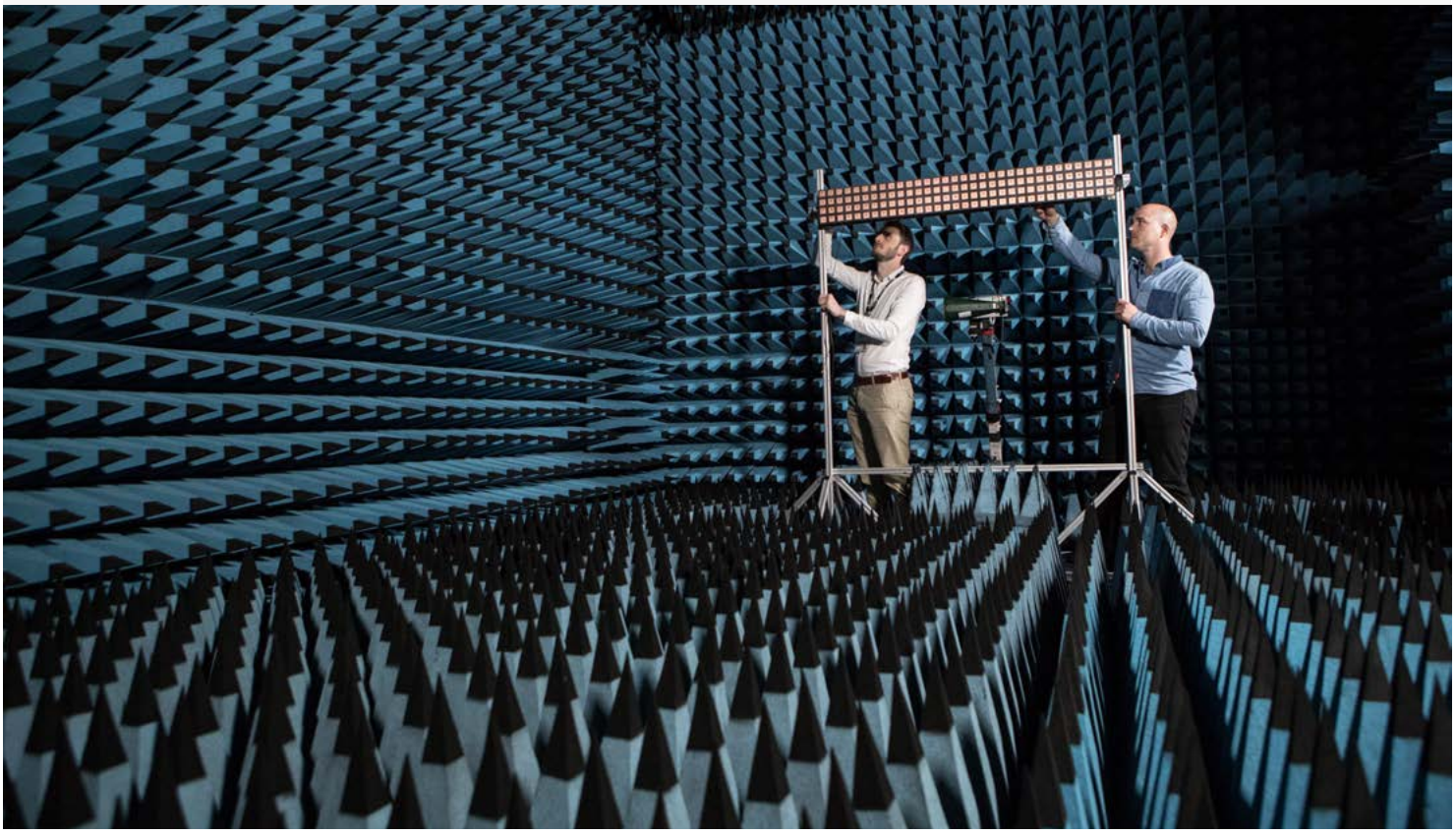
Solution Brief

LabVIEW Reference Design for Wireless Research with NI Ettus USRP X410

Explore NI's Solutions

The latest generation of cellular communications standards for 5G are significantly more complex than previous generations. NI offers engineers and researchers a cost effective, open, and easy to set up system that provides a great starting point for research.



Evolution of 5G toward 6G

As 5G deployments gain traction and infrastructure providers roll out new capabilities, the research community is starting to look at what's next. 6G is coming and could involve covering much higher frequencies (into the THz bands), implementing phased-array antenna solutions, and increasing bandwidths and modulation densities. We can also expect to see the proliferation of new use cases in massive machine-to-machine communication, as well as new levels of reliability, security, and network response time. The vision for 6G is just starting to be defined and will expand to more applications based on new enabling technologies. Some interesting and important technical areas that have been identified for 6G are joint communications and sensing, THz/sub-THz, extreme MIMO, and artificial intelligence/machine learning (AI/ML).

Enabling Technologies That Could Drive 6G

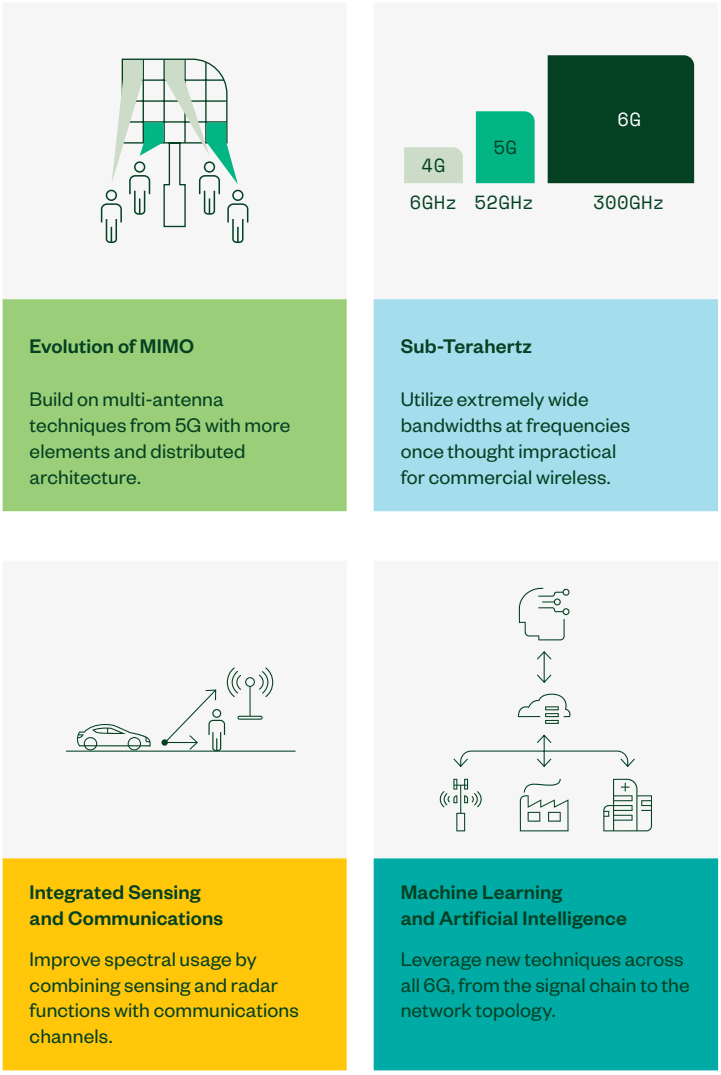


FIG 1 | 6G innovation

Rapidly Prototyping the New Concept

While needing to develop increasingly complex applications, wireless researchers still face the pressure to innovate faster and prototype new concepts. Building testbed infrastructure is complicated and time-consuming, and it is more valuable for researchers to focus on their ideas rather than spend time proving the testbed works. Researchers must also find flexible solutions that can adapt to emerging requirements, scale for multichannel architectures, have AI for cognitive capability, and employ a software framework to rapidly gather real data. NI's software defined radio (SDR) with a standard reference design accelerates this transition from concept to reality.

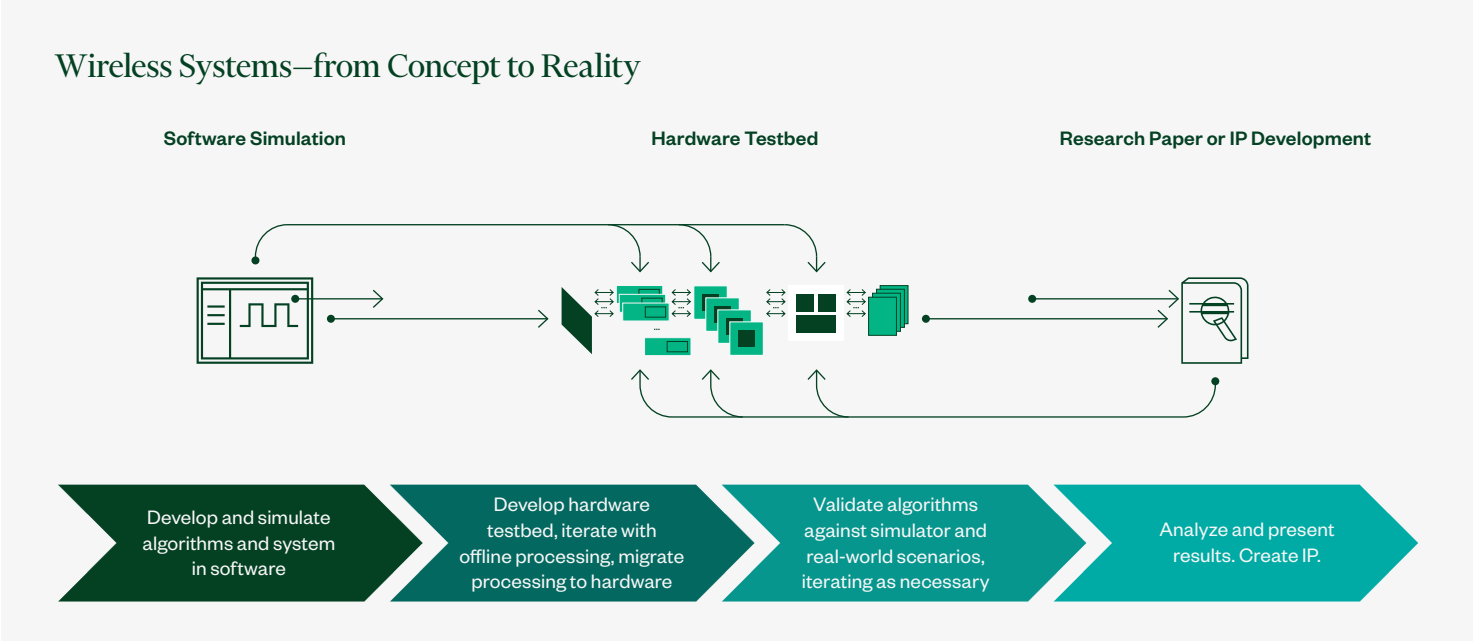


FIG 2 | From concept reality

LabVIEW Reference Design Overview

The LabVIEW Reference Design for Wireless Research with NI Ettus USRP X410 provides an open and flexible platform for wireless researchers to rapidly prototype their innovative ideas. This reference design covers transmission, reception, analysis, recording, and playback for RF signals. Researchers can then build customized applications based on the reference design to build testbeds for MIMO, communications and sensing, wireless AI, mmWave beamforming, reflective intelligent surface (RIS), and more. Based on NI hardware and software, the LabVIEW Reference Design has been validated to ensure performance and is ideal for rapidly transitioning from software simulation to proof-of-concept demonstration.

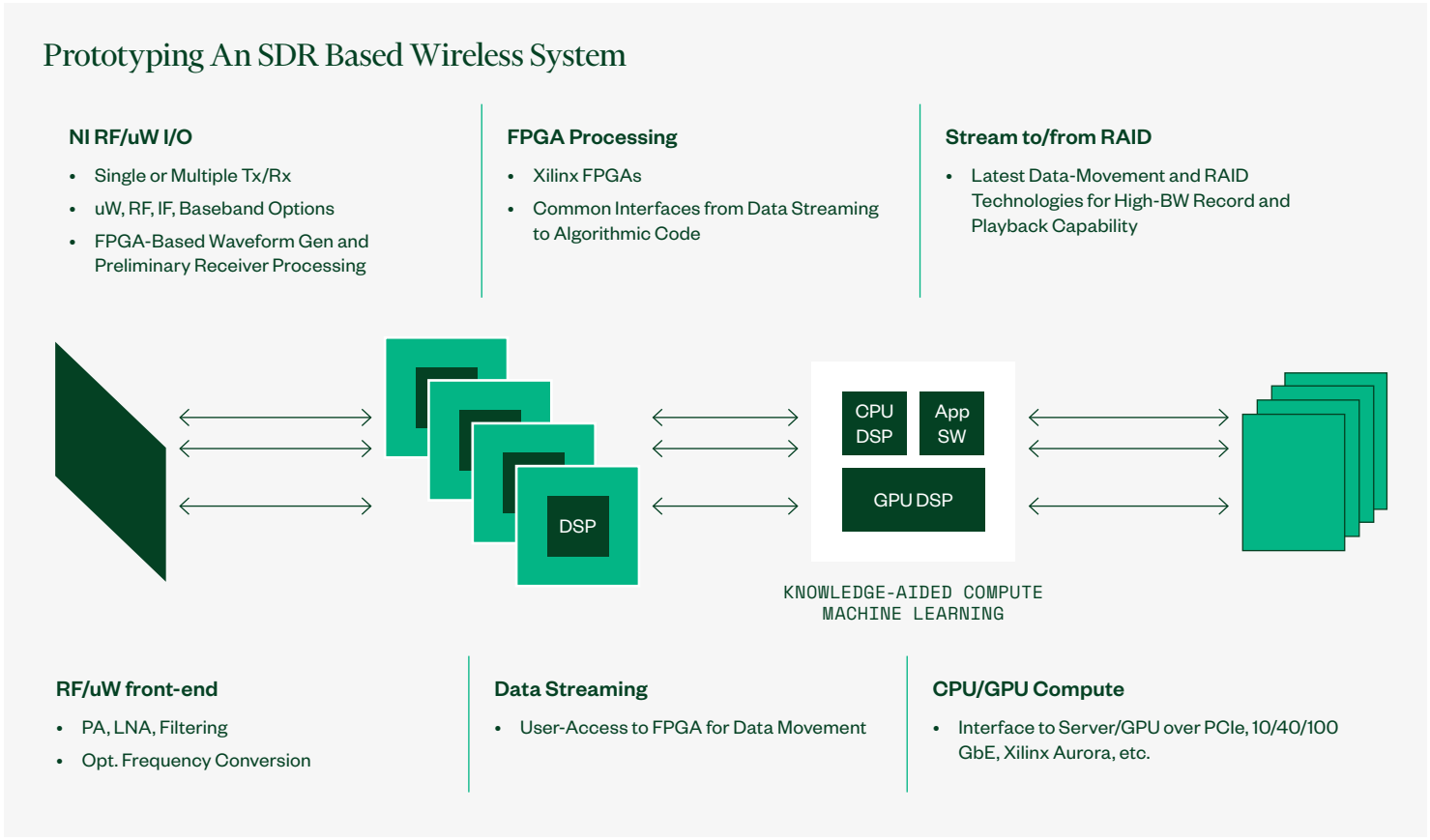


FIG 3 Architecture for Wireless System Prototyping

Key Capabilities

To prototype novel capabilities for wireless systems, researchers must quickly develop a testbed for evaluating new ideas. The LabVIEW Reference Design provides the following key capabilities for wireless research:

Best-in-class system performance.

The LabVIEW Reference Design is built based on NI's most powerful software defined radio (SDR), NI Ettus USRP X410. With a frequency range of 1 MHz to 7.2 GHz, NI Ettus USRP X410 features a two-stage superheterodyne architecture with four independent TX and RX channels capable of 400 MHz of instantaneous bandwidth each. Digital interfaces for data offload and control include two QSFP28 interfaces capable of 100 GbE and a PCIe Gen3 x8 interface. With the addition of PXI high-speed storage and bus extension modules, the system is capable of recording and playback at 491 MS/s with one channel and 122 MS/s on all four channels. The NI PXIe-8267 can provide storage up to 4 TB. Error Vector Magnitude (EVM) is one of the key RF metrics to evaluate the wireless system performance. The total system can achieve up to -40 dB for a 5G New Radio (NR) signal.

A higher starting point to enable outstanding 6G research.

Standalone instruments require a lot of initial hardware setup and programming from underlying APIs. The LabVIEW Reference Design features a standard hardware configuration and ready-to-use prototype software with an intuitive user interface to easily abstract and standardize systems for wireless research. Using step-by-step instructions, researchers can build up a running referenced system quickly, accelerating progress from software simulation to hardware demonstration. The LabVIEW Reference Design is very flexible and easy to modify for different applications, giving wireless researchers more time to discover important findings.

Support mmWave beamforming with phased-array antenna.

The frequency range of the NI Ettus X410 USRP can be extended to mmWave and beyond. The reference design showcases the integration of third-party radioheads. With the mmWave extension, engineers can use the beamformer to fine-tune the gain and phase of multiple RF channels, and the up-and-down converter to expand the NI USRP spectrum to 5G FR2 mmWave bands while maintaining excellent EVM performances.

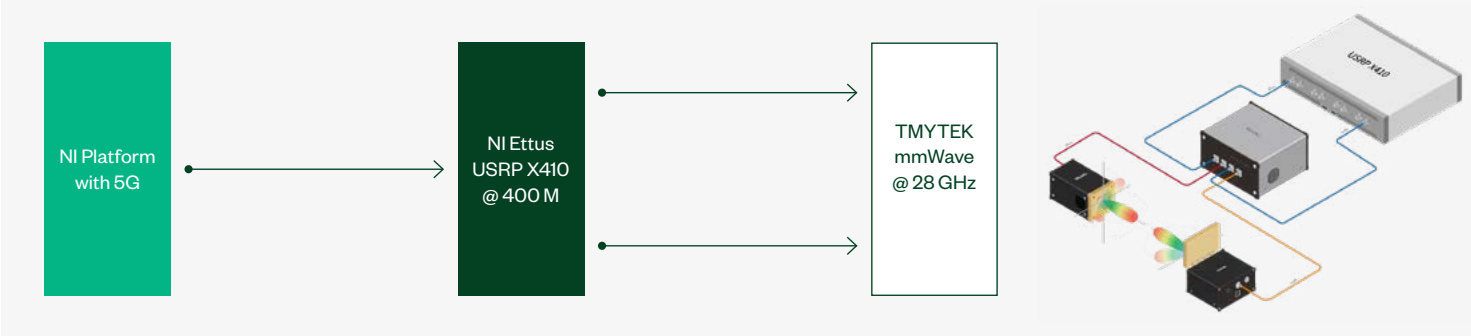


FIG 4 | System Overview with mmWave Extension

Solution Details

A Validated Design Pattern

The LabVIEW Reference Design integrates the NI Ettus USRP X410, NI PXI systems, and mmWave extensions from NI Partners to satisfy the requirements of building wireless testbeds. The following resources are available to users in the Reference Design:

01

Complete bill of materials including NI Ettus USRP X410, PXI system, cables, and other hardware required for system assembly

02

User manual including system setup instructions and measured specifications

03

Powerful refernce code, written in LabVIEW, that demonstrates RF signal transmission, reception, analysis, recording, and playback

System Overview

The LabVIEW Reference Design provides hardware, software, and documentation that accelerates the path from concept to prototype.

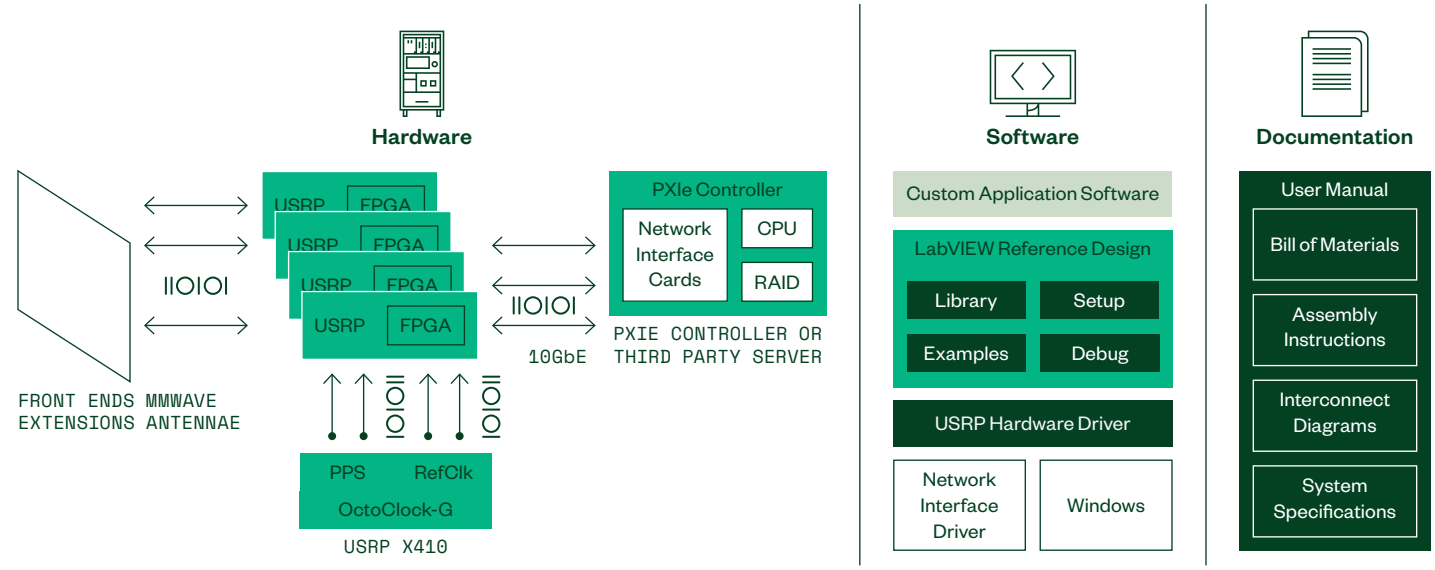


FIG 5 LabVIEW Reference Design Overview

PARAMETER	NI ETTUS USRP X410 ONLY		X410 + MMWAVE EXTENSION
FREQUENCY BAND	1 MHz–7.2 GHz		28 GHz
CHANNELS	4		1
DIGITAL INTERFACE	PCIe		PCIe
RECORDING IQ RATE	1 channel	Up to 491 MSps	Up to 491 MSps
	2 channels	Up to 491 MSps	
	4 channels	Up to 122 MSps	
STORAGE	4 TB with 8267		4 TB with 8267
EVM	Up to -40 dB		Up to -35 dB

TABL 1 System Specification

Key Specifications

01

Four TX and four RX channels with a frequency range from 1 MHz to 7.2 GHz, a bandwidth of 400 MHz, and 100 GbE ports for high throughput streaming

02

Large-volume and high-speed data storage for writing wide bandwidth IQ data to disk for post-processing or playback

03

Recording at 491 MS/s on one channel or 122 MS/s on four channels on a single device

04

Out-of-the-box streaming functionality for FR1 and FR2 bands with super low EVM

05

Robust architecture for lossless RF data collection and storage to evaluate 6G technologies such as RIS, communications and sensing, AI/ML, and more

Hardware Components

NI Ettus USRP X410 Software Defined Radio

The NI Ettus USRP X410 is a high-performance, multichannel software defined radio (SDR) specially designed for prototyping high-performance wireless systems and performing over-the-air signal generation and analysis. The SDR is designed for frequencies from 1 MHz to 7.2 GHz and features a two-stage superheterodyne architecture with four independent TX and RX channels capable of 400 MHz of instantaneous bandwidth each. Digital interfaces for data offload and control include two QSFP28 interfaces capable of 100 GbE and a PCIe Gen3 x8 interface. There are also standard command, control, and debug interfaces: USB-C JTAG, USB-C console, and Ethernet 10/100/1000. The NI Ettus USRP X410 is an all-in-one device built on the Xilinx Zynq Ultrascale+ ZU28DR RF System on Chip (RFSoC) with built-in digital up-and-down conversion and onboard Soft-Decision Forward Error Correction (SD-FEC) IP.

FIG 6 NI Ettus USRP X410

High-Performance PXI Module

High-Speed Data Storage Module

The PXIe-8267 high-speed data storage module features large-capacity, high-throughput storage in a single PXI Express slot. This module has a 4 TB storage capacity and up to 5 GB/s sustained throughput. With M.2 solid-state drives, the PXIe-8267 is ideal for stream-to-disk or stream-from-disk applications requiring sustained, reliable data throughputs such as high-speed signal intelligence, RF record, and playback.

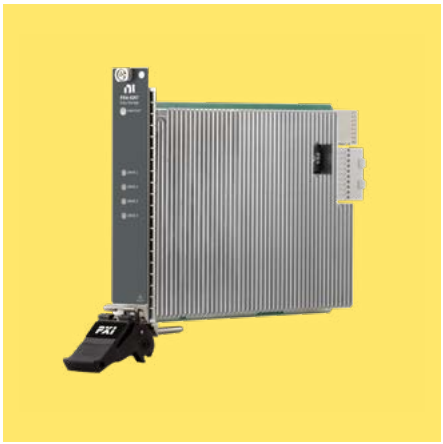


FIG 7 High-Speed Storage Module

PXI Bus Extension Module

PXIe 8394 is an x8, Gen3, Daisy-Chain interface for USRP to route the RF signal to the host (PXI controller) for the RF signal analysis. The module is capable of 7.9 GB/s MXI bandwidth.

Validated Third-Party mmWave Extensions

Integrating the third-party mmWave extensions into the NI USRP platform enables system developers to realize and experiment with their protocol and algorithm innovations with full mmWave capabilities.

For example, the reference software already supports the integration of mmWave extensions from TMYTEK. This includes the UD Box 5G, an up-and-down converter for 24 GHz to 44 GHz, and the BBox 5G series mmWave beamformers with a choice of 4x4 or 1x4 array antenna kit. It has been intensively tested for system compatibility and performance, giving users a streamlined experience.

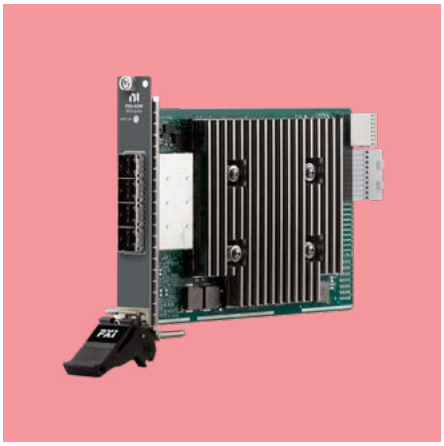


FIG 8 PXI Bus Extension Module

COMPONENTS	NAME	DESCRIPTION
Software Defined Radio	NI Ettus USRP X410	Frequency: 1 MHz to 7.2 GHz, 400 MHz Bandwidth Channels: 4 RX and 4 TX Output Power: TX up to 22 dBm Sync: GPS-Disciplined OCXO, Ref In/Out
PXI Data Storage Module	PXIe-8267	Total Storage Capacity: 4 TB Sustained Throughput: 5 GB/s
PXI Bus Extension Module	PXIe-8394	PXIe, x8, Gen 3 MXI-Express Daisy-Chain Interface MXI Bandwidth: 7.9 GB/s
mmWave Extensions (optional)	TMYTEK UD Box 5G: Up-and-Down Converter	RF: 24–44 GHz IF: 0.01–14 GHz
	TMYTEK BBox 5G: Beamformer with Antenna Kit	Frequency: n257 (28 GHz), n258 (26 GHz), n260 (39 GHz) Antenna Elements: 4, 16
PXI Chassis	PXIe-1092 with Timing	10-Slot (7 Hybrid Slots, 1 PXI Express System Timing Slot, 1 Peripheral Expansion Slot), up to 24 GB/s PXI Chassis
PXI Controller	PXIe-8881	PXIe, 3.9 GHz 8-Core PXI Controller Maximum Controller Bandwidth: 24 GB/s

For more details of TMYTEK mmWave extensions, visit tmytek.com.

TABL 2 Typical Hardware Configuration

Software Components

Standard Software Framework

NI is dedicated to providing best-in-class software architecture to support powerful toolchains and hardware connections. NI's software framework, from basic drivers to the high-level reference designs, gives users a streamlined experience on system setup while keeping the openness for custom applications. Learn about all the benefits of NI's software architecture:

Hardware Drivers: Provide best-in-class APIs and DLLs to control NI USRP or other hardware functionality.

RFmx: Simplifies the 5G/6G signal generation and analysis experience and supports the 3GPP standard. The RFmx is a set of interoperable software applications that optimize NI RF instrumentation for general-purpose, cellular connectivity.

LabVIEW: Enables engineers to conduct 5G/6G wireless research algorithms and implementations through a graphical programming environment.

LabVIEW FPGA: Enables the real-time processing in USRP.

LabVIEW Reference Design: Reduces system setup time significantly with standard and ready-to-use software for 5G post signal processing as well as the wireless system prototype to stream IQ data by the algorithm into a real physical signal.

Custom Application: Modifies the reference codes according to research applications without starting from scratch, accelerating the outstanding 6G research in rich applications.

Software

LabVIEW Reference Design

Software for 5G NR, Streaming, mmWave Extension

USRP Driver

Control USRP Functionality

LabVIEW FPGA

Enables FPGA Processing in USRP

NR RFmx

Generate/Analysis 5G Waveform

mmWave Extension from Third Party

DLL/APIs/Control Kit for RF and Beamforming Contro

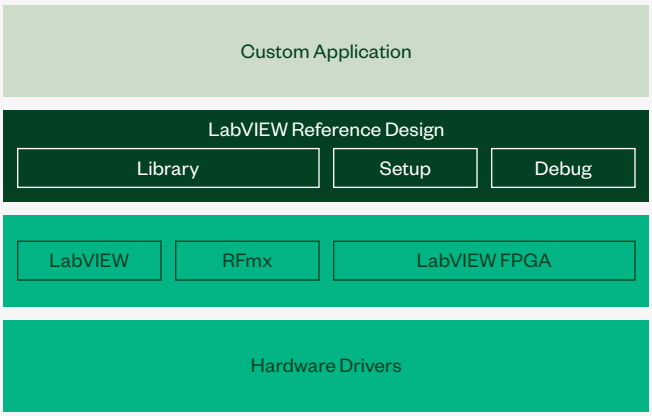


FIG 9 NI Wireless Research Software Framework

Super Intuitive User Interface

The NI Ettus USRP X410 prototype software is developed using LabVIEW, with a clean and interactive user interface. Researchers can easily set up their system using a detailed user manual and conduct 5G/6G research through simple parameter configurations.

RF Recording UI

With the RF data recording UI, after configuring the parameters such as the total samples and samples per reading, users can observe the recording data speed and data size dynamically as it is happening. There is even a recording progress bar, so users can monitor all the progress in real time.

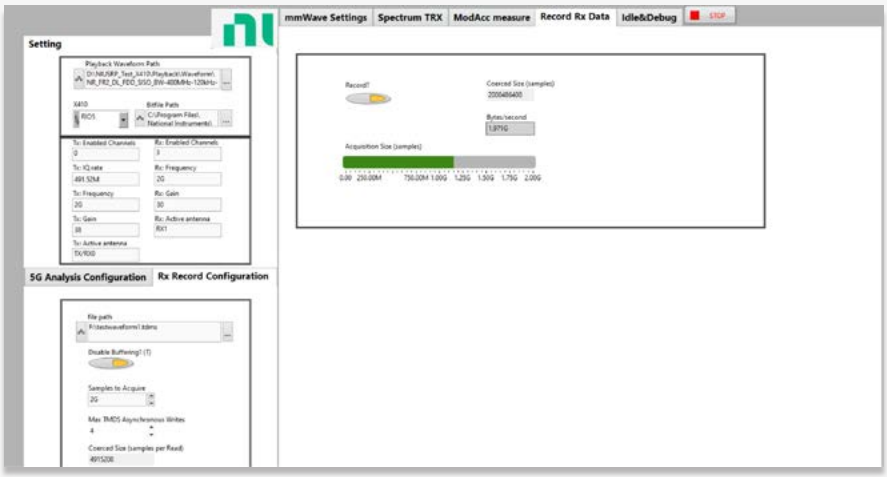


FIG 10 Recording UI

Wireless System Configuration UI

With the configuration UI, users can configure the most commonly used parameters such as the file path of RF waveforms, frequency, gain, bandwidth, and carrier spacing. Additionally, the configuration UI supports multiple standard and custom RF waveform transmissions, including 5G NR in FR1 and FR2. With a simple configuration in the soft front panel, users can stream their custom IQ data as a real RF transmission.

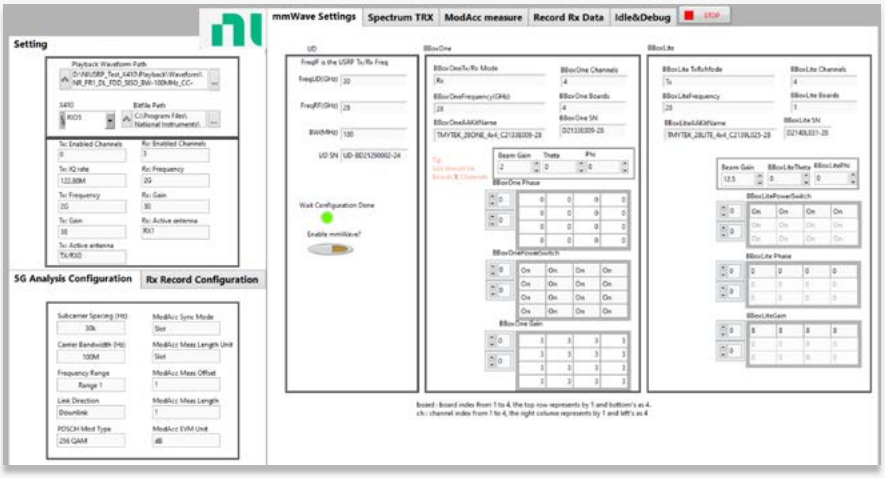


FIG 11 a Configuration UI

Wireless Measurements UI

On the measurements side, after receiving the RF signals, the system can quickly analyze them using NI RFmx application software, showing key metrics such as TX/RX spectrum, constellation, and EVM, which helps researchers quickly evaluate wireless systems.

FIG 12 Measurements UI

System Integration on Your Terms

NI offers a variety of solution integration options customized to your application-specific requirements. You can use your own internal integration teams for full system control, or leverage the expertise of our worldwide network of Alliance Partners to obtain a turnkey system.

Contact your account manager or call or email us to learn more about how NI can help you increase product quality and accelerate test timelines at (888) 280-7645 or info@ni.com.

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