LabVIEW MIMO 5G/6G Research Design Library Getting Started

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LabVIEW MIMO 5G/6G Research Design Library Overview

The LabVIEW MIMO 5G/6G Research Design Library helps you generate and analyze 5G NR signals in Physical Downlink Shared Channels (PDSCHs) with the Ettus USRP X410.

Related information:

- License Setup and Activation

Key Features

The features that set the LabVIEW MIMO 5G/6G Research Design Library apart include the following.

- Support for 30 kHz subcarrier spacing with up to 100 MHz bandwidth in the Frequency Range 1 (FR1) band
- Configurable physical-layer parameters for 5G NR waveforms
- 4x4 MIMO operation
- Video streaming
- System configuration with the gNodeB and UE LabVIEW Real-Time VIs
- Function customization with the gNodeB and UE X410 (FPGA) VIs

New Features and Changes

Learn about updates—including new features and behavior changes—introduced in each version of the LabVIEW MIMO 5G/6G Research Design Library.

LabVIEW MIMO 5G/6G Research Design Library 2.0 New Features and Changes

- Supports configuring the physical-layer parameters in `config_user.json` for 5G NR waveforms on both the gNodeB and UE sides.
- Adds the `5G NR miniRAN gNB L1C` and `5G NR miniRAN UE L1C (NSA & SA)` VIs for system configuration.
- Supports customizing functions with the `5G NR miniRAN gNB X410(FPGA)` and `5G NR miniRAN UE X410(FPGA)` VIs.
- Requires LabVIEW 2020 Digital Filter Design Toolkit (32-bit).

Related tasks:

- Configuring the System
- Installing the Software

Related reference:

- Customizing Functions

LabVIEW MIMO 5G/6G Research Design Library System Components

The LabVIEW MIMO 5G/6G Research Design Library system is a configurable hardware and software system designed for generating and analyzing 5G NR signals in PDSCHs.

Hardware Components

Table 1. Required Hardware Components from NI

Part Number	Description	Quantity
786991-01	PXIe-1092, 9-slot 3U PXI Express chassis with Timing and Synchronization option	2
787806-01	PXIe-8881 Xeon 18-core controller	2
787272-01	Ettus USRP X410 (4 TX and 4 RX, 400 MHz bandwidth, 1 MHz to 7.2 GHz SDR, GPSDO)	2
785157-01	PXIe-8394, x8, Gen 3 MXI-Express Daisy-Chain Interface	2
784306-01	CDA-2990 8-channel clock distribution accessory with GPSDO	1
785550-01	MXI-Express cable, Gen 3 x8, copper, 1 m	2
Depending on locations	Power cord, 125 V, 15 A	4
783469-01	Cable assembly, SMA to SMA, 1 m	10

Table 2. Required Hardware Components from Third-Party Vendors

Component	Quantity
Monitor	2
Keyboard	2
Mouse	2
ETH cable	8
VAT-30+ Attenuator	4
Network switch	1
Desktop PC or laptop	2

Table 3. Optional Hardware Components from NI for Upgrading

Part Number	Description	Quantity
786774-01	1 TB NVMe Solid State Drive Upgrade, M.2, 80 mm	2
785971-01	PXIe-1095, 18-slot 3U PXI Express chassis with Timing and Synchronization option	2

Software Components

- LabVIEW MIMO 5G/6G Research Design Library
- Windows 10 64-bit Operating System (for the Control PC)
- LabVIEW Real-Time (NI Linux Real-Time) Operating System (for the PXI Controller)
- LabVIEW 2020 (32-bit)
- LabVIEW 2020 FPGA Module
- LabVIEW 2020 Real-Time Module
- NI-USRP 21.0
- LabVIEW 2020 Digital Filter Design Toolkit (32-bit)

Additional Required Components

Prepare components required for setting up Ettus USRP X410 as described in the ***Ettus USRP X410 Getting Started Guide***.

Related information:

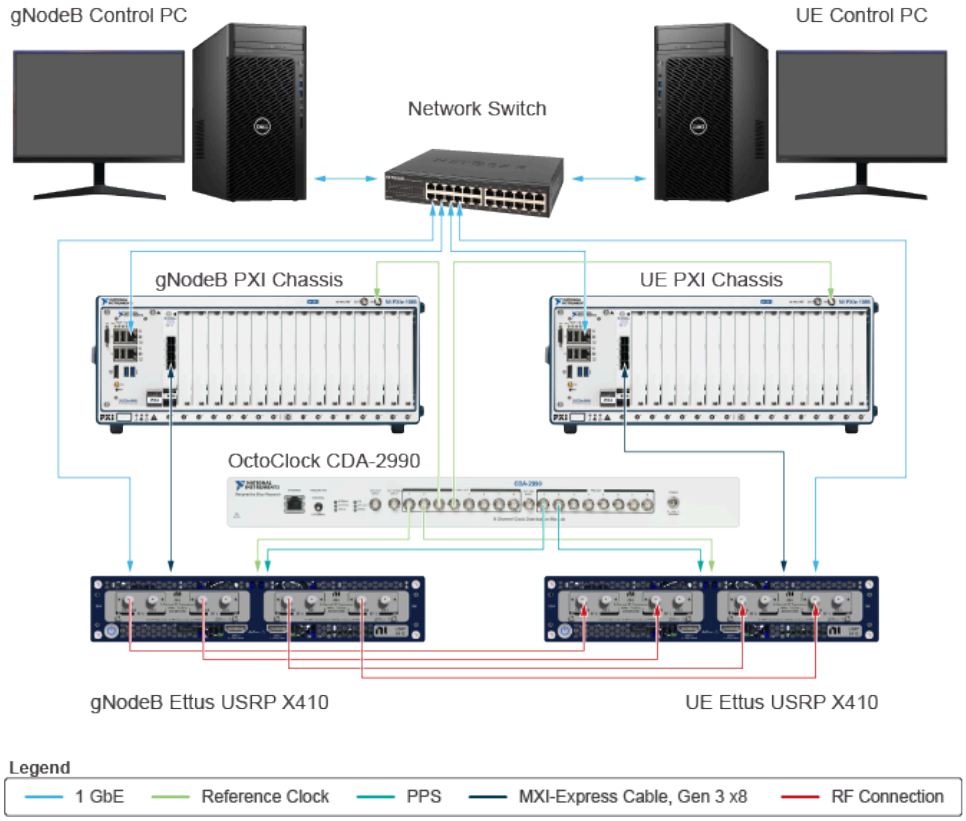
- Ettus USRP X410 Getting Started Guide

Setting Up a System

Complete the following steps to set up a LabVIEW MIMO 5G/6G Research Design Library system:

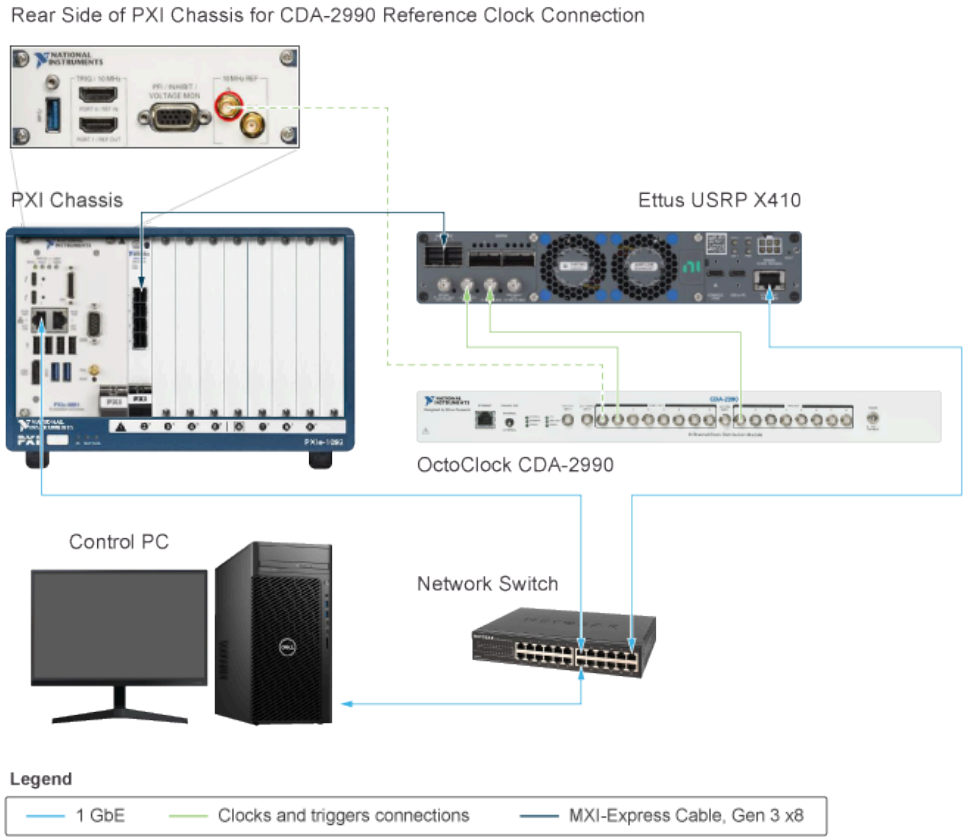
1. Install the PXI controller and modules into the PXI chassis on both the gNodeB and UE sides.
   Refer to the documentation of PXI instruments for installation instructions. Visit the NI Product Documentation Center for the latest documentation.
2. Connect hardware components on the front side as the following figure shows.

Figure 1. Hardware Connections on the Front Side



3. On both the gNodeB and UE sides, connect hardware components on the rear side as the following figure shows.

Figure 2. Hardware Connections on the Rear Side



4. On the OctoClock, set the PRIMARY REF switch to INTERNAL.

Related information:

- NI Product Documentation Center

Installing the Software

Complete the following steps on both the gNodeB and UE sides:

1. Install LabVIEW and Drivers on the control PC.
   a. In NI Package Manager, search for LabVIEW and Drivers.
   b. Select **2020** and **32-bit** for **Version** and **Bitness**, respectively.
   c. Click **INSTALL**.
   d. Select the following modules:
      - LabVIEW
      - LabVIEW Real-Time Module
      - LabVIEW FPGA Module
      - LabVIEW Digital Filter Design Toolkit
   e. Follow the instructions in the installation prompts.
2. Install the NI-USRP 21.0 on the control PC.
3. Update the FPGA bitfile for Ettus USRP X410.
   Refer to ***NI-USRP*** in ***Ettus USRP X410 Getting Started Guide*** for more information.
4. Contact your NI sales representative, Technical Support Engineer (TSE), or Applications Engineer (AE) to obtain the Real-Time image and the LabVIEW MIMO 5G/6G Research Design Library package.
5. Install the package by running `Install.exe` in the package folder.
6. After the installation completes, unzip the `XilinxsIp` folder in the `C:\Program Files (x86)\National Instruments\LabVIEW 2020\examples\LabVIEW MIMO 5G-6G Research Design Library\Common` directory.

Related reference:

- LabVIEW MIMO 5G/6G Research Design Library 2.0 New Features and Changes

Related information:

- Ettus USRP X410 Getting Started Guide

Imaging PXI Controllers

Complete the following steps on both the gNodeB and UE sides to image the PXI controllers:

Note The Ettus USRP X410 has an image or filesystem installed.

1. Create a Clonezilla Live USB flash drive with either Rufus USB Creator or YUMI – Multiboot USB Creator.
   Visit links in Related information for details.
2. Copy and extract the Real-Time image to an external USB hard drive.
3. Turn off the PXI controller.
4. Insert the Clonezilla Live USB flash drive and the external USB hard drive into the PXI controller.
5. Turn on the PXI controller.
6. Select **F10** to open the boot menu.
7. Select the Clonezilla Live UEFI USB flash drive as the boot device.
   The Clonezilla Live boots from your USB flash drive.
8. Restore the Real-Time image.
   Refer to ***Restore disk image*** on the Clonezilla site for instructions.
9. Turn off the PXI controller.
10. Remove the Clonezilla Live USB flash drive and the external USB hard drive from the PXI controller.
11. Turn on the PXI controller again.
    NI Linux Real-Time operating system starts normally.
12. Run the following command to set the hostname of the PXI controller: `nirtcfg --set section=systemsettings,token=host_name,value=<HOSTNAME>`.
13. Run the following command to double-check the hostname: `nirtcfg --get section=systemsettings,token=host_name`.
14. Add the PXI chassis to **Remote Systems** in NI Measurement & Automation Explorer (MAX).
    Refer to ***Creating a Remote System*** in ***Measurement and Automation***

Explorer for instructions.

Related information:

- Clonezilla Live on USB flash drive or USB hard drive
- Rufus USB Creator
- YUMI - Multiboot USB Creator
- Restore disk image
- Creating a Remote System

Assigning IP Addresses to Control PC and Ettus USRP X410

Before assigning IP addresses, you must connect the control PC and the Ettus USRP X410 with a USB cable and image the PXI controller. The PXI controller is automatically assigned an IP address after imaging.
Complete any of the following steps on both the gNodeB and UE sides to assign IP addresses to the control PC and the Ettus USRP X410:

- Statically assign IP addresses to the control PC and the Ettus USRP X410.
  The IP addresses of the control PC and the Ettus USRP X410 should be in the same domain as the IP address of the PXI controller.
- If you find the IP address of the control PC is not in the same domain as the IP address of the PXI controller, change the IP address of the control PC to the same domain as the PXI controller.
- If you find the IP address of the Ettus USRP X410 is not in the same domain as the IP address of the PXI controller, login to PuTTY using the root user account with no password and change the IP address of the Ettus USRP X410 by running the following command: `ifconfig eth0 <ip address> netmask <255.255.255.0> up`.

Related tasks:

- Setting Up a System
- Imaging PXI Controllers

Verifying System Setup

Before verifying system setup, you must turn on the following system components in sequence.

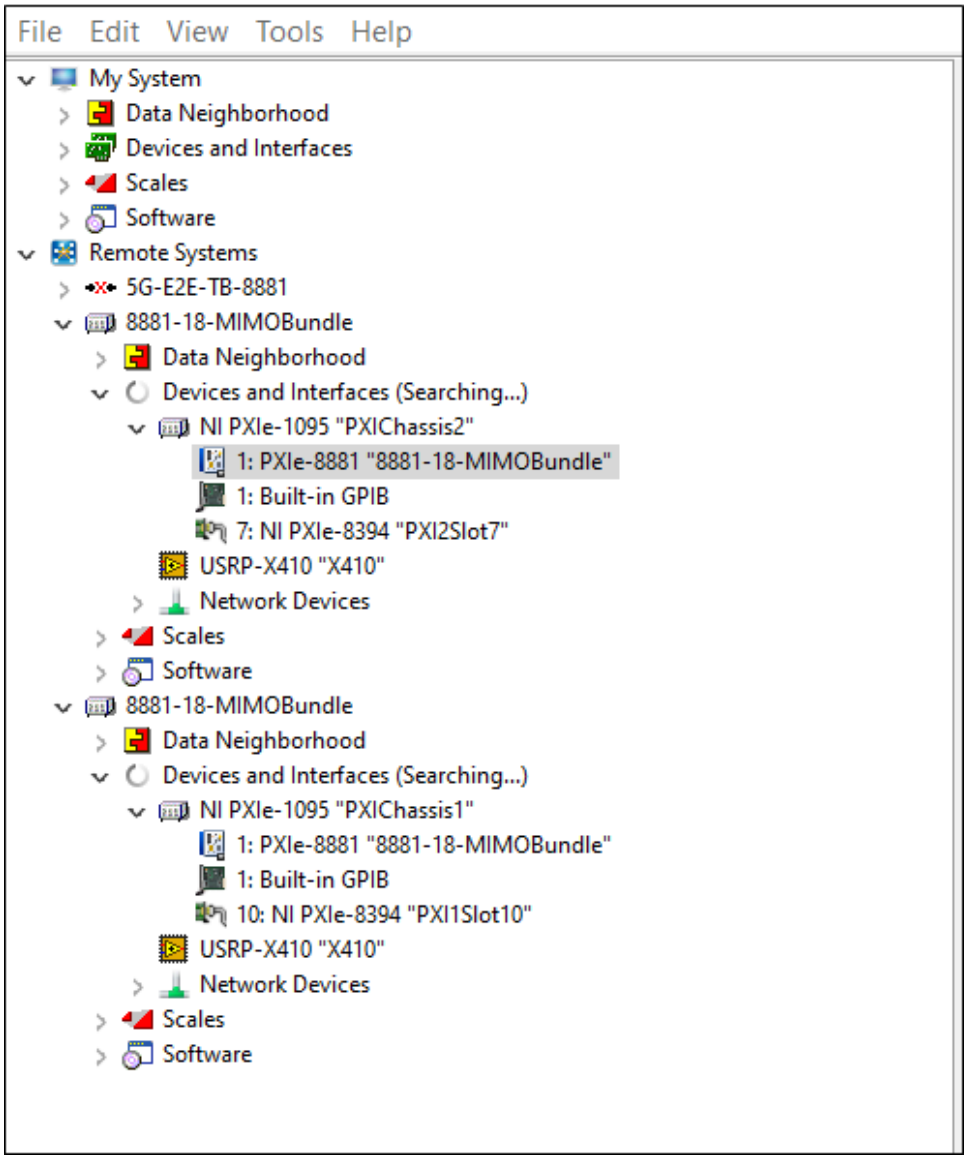
1. OctoClock
2. Ettus USRP X410
3. PXI chassis

Complete the following steps on both the gNodeB and UE sides to verify system setup.

1. Open NI MAX on the control PC.
2. In NI MAX, verify the name of the Ettus USRP X410 in the gNodeB and UE systems is "X410". If not, change the name to "X410".
3. Verify NI MAX detects all PXI modules in the PXI chassis and check the information of each module, such as slot number and alias.

   The following figure shows example devices that NI MAX detects.

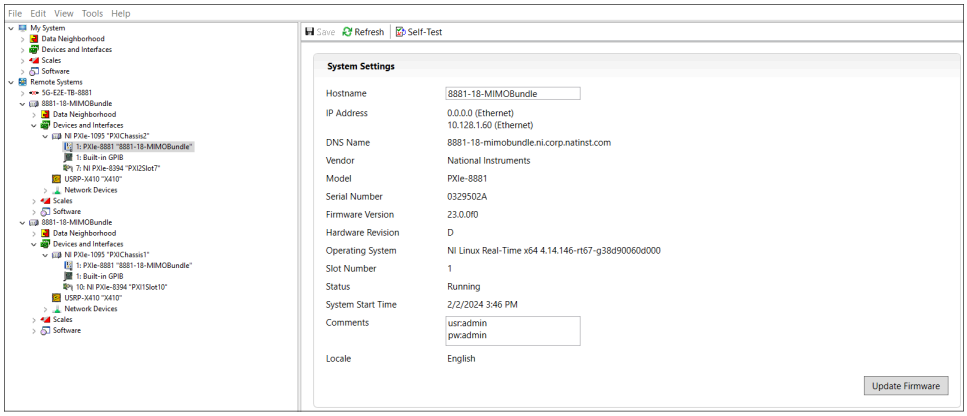
Figure 3. Example Devices in NI MAX



4. Click the PXI controller to open **System Settings**.
5. Check the system settings.

   The firmware version for PXIe-8881 must be 23.0.0f0 or later. The following figure shows example system settings.

Figure 4. Example System Settings



Customizing Functions

Introduced in LabVIEW MIMO 5G/6G Research Design Library 2.0

You can customize functions by modifying the FPGA code in the `5G NR miniRAN gNB X410(FPGA)` and `5G NR miniRAN UE X410(FPGA)` VIs. When loading the VIs, open the `.dll` file in the directory that LabVIEW indicates.

Contact your NI sales representative, TSE, or AE for more information and support.

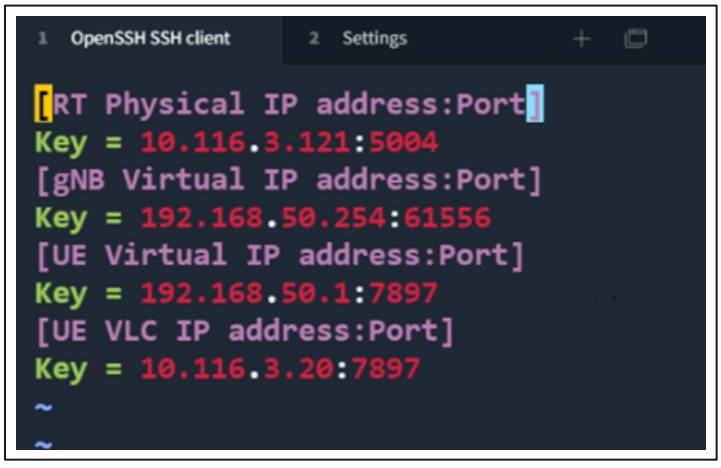
Related reference:

- LabVIEW MIMO 5G/6G Research Design Library 2.0 New Features and Changes

Configuring the System

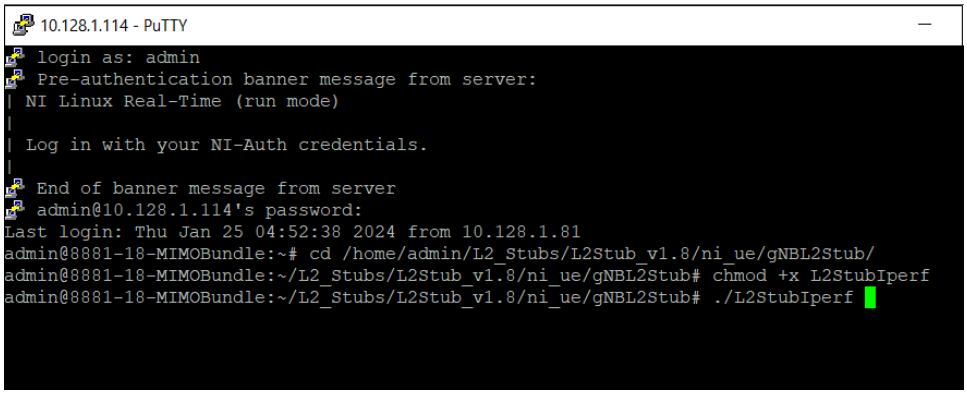
Complete the following steps on both the gNodeB and UE sides to configure the LabVIEW MIMO 5G/6G Research Design Library system:

1. Login to PuTTY with the following information.
   - IP address of the PXI controller
   - Username: admin
   - Password: admin
2. Run the following command on the gNodeB and UE PXI controllers to configure `"Configuration_File_videostream.ini"`: `vim /home/admin/Configuration_File_videostream.ini`.
3. On **OpenSSH SSH client** of both the gNodeB and UE `"Configuration_File_videostream.ini"`, add the following IP addresses and port numbers.
   - `RT Physical IP address:Port`: Add the IP address and port number of the gNodeB or UE PXI controller.
   - `gNB Virtual IP address:Port`: Add the same IP address and port number in the following figure.
   - `UE Virtual IP address:Port`: Add the same IP address and port number in the following figure.
   - `UE VLC IP address:Port`: Add the IP address and port number of the UE control PC.



4. **Optional:** Configure the physical-layer parameters.
   a. Run the following command to open gNodeB or UE `config_user.json` with a File Transfer Protocol application, such as WinSCP, or a text editor, such as Vim.
      - gNodeB: `cd /home/admin/L2_Stubs/L2Stub_v1.8/ni_ue/gNBL2Stub/config_user.json`
      - UE: `cd /home/admin/L2_Stubs/L2Stub_v1.8/ni_ue/ueL2Stub/config_user.json`
   b. Follow the comments in `config_user.json` to modify the physical-layer parameters.
   c. Save `config_user.json`.
5. Run the following commands in sequence on both the gNodeB and UE sides to access the gNBL2Stub and ueL2Stub directories on the PXI controllers.
   a. Either of the following commands.
      - gNodeB: `cd /home/admin/L2_Stubs/L2Stub_v1.8/ni_ue/gNBL2Stub/`
      - UE: `cd /home/admin/L2_Stubs/L2Stub_v1.8/ni_ue/ueL2Stub/`
   b. Run the following command only when you configure the system for the first time: `chmod +x L2StubIperf`.
   c. `./L2StubIperf`

   The following figure shows an example of running the previous commands in sequence.



6. Run the gNodeB or UE LabVIEW Real-Time VI in the following directories.
   - gNodeB VI: `C:\Program Files (x86)\National Instruments\`

LabVIEW 2020\examples \LabVIEW MIMO 5G-6G Research Design Library\gNB\5G NR miniRAN gNB L1C

- UE VI: C:\Program Files (x86)\National Instruments\LabVIEW 2020\examples \LabVIEW MIMO 5G-6G Research Design Library\UE\5G NR miniRAN UE L1C (NSA & SA)

7. Once **System State** on the front panel of the LabVIEW Real-Time VI returns **Starting Slot Procedure**, open the gNodeB or UE GUI in the following directories.
   - gNodeB GUI: LabVIEW MIMO 5G-6G Research Design Library \GUI\gNB Monitoring GUI
   - UE GUI: LabVIEW MIMO 5G-6G Research Design Library \GUI\ UE Monitoring GUI
8. On the **General** tab of the GUI, enter the IP address of the PXI controller in the **IPv4** box.
9. Click **Connect** to connect to the PXI controller.
10. Ensure the **System** tab appears on the GUI after the connection is established.

The following figures show example **System** tabs on the gNodeB and UE GUIs.

Figure 5. Example System Tab on the gNodeB GUI

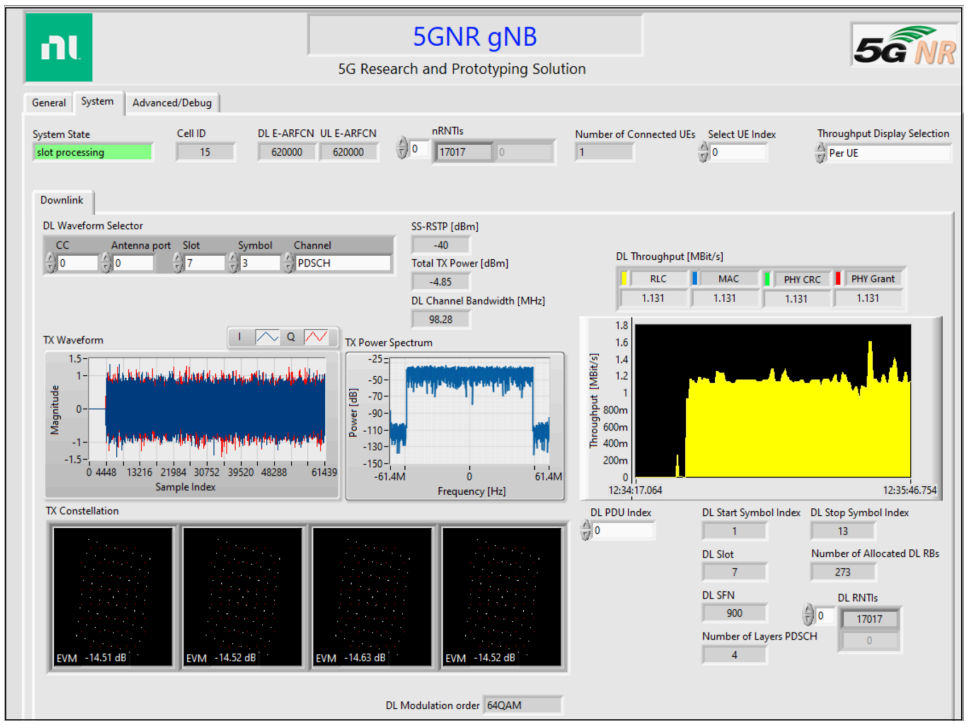
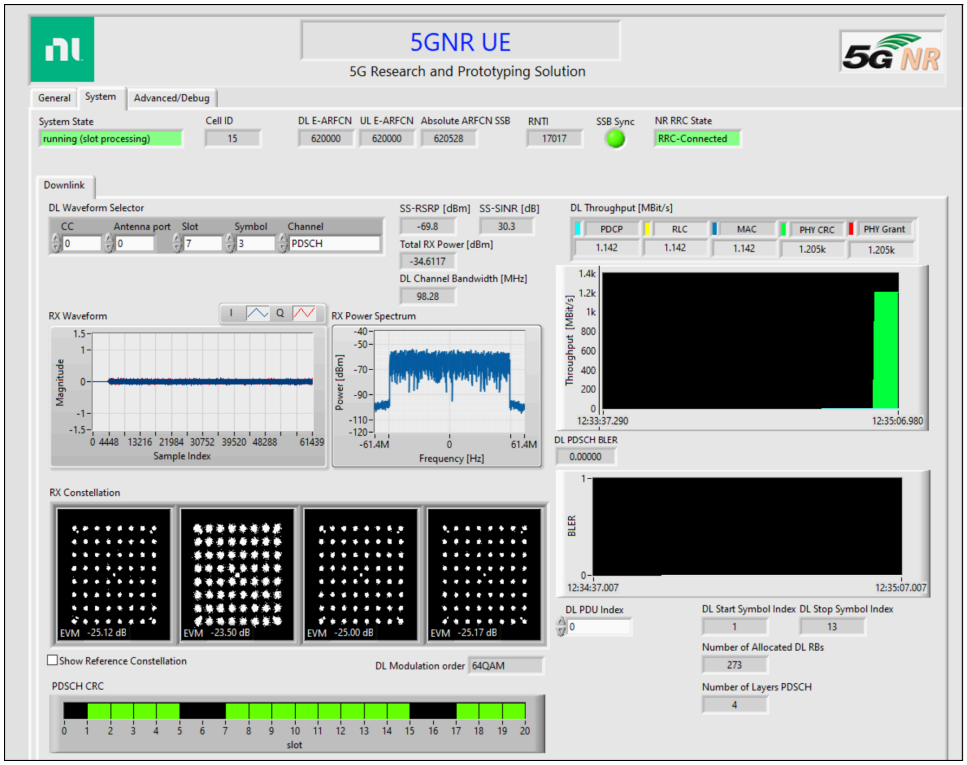


Figure 6. Example System Tab on the UE GUI



Related reference:

- LabVIEW MIMO 5G/6G Research Design Library 2.0 New Features and Changes

Running Video Streaming

Before running video streaming, you must configure the LabVIEW MIMO 5G/6G Research Design Library system and install the VLC media player.
Complete the following steps to run video streaming:

1. On the gNodeB side, open a VLC media player window and complete the following steps.
   a. Select **Media » Stream**.
      An **Open Media** dialog appears.
   b. On **File Selection**, click **Add** to add a video file for streaming.
   c. Click **Stream** to open a **Stream Output** dialog.
   d. On **Source**, click **Next**.
   e. On **Destinations**, select the **Display locally** checkbox, select **UDP (legacy)** from the list, and then click **Add**.
   f. Enter `RT Physical IP address:Port` you previously added to the gNodeB `"Configuration_File_videostream.ini"` into **Address** and **Port**, respectively.
   g. On **Transcoding options**, make sure the **Activate Transcoding** checkbox is selected, select the video format you are transmitting from the list, and then click **Next**.
   h. On **Miscellaneous Options**, select the **Stream all elementary streams** checkbox and then click **Stream**.
2. On the UE side, open a VLC media player window and complete the following steps.
   a. Select **Media » Open Network Stream**.
      A **Open Media** dialog appears.
   b. On **Network**, enter udp://@:UE control PC port number you previously added for `UE VLC IP address:Port`.
   c. Click **Play**.

Related tasks:

- Configuring the System

Monitoring System with GUIs

Monitor the gNodeB or UE system with graphical user interfaces (GUIs) on the control PC.

1. Open a UE or gNodeB GUI based on the system you want to monitor.
   - A UE GUI monitors a single UE system that connects to a single gNodeB.
   - A gNodeB GUI monitors a single gNodeB system that connects to a single UE.
2. On the **General** tab, verify a connection to the PXI controller has been successfully established.

   Refer to ***Configuring the System*** for instructions for connecting to the PXI controller.
3. On the **General** tab, check **Error Messages** from the respective stacks.
4. On the **System** tab, configure parameters under **DL Waveform Selector** as the following table shows.

Parameter	Value
`CC`	Only one `CC` is supported.
`Antenna port`	A value from 0 through 3
`Slot`	A value from 0 through 19
`Symbol`	A value from 0 through 13
`Channel`	PDSCH

5. On the **System** tab, observe graphs to monitor the connections between the gNodeB and its associated UEs and the state of PXI system stacks when the system is running.

Related tasks:

- Configuring the System

Troubleshooting

Troubleshoot common issues you may encounter when using the LabVIEW MIMO 5G/6G Research Design Library.

What Should I Do If Slot Processing Takes Longer Than Expected After I Ran the `L2StubIperf` Command?

Make sure you access the gNBL2Stub or ueL2Stub directory on the PXI controller, and then run the following commands to reboot the gNBL2Stub or ueL2Stub:

1. `/etc/init.d/nilvrt stop`
2. `/etc/init.d/nilvrt start`
3. `./L2StubIperf`

If the issue persists, reboot the software or hardware.

What Should I Do If PDSCH CRC Is Flickering on the UE GUI or DL Channel Bandwidth, EVM, and DL Modulation order Are Flickering on Both the gNodeB and UE GUIs?

This issue occurs because `fixedSchedule` is set to `True` in `config_user.json`. Change the parameter value to `False`.

What Should I Do If a Memory Full Error Occurs When I Am Trying to Connect to the gNodeB GUI?

This issue occurs because `DL subcarrierSpacing` is set to `15` in `config_user.json`. Change the parameter value to `30`.