NI-mmWave

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Contents

NI-mmWave 19.0 to 20.0 Manual

This manual contains information about using NI-mmWave 19.0 to 20.0 to program your mmWave Transceiver System with LabVIEW 2018, 2019, and 2020.

Using the mmWave Transceiver System as a Multichannel Transceiver

The NI mmWave Reference Project contains an example VI that demonstrates how to use the mmWave Transceiver System as a multichannel transceiver.

Note Before running the VI, examine the hardware setup and ensure that all cables are securely connected.

1. Open the project file located in the LabVIEW folder at `<NIDIR>\LabVIEW<Year>\examples\instr\niMmWave\niMmWave Reference Project\niMmWave Reference Project.lvproj`.
   The project consists of several host example VIs and the following variants of an FPGA target, including two sample rate options:

FPGA Target	Sample Rates	Description
Transmit FPGA 7902R	2.94912 GSps	This FPGA target demonstrates how to configure the PXIe-7902 High-Speed Serial Instrument to generate the in-phase/quadrature (I/Q) baseband data written to the input/output (I/O) socket defined in DacAuroraClip.
	3.072 GSps	
Receive FPGA 7902R	2.94912 GSps	This FPGA target demonstrates how to

FPGA Target	Sample Rates	Description
	3.072 GSps	configure the PXIe-7902 module to process the I/Q baseband data acquired from the I/O socket defined in AdcAuroraClip.
Processing FPGA 7902R	2.94912 GSps	This FPGA target demonstrates how to configure the PXIe-7902 module to send or receive data through the serial lanes for all six multi-gigabit transceiver (MGT) ports using Aurora protocol.
	3.072 GSps	

2. Open the Multichannel Transceiver (Host) VI.
   This example uses pre-compiled FPGA bitfiles that use the FPGA VIs defined under Transmit FPGA 7902R and Receive FPGA 7902R targets.
3. Examine the front panel input controls and specify values appropriate for your device.

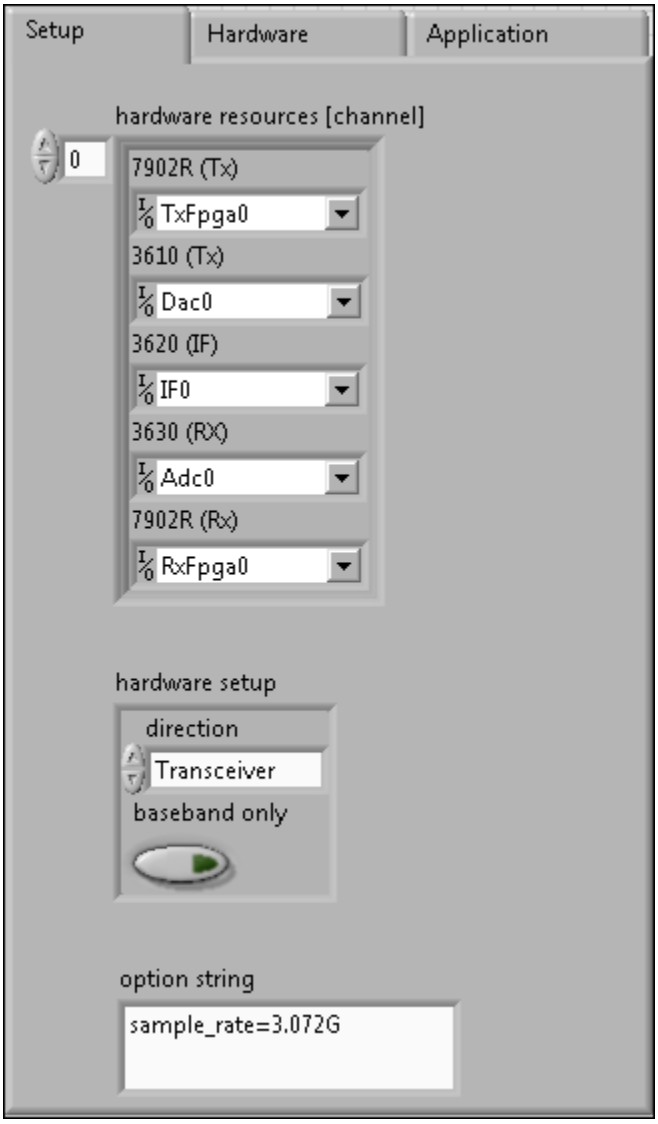
> **Note** Values shown in the following examples are optional unless otherwise specified.

   a. Select the **Setup** tab and specify the values appropriate for your device.
      - **hardware resources [channel]**—Specifies the device resource names.
      - **hardware setup**—Specifies one of the following directional values: **Transmitter**, **Receiver**, or **Transceiver**.
      - **option string**—Sets the initial values of certain properties for the session. The format of this string is `PropertyName=Value`, where ***PropertyName*** is the name of the property and ***Value*** is the value to which the property is set. To set multiple properties, separate their assignments with a comma. The following table lists the properties you can use with this parameter and their valid values.

Property	Use	Valid Values	Example
Sample Rate	Specify the sample rate to use.	`2.94912G`, `3.072G` (default)	`sample_rate=2.94912G`

Note The default value is 3.072G when the **option string** field is left blank.

Figure 1. Setup Tab



b. Select the **Hardware** tab and specify the values appropriate for your device.
   - **port select**—Specifies one of the following values: **IF Port**, **Loopback**, and **Sync Port**.

> **Note** **Sync Port** is not currently supported.

- **Rx hardware configuration** Cluster
  - **gain (dB)**—Specifies the receiver gain.
  - **frequency (Hz)**—Specifies the receiver frequency.
  - **mmWave adapter**—Specifies the mmWave radio head being used. Set this to **None** for intermediate frequency (IF) only operation.
  - **adapter active port**—Specifies the mmWave radio head active port for the receiver channel. The only valid values are **RX1** and **RX2**.

    > **Note** **RX2** is only supported for mmRH-3602/3603 mmWave Radio Heads.

- **Tx hardware configuration** Cluster
  - **gain (dB)**—Specifies the transmitter gain.

    > **Notice** The receiver may become damaged if too much gain is used. Refer to the device specifications to ensure you choose values within an acceptable gain range.

  - **frequency (Hz)**—Specifies the transmitter frequency.
  - **mmWave adapter**—Specifies the mmWave radio head being used. Set this to **None** for IF only operation.
  - **adapter active port**—Specifies the mmWave radio head active port for the receiver channel. The only valid value is **TX1**. This value is ignored in IF only operation.

> **Note** Refer to NI-mmWave Configuration API when using mmWave radio heads.

Figure 2. Hardware Tab (IF Only)

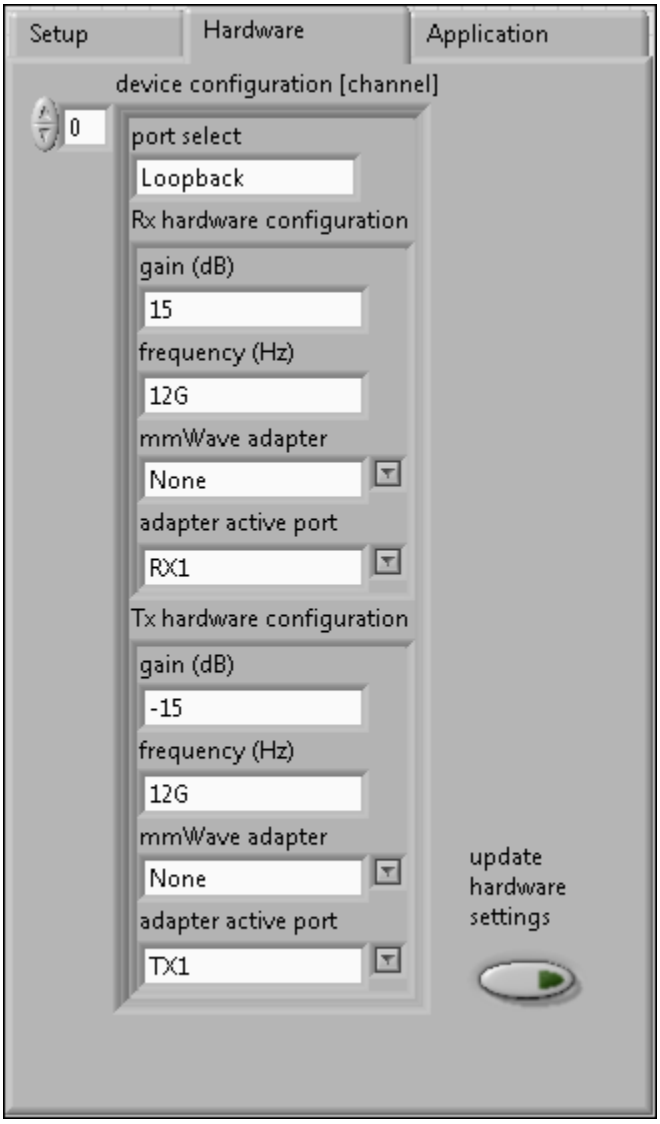
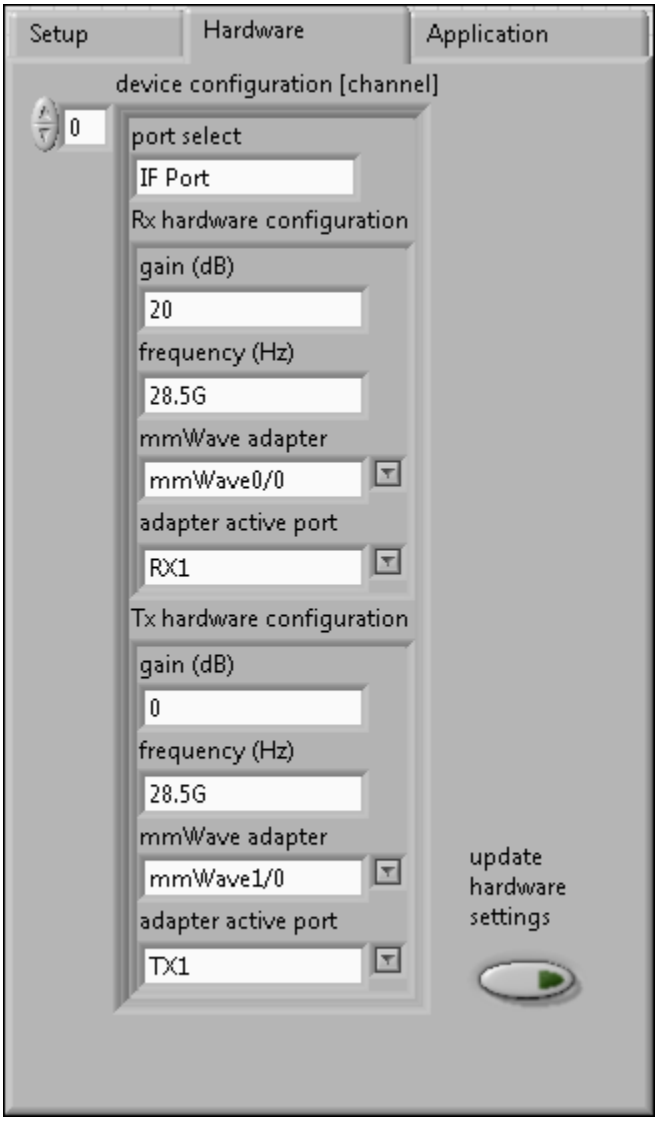
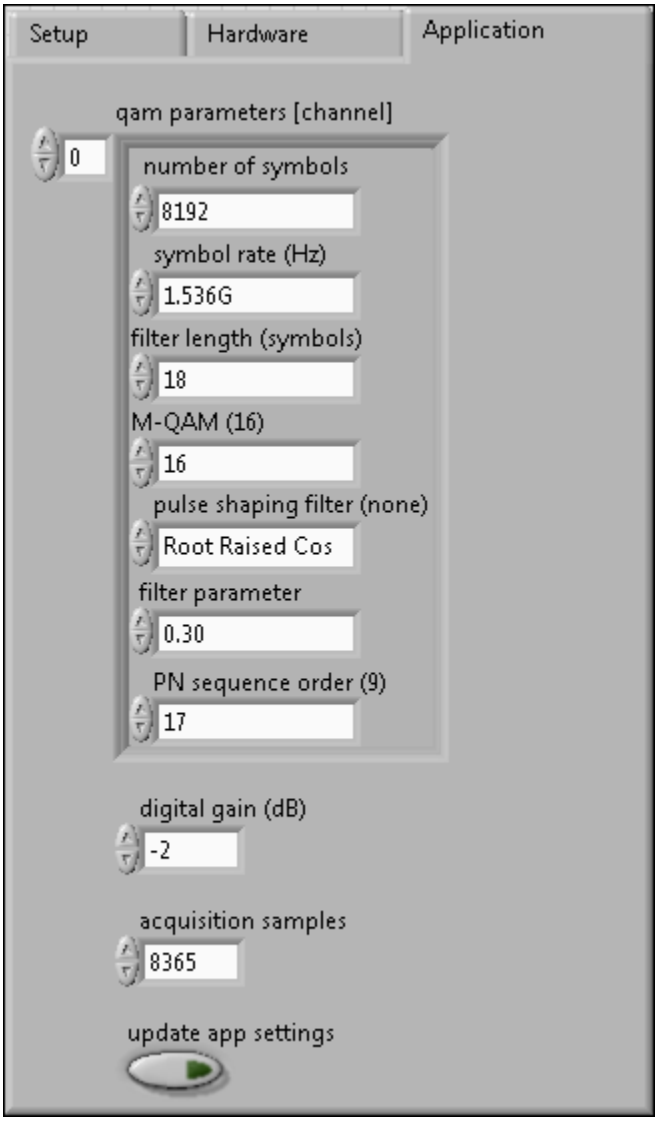


Figure 3. Hardware Tab (with mmWave Radio Heads)



c. Select the **Application** tab and specify the values appropriate for your device.
   - **qam parameters [channel]**—Specifies the quadrature amplitude modulation (QAM) parameters.
   - **digital gain (dB)**—Specifies the digital gain on the generated signal on Transmit FPGA 7902R.
   - **acquisition samples**—Specifies the number of samples to acquire.

Figure 4. Application Tab



4. Run the VI.

Figure 5. Time Domain Tab

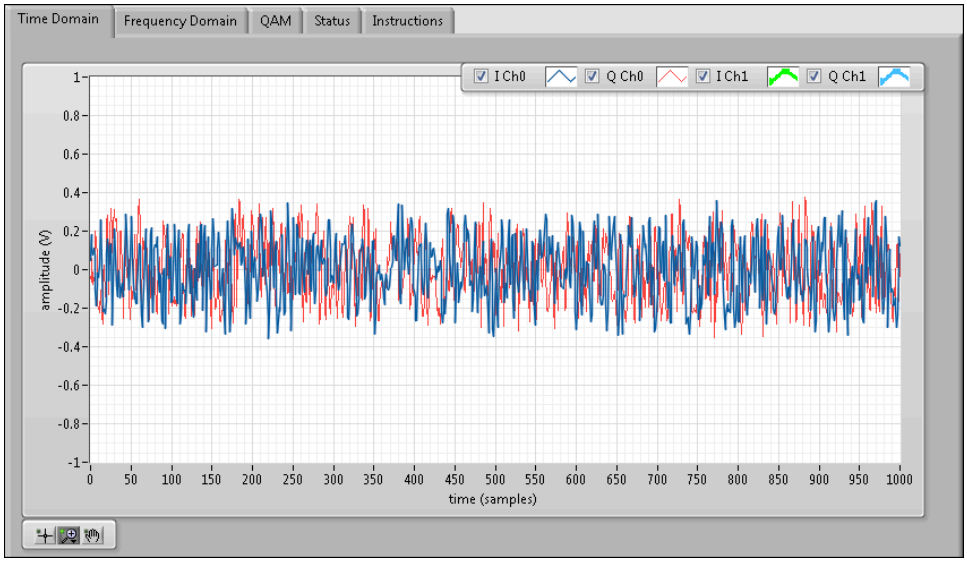


Figure 6. Frequency Domain Tab

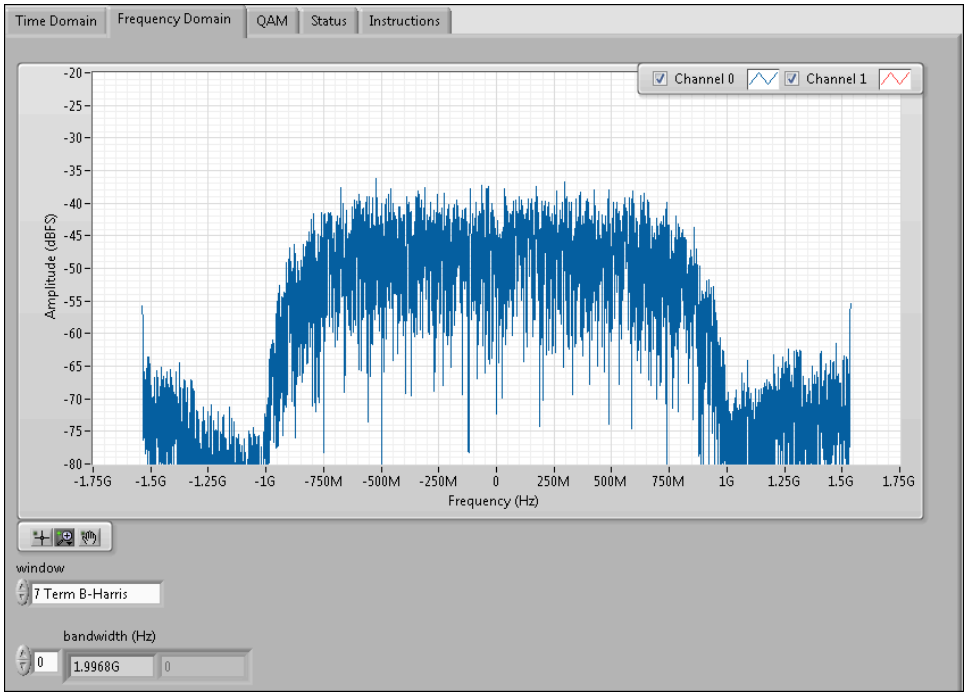
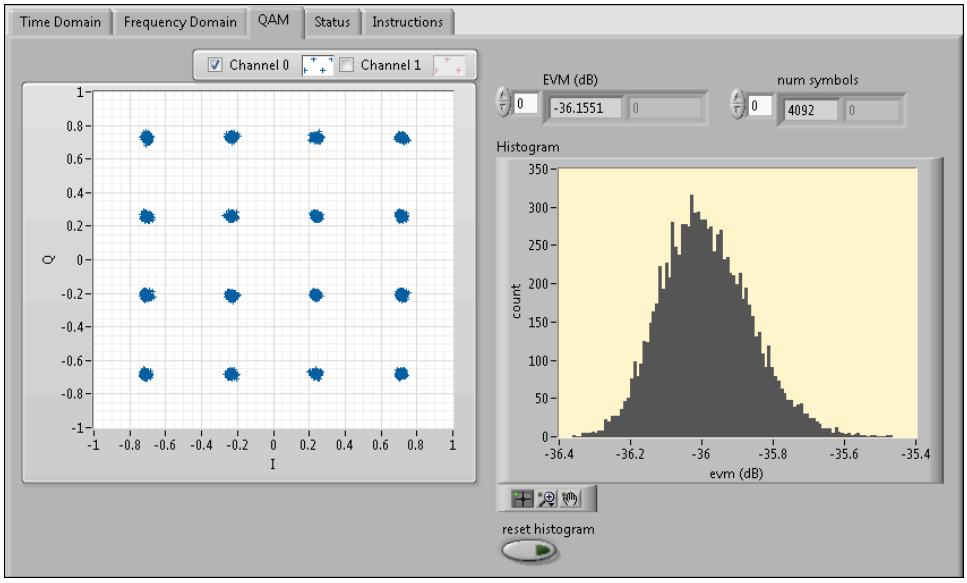


Figure 7. QAM Tab



Related concepts:

- NI-mmWave Configuration API
- System Calibration Utility

NI-mmWave Configuration API

scope Input

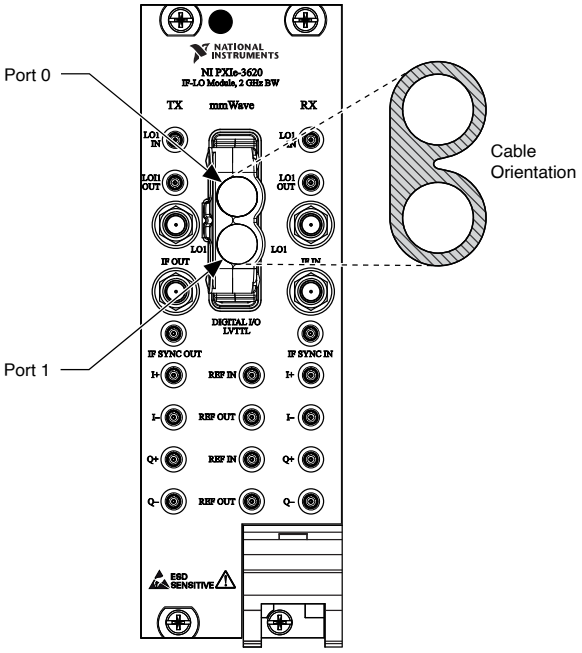
Most VIs in the NI-mmWave Configuration API require a `scope` input string. This string specifies the scope of the configuration for the VI. Each VI has a unique set of valid values for this input. Refer to the context help in LabVIEW for specific values for each VI.

mmWave adapter Input

Some VIs in the NI-mmWave Configuration API require a `mmWave adapter` input string when you use a mmWave radio head. Refer to the `mmWave adapter` data returned by the Open Session 2 VI to determine the location of the mmWave radio head. The driver uses the following mmWaveX/Y format to show the location of the mmWave radio head as described below.

- X—Refers to the port number of the DIGITAL I/O connector of the PXIe-3620 RF Upconverter and Downconverter Module front panel that is connected to the mmWave radio head, as shown in the following figure.

  Figure 8. EPLSP Cable Orientation



- Y—Indicates which mmWave radio head is serially connected to the X port of the DIGITAL I/O connector of the PXIe-3620 front panel. The only valid value is 0.

Table 1. `mmWave adapter` Inputs

Input	Use
mmWave0/0	Indicates the mmWave radio head connected to the DIGITAL I/O port 0 connector of the PXIe-3620 front panel connector.
mmWave1/0	Indicates the mmWave radio head connected to the DIGITAL I/O port 1 connector of the PXIe-3620 front panel connector.

Related tasks:

- Using the mmWave Transceiver System as a Multichannel Transceiver

System Calibration Utility

The system calibration utility is included in the NI mmWave Reference Project. This utility calibrates the system by measuring in-phase/quadrature (I/Q) impairments for each channel. To use this utility, the mmWave Transceiver System must be configured as a transceiver or a receiver.

Table 2. Devices Calibrated in Configuration Modes

Mode	Devices Calibrated
Receiver	Receiver
Transceiver	Receiver and transmitter
Transmitter	None

Note Warm up the mmWave Transceiver System before using the system calibration utility. To warm up the mmWave Transceiver System, use the NI mmWave Reference Project to run the mmWave Transceiver System for 20 minutes so that the system reaches a steady-state temperature.

You must recalibrate the system if you exchange any of the following components:

- PXIe-3610 Waveform Generator
- PXIe-3620 RF Upconverter and Downconverter Module
- PXIe-3630 Digitizer
- MMPX(m)-to-MMPX(m) cables

The measured I/Q impairments are stored on the PXIe-3620 module.

When using the reference FPGA design and host code provided by the NI mmWave Reference Project, the measured I/Q impairments are retrieved from the device by the Open VI and used by the Configure VI to correct the system.

Related tasks:

- Using the mmWave Transceiver System as a Multichannel Transceiver

Amplitude Corrections

You can configure the analog gain on both the receiver (RX) and transmitter (TX) signal paths with the NI-mmWave Configuration API. Corrections are applied based on device characteristics stored on the device(s). NI does not specify the accuracy of configured gain versus actual gain.

When a mmWave radio head is in use, these amplitude corrections are applied with the assumption that the device is being operated at the system's default IF frequency. The API will automatically configure the appropriate default IF frequency depending on which mmWave radio head is attached. You can also manually configure the IF frequency to a different value.

Note Using a manually configured IF frequency may degrade the accuracy of the amplitude corrections.

Fast Configuration Overview

The mmWave Transceiver System supports fast configuration of gain and mmWave port switches.

The PXIe-7902 High-Speed Serial Instrument can send commands to the PXIe-3620 RF Upconverter and Downconverter Module and mmWave radio heads directly from the FPGA. By bypassing the host for configuration, you can configure a new gain or port configuration more quickly. This is useful for applications that require low latency automatic gain or port configuration.

Related concepts:

- Fast mmWave Port Switching
- Fast Gain Ranging

Fast mmWave Port Switching

You can configure the mmRH-3602/3603 to route mmWave signals to and/or from one of the following two mmRH-3602/3603 radio head antenna ports: TX1/RX1 and RX2.

Use the NI mmWave Reference Project and the Configure mmWave Port VI for general configuration of the mmRH-3602/3603 radio head. If you require <2 µs port reconfiguration, you can configure the mmRH-3602/3603 radio head to monitor a PXI trigger line and switch between the two port states on a trigger state change.

To learn more about using the fast mmWave port switching feature, open the NI mmWave Reference Project at `<NIDIR>\LabVIEW<Year>\examples\instr\niMmWave\niMmWave Reference Project\niMmWave Reference Project.lvproj` and select the Fast mmWave Port Switching VI from the Project Explorer window.

Related tasks:

- Using the mmWave Transceiver System as a Multichannel Transceiver

Fast Gain Ranging

You can set a rough gain very quickly and adjust to an exact gain slightly later by using fine gain ranging and coarse gain ranging together. The benefits of using fine gain ranging and coarse gain ranging are described in the following table.

Table 3. Fine Gain Ranging and Coarse Gain Ranging

Type	Implementation	Gain Configuration	Time to Apply Gain (Typical)	Receiving and Transmitting Support
Fine Gain Ranging	Using peer-to-peer (P2P) packets	Any arbitrary gain	3 µs to 5 µs, depending on other P2P traffic in the system	Simultaneously or one at a time
Coarse Gain Ranging	Using two PXI triggers	One of four values	<2 µs	One at a time

Note Fast gain ranging features use PXI trigger lines. Ensure that you are using the Route Triggers Gain Ranging VI or that you have manually reserved the specified triggers. If trigger writer and trigger reader modules are not in the same PXI trigger bus, ensure that the trigger lines are routed between

buses.

To learn more about using the fast gain ranging feature, open the NI mmWave Reference Project at `<NIDIR>\LabVIEW<Year>\examples\instr\niMmWave\niMmWave Reference Project\niMmWave Reference Project.lvproj` and select the Gain Ranging Example VI from the Project Explorer window.

Note Once gain ranging is enabled for the receiver `scope`, you must disable gain ranging before changing any non-gain ranging configurations for the receiver scope. The same is independently true for the transmitter `scope`.

Related concepts:

- NI-mmWave Configuration API

Related tasks:

- Using the mmWave Transceiver System as a Multichannel Transceiver

LO Sharing

You can configure the PXIe-3620 RF Upconverter and Downconverter Module module to use an external local oscillator (LO) signal when preparing the signal for upconversion or downconversion.

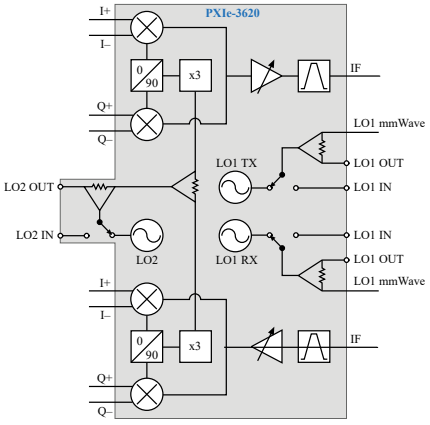
You can configure the PXIe-3620 to use internal or external LOs, but the module uses internal LOs by default. The LOs have the following uses:

- LO1—LO source for the mmWave radio head.
- LO2—Upconverts an in-phase/quadrature (I/Q) baseband signal to an intermediate frequency (IF) signal, and downconverts from an IF signal to an I/Q baseband signal, as shown in the following figure.

  Note When simultaneously using the transmit and receive channels, the

> IF frequencies for receiving and transmitting will be the same.

Figure 9. PXIe-3620 Block Diagram



Devices	LO Injection	RF Frequency	Formulas
mmRH-3602/3642/3652 mmWave Radio Heads	High-side	***RF Frequency*** = ***LO Frequency*** - ***IF Frequency***	• ***LO Frequency*** = ***LO1 Frequency*** × 4 • ***IF Frequency*** = ***LO2 Frequency*** × 3
mmRH-3603/3643/3653 mmWave Radio Heads	Low-side	***RF Frequency*** = ***LO Frequency*** + ***IF Frequency***	• ***LO Frequency*** = ***LO1 Frequency*** × 3 • ***IF Frequency*** = ***LO2 Frequency*** × 3
mmRH-3647/3657 mmWave Radio Heads	Low-side	***RF Frequency*** = ***LO Frequency*** + ***IF Frequency***	• ***LO Frequency*** = ***LO1 Frequency*** × 8 • ***IF Frequency*** = ***LO2 Frequency***

Devices	LO Injection	RF Frequency	Formulas
			× 3

The following table shows a variety of examples of resultant LO frequencies for desired RF frequencies.

Table 4. Example Frequencies

mmWave Radio Heads	Mode	*RF Frequency*	*IF Frequency*	*LO1 Frequency*	*LO2 Frequency*
Any/none	IF only	—	11 GHz	—	3.667 GHz
mmRH-3602/3642/3652	mmWave	28.5 GHz	10.56 GHz	9.765 GHz	3.52 GHz (default)
mmRH-3603/3643/3653	mmWave	40 GHz	10.56 GHz	9.813 GHz	3.52 GHz (default)
mmRH-3647/3657	mmWave	73 GHz	12 GHz	7.625 GHz	4 GHz (default)

Synchronization Overview

Synchronization occurs between all baseband transmitters and baseband receivers in your system so that generation and acquisition can begin on the FPGA during the same cycle. For example, in the bidirectional single-input, single-output (SISO) system, the receiver baseband and the transmitter baseband are synchronized.

In systems with multiple baseband receivers, the baseband receivers can be synchronized so that they are aligned at analog-to-digital (ADC) conversion. This results in very small channel-to-channel skew.

Before attempting to synchronize your mmWave Transceiver System and mmWave radio heads, notice the following caveats:

- Synchronization does not account for differences in analog signal paths. For example, there might be some variation between the PXIe-3620 RF Upconverter

and Downconverter Modules, the cables, and the mmWave radio heads that synchronization will not account for.
- Synchronization does not account for data pipeline delays that occur before or after the synchronization VIs.
- Sources of error, such as common clock propagation delay, cabling and cable lengths, analog delays in the FPGA, and skew/jitter in the common clock, can affect frequency and phase relationships within the system.
- You must use PXIe-3610 Waveform Generatorrevision B modules with other PXIe-3610revision B modules. You can achieve tight synchronization with the PXIe-3610revision B module using an updated phase-locked loop (PLL).

  Note You will receive the following error message if you are using mismatched module revisions: “All PXIe-3610 and PXIe-3630 modules must have baseband sync or none at all.”

- External signals must not be present at the I/Q inputs of the PXIe-3630 modules for synchronization on systems with one or more baseband receivers. Synchronization will likely fail if such signals are present.

To achieve synchronization across multiple chassis, you must use a PXIe-6674T Synchronization Module.

Note To configure multiple chassis, you must use a PXIe-3610revision A module and a PXIe-3630revision A module.

Note NI-mmWave example code does not configure the PXIe-6674T.

Related tasks:

- Identifying PXIe-3610/3630 Module Revision

TX-RX Determinism

The PXIe-3610 Waveform Generatorrevision B module and the PXIe-3630 Digitizerrevision B module support transmitter (TX) to receiver (RX) improved (deterministic) data alignment.

The time from when generation is configured and written to the PXIe-3610 to when the PXIe-3630 receives the signal is deterministic and within one clock cycle of the Data Clock domain. This is repeatable through distinct sessions.

Note You will receive the following error message if you are using mismatched module revisions: “All PXIe-3610 and PXIe-3630 modules must have baseband sync or none at all.”

Related tasks:

- Identifying PXIe-3610/3630 Module Revision

Identifying PXIe-3610/3630 Module Revision

To determine which module revision you have of the PXIe-3610 Waveform Generator or PXIe-3630 Digitizer, complete one of the following tasks:

- Refer to the label on the side of your module; the part number is printed on the label. The letter in the part number identifies the revision of the module. For example, part number 140137A-01L identifies a PXIe-3610revision A module.
- Run Get Module Information from the ni3610_and_ni3630_Driver_Lib.lvlib API.