LabVIEW Reference Design for Wireless Research with NI Ettus USRP X410 Getting Started

2025-03-22

Contents

Overview

This document explains how to install, configure, and verify the record & playback and fast beam steering features of LabVIEW Reference Design for Wireless Research with NI Ettus USRP X410, and describes common tasks you may perform. This document applies to all design variants, such as the PCIe or PXIe option.

Use the record & playback feature to generate and process 5G signals and perform continuous streaming with the Ettus USRP X410.

Use the fast beam steering feature to control beams in real time. The Ettus USRP X410 generates an SPI command based on user-defined beam patterns and sends the SPI command to the mmWave BBox devices. The mmWave BBox devices perform fast beam steering after receiving the SPI command.

> **Notice** Using record & playback in a manner not described in this document might impair the functionality of the reference design or damage the hardware.

New Features and Changes

Learn about updates—including new features and behavior changes—introduced in each version of the LabVIEW Reference Design for Wireless Research with NI Ettus USRP X410.

LabVIEW Reference Design for Wireless Research with NI Ettus USRP X410 2.0 New Features and Changes

- Support up to 64 preconfigured beams for fast beam steering in Tx mode and Rx mode, respectively.
- Support single beam steering in 2 µs.
- Build custom reference FPGA bitfiles for fast beam steering using the FPGA project included with the LabVIEW Reference Architecture Software for Prototyping Wireless Systems with Ettus USRP X410.
- Change the offering name from Wireless Prototype System for USRP X410 to LabVIEW Reference Design for Wireless Research with NI Ettus USRP X410.

Related tasks:

- Fast Beam Steering
- Customizing the Reference FPGA

LabVIEW Reference Design for Wireless Research with NI Ettus USRP X410 1.1 New Features and Changes

- Support up to 245.76 MSps with four channels for multi-channel Rx recording.
- Support multi-channel Tx playback.
- Build custom reference FPGA bitfiles for Rx recording and Tx playback using the FPGA project included with the LabVIEW Reference Architecture Software for Prototyping Wireless Systems with Ettus USRP X410.

Related tasks:

- Multi-Channel Rx Recording (Single Device)
- Multi-Channel Tx Playback (Single Device)
- Customizing the Reference FPGA

Receiving the Shipment

Read the documentation, such as specifications and getting started guides, of the components included in your LabVIEW reference design. Visit the NI Product Documentation Center for the latest documentation.
LabVIEW Reference Design for Wireless Research with NI Ettus USRP X410 arrives with all the accessories based on the reference design part number you ordered.
Related information:

- NI Product Documentation Center

Verifying Shipment Contents

Verify the following items are included in the shipment based on your reference design part number.

Table 1. Shipment Contents By Reference Design Part Number

Reference Design Part Number	Component	Quantity
868001-04, USRP X410 LabVIEW Bundle for 6G Research Standard	Cable assy, SMA to SMA, coax, RG-402, 50 Ω, 1 m	2
	PXIe-8394, x8, Gen 3 MXI-Express Daisy-Chain Interface	1
	PXIe-8267 high-speed NVMe data storage module, 4 TB	1
	MXI-Express cable, Gen 3 x8, copper, 3 m	1
	PXIe-1092, 9-slot 3U PXI Express chassis with Timing and Synchronization option	1
	Ettus USRP X410 (4 TX and 4 RX, 400 MHz bandwidth, 1 MHz to 7.2 GHz SDR, GPSDO)	1
	PXIe-8881 Xeon 18-core controller, Windows 10 64-bit (Multiple Languages)	1

Reference Design Part Number	Component	Quantity
	Packaging BOM, 37.4" × 25.98" × 18.7" box, PADPAK58 QTY 21	1
868001-03, USRP X410 LabVIEW Bundle for 6G Research Standard - Chinese Language Controller	Cable assy, SMA to SMA, coax, RG-402, 50 Ω, 1 m	2
	PXIe-8394, x8, Gen 3 MXI-Express Daisy-Chain Interface	1
	PXIe-8267 high-speed NVMe data storage module, 4 TB	1
	MXI-Express cable, Gen 3 x8, copper, 3 m	1
	PXIe-1092, 9-slot 3U PXI Express chassis with Timing and Synchronization option	1
	Ettus USRP X410 (4 TX and 4 RX, 400 MHz bandwidth, 1 MHz to 7.2 GHz SDR, GPSDO)	1
	PXIe-8881 Xeon 18-core controller, Windows 10 64-bit (Simplified Chinese)	1
	Packaging BOM, 37.4" × 25.98" × 18.7" box, PADPAK58 QTY 21	1
868002-03, USRP X410 LabVIEW Bundle for 6G Research PCIe Base	Cable assy, SMA to SMA, coax, RG-402, 50 Ω, 1 m	2
	Ettus USRP X410 (4 TX and 4 RX, 400 MHz bandwidth, 1 MHz to 7.2 GHz SDR, GPSDO)	1
	PCIe Gen3 Interface Kit for Ettus USRP X4xx (Desktop)	1
	Packaging BOM, Container 56.6 × 47.7 × 35.5 cm W/ PADPAK58-20	1
868003-03, USRP X410 LabVIEW Bundle for 6G Research PXIe Base	Cable assy, SMA to SMA, coax, RG-402, 50 Ω, 1 m	2
	PXIe-8394, x8, Gen 3 MXI-Express Daisy-Chain Interface	1
	MXI-Express cable, Gen 3 x8, copper, 3 m	1
	Ettus USRP X410 (4 TX and 4 RX, 400 MHz	1

Reference Design Part Number	Component	Quantity
	bandwidth, 1 MHz to 7.2 GHz SDR, GPSDO)	
	Packaging BOM, Container 51.1 × 37.5 × 31.1 cm W/ PADPAK58-06	1
868064-26, USRP RF Extension, TMYTEK-NI BBox One 5G 28GHz Beamformer Box 16 Channels	TMYTEK-NI BBox One 5G 28GHz Beamformer Box 16 Channels	1
868064-24, USRP RF Extension, TMYTEK-NI BBox Lite 5G 28GHz Beamformer Box 4 Channels	TMYTEK-NI BBox Lite 5G 28GHz Beamformer Box 4 Channels	1
868064-22, USRP RF Extension, TMYTEK-NI UD Box 5G Series - Dual Channels	TMYTEK-NI UD Box 5G Series - Dual Channels	1
868064-21, USRP RF Extension, TMYTEK-NI UD Box 5G Series - Single Channel	TMYTEK-NI UD Box 5G Series - Single Channel	1

Required Components

Prepare additional items for device setup following the ***Ettus USRP X410 Getting Started Guide***.

Related information:

- Ettus USRP X410 Getting Started Guide

Connecting the Hardware

Connecting Hardware for Record & Playback

If you want to use record & playback, connect hardware components by following the ***NI-USRP*** section in the ***Ettus USRP X410 Getting Started Guide***.

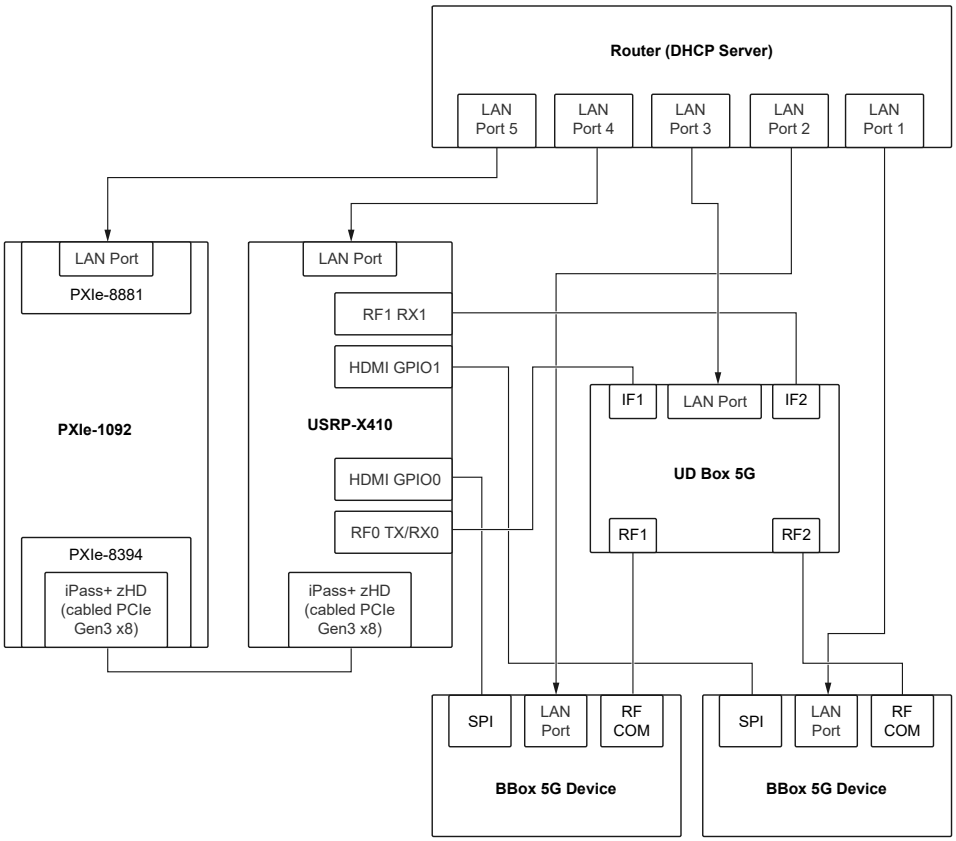
> **Note** If your part number contains PXIe-8267, set up PXIe-8267 by following the ***PXIe-8267 Getting Started Guide***.

Connecting Hardware for Fast Beam Steering

The following figure shows an example of hardware connections for fast beam steering. You can adjust hardware connections based on your test needs.

You must keep the IP addresses of all the hardware components in the same domain.

Figure 1. Hardware Connections for Fast Beam Steering



Related information:

- Ettus USRP X410 Getting Started Guide
- PXIe-8267 Getting Started Guide

Installing the Software

Before installing the LabVIEW Reference Architecture Software for Prototyping Wireless Systems with Ettus USRP X410, you must complete the steps described in the ***Installing the Software*** sections of the ***Ettus USRP X410 Getting Started Guide*** and ensure your LabVIEW reference design meets the following software requirements:

- Windows 10 (64-bit)
- LabVIEW 2022 Q3 (64-bit)
- LabVIEW 2022 Q3 FPGA Module
- (Optional) RFmx NR 2022 Q3

  Note Install NI-RFSA when installing RFmx NR.

- NI-USRP 2022 Q4

1. Download the LabVIEW Reference Architecture Software for Prototyping Wireless Systems with Ettus USRP X410 from ni.com.
2. Install the software.
3. Activate the software with NI License Manager.
4. Find the source code in the `C:\Program Files\National Instruments\LabVIEW 2022\examples\Wireless Prototype Software for USRP X410` directory.

Related information:

- Ettus USRP X410 Getting Started Guide

Configuring and Running the Reference Design

Launch NI Measurement & Automation Explorer (MAX) and ensure MAX detects all the devices in your reference design.

For more information about detecting devices in MAX or troubleshooting, refer to the ***Ettus USRP X410 Getting Started Guide***.

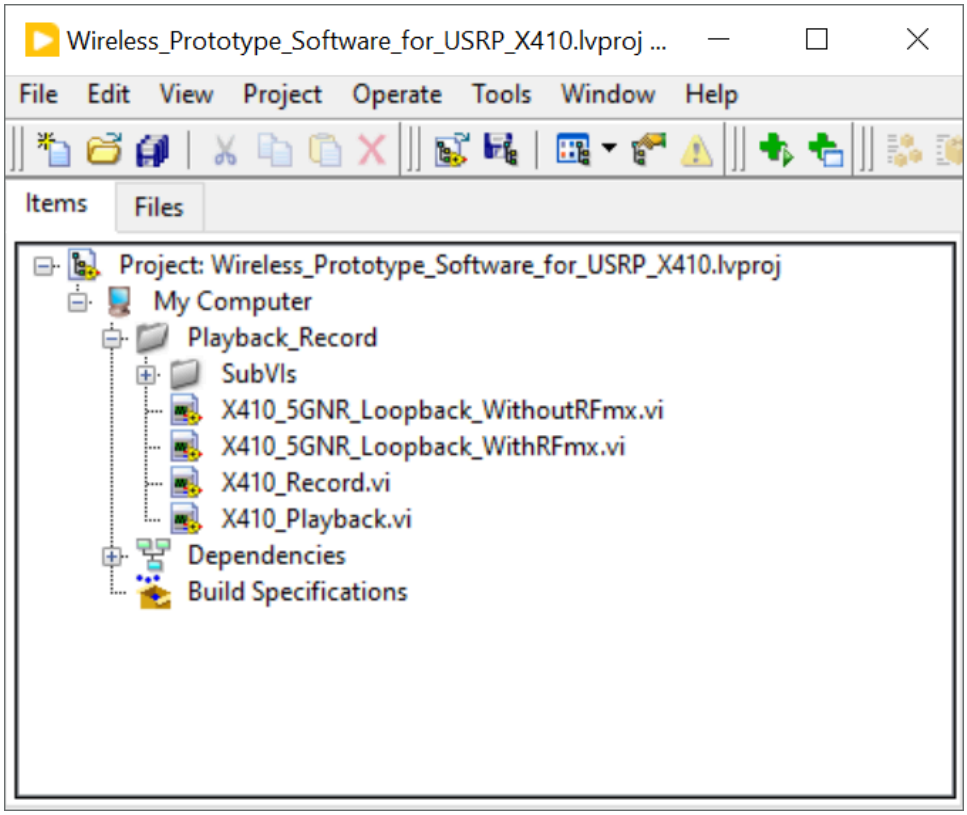
Related information:

- Ettus USRP X410 Getting Started Guide

5G Signal Generating and Processing

1. Run LabVIEW Reference Architecture Software for Prototyping Wireless Systems with Ettus USRP X410 as Administrator.
2. Open the LabVIEW project `Wireless_Prototype_Software_for_USRP_X410.lvproj`.

Figure 2. LabVIEW Project View



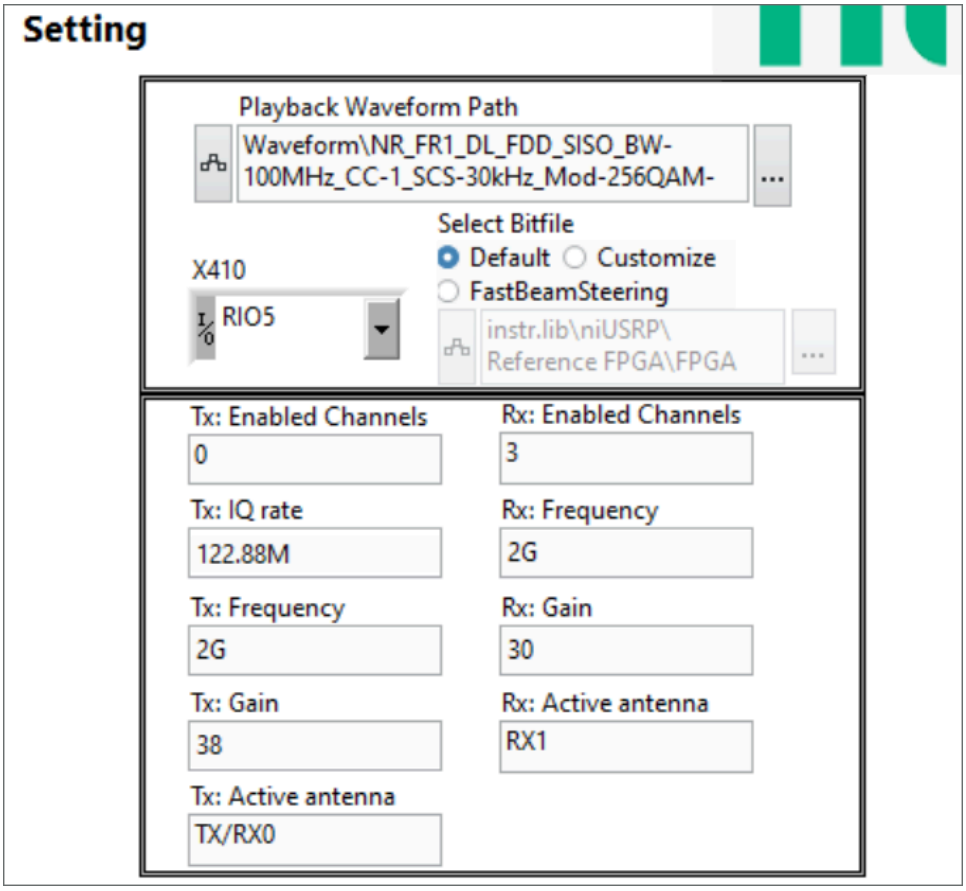
3. Choose the VI to configure according to your use case:

VI	Use Case
`X410_5GNR_Loopback_WithRFmx.vi`	Performs 5G NR transmission and analysis.
`X410_5GNR_Loopback_WithoutRFmx.vi`	Performs signal transmission and recording.

You must install RFmx NR in your reference design if you use `X410_5GNR_Loopback_WithRFmx.vi`.

4. Configure **Setting** with the NR waveform you want to playback.
   a. In MAX, configure **X410** with Device name.
   b. Select **Default** under **Select Bitfile** to load the default bitfile `X410ReferenceFpga_4ch_4spc.lvbitx`. Alternatively, select **Customize** and click the ... button to load a customized bitfile.
   c. Configure values or use the default values for the RF parameters of X410 as shown in the following figure. Pay attention to the Tx:Gain and Rx:Gain according to your hardware connection.

Figure 3. Setting

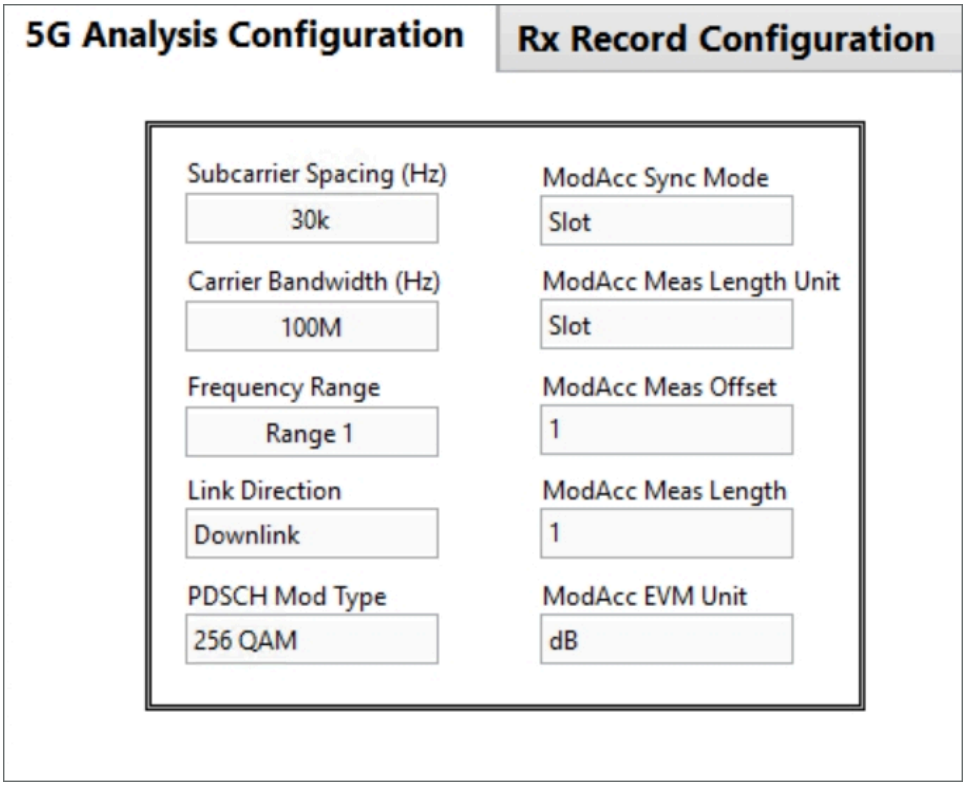


5. Configure the following tabs.

> **Note** You can enable only one function with one run, 5G Analysis or Rx Record.

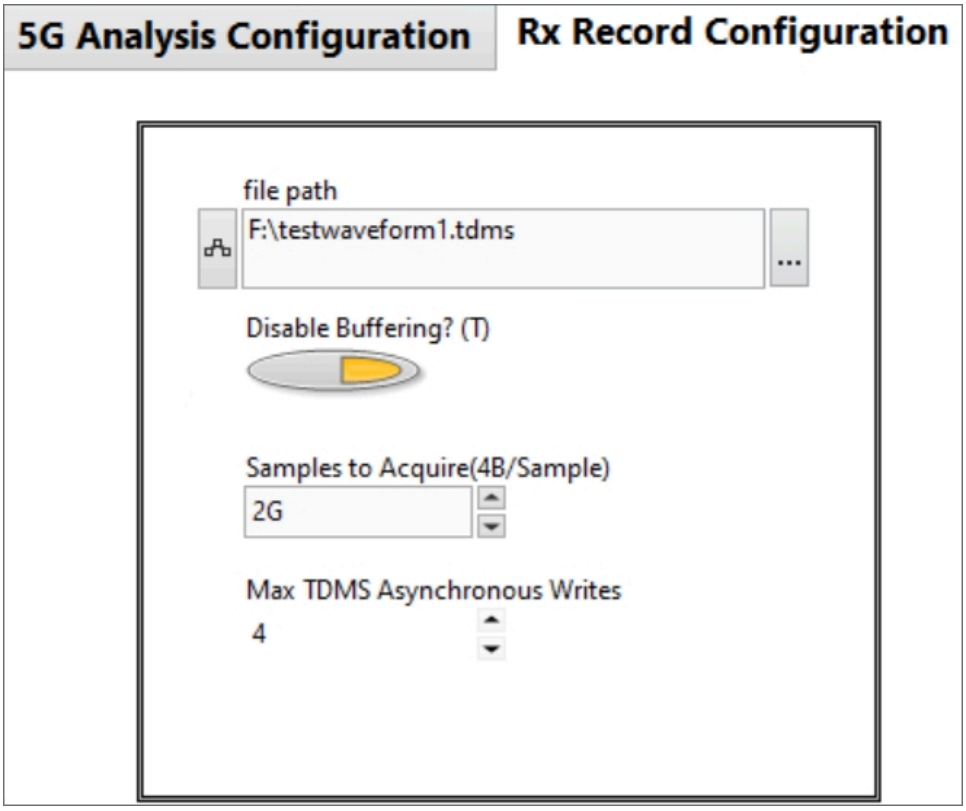
   - 5G Analysis Configuration: Analyzes NR waveform. All the NR parameters must exactly match the parameters of NR waveform you are transmitting.

Figure 4. 5G Analysis Configuration



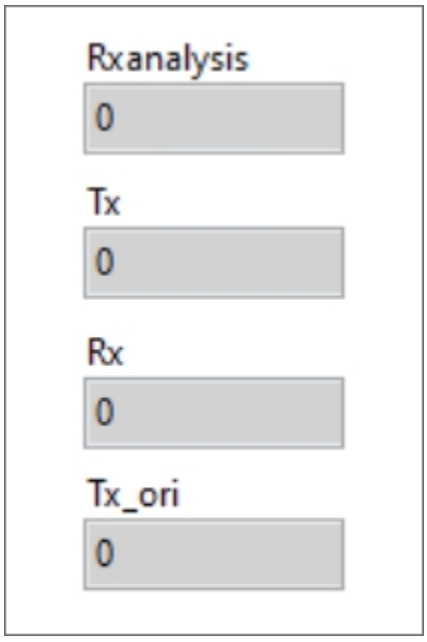
- Rx Record Configuration: Records with Rx. Click the **file path** browse button and specify a location to save the record files, such as RAID. Enable **Disable Buffering** to speed up data transfers in certain situations. Specify the record size, in four bytes per sample, in **Samples to Acquire**. Specify **Max TDMS Asynchronous Writes** to complete the configuration. The saved data has real (I) and imaginary (Q) components. I and Q are interleaved (I, Q, I, Q, ...) in the saved files.

Figure 5. Rx Record Configuration



6. Click **Run**. The initialization process takes a few minutes. Do not switch tabs until the Initialization parameters have non-zero values in the Idle&Debug tab.

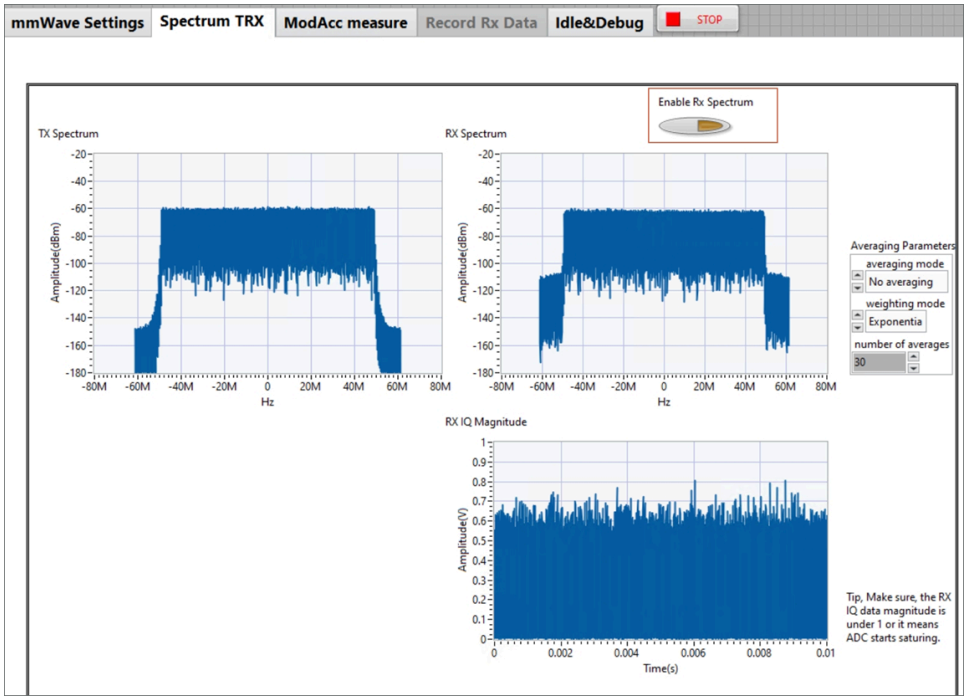
Figure 6. Initialization Parameters During Initialization



Tip To optimize performance, disable the **Enable Spectrum View** button

> when navigating away from the Idle&Debug tab.

Figure 7. Rx - Spectrum



a. Switch to the ModAcc measure tab to view the EVM of NR Rx waveform.
b. If you previously set the Rx Record Configuration, start and monitor the record process in the Record Rx Data tab.

7. Click **Stop**.

Extending to mmWave

If you have the following mmWave devices, the 5G signal generating and processing functions can be extended to mmWave using the reference code that the LabVIEW Reference Design for Wireless Research with NI Ettus USRP X410 provides.

- TMYTEK-NI UD Box 5G - Dual Channel x1
- TMYTEK-NI BBox One 5G x1
- TMYTEK-NI BBox Lite 5G x1

For more information about TMYTEK-NI mmWave devices, visit ***Research 6G Technologies with Wideband RF Record and Playback Systems*** or contact your local NI sales representative.

1. Switch to **mmWave Settings**.
2. Specify parameters in the **BBoxOne** or **BBoxLite** section according to the mmWave BBox devices you have. In this case, X410 is working as an IF device and the IF output/input should be connected to UD Box.
3. Click **Control by LAN**.
4. Click **Enable mmWave?** in the **UD** section to enable your mmWave devices.
5. Wait for 10 seconds until **Active** in the **BBoxOne** or **BBoxLite** section is on (green).

Related information:

- Research 6G Technologies with Wideband RF Record and Playback Systems

Fast Beam Steering

1. Open `X410_5GNR_Loopback_WithRFmx.vi` or `X410_5GNR_Loopback_WithoutRFmx.vi`.

   Note You must install RFmx NR in your reference design if you use `X410_5GNR_Loopback_WithRFmx.vi`.

2. In the **Setting** section, select **FastBeamSteering** under **Select Bitfile** to load `X410ReferenceFpga_4ch_4spc_FBS.lvbitx`. Alternatively, select **Customize** and click the ... button to load a customized fast beam steering bitfile.
3. Switch to the **mmWave Settings** tab.
4. Specify parameters in the **BBoxOne** or **BBoxLite** section according to the mmWave BBox devices you have.
5. Click **Control by SPI**.
6. Click **Enable mmWave?** in the **UD** section to enable your mmWave devices.
7. Wait for 10 seconds until **Active** in the **BBoxOne** or **BBoxLite** section is on (green).
8. Under **Control by SPI**, select a row in **Beam Pattern Table**.
   Each row specifies a default beam pattern.
9. **Optional:** Click **Edit selected pattern** and modify beam forming parameters to adjust the default beam pattern based on your test needs.
10. Select a port from the **SPI Port** list according to your hardware connection.
11. Click **Commit**.
    The Ettus USRP X410 generates an SPI command based on the beam pattern you configured and sends the SPI command to the mmWave BBox devices. The

mmWave BBox devices perform fast beam steering after receiving the SPI command.

12. Switch to the **Spectrum TRX** tab to check the impact of fast beam steering on spectrums.

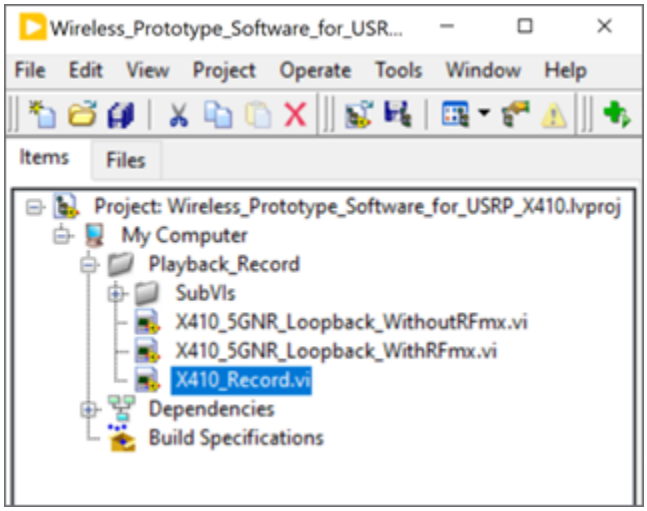
Related reference:

- LabVIEW Reference Design for Wireless Research with NI Ettus USRP X410 2.0 New Features and Changes

Multi-Channel Rx Recording (Single Device)

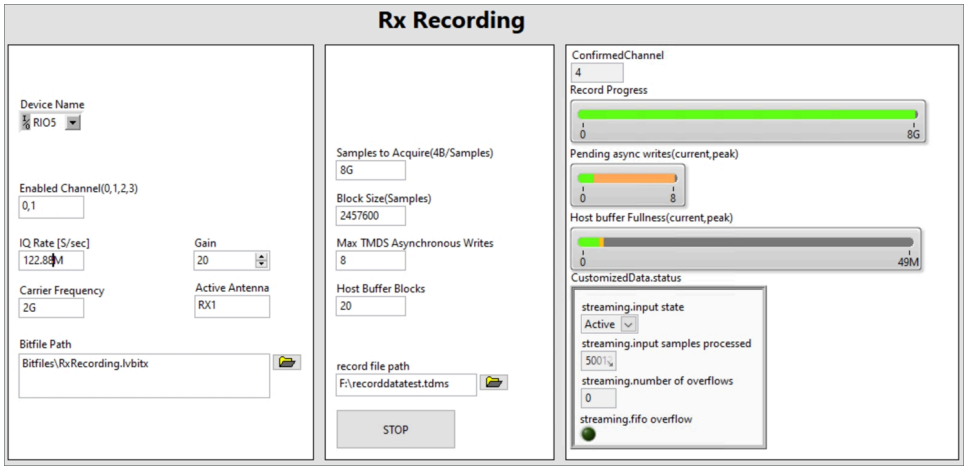
1. Run LabVIEW Reference Architecture Software for Prototyping Wireless Systems with Ettus USRP X410 as Administrator.
2. Open the LabVIEW project `Wireless_Prototype_Software_for_USRP_X410.lvproj`.

Figure 8. LabVIEW Project View - X410_Record.vi



3. Open `X410_Record.vi` for multi-channel streaming with a single X410 device.

Figure 9. Rx Recording - Multi-Channels



4. Complete the following configuration:
   a. Specify **Device Name** according to the X410 name in MAX.
   b. Specify **Enabled Channel (0, 1, 2, 3)** to capture signal. You can only enable one, two, or four channels. When specifying more than one channel, enter channel names in numerical order. For example, to enable four channels, enter channel names as `0, 1, 2, 3`.
   c. Specify **IQ rate**. IQ rate can be up to 491.52 MSps with one or two channels enabled, and up to 245.76 MSps with four channels enabled.
   d. Under **Bitfile Path**, keep the default bitfile `RxRecording.lvbitx` or load a customized Rx recording bitfile.
   e. Specify Rx **Gain** according to the received signal, RF frequency, and **Active Antenna** as RX1.
   f. Specify file information, including file path, file size, and block size per write. You can use the default values or specify values based on your test needs. This recording VI saves data as Samples of U32 (combining I data I16 and Q data I16 into U32, with high-order byte is Q and low-order byte is I). For example, if you use PXIe-8267, the maximum samples to acquire is close to 1 T samples.
5. Click **Run** to start recording.
6. Monitor the **CustomizedData.status**. If overflow shows up, you can adjust your setting parameters.
7. `X410_Record.vi` stops when recording finishes.

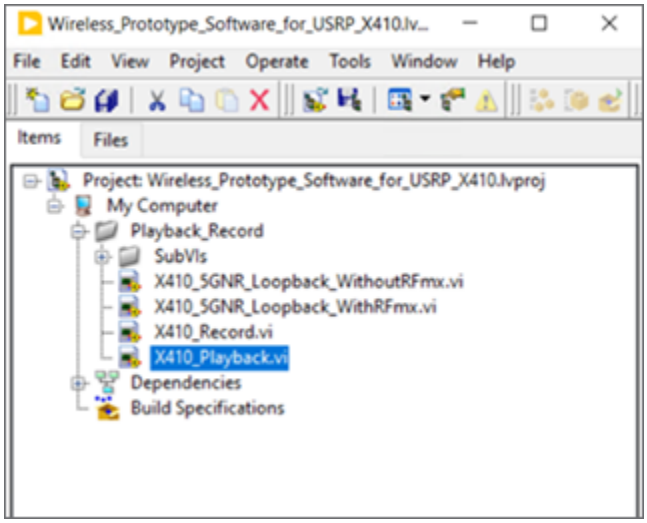
Related reference:

- LabVIEW Reference Design for Wireless Research with NI Ettus USRP X410 1.1 New Features and Changes

Multi-Channel Tx Playback (Single Device)

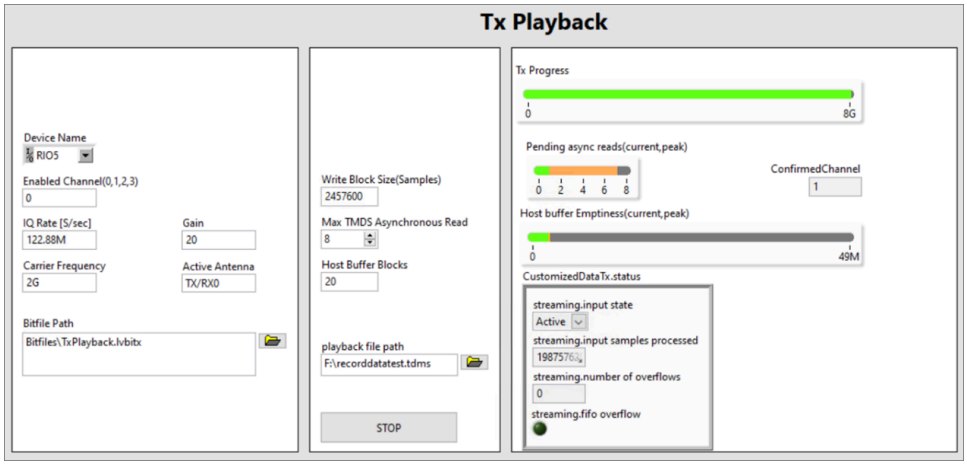
1. Run LabVIEW Reference Architecture Software for Prototyping Wireless Systems with Ettus USRP X410 as Administrator.
2. Open the LabVIEW project `Wireless_Prototype_Software_for_USRP_X410.lvproj`.

Figure 10. LabVIEW Project View - X410_Playback.vi



3. Open `X410_Playback.vi` for multi-channel streaming with a single X410 device.

Figure 11. Tx Playback - Multi-Channels



4. Complete the following configuration:
   a. Specify **Device Name** according to the X410 name in MAX.
   b. Specify **Enabled Channel (0, 1, 2, 3)** to transmit signal. You can only enable one, two, or four channels. When specifying more than one channel, enter channel names in numerical order. For example, to enable four channels, enter channel names as `0, 1, 2, 3`.

c. Specify **IQ rate**. IQ rate can be up to 491.52 MSps with one or two channels enabled, and up to 245.76 MSps with four channels enabled.
d. Under **Bitfile Path**, keep the default bitfile `TxPlayback.lvbitx` or load a customized Tx playback bitfile.
e. Specify Tx **Gain** according to the received signal, RF frequency, and **Active Antenna** as Tx/RX0.
f. Specify file information, including playback file path, write block size, and Max TDMS Asynchronous Read. You can use the default values or specify values based on your test needs. This playback VI transmits data as Samples of U32 (combining I data I16 and Q data I16 into U32, where high-order byte is Q and low-order byte is I). For example, if you use PXIe-8267, the maximum samples to transmit is close to 1 T samples.

5. Click **Run** to start transmitting.
6. Monitor the **CustomizedDataTx.status**. If overflow shows up, you can adjust your setting parameters.
7. `X410_Playback.vi` stops when transmitting finishes.

Related reference:

- LabVIEW Reference Design for Wireless Research with NI Ettus USRP X410 1.1 New Features and Changes

Customizing the Reference FPGA

To modify the reference FPGA project, you must install the NI Streaming Controller IP from VI Package Manager (VIPM). The NI Streaming Controller IP contains VIs that the reference FPGA project requires.

The reference FPGA project source code is in the `C:\Program Files\National Instruments\LabVIEW 2022\examples\Wireless Prototype Software for USRP X410\Reference FPGA Project` directory. The source code contains the following projects:

- `referenceFPGA (USRP-X410 4ch-4spc) CustomizedFIFORx.lvproj`—Rx Recording project for building the Rx recording bitfile.
- `referenceFPGA (USRP-X410 4ch-4spc) CustomizedFIFOTx.lvproj`—Tx Playback project for building the Tx playback bitfile.
- `referenceFPGA (USRP-X410 4ch-4spc) FastBeamSteering.lvproj`—Fast beam steering project for building the fast beam steering bitfile.

You can modify these bitfiles to fit your application needs. The customized bitfiles are saved to the `C:\Program Files\National Instruments\LabVIEW 2022\examples\Wireless Prototype Software for USRP X410\Reference FPGA Project\FPGA Bitfiles` directory by default. You can specify another directory to save your bitfiles.

Related reference:

- LabVIEW Reference Design for Wireless Research with NI Ettus USRP X410 1.1 New Features and Changes
- LabVIEW Reference Design for Wireless Research with NI Ettus USRP X410 2.0 New Features and Changes

Troubleshooting

Troubleshoot common issues with the solutions provided in the following table. For unexpected behavior not covered in the table, restart the system.

Table 2. Common Issues and Solutions in LabVIEW Reference Design for Wireless Research with NI Ettus USRP X410

Issue	Solution
I receive an Error -68002.	Run LabVIEW as Administrator.
An overflow occurs while streaming.	Adjust streaming-related parameters like `file destination`, `block size per write`, `Max TDMS Asynchronous Writes`, and increase `Host Buffer Blocks`.
I cannot find the USRP X410 in NI MAX.	Try the following solutions: • Turn off the Windows Firewall. • Ensure you power on the USRP X410 before powering on the PXIe-8881. • Ensure you use the Ettus USRP X410 with NI-USRP 2022 Q4. • Check cabling.

Contact your designated support channel if restarting the system or trying the above troubleshooting solutions does not resolve your issues.