

Wireless Testbench™

Getting Started Guide



MATLAB®

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Wireless Testbench™ Getting Started Guide

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Revision History

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| | | |
|----------|---|-------------|
| | Product Overview | |
| 1 | <hr/> | |
| | Wireless Testbench Product Description | 1-2 |
| | | |
| | About Wireless Testbench Applications Using SDR | |
| 2 | <hr/> | |
| | Wireless Testbench Reference Applications on SDR | 2-2 |
| | Supported Radio Devices | 2-3 |
| | | |
| | Tutorials | |
| 3 | <hr/> | |
| | Capture from Frequency Band | 3-2 |
| | Transmit Waveform | 3-5 |
| | Loopback Transmit and Capture | 3-8 |
| | Triggered Capture Using Preamble Detection | 3-11 |

Product Overview

Wireless Testbench Product Description

Explore and test wireless reference applications in real time on SDR hardware

Wireless Testbench provides reference applications that are ready to run on off-the-shelf software-defined radio (SDR) hardware such as USRP™ using over-the-air signals for high-speed data transmit, capture, and spectrum monitoring.

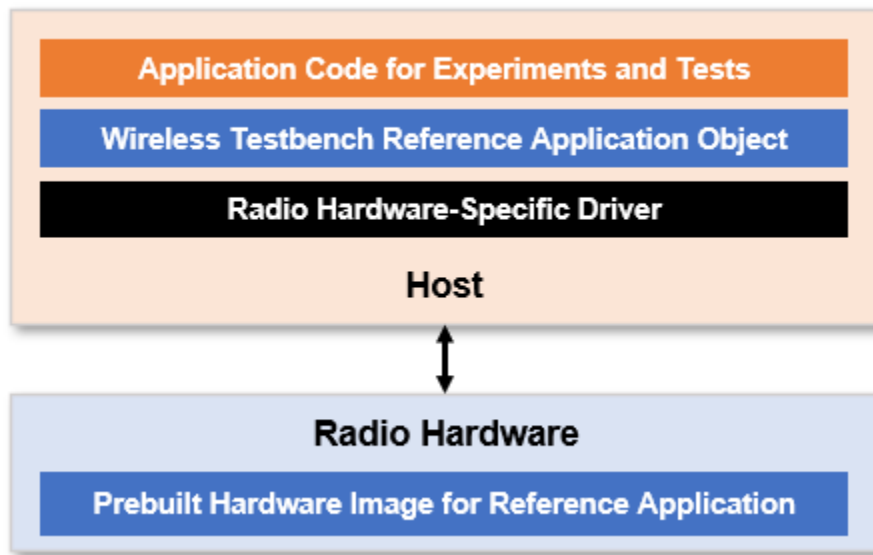
Using MATLAB® command line instructions, you can connect to supported SDR hardware, configure and execute prebuilt FPGA bitstreams as reference applications, and perform real-time measurements.

Using the configurable preamble detector, you can define a trigger to capture only the signal of interest for offline analysis in MATLAB.

About Wireless Testbench Applications Using SDR

Wireless Testbench Reference Applications on SDR

Wireless Testbench reference applications are prebuilt hardware images that enable you to explore wireless applications for software-defined-radio (SDR) hardware by using MATLAB objects. This diagram is a high-level overview of how Wireless Testbench reference application objects integrate SDR capabilities of supported radios.



Using a Wireless Testbench reference application object, you can configure the prebuilt hardware image to transmit, capture, or detect wireless signals and write your application code for experimenting and testing.

| Wireless Testbench Reference Application Object | Description |
|---|---------------------------------------|
| basebandReceiver | Configure SDR as baseband receiver |
| basebandTransceiver | Configure SDR as baseband transceiver |
| basebandTransmitter | Configure SDR as baseband transmitter |
| preambleDetector | Configure SDR as preamble detector |

See Also

More About

- “Supported Radio Devices” on page 2-3

Supported Radio Devices

Wireless Testbench Support Package for NI™ USRP Radios provides support for these radios.

USRP Networked Series

- USRP N310
- USRP N320
- USRP N321

See Also

More About

- “Install Support Package for NI USRP Radios”
- “Connect and Set Up NI USRP Radios”

Tutorials

Capture from Frequency Band

This example shows how to use a software-defined radio (SDR) to capture data from a specified frequency band. The example then plots the frequency spectrum of the captured data.

Set Up Radio

Call the `radioConfigurations` function. The function returns all available radio setup configurations that you saved using the Radio Setup wizard. For more information, see “Connect and Set Up NI USRP Radios”.

```
radios = radioConfigurations;
```

Specify the name of a saved radio setup configuration to use with this example.

```
radioName = radios(1).Name;
```

Specify Frequency Band

Specify the start and the end of the frequency band. By default, this example captures the 87.5-108 MHz frequency band, typically allocated to FM radio.

```
frequencyBand.Start = 87500000;
frequencyBand.End = 108000000;
frequencyBand.Width = frequencyBand.End - frequencyBand.Start;
frequencyBand.MidPoint = frequencyBand.Start + frequencyBand.Width/2;
```

Configure Baseband Receiver

Create a baseband receiver object with the specified radio. To speed up the execution time of this example upon subsequent runs, reuse the workspace object from the first run of the example.

```
if ~exist("bbrx", "var")
    bbrx = basebandReceiver(radioName);
end
```

To capture the full width of the frequency band:

- Set the `SampleRate` property to a value that is greater than or equal to the width of the frequency band.
- Set the `CenterFrequency` property to the value that corresponds to the middle of the frequency band.

Set the `RadioGain` property according to the local signal strength.

```
bbrx.SampleRate = frequencyBand.Width;
bbrx.CenterFrequency = frequencyBand.MidPoint;
bbrx.RadioGain = 60;
bbrx.Antennas = 'RF0:RX2';
```

Capture IQ Data

To capture IQ data from the the specified frequency band, call the `capture` function on the baseband receiver object. Specify the length of the capture.

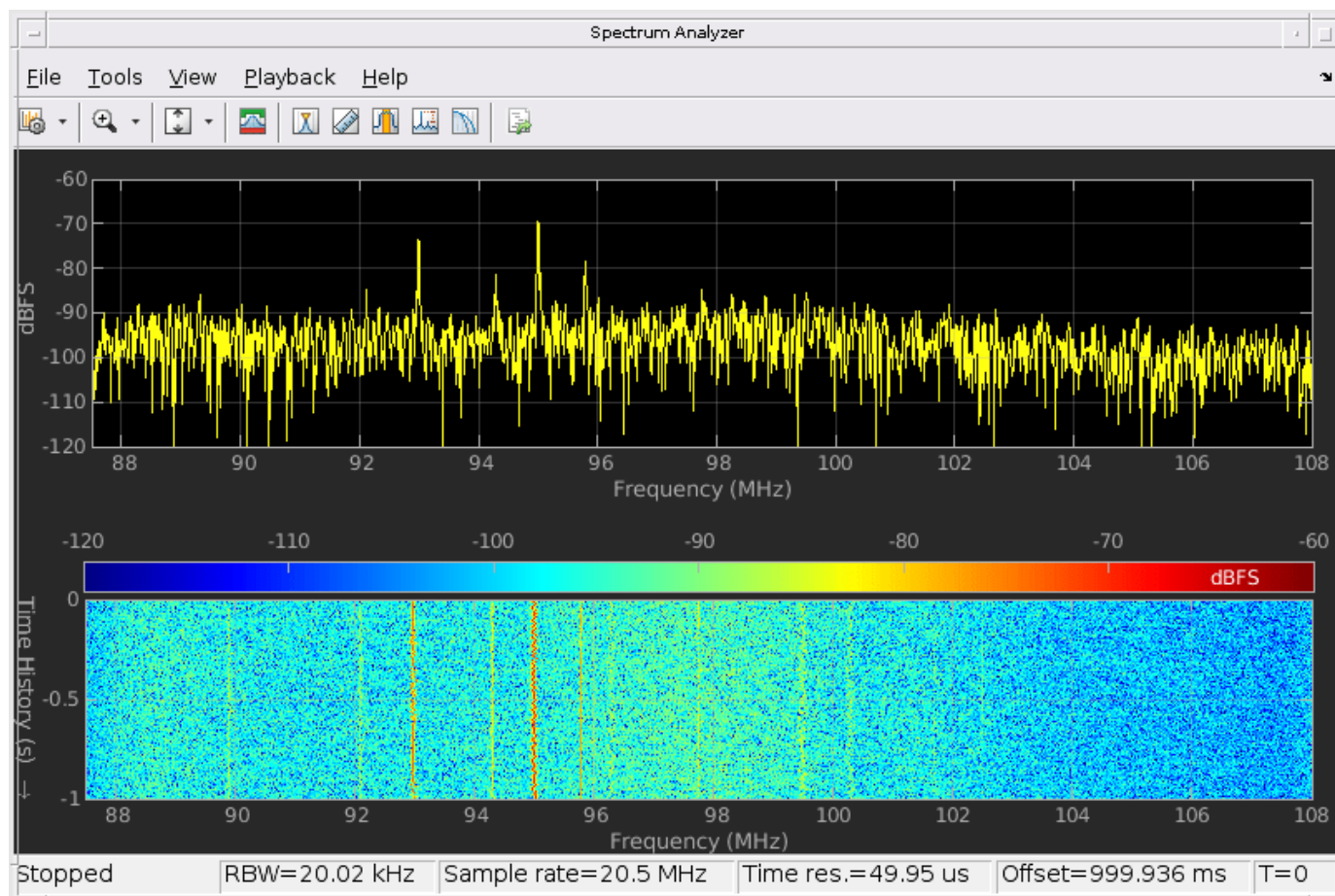
```
captureLength = milliseconds();
data = capture(bbrx,captureLength);
```

Plot Spectrum of Captured Data

Create a `dsp.SpectrumAnalyzer` object. Set the sample rate of the spectrum analyzer object to the sample rate of the baseband receiver object. Plot the spectrum and spectrogram of the captured data.

```
PlotPowerLimits = [, ];
```

```
spectrumScope = dsp.SpectrumAnalyzer;
spectrumScope.SampleRate = bbrx.SampleRate;
spectrumScope.FrequencyOffset = bbrx.CenterFrequency;
spectrumScope.ViewType = "Spectrum and spectrogram";
spectrumScope.TimeSpanSource = "Property";
spectrumScope.TimeSpan = seconds(captureLength);
spectrumScope.YLimits = PlotPowerLimits;
spectrumScope.ColorLimits = PlotPowerLimits;
spectrumScope.SpectrumUnits = "dBFS";
spectrumScope.FullScaleSource = "Property";
spectrumScope.FullScale = double(intmax('int16'));
spectrumScope(data);
release(spectrumScope);
```



See Also

Functions

radioConfigurations

Objects

basebandReceiver

More About

- “Capture from Frequency Band with Multiple Antennas”
- “Supported Radio Devices” on page 2-3

Transmit Waveform

This example shows how to use a software-defined radio (SDR) to transmit a custom generated wireless waveform.

Set Up Radio

Call the `radioConfigurations` function. The function returns all available radio setup configurations that you saved using the Radio Setup wizard. For more information, see “Connect and Set Up NI USRP Radios”.

```
radios = radioConfigurations;
```

Specify the name of a saved radio setup configuration to use with this example.

```
radioName = radios(1).Name;
```

Specify Wireless Waveform

Use the attached `QAM-4-GeneratedWaveform.mat` file to specify the transmit waveform. The `waveStruct` structure contains a QAM-4 waveform that is generated by using the Wireless Waveform Generator app.

```
load("QAM-4-GeneratedWaveform.mat")
```

Configure Baseband Transmitter

Create a baseband transmitter object with the specified radio. To speed up the execution time of this example upon subsequent runs, reuse the workspace object from the first run of the example.

```
if ~exist("bbtx", "var")
    bbtx = basebandTransmitter(radioName);
end
```

Configure the baseband transmitter object according to the parameters of the wireless waveform.

- Set the `SampleRate` property to the sample rate of the generated waveform.
- Set the `CenterFrequency` property to a value in the frequency spectrum indicating the position of the waveform transmission.

```
bbtx.SampleRate = waveStruct.Fs;
bbtx.CenterFrequency = 2.4e9;
```

Set the `RadioGain` property according to the local wireless channel. Specify the transmit antennas.

```
bbtx.RadioGain = 10;
bbtx.Antennas = 'RF0:TX/RX';
```

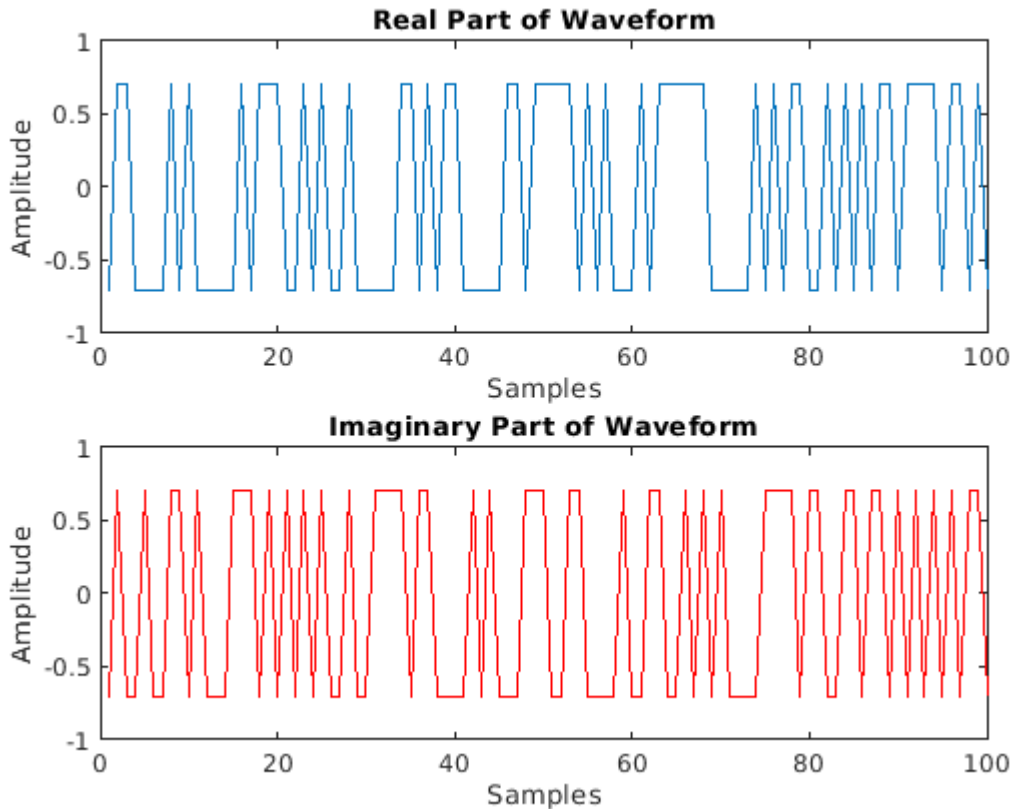
Plot Wireless Waveform

Plot the first hundred samples of the wireless waveform.

```

waveform = waveStruct.waveform;
figure();
subplot(2,1,1); plot(real(double(waveform(1:100))));
title("Real Part of Waveform")
xlabel("Samples"); ylabel("Amplitude");
subplot(2,1,2); plot(imag(double(waveform(1:100))),color='r');
title("Imaginary Part of Waveform")
xlabel("Samples"); ylabel("Amplitude");

```



Transmit Wireless Waveform

Call the `transmit` function on the baseband transmitter object. Specify the type of transmission.

```

transmit(bbtX,waveform,  );

```

End Transmission

To end a continuous transmission, call the `stopTransmission` function on the baseband transmitter object.


```
stopTransmission(bbtX);
```

See Also

Functions

radioConfigurations

Objects

basebandTransmitter

More About

- “Capture from Frequency Band” on page 3-2
- “Supported Radio Devices” on page 2-3

Loopback Transmit and Capture

This example shows how to use a software-defined radio (SDR) to transmit and capture a custom wireless waveform over the air.

Set Up Radio

Call the `radioConfigurations` function. The function returns all available radio setup configurations that you saved using the Radio Setup wizard. For more information, see “Connect and Set Up NI USRP Radios”.

```
radios = radioConfigurations;
```

Specify the name of a saved radio setup configuration to use with this example.

```
radioName = radios(1).Name;
```

Specify Wireless Waveform

Use the attached `TestTone.mat` file to specify the transmit waveform. The `waveStruct` structure contains a complex sine tone that is generated by using the Wireless Waveform Generator app.

```
load("TestTone.mat")
```

Configure Baseband Transceiver

Create a baseband transceiver object with the specified radio. To speed up the execution time of this example upon subsequent runs, reuse the workspace object from the first run of the example.

```
if ~exist("bbtrx", "var")
    bbtrx = basebandTransceiver(radioName);
end
```

Configure the baseband transceiver object using the parameters of the wireless waveform.

- Set the `SampleRate` property to the sample rate of the generated waveform.
- Set the `CenterFrequency` property to a value in the frequency spectrum indicating the position of the waveform transmission.

```
bbtrx.SampleRate = waveStruct.Fs;
bbtrx.TransmitCenterFrequency = 2.4e9;
bbtrx.CaptureCenterFrequency = bbtrx.TransmitCenterFrequency;
```

Set the `TransmitRadioGain` and `CaptureRadioGain` properties according to the local wireless channel. Specify the transmit and capture antennas.

```
bbtrx.TransmitRadioGain = 10;
bbtrx.CaptureRadioGain = 10;
bbtrx.TransmitAntennas = RF0:TX/RX;
bbtrx.CaptureAntennas = RF0:RX2;
```

Transmit Wireless Waveform

Call the `transmit` function on the baseband transceiver object. Specify a continuous transmission.

```
transmit(bbtrx, waveStruct.waveform, "continuous");
```

Capture IQ Data

To capture the transmitted waveform, call the `capture` function on the baseband receiver object. Specify the length of the capture.

```
pause(1)
captureLength = milliseconds(1000);
data = capture(bbtrx, captureLength);
```

End Transmission

To end the continuous transmission, call the `stopTransmission` function on the baseband transceiver object.

```
stopTransmission(bbtrx);
```

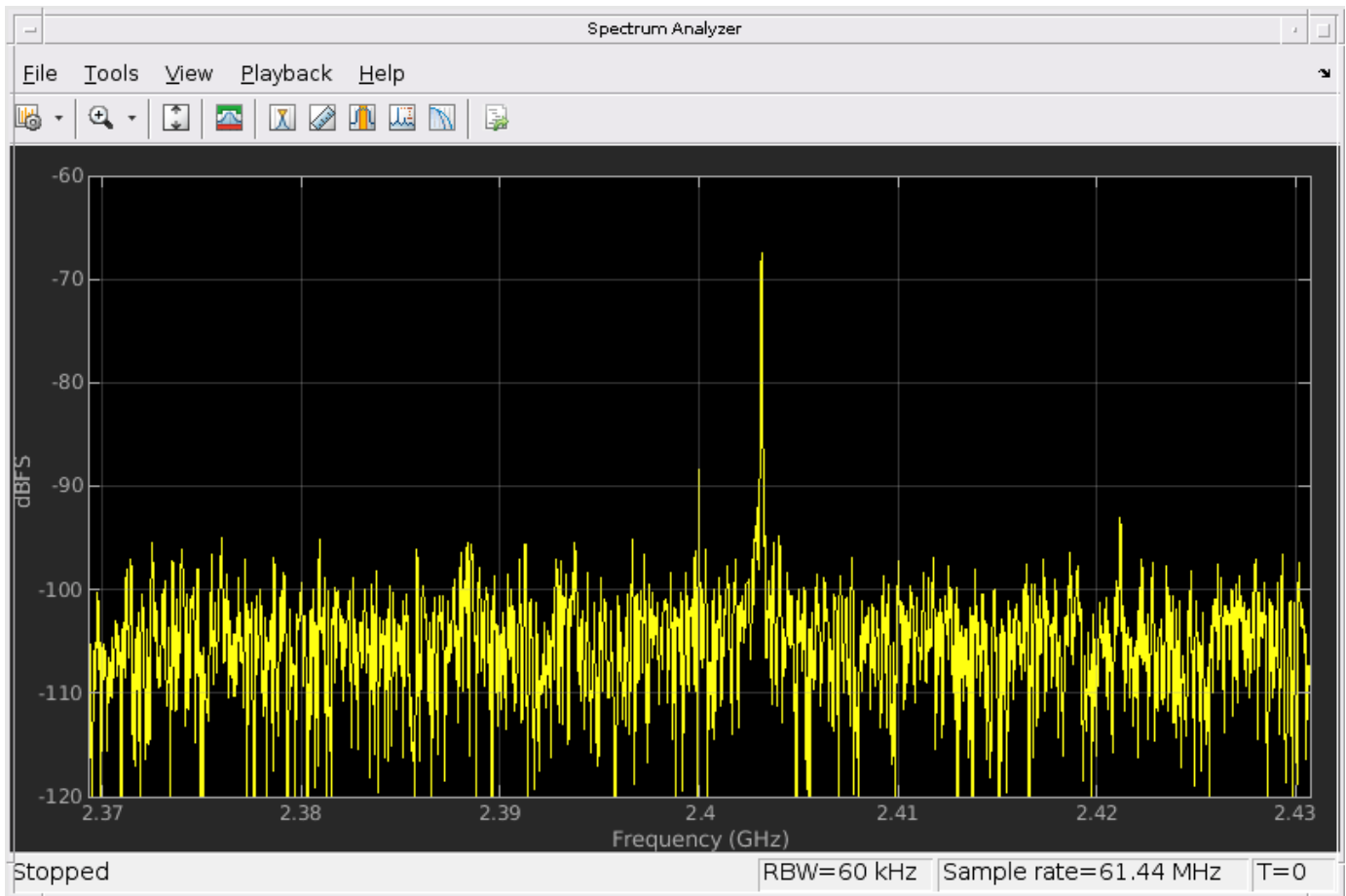
Plot Spectrum of Captured Waveform

Create a `dsp.SpectrumAnalyzer` object. Set the sample rate of the spectrum analyzer object to the sample rate of the baseband transceiver object. Plot the spectrum of the captured data.

```
PlotPowerLimits = [-120, -60];
```

Transmit, Capture, and plot frequency spectrum

```
spectrumScope = dsp.SpectrumAnalyzer;
spectrumScope.SampleRate = bbtrx.SampleRate;
spectrumScope.FrequencyOffset = bbtrx.CaptureCenterFrequency;
spectrumScope.YLimits = PlotPowerLimits;
spectrumScope.SpectrumUnits = "dBFS";
spectrumScope.FullScaleSource = "Property";
spectrumScope.FullScale = double(intmax('int16'));
spectrumScope(data);
release(spectrumScope);
```



See Also

Functions

radioConfigurations

Objects

basebandTransceiver

More About

- "Transmit Waveform" on page 3-5
- "Supported Radio Devices" on page 2-3

Triggered Capture Using Preamble Detection

This example shows how to use a software-defined-radio (SDR) to capture data from the air using preamble detection. The example also shows how to use the transmit capabilities of the same radio to loop back a test waveform.

Introduction

The example demonstrates these steps.

- 1 Generate a waveform containing a preamble.
- 2 Configure the preamble detector to detect the preamble sequence.
- 3 Use the `plotThreshold` function to calibrate a fixed or adaptive threshold and capture data.
- 4 Explore trigger offset.

Set Up Radio

Call the `radioConfigurations` function. The function returns all available radio setup configurations that you saved using the Radio Setup wizard. For more information, see “Connect and Set Up NI USRP Radios”.

```
radios = radioConfigurations;
```

Specify the name of a saved radio setup configuration to use with this example.

```
radioName = radios(1).Name;
```

Generate Transmission Waveform

Create a transmission waveform containing a Zadoff-Chu preamble sequence. To enable straightforward demonstration of the preamble detection workflow, concatenate zeros before and after the preamble.

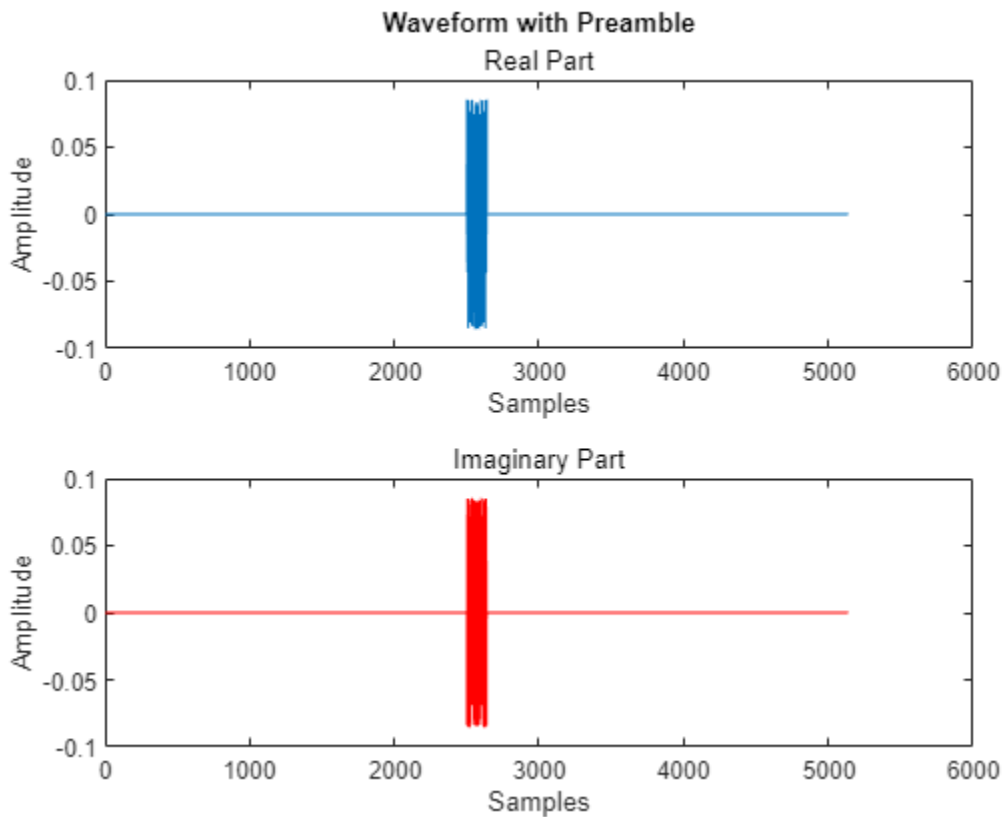
Generate a preamble sequence of length 137 by using 38th root of the Zadoff-Chu sequence and normalize. Concatenate with zeros.

```
preamble = zadoffChuSeq(38,137);
preamble = preamble/norm(preamble,2);
prePadLen = 2501;
postPadLen = 2500;
headSignal = complex(zeros(prePadLen,1),zeros(prePadLen,1));
rearSignal = complex(zeros(postPadLen,1),zeros(postPadLen,1));
inputSignal = [headSignal; preamble; rearSignal];
```

Plot transmission waveform.

```
figure();
subplot(2,1,1); plot(real(inputSignal));
subtitle("Real Part");
xlabel("Samples");
ylabel("Amplitude");
title("Waveform with Preamble");
subplot(2,1,2);
plot(imag(inputSignal),Color='r');
subtitle("Imaginary Part");
```

```
xlabel("Samples");
ylabel("Amplitude");
```



Configure Preamble Detector

Create a preamble detector object with the specified radio. To speed up the execution time of this example upon subsequent runs, reuse the workspace object from the first run of the example.

```
if ~exist("pd", "var")
    pd = preambleDetector(radioName);
end
```

Set the RF properties of the preamble detector. Set the `RadioGain` property according to the local wireless channel.

```
pd.SampleRate      = 30720000;
pd.CenterFrequency = 2450000000;
pd.Antennas        = RF0:RX2;
pd.RadioGain       = 45; % Increase if signal levels are low.
```

Configure the preamble sequence for preamble detection.

```
pd.Preamble = preamble;
```

Set the capture data type to the data type of the generated transmission waveform.

```
pd.CaptureDataType = "double";
```

Configure Transmission Variables

Set the transmit gain and transmit antenna values. Set the transmit gain variable according to the local wireless channel.

```
txGain      = 45; % Increase if signal levels are low.
txAntenna   = RF0:TX/RX;
```

Detect Preamble Using Fixed Threshold and Capture Data

Data capture is triggered when the correlator output is greater than the fixed threshold. By setting the fixed threshold to 0, you can analyze the behavior of the preamble detector and understand how to set the fixed threshold value for successful detection.

Set the preamble detector to use fixed threshold. To set the threshold method, stop any ongoing transmission.

```
stopTransmission(pd);
pd.ThresholdMethod = "fixed";
```

Set the fixed threshold initially to 0.

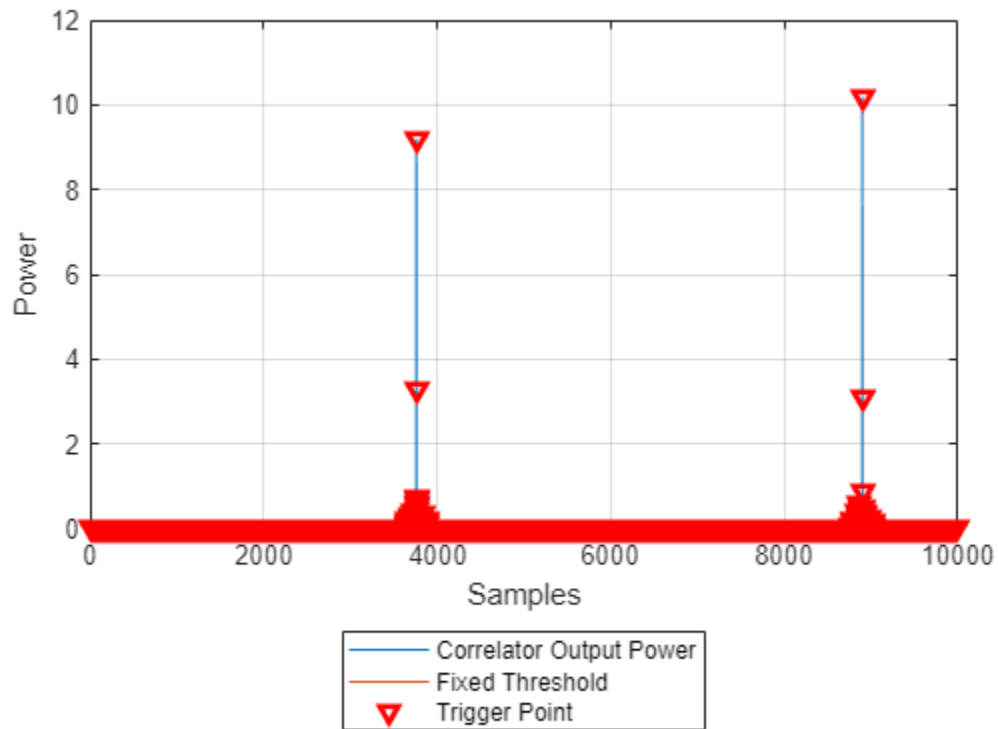
```
pd.FixedThreshold = 0;
```

Transmit the test waveform.

```
transmit(pd,inputSignal,"continuous",TransmitGain=txGain, ...
    TransmitCenterFrequency=pd.CenterFrequency,TransmitAntennas=txAntenna);
```

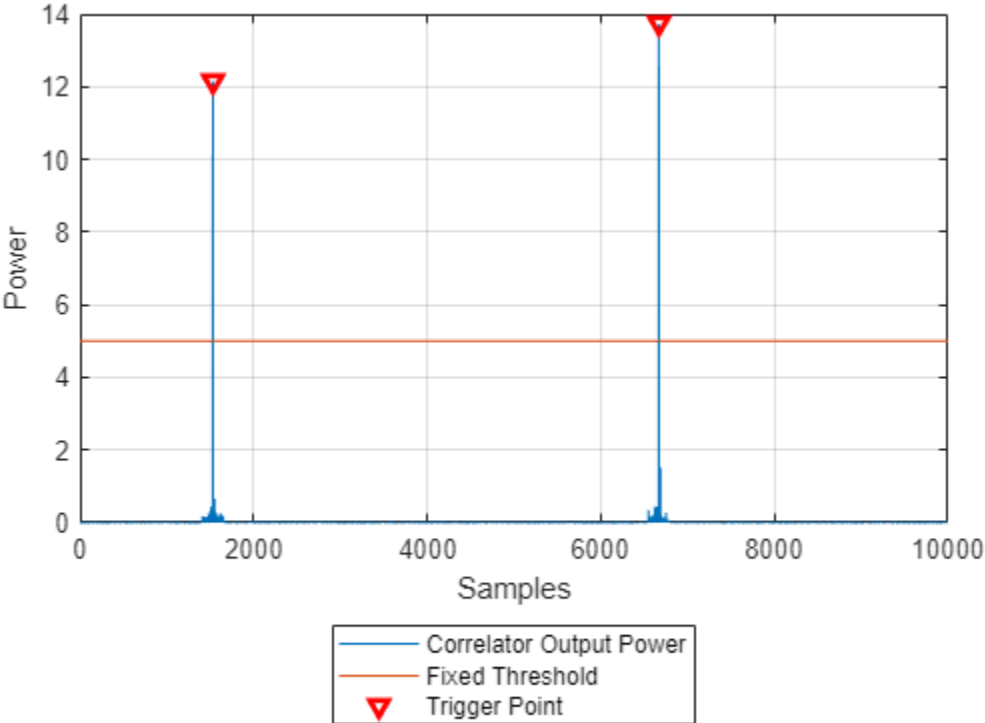
Use the `plotThreshold` function to analyze the behavior of the detector by plotting 10,000 samples. Because the fixed threshold value is 0, all samples from the correlator output are possible trigger points. Check the correlator output values at the peak trigger points. Because the sampling phase determines the quality of the correlator peak, run the `plotThreshold` function multiple times to see how the trigger points change.

```
plotThreshold(pd,10e3);
```



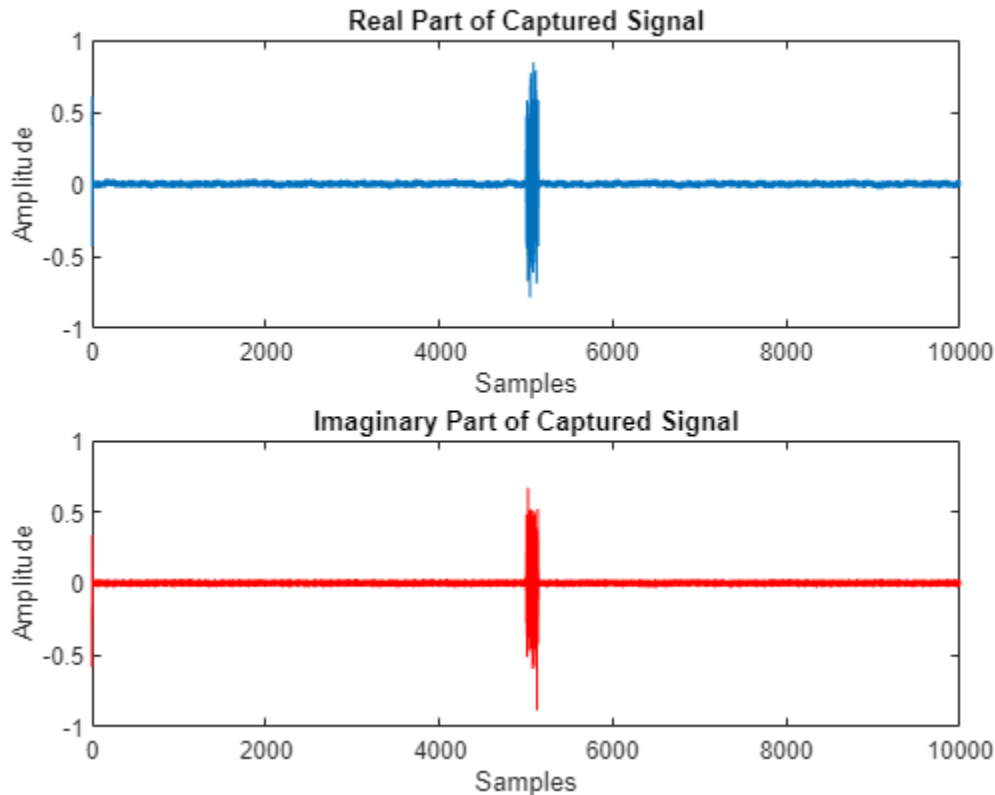
Choose a threshold value that is below any of the trigger point values. Plot the threshold information again and adjust the fixed threshold until the trigger points appear only on the correlator output peak.

```
pd.FixedThreshold = 5;  
plotThreshold(pd, 10e3);
```

Once the threshold is set, capture data.

```
[data, ~, ~, status] = capture(pd, 10e3, seconds(1));  
plotCapturedData(data,status);
```



Detect Preamble Using Adaptive Threshold and Capture Data

As an alternative to the fixed threshold, data capture can be triggered when the correlator output is greater than the adaptive threshold, which dynamically varies with the input signal power. By setting the adaptive threshold gain and offset to 0, you can analyze the behavior of the preamble detector and understand how to configure the adaptive threshold for successful detection.

Set the preamble detector to use adaptive threshold. To set the threshold method, stop any ongoing transmission.

```
stopTransmission(pd);
pd.ThresholdMethod = 'adaptive';
```

Set the adaptive threshold gain and offset initially to 0.

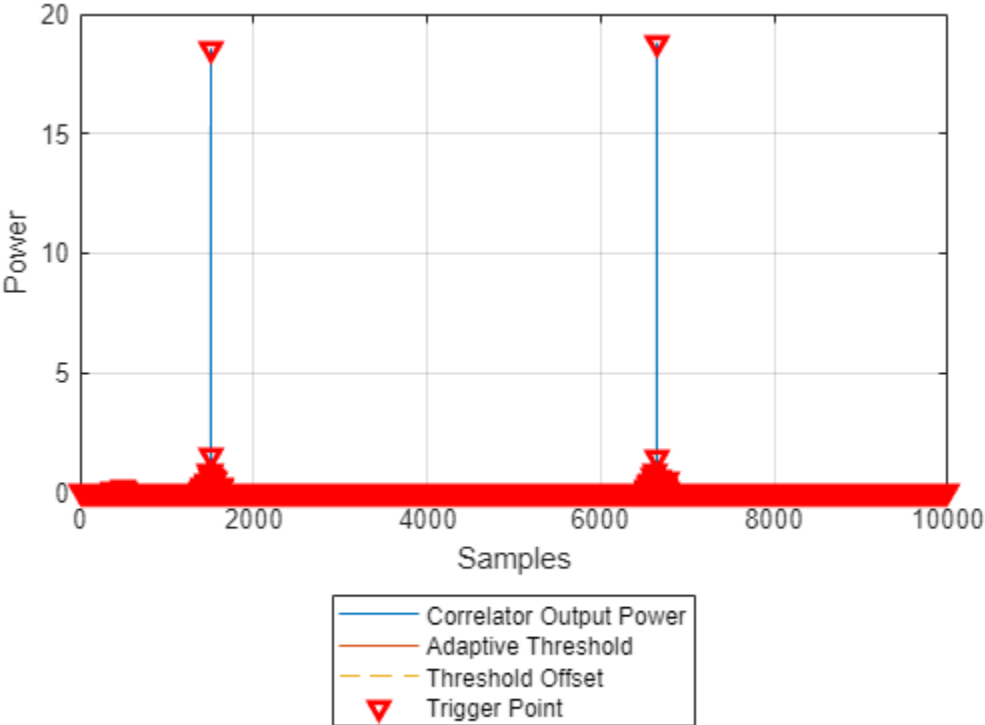
```
pd.AdaptiveThresholdGain = 0;
pd.AdaptiveThresholdOffset = 0;
```

Transmit the test waveform.

```
transmit(pd, inputSignal, "continuous", TransmitGain=txGain, ...
    TransmitCenterFrequency=pd.CenterFrequency, TransmitAntennas=txAntenna);
```

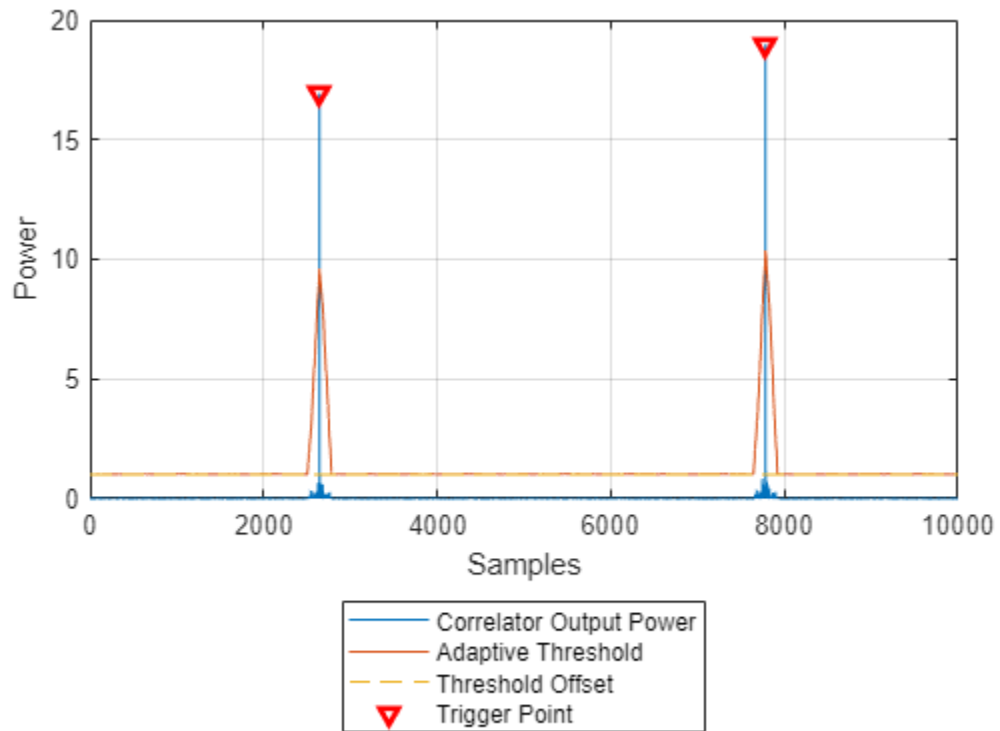
Use the `plotThreshold` function to analyze the behavior of the detector by plotting 10,000 samples. Check the correlator output values at the peak trigger points and run the `plotThreshold` function multiple times if necessary.

```
plotThreshold(pd, 10e3);
```



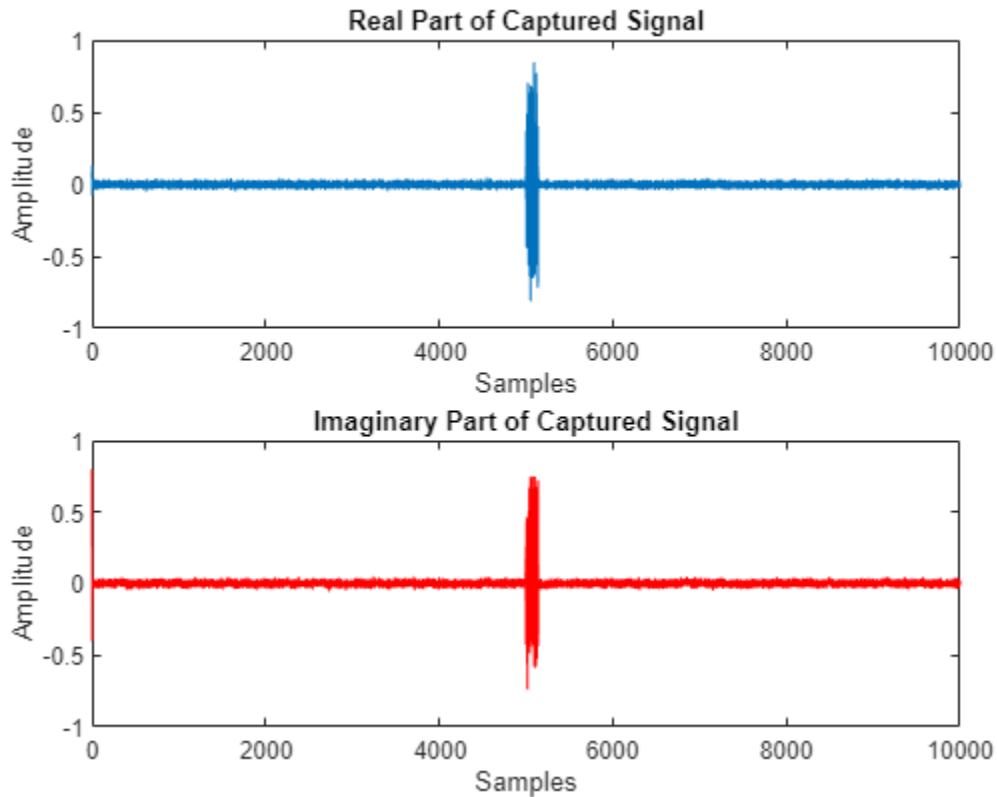
To remove all the trigger points from the bottom of the plot, set the adaptive threshold offset to a value that is above the noise floor. Adjust the adaptive threshold gain and plot the threshold information repeatedly until the correlator output is greater than the adaptive threshold.

```
pd.AdaptiveThresholdOffset = 1;  
pd.AdaptiveThresholdGain = 0.25;  
plotThreshold(pd, 10e3);
```



Once the threshold is configured, capture data.

```
[data, ~, ~, status] = capture(pd, 10e3, seconds(1));  
plotCapturedData(data,status);
```



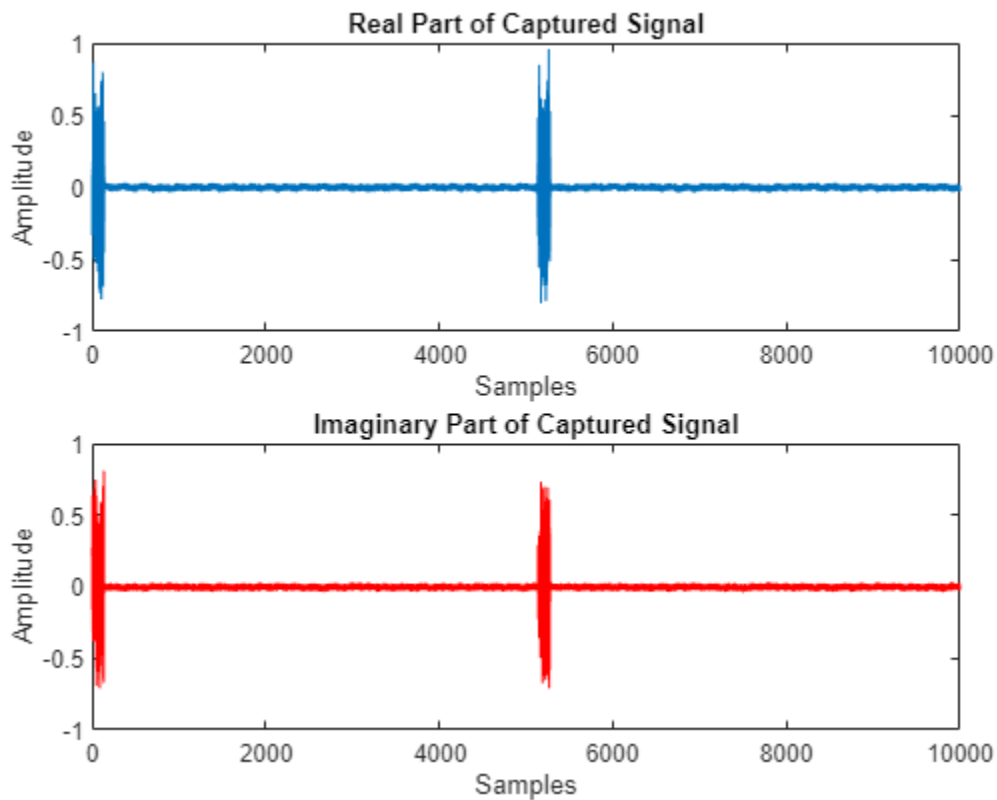
Set Trigger Offset to Include Preamble in Captured Data

To capture the preamble sequence, set the trigger offset to the length of the preamble. To set the trigger offset, stop any ongoing transmission.

```
stopTransmission(pd);
pd.TriggerOffset = ;
```

Transmit the test waveform and capture data.

```
transmit(pd, inputSignal, "continuous", TransmitGain=txGain, ...
    TransmitCenterFrequency=pd.CenterFrequency, TransmitAntennas=txAntenna);
% Detect and capture 10,000 samples, with a 1 second timeout
[data, ~, ~, status] = capture(pd, 10e3, seconds(1));
plotCapturedData(data, status);
```



End Transmission

To end the continuous transmission, call the `stopTransmission` function on the preamble detector object.

```
stopTransmission(pd);
```

Local Functions

```
function plotCapturedData(data,status)
    if status % If detection is successful, plot data
        figure();
        subplot(2,1,1); plot(real(double(data)));
        title("Real Part of Captured Signal")
        xlabel("Samples"); ylabel("Amplitude");
        subplot(2,1,2); plot(imag(double(data)),color='r');
        title("Imaginary Part of Captured Signal")
        xlabel("Samples"); ylabel("Amplitude");
    else
        disp("Detection failed.")
    end
end
```

See Also

Functions

`radioConfigurations`

Objects

preambleDetector

More About

- “Capture from Frequency Band” on page 3-2
- “Supported Radio Devices” on page 2-3

