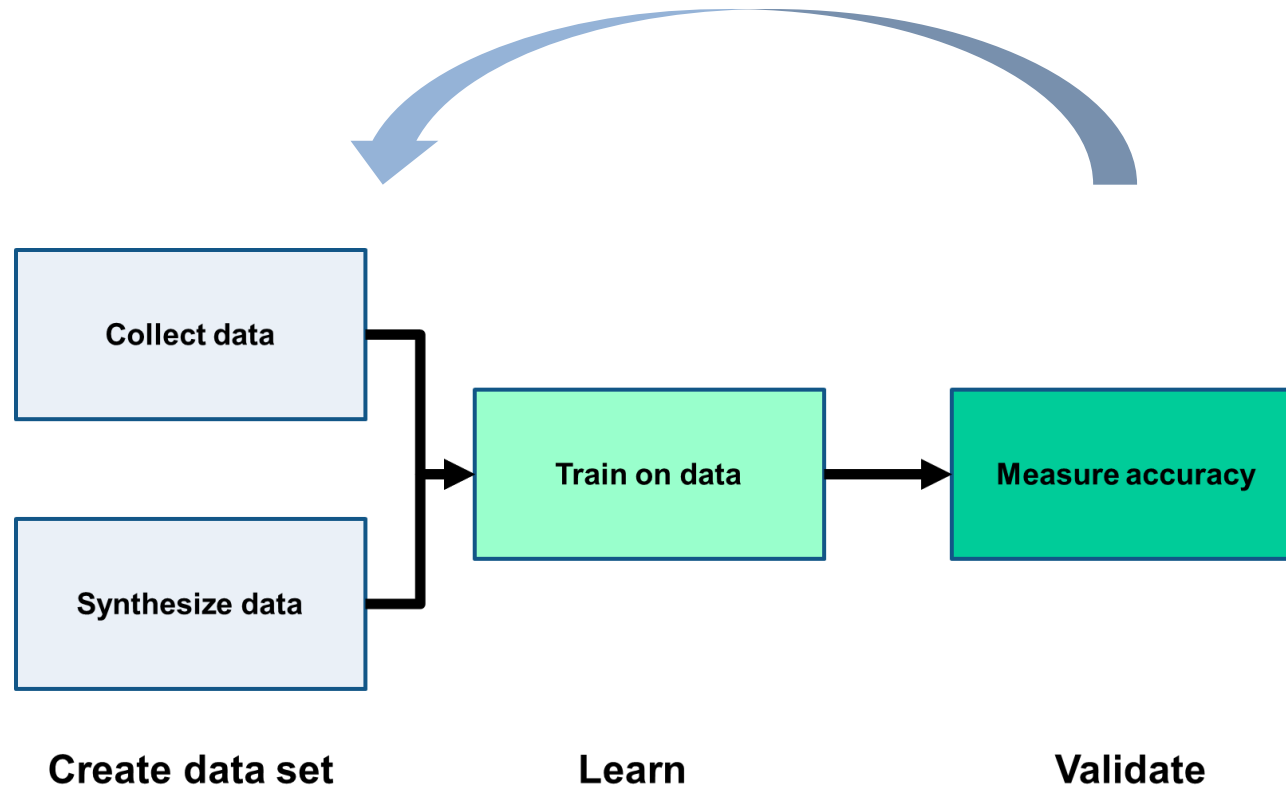
Feature Extraction



Extract features: 700 samples/object -> 8 samples/object with Wavelet Transform

```
trainingData = varfun(@(x)modwptHelper(x, 'fk6', 2), RCSReturns);
trainingData = array2table(table2array(trainingData)');
trainingData.Type = shapeTypes([ones(50,1); zeros(50,1)]+1); % 50 cylinders followed by 50 cones
```

Testing Against Training Data

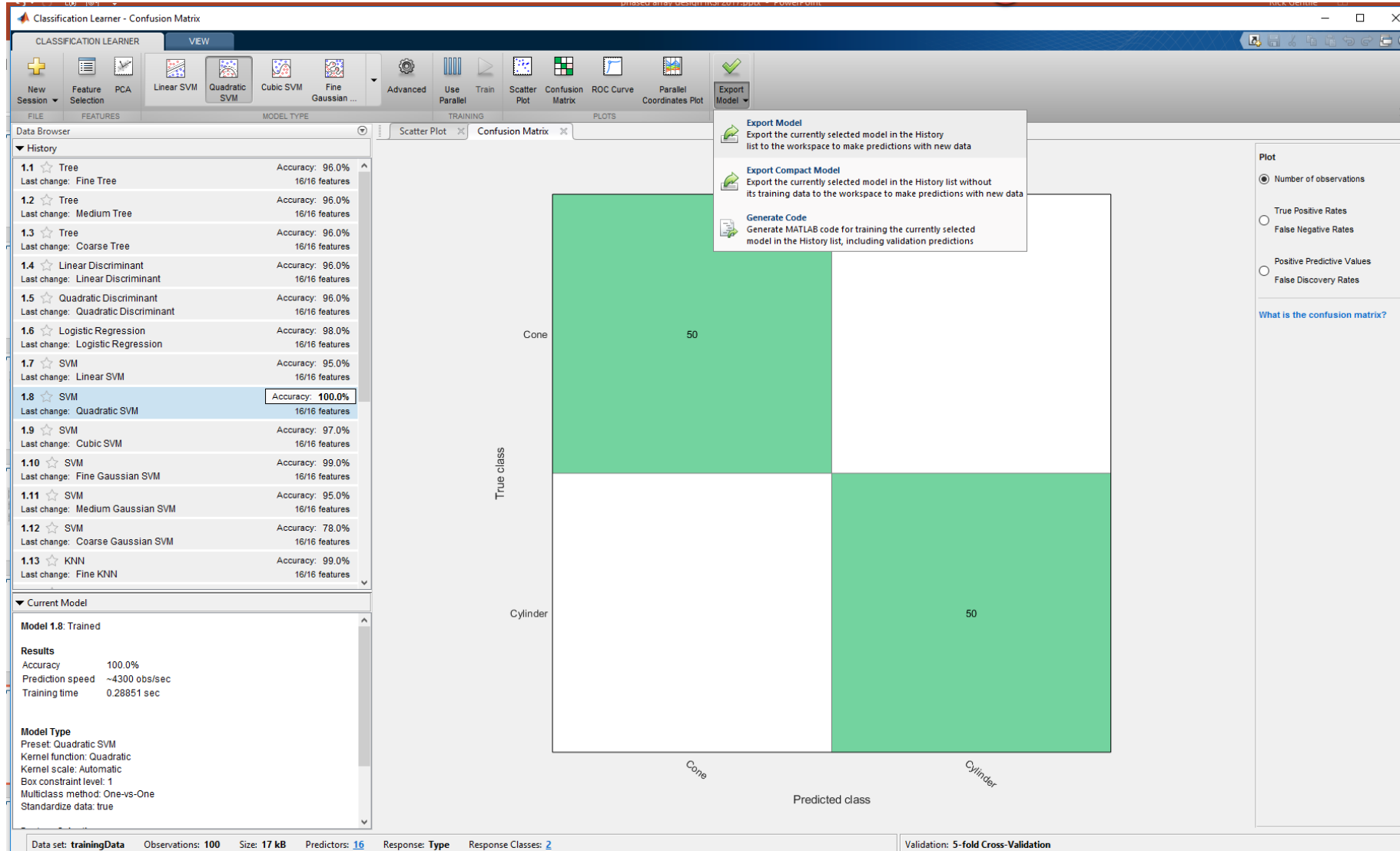


```
accuracy =
```

```
    16     9  
     0    25
```

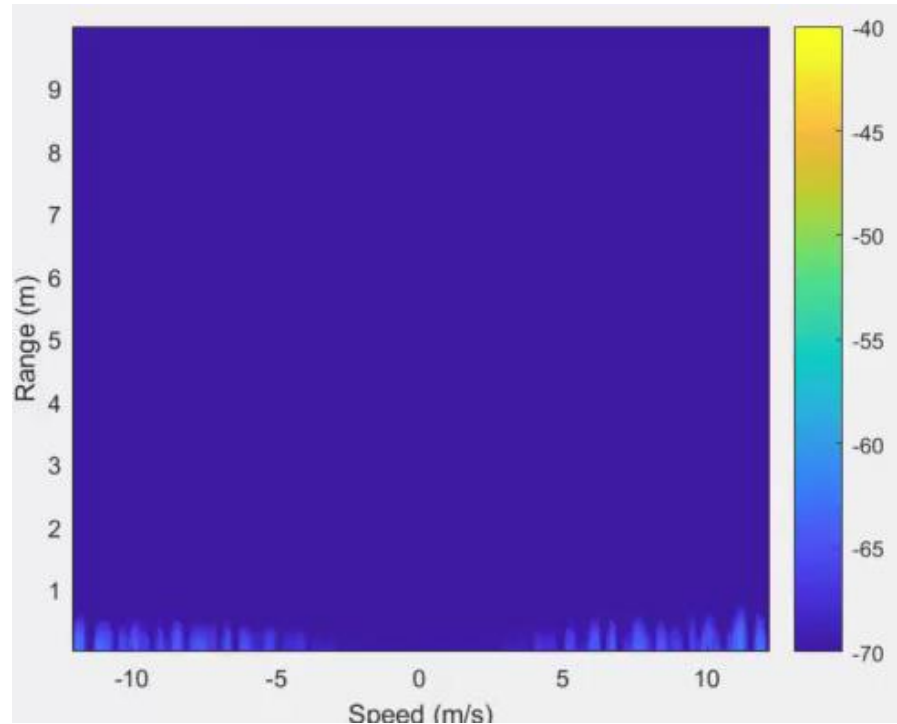
```
Test Accuracy 82.00
```

Classification Learner App

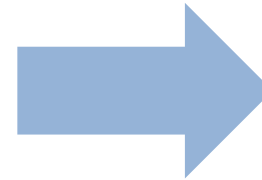


Algorithms for training
 MATLAB code gen
 Classification metrics

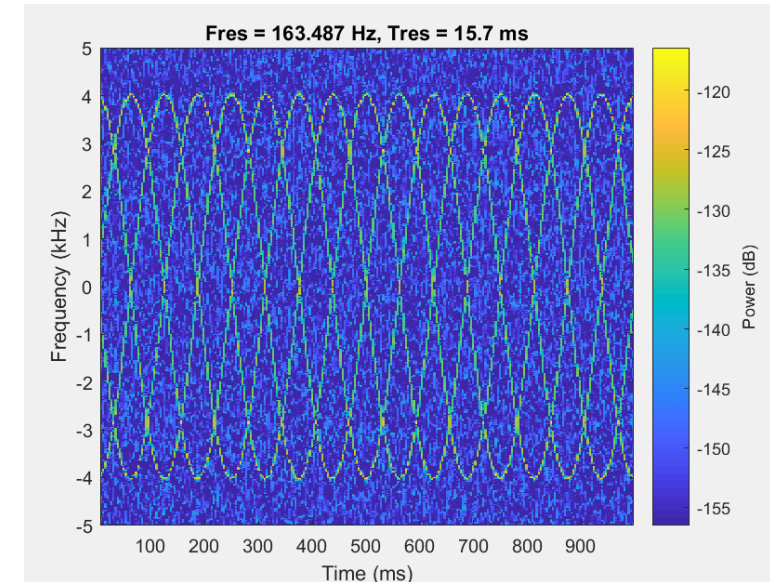
Example 2: Micro-Doppler for Drones



Range-Doppler from Parrot Quadcopter



Micro-Doppler returns

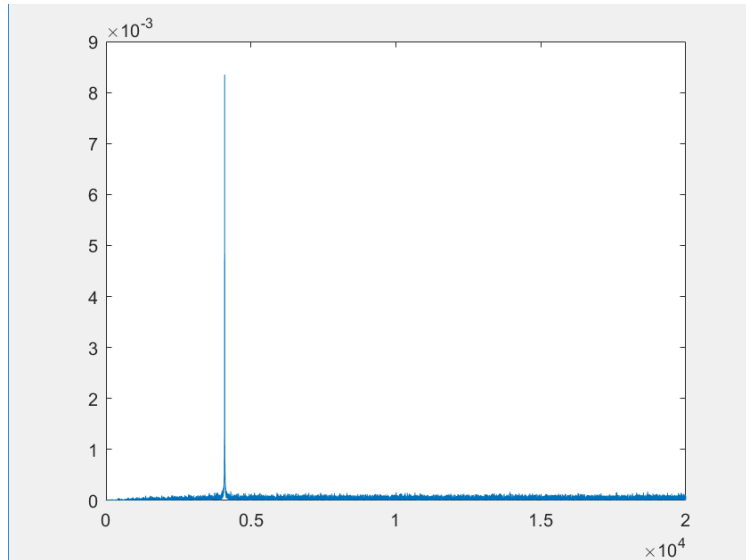


We can identify:

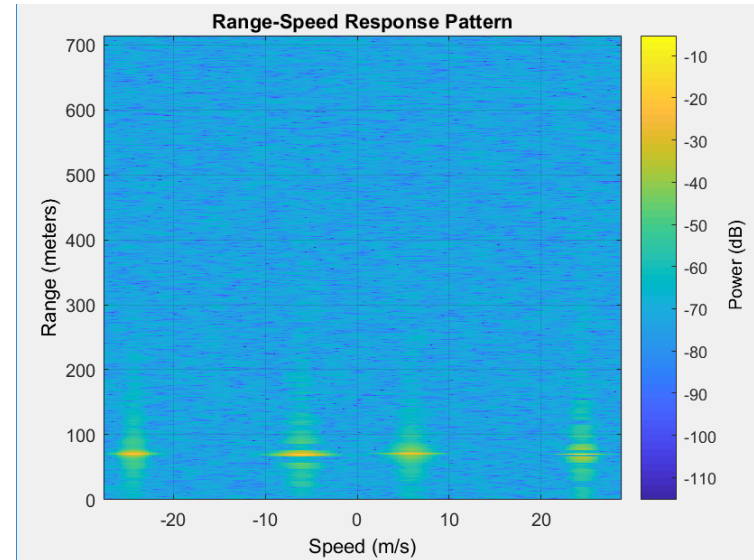
- Rotation rate
- Number of blades
- Tip velocity
- Blade length

Synthesize Micro-Doppler Motion

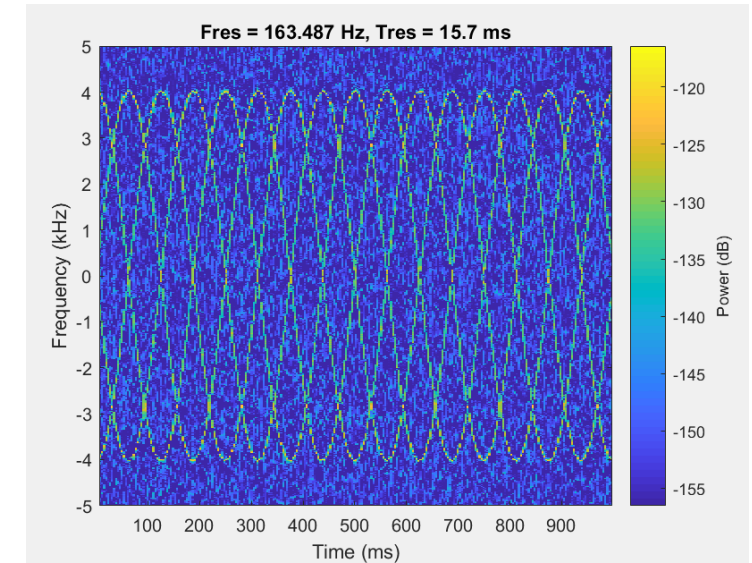
Radar return



Range-Doppler of blade

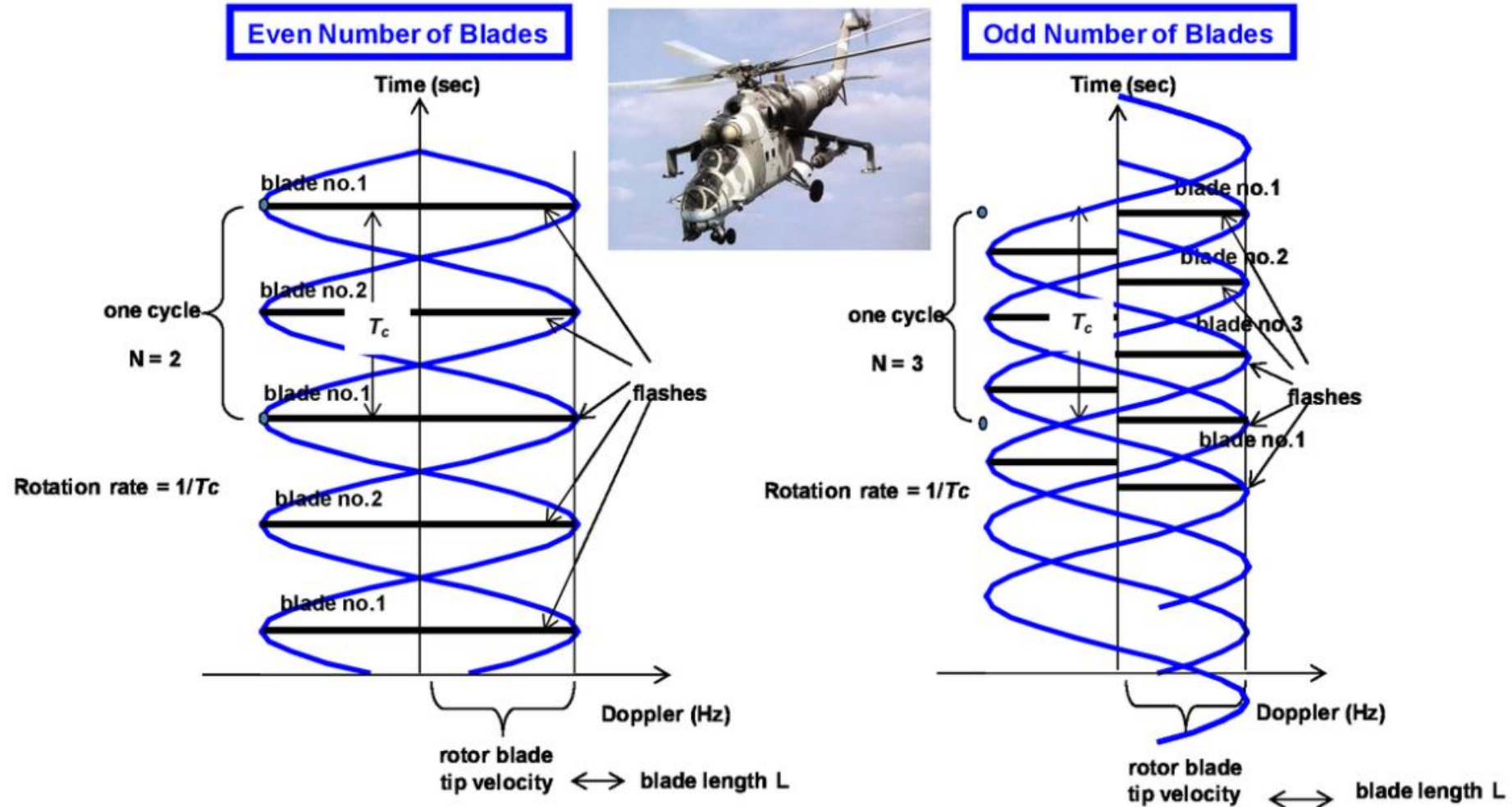


Micro-Doppler Time-frequency

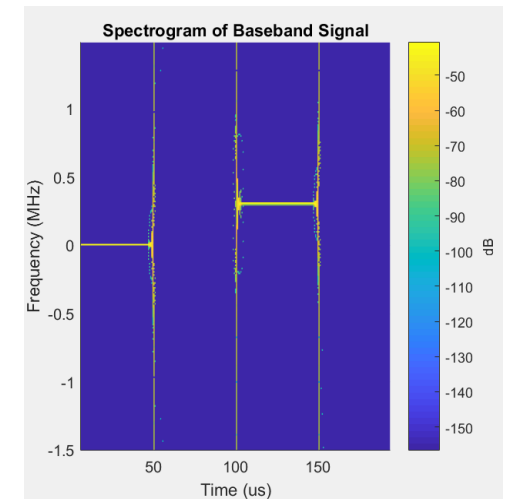
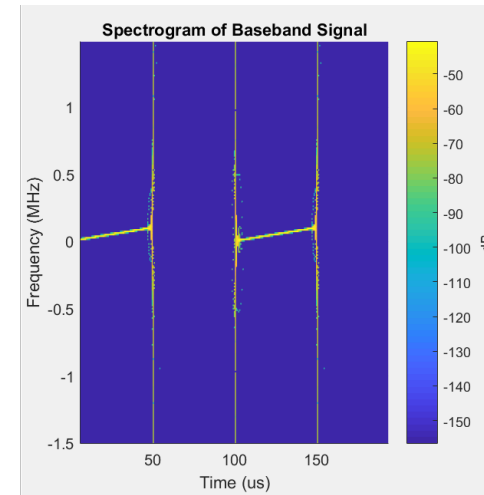
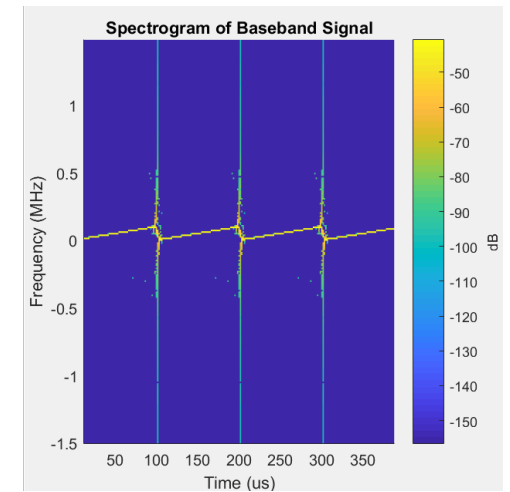
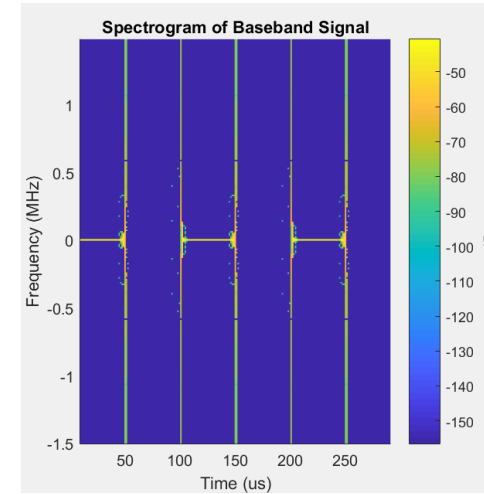
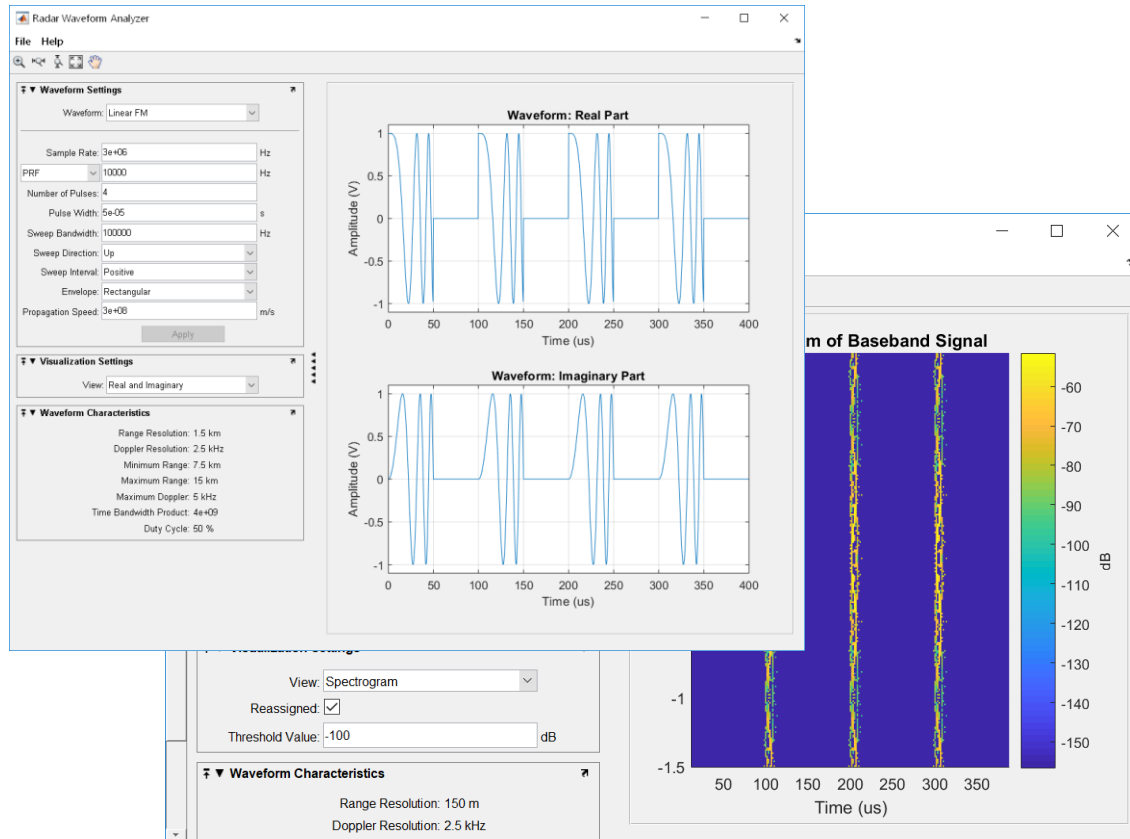


Rotation rate
 Number of blades
 Tip velocity
 Blade length

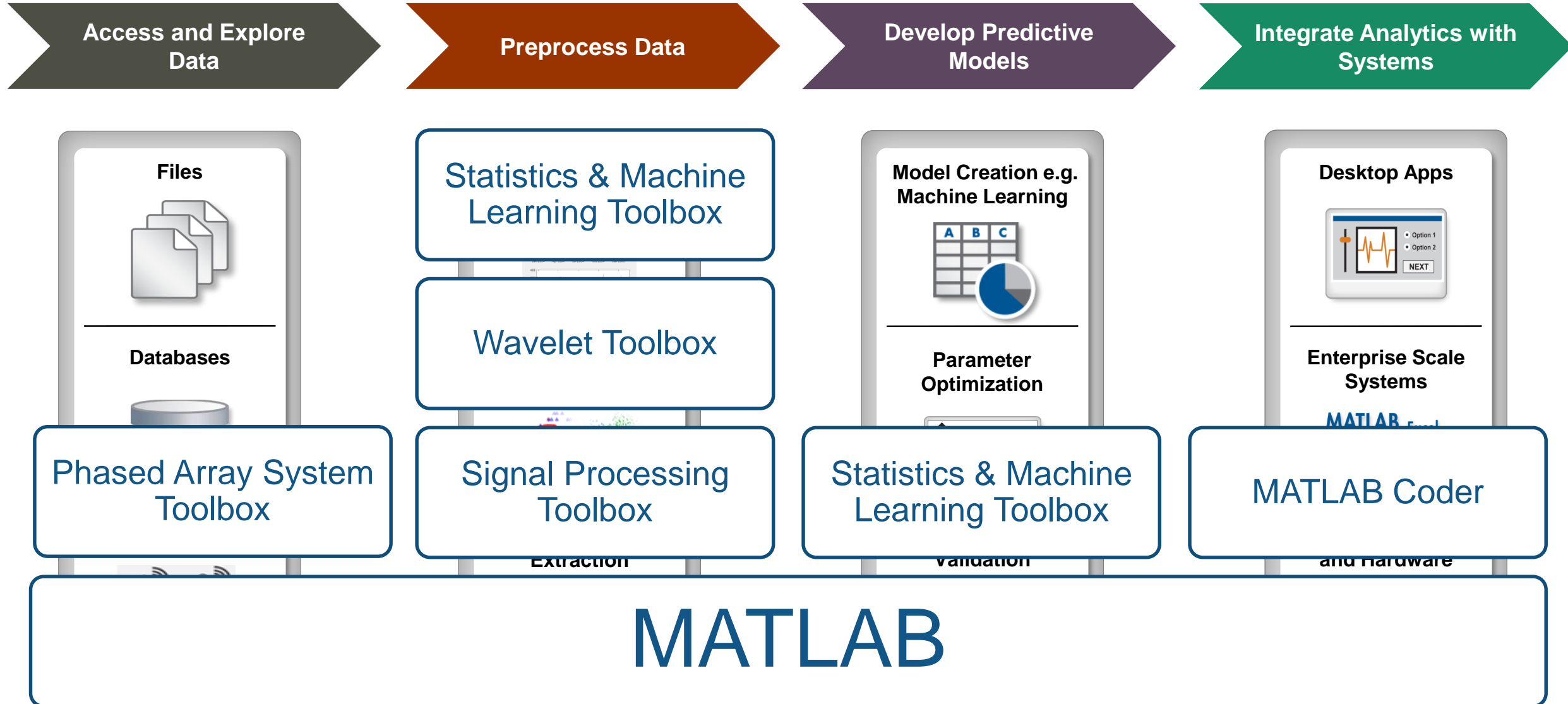
Micro-Doppler in Time-Frequency Domain



Example 3: Waveform Modulation ID for RWR



Radar & EW Classification – Workflow



Key Takeaways

- **Radar and EW modeling**
- **Synthesizing data for Machine Learning workflows**
- **Machine Learning Examples**
 - Synthesize Return, Micro-Doppler, Waveform
 - Classification: Target, Radar

Resources to Help You Get Started

[매트랩과 머신러닝 \(eBook\)](#)



머신러닝에 관심을 가져 주셔서 감사합니다.

이제 다음 eBook을 다운로드할 수 있습니다.

- [섹션 1: 머신러닝 소개](#)
- [섹션 2: 머신러닝 시작하기](#)
- [섹션 3: 비지도\(unsupervised\) 학습 적용](#)
- [섹션 4: 지도\(supervised\) 학습 적용](#)



머신러닝에 대한 추가 정보:

- [머신러닝으로 간편하게 \(34:34\)](#)
- [센서 데이터 분석을 위한 신호 처리 및 머신러닝 기법 \(42:45\)](#)
- [지도\(supervised\) 학습 워크플로우 및 알고리즘](#)
- [MATLAB 분석을 사용한 데이터 기반 통찰력: 에너지 부하 예측 사례 연구](#)
- [MATLAB 머신러닝 예제](#)

The image shows a MATLAB interface with a plot of radar returns. The plot displays a cluster of blue data points in a 2D space. Below the plot, there is a title 'Radar Target Classification Using Machine Learning' and a description: 'Classify radar returns using feature extraction followed by a support vector machine (SVM) classifier.' At the bottom, there is a 'R2018a' logo and an 'Open Script' button.