# Connecting MATLAB® to USRP™ for Wireless System Design

*Jeremy Twaits, NI*

*Vijayendra Kumar, MathWorks*

MATLAB EXPO

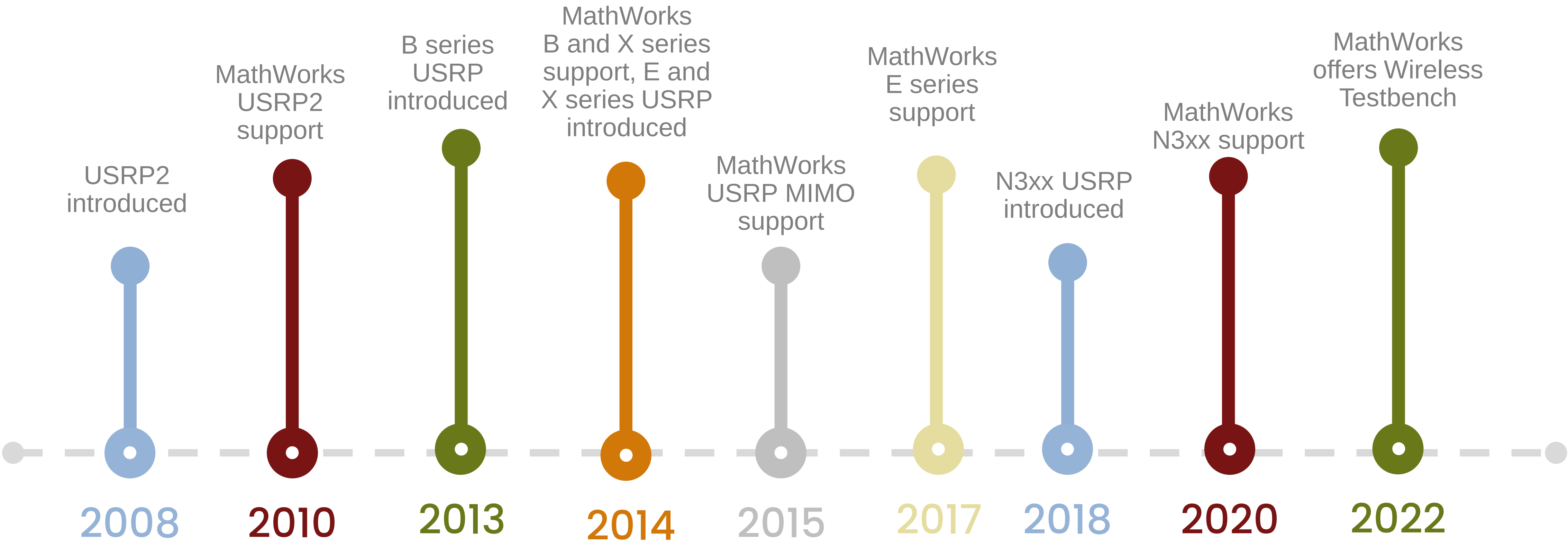

**MathWorks**

@MathWorks

Share the EXPO experience

**#MATLABEXPO**

# A History of MathWorks/NI SDR Collaboration



# Signal Detection: A Wireless Design Requirement


**Primary Goal: Signal Detection**

- Explore and test the feasibility of wireless system design
- Freeze the specs and prototype the **signal detector**

# Agenda

**Workflows**
Supported Workflows

**Hardware**
Supported USRPs

## Workflows

Supported Workflows

## Hardware

Supported USRPs

# Wireless Testbench: Supported Hardware


N310


N320


N321

Ettus Research™
A National Instruments Company

USRP

# USRP N310 Software Defined Radio Device


## Features

- Channels: up to 4x4 per device
- 100 MHz bandwidth/channel
- 10 MHz – 6 GHz
- Embedded ARM processor for stand-alone operation
- Large user-programmable FPGA, Zynq-7100
- 2 x 10 GbE streaming support
- Remote management support
- Rack mountable, half wide, 1U
- Support for Open Source – GNU Radio, UHD, RFNoC
- L = 14.06”; W = 8.31”; H = 1.72”
- Weight 6.9 lb = 3.13 kg

## Applications

- Communications System Design/Prototyping
- 802.11, LTE Research
- 5G NR FR1
- SATCOM
- UE emulation
- Massive MIMO
- SIGINT/EW
- Spectrum Monitoring
- Record & Playback

# USRP N320/N321 Feature Highlights

## Common:
- 3 MHz – 6 GHz range
- 200 MHz BW per channel
- 2x2 MIMO
- 200/245.76/250 MHz sample rates
- Preselection filters
- Dual SFP+ ports (1 GbE, 10 GbE, Aurora)
- QSFP+, RJ45
- GPSDO
- Ethernet-based sync (White Rabbit)
- Stand-alone operation

## N320:
- Zynq XC7Z100-2FFG900I
- External LO input ports

## N321:
- LO Distribution for up to 128x128 MIMO

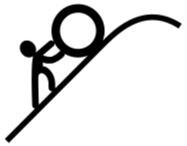
## Applications:
- Phase Coherent Wireless Testbeds
- Wideband Spectrum Monitoring
- Radar Prototyping
- Direction Finding

# SDR Use Cases, Applications and Current Challenges

**Traditional Use Cases and Applications**

- Transmit/Capture of standard-based and custom wireless signals
- Stream wireless signals to the host with live data processing
- Run prebuilt wireless applications on the FPGA/SOC of SDR for early design exploration and testing
- Run any custom wireless application on the FPGA/SOC on SDR hardware

**Current Challenges**



- Bandwidth hungry applications require high-speed transmit and capture solutions
- Real time and near real time processing for wireless applications require
  - Optimal use of hardware resources
  - Intelligent signal detection and data capture
  - Efficient host processing
- Large amount of real time data is needed for training of AI models

# New Solution and Supported Workflows

## Wireless Testbench


Explore and test wireless designs using high speed and intelligent data transmit and capture

## Wireless Testbench Workflows

**High-Speed data transmit and capture**

**Intelligent signal detection**

## Workflows

Supported Workflows

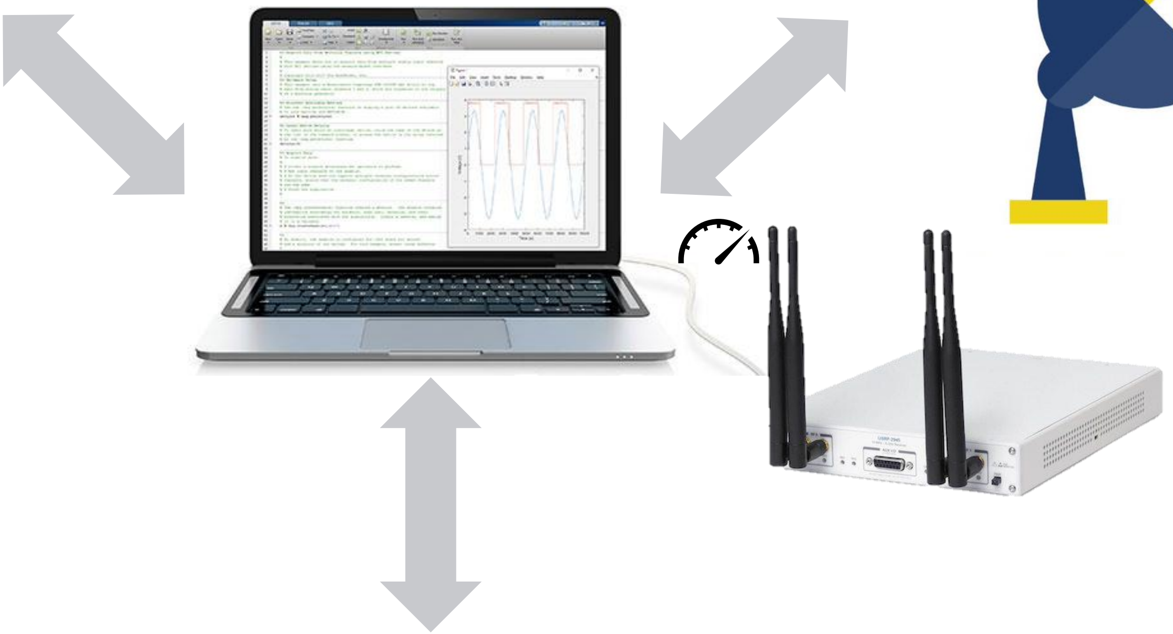
## Hardware

Supported USRPs

# Workflow: High-Speed Transmit and Capture

- ***Channel effects***
- ***Frontend validation***
- ***Loopback***
- ***End-to-end transceiver design***

Baseband Transceiver



- ***Custom signal***
- ***Noise***
- ***Interfering waveform***
- ***Receiver design***

Baseband Transmitter

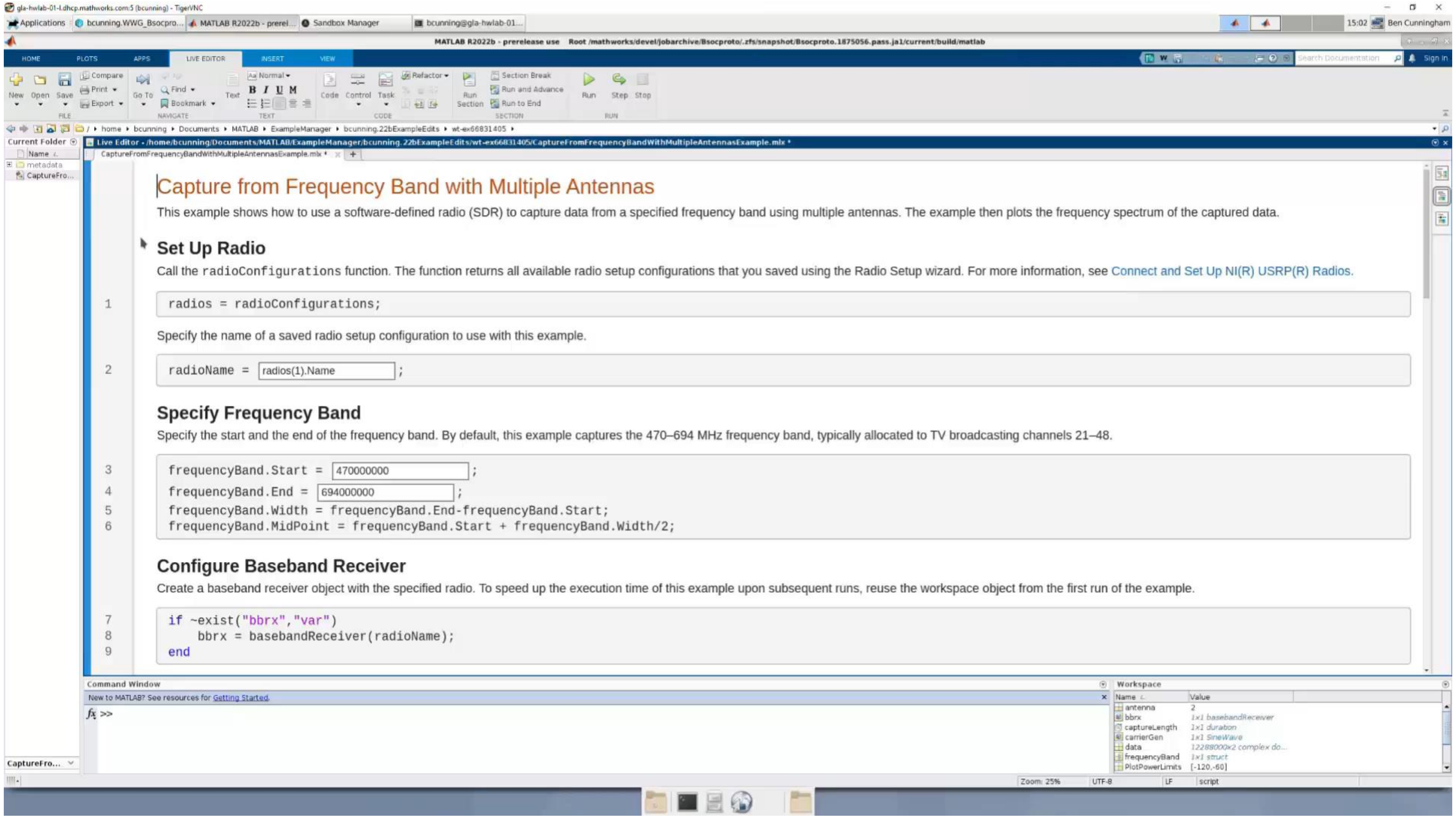
<u>**Key Features**</u>

- Full rate transmit/capture (up to 250 MSPS) Tx/Rx
- Baseband receiver, transmitter, and transceiver workflows

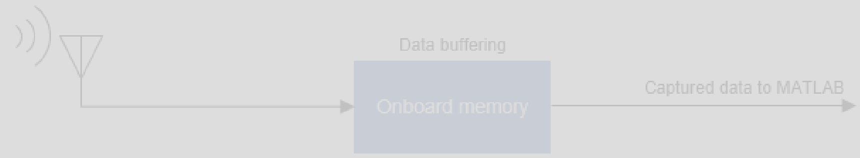
- ***5G, WLAN, Satellite***
- ***Custom signal***
- ***Cognitive radio***
- ***Spectrum sensing***

Baseband Receiver

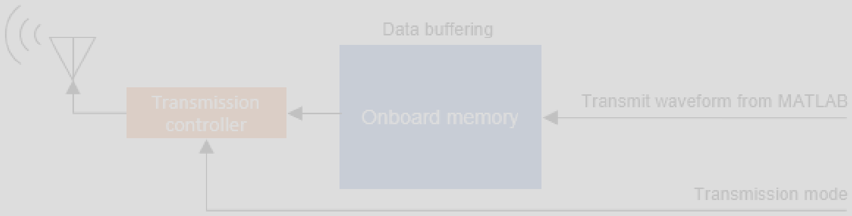
# High-Speed Transmit and Capture: Baseband Receiver Demo



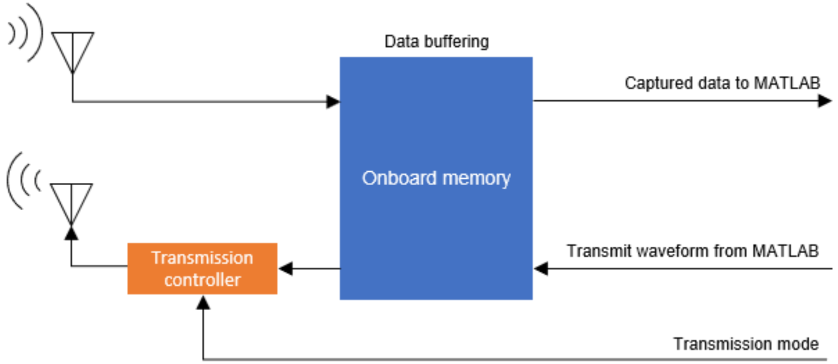
# High-Speed Transmit and Capture: Receiver, Transmitter, Transceiver




```
bbrx = basebandReceiver("MyRadio")
bbrx.SampleRate = 122.88e6;
bbrx.CenterFrequency = 2.2e9
[data,~] = capture(bbrx,milliseconds(3));
```

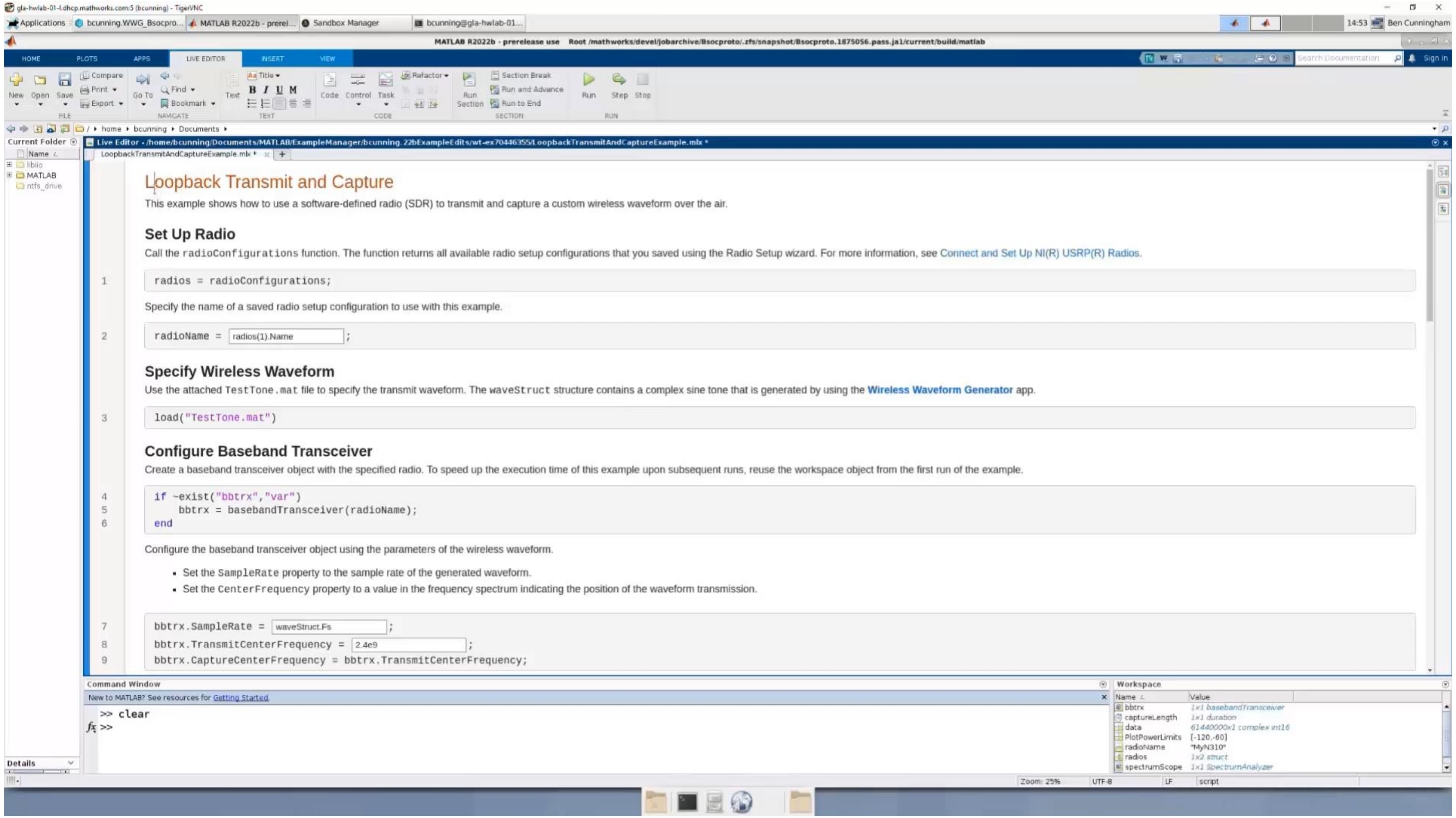



```
bbtx = basebandTransmitter("MyRadio")
bbtx.SampleRate = 122.88e6;
bbtx.CenterFrequency = 2.2e9;
transmit(bbtx,txWaveform,"continuous");
pause(5);
stopTransmission(bbtx);
```

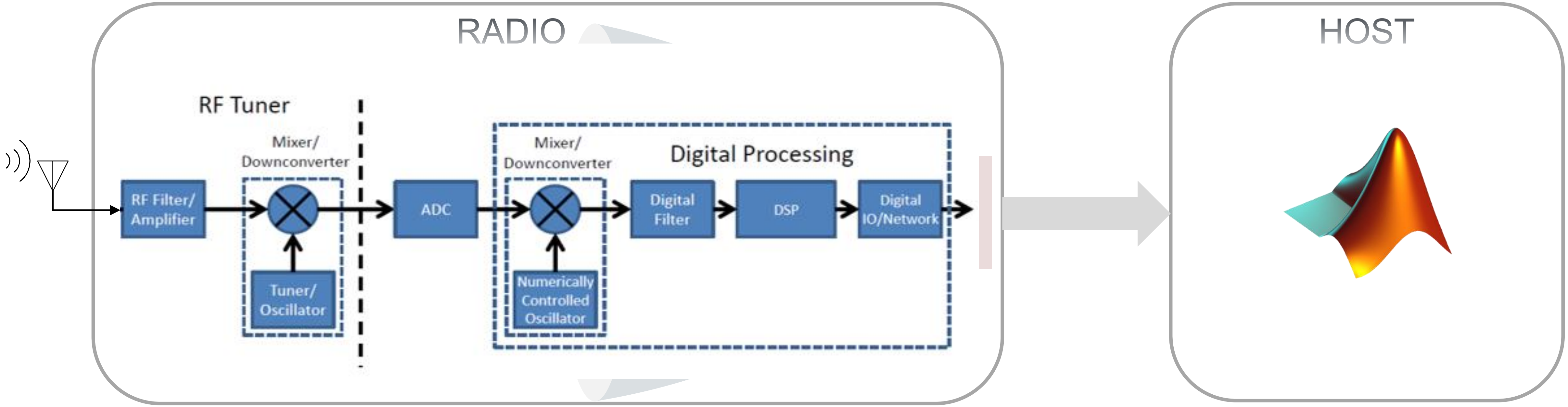



```
bbtrx = basebandTransceiver("MyRadio")
bbtrx.SampleRate = 122.88e6;
bbtrx.TransmitCenterFrequency = 2.2e9;
bbtrx.CaptureCenterFrequency = 2.2e9;
txWaveform = complex(randn(1000,1),randn(1000,1));
transmit(bbtrx,txWaveform,"continuous");
[data,~] = capture(bbtrx,milliseconds(3));
stopTransmission(bbtrx);
```

# High-Speed Transmit and Capture: Baseband Transceiver Demo



# Workflow: Intelligent Signal Detection and Data Capture



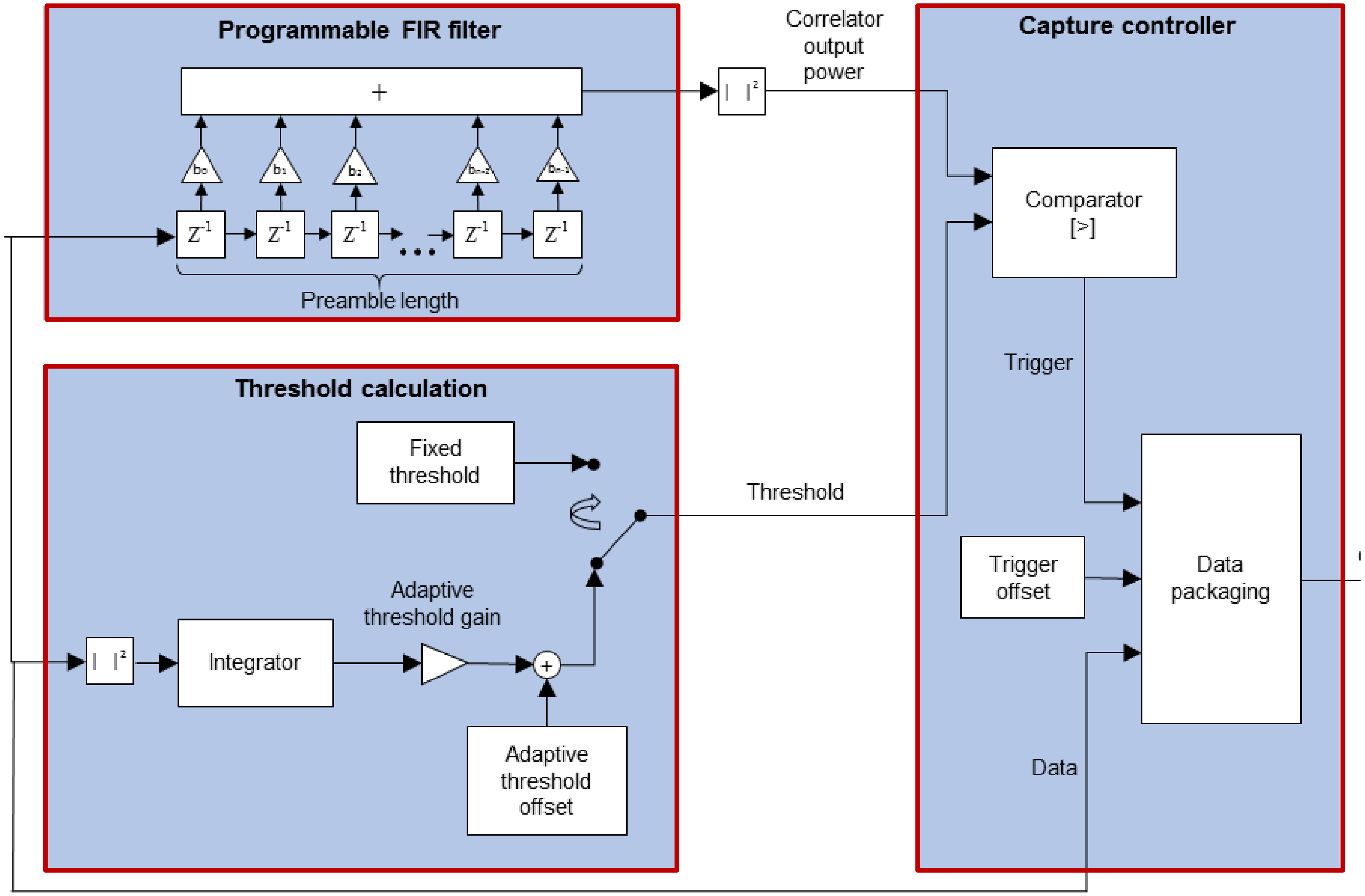

## Use cases/Applications

- Spectral conformance
- Signal detection
- Spectrum monitoring
- Signal classification
- Cognitive radio
- Signal intelligence
- Radar

## Features

- Intelligent Capture @ 250 MSPS
- Prebuilt application

# Intelligent Signal Detection and Data Capture: Internal Architecture

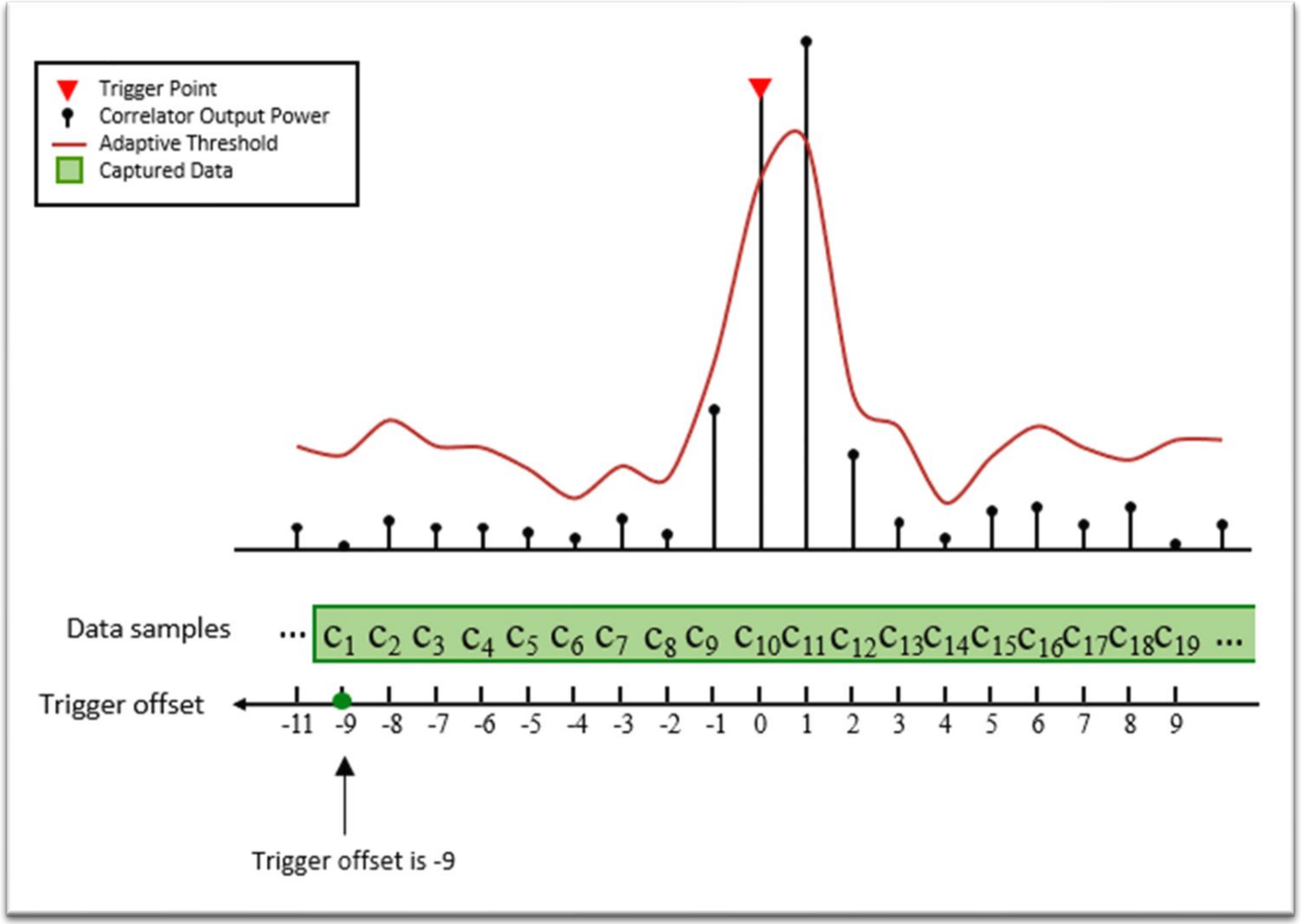



**Programmable FIR filter**
- Correlates the input signal with a known preamble sequence

**Threshold calculation**
- Fixed and Adaptive Threshold

**Capture Controller**
- Calculates the trigger point
- Captures data

# Intelligent Signal Detection and Data Capture: Thresholding, Triggering and Capturing

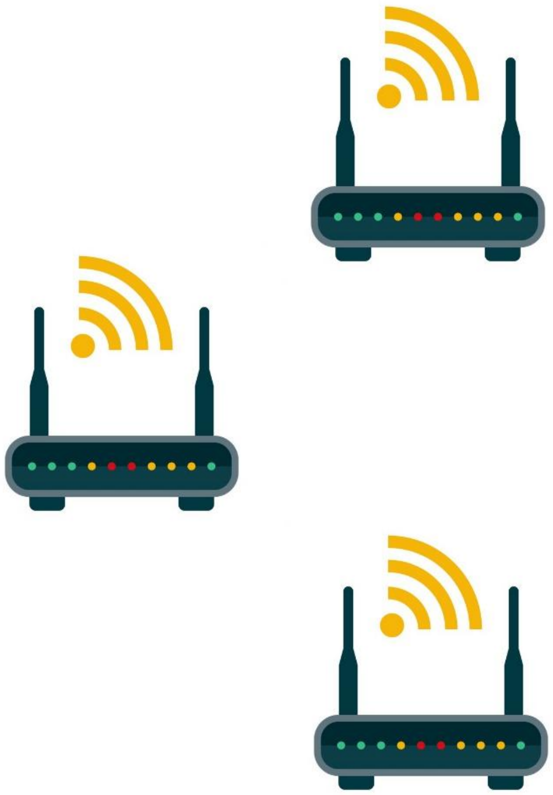


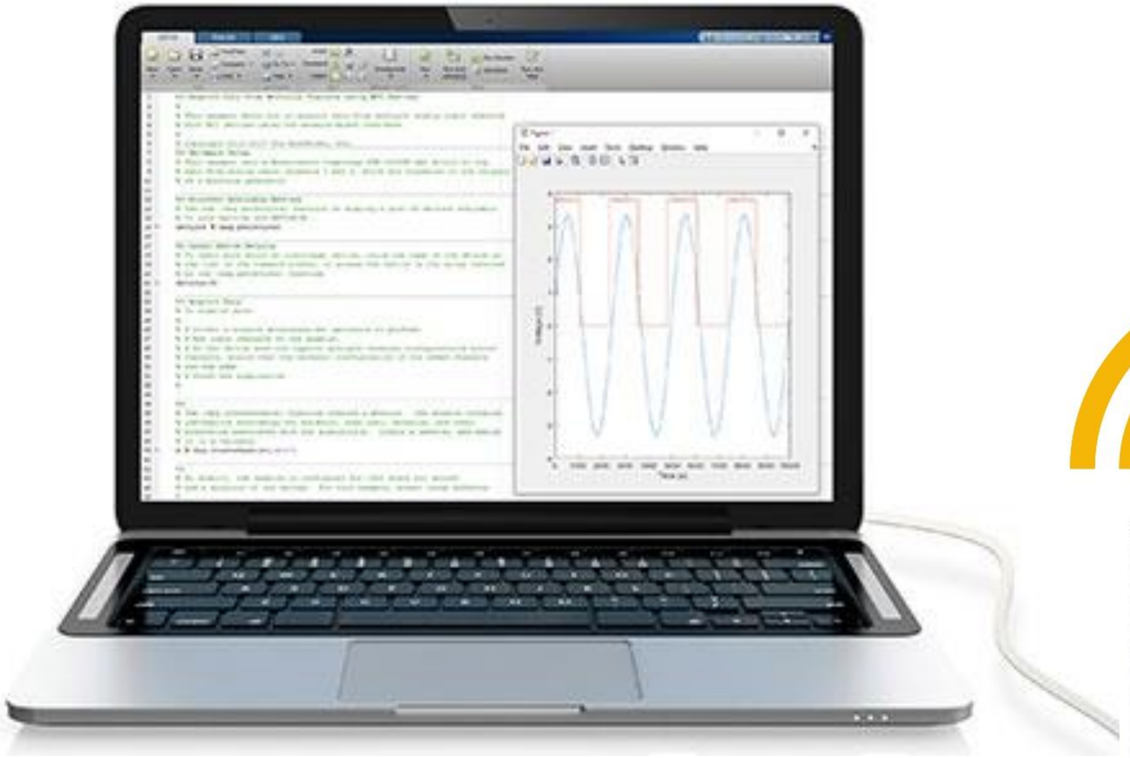

- Calibrate the thresholding and triggering

  - Filter output power
  - Scaled signal power signals

- Trigger delays are used to capture signals around the trigger point

# Workflow: Intelligent Data Detection and Capture

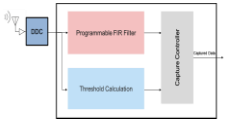




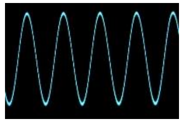
*WLAN signal detection using MATLAB and USRP N320*

# Intelligent Data Detection and Capture: Steps

The scanning procedure comprises of 5 steps


Configure the preambleDetector object



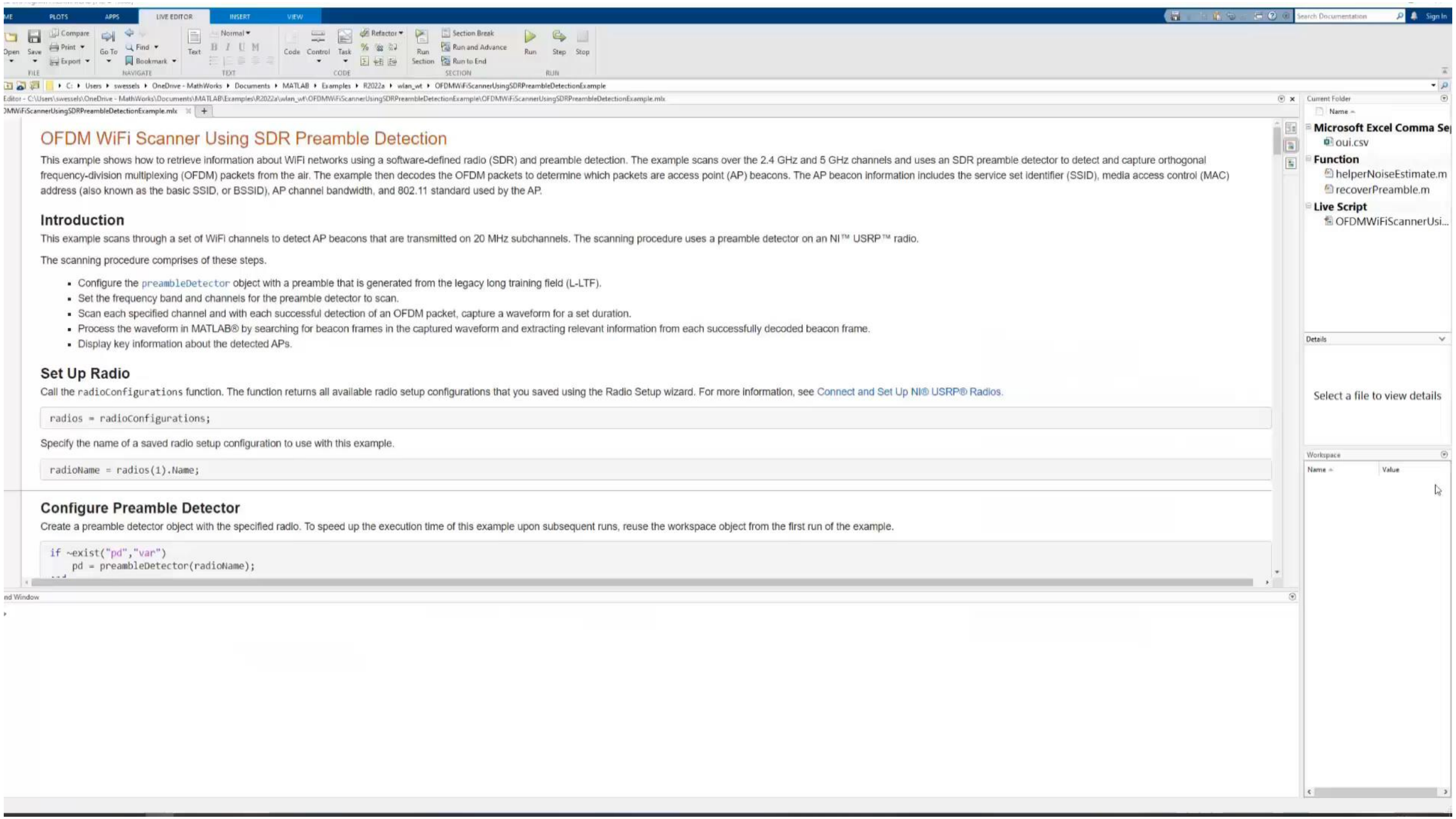
Set the frequency band and channels for the preamble detector to scan.

Scan each specified channel and capture a waveform on successful detection

Process the waveform in MATLAB

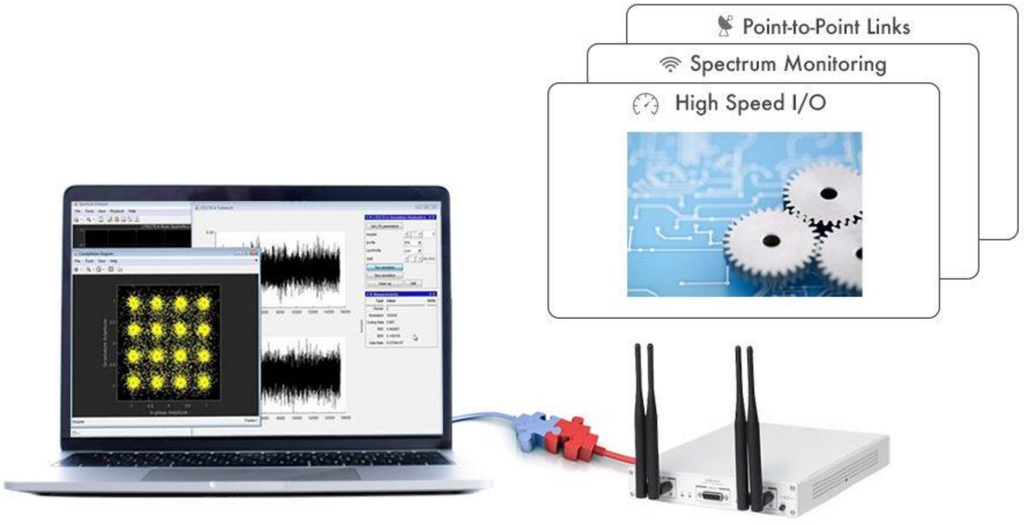
Display key information about the signal.

# Intelligent Data Detection and Capture: WLAN Scanner MATLAB Demo



# Wireless Testbench

Explore and test wireless designs using high speed and intelligent data transmit and capture




**Transmit and capture wideband signals at up to 250 MSPS**

*End-to-end transceiver design, Standard-based and custom signal transmitter/receiver design*

**Intelligent data capture using preamble detector**

*Reduce data requirements by intelligently capturing only waveforms of interest by preamble detection.*

**Arbitrary sample rate**

*Work with 5G, WLAN, and DVB-S2 and custom signals using MATLAB and supported SDR*

## Other Features

- USRP SDR support
- Simple radio set up
- Prebuilt reference applications

# Summary

- Close collaboration between NI and MathWorks for SDR solutions
- Tight integration between MATLAB and USRP radio
- Accelerating transition from simulation to prototyping
- N310, N320, N321 provide capabilities for apps like high-speed transmit/capture, spectrum monitoring

# Thank you