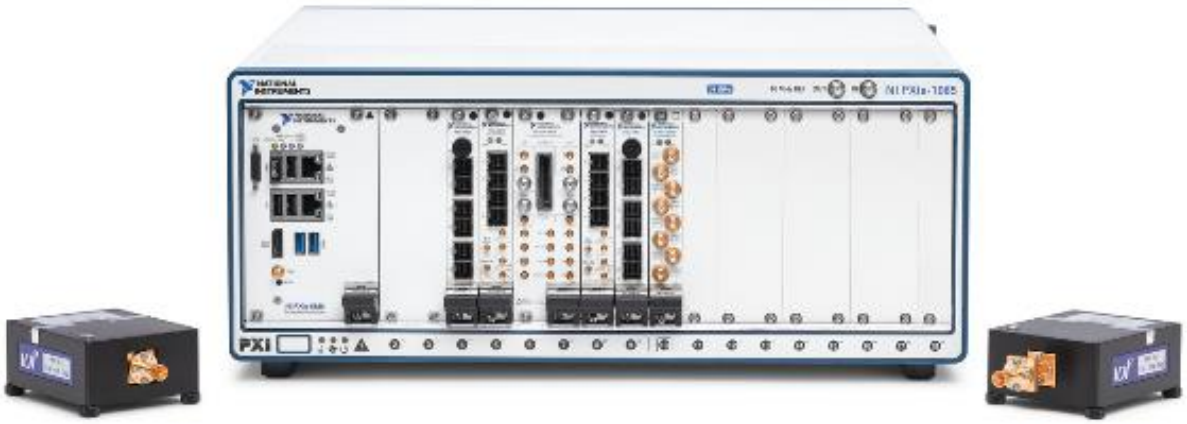
Sub-THz and mmWave Transceiver System



Explore New Frequencies for 5G and Beyond

The sub-THz and mmWave Transceiver System (MTS) is a software-defined platform that enables high-frequency research and prototyping. Flexible hardware and software can be configured to address channel sounding or physical layer IP prototyping use cases for next generation wireless technologies.

Solution Benefits

- Address real-time, over-the-air (OTA) measurements with 2 GHz instantaneous bandwidth and flexible frequency coverage for 28 GHz, 39 GHz, and beyond.
- Perform channel sounding measurements like channel impulse response, delay spread, and time of arrival for mmWave and sub-THz research.
- Accelerate physical layer IP prototyping for single carrier or OFDM signals with modifiable LabVIEW reference examples.
- Scale from uni- to bi-directional, SISO to MIMO configurations in a cost-effective, compact footprint.

Solution Overview

The sub-THz and mmWave Transceiver System (MTS) provides a flexible, high-performance platform to demonstrate real-world results for high-frequency research and prototyping. The modular system architecture can be configured to meet a variety of use cases, built on a common set of components. LabVIEW reference examples provide a starting point for channel sounding and physical layer IP experiments, while allowing the user to modify IP to perform research into new areas. A multi-FPGA processing architecture enables a truly real-time system with no offline processing needed and with 2 GHz of real-time bandwidth, enabling over-the-air (OTA) prototypes of two-way communications links.

The hardware consists of a PXI subsystem for baseband and IF processing, which can be combined with mmWave or sub-THz radio heads to provide up- and down-conversion to reach the final desired frequency range.

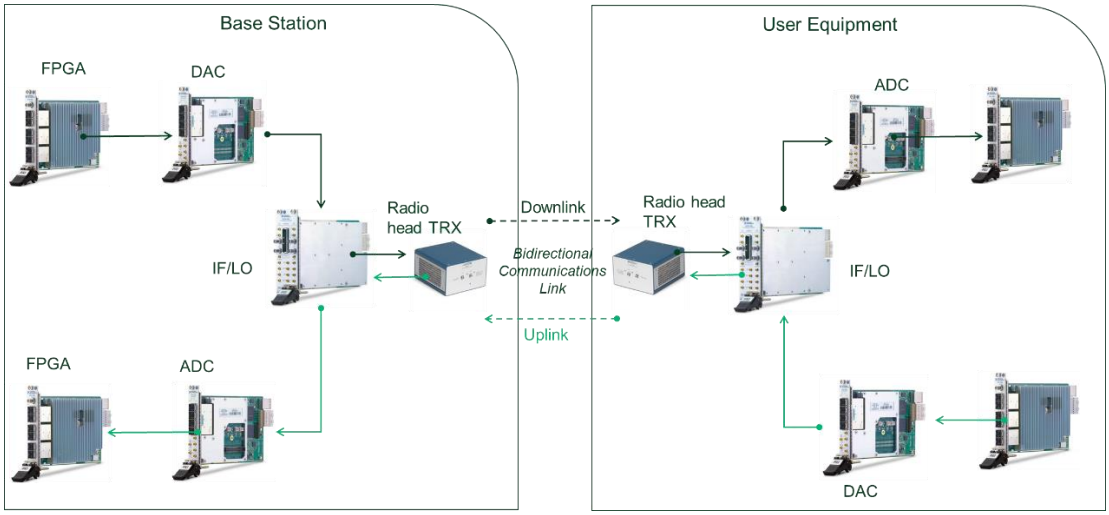


Figure 1: Simplified Block Diagram of a Bidirectional System Capable of Real-time Two-way Communications

Key Features

Modular Flexibility

While the complete NI system with baseband, IF, and mmWave radio heads offers demonstrated capability out of the box, the modular design also enables additional flexibility to use just NI's baseband or the baseband and IF. This allows users to connect RFICs, third-party radio heads, or other custom mmWave hardware to take advantage of the software benefits that LabVIEW offers.

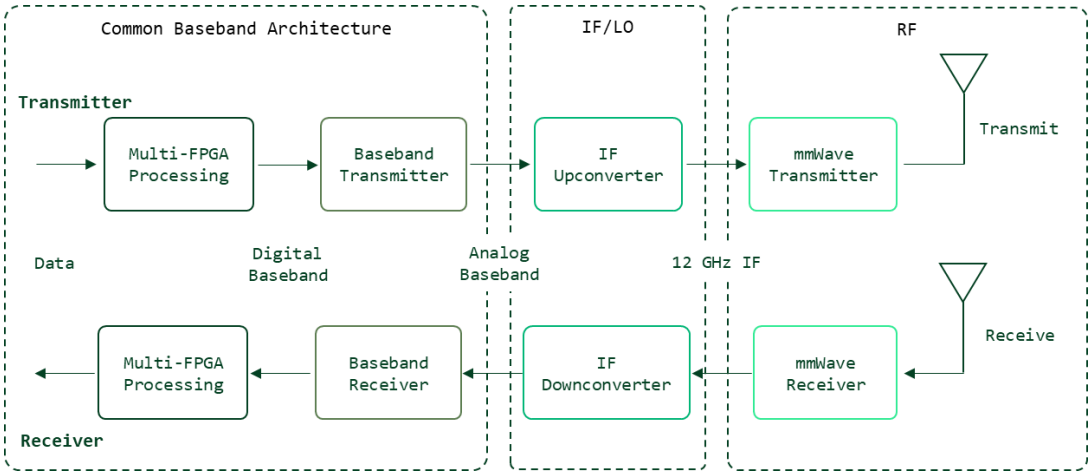


Figure 2: System Diagram of Transmit and Receive Chains

Parallel Processing

The PXI baseband/IF subsystem is capable of not only streaming 2 GHz of bandwidth per channel in real time, but also processing it in real time using LabVIEW FPGA, parallel processing, and a multi-FPGA architecture. In most FPGA processing, the clock rate of the FPGA drives the rate at which data can be processed. For example, a typical FPGA clock rate is 192 MHz, where 192 MS/s can be processed. In order to process up to 2 GS/s, the received data must be split into 192 MS chunks, processed, and recombined while maintaining data integrity. Even relatively simple processing tasks like computing an FFT using pre-built Xilinx IP requires extra effort. For the case of processing an FFT, the Cooley-Tukey method can be used to apply twiddle factors as shown in Figure 3.

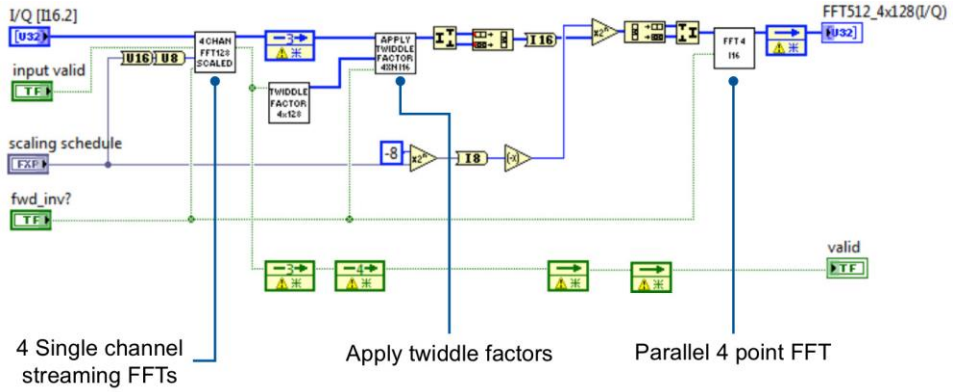


Figure 3: Cooley-Tukey Multi-sample FFT in LabVIEW FPGA Used to Process the Full 2 GHz of Bandwidth

Multi-FPGA Architecture

In addition to using parallel processing to handle large amounts of raw data, multiple FPGAs are also used to build the processing used in highly complex wireless communications systems. Specifically, for 5G mmWave signals, a combination of computationally intensive algorithms are used to encode, decode, modulate, demodulate, and multiplex signals in the physical layer. The physical (PHY) layer and portions of the MAC layer need to be processed in less than one subframe, on the order of nanoseconds, for the system to be able to behave as a real-time communications system and to create a successful wireless link. Figure 4 shows a high-level block diagram of computational blocks and where processing occurs inside of a 5G communications link.

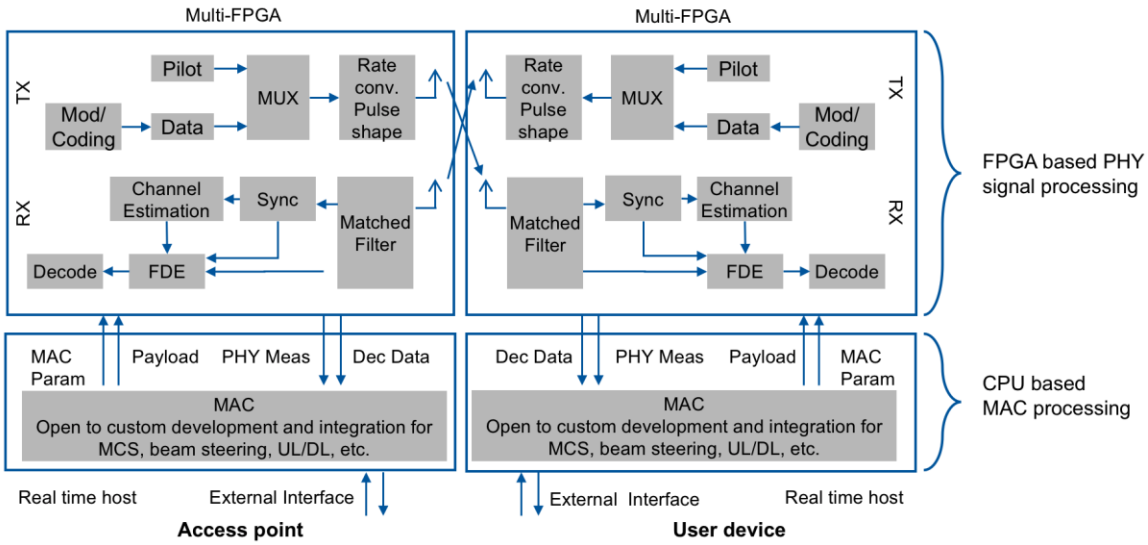


Figure 4: 5G PHY and MAC Layer Processing Block Diagram

Software Tools

5G Physical Layer Software Reference Examples

The sub-THz and mmWave Transceiver System is uniquely positioned to serve in prototyping over-the-air communications links for advanced wireless research, like 5G and 6G. To give researchers an out-of-the-box starting point, NI has developed two 5G physical layer reference examples: one based on the Verizon 5GTF specification OFDM waveform, and a second based on a single carrier modulation scheme. The reference examples are delivered as source code and are completely open and modifiable to provide the greatest amount of flexibility for wireless communications research.

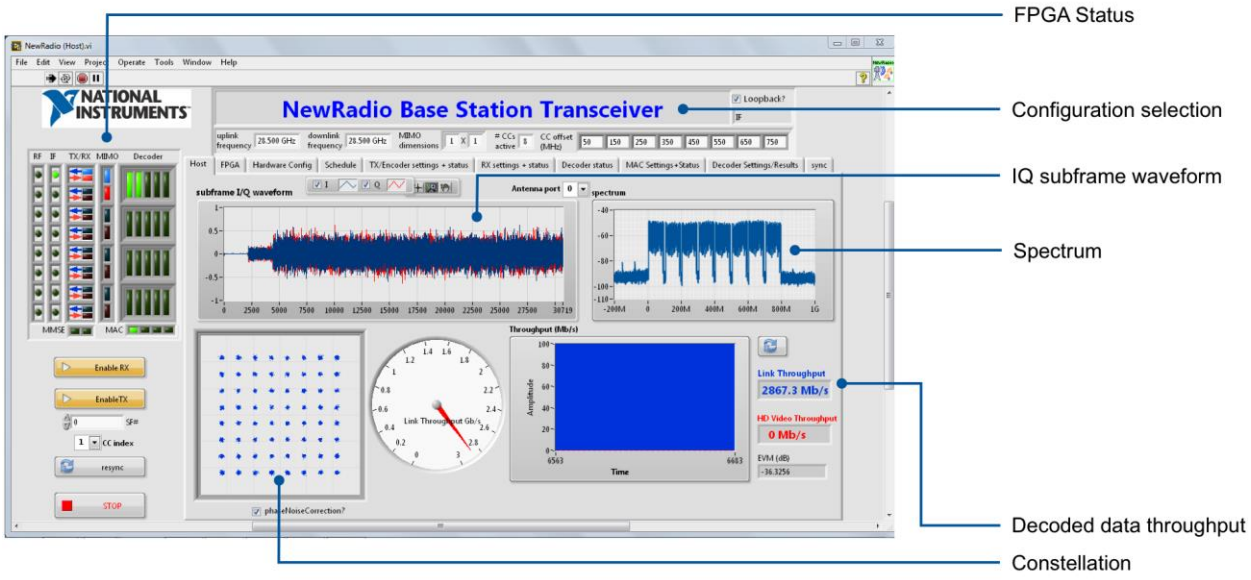


Figure 5: 5G OFDM Reference Example Front Panel

NI-mmWave Application Programming Interface (API)

The NI-mmWave driver includes a best-in-class API that works with LabVIEW and LabVIEW FPGA. The driver provides access to help files, documentation, self-test VIs, and ready-to-run sample streaming projects which can be used as starting points for your application. Like the driver for other NI reconfigurable I/O products, the NI-mmWave sample streaming project includes software that runs on the host and software that runs on the FPGA. A snippet of the host-based API can be seen below in Figure 6.

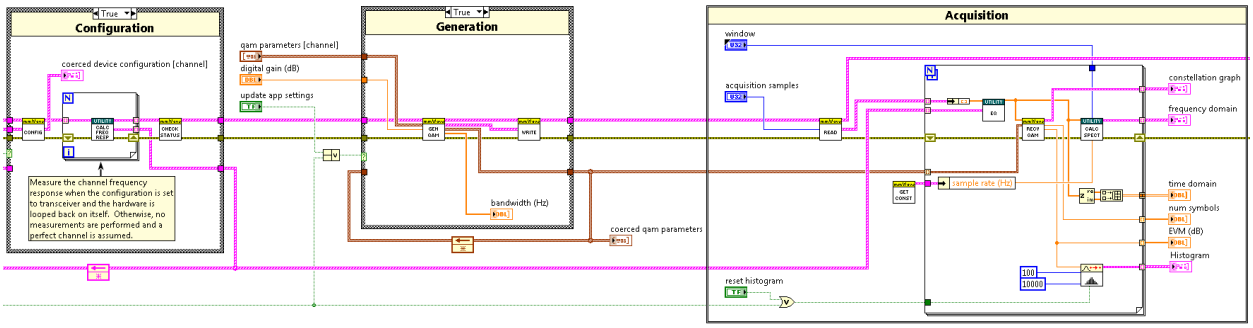


Figure 6: Snippet of NI-mmWave Driver Host-based API

System Configurations

The basic configuration for the sub-THz and mmWave Transceiver System is composed of the PXI baseband/IF subsystem and radio head, but more complex configurations can be built up to address different use cases. Unidirectional configurations include separate transmit and receive systems for use cases like channel sounding or downlink-only communications link, where signals only need to go in one direction. A bidirectional configuration is built from two transceiver systems and can be used for both uplink and downlink communications systems, with both systems able to transmit and receive.

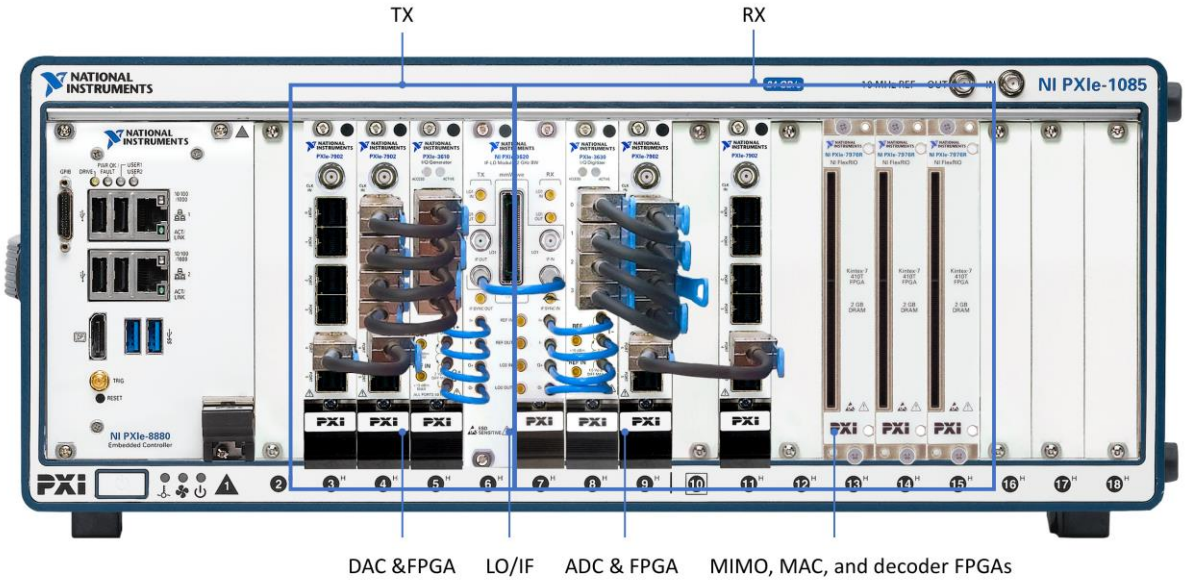


Figure 7: One Half of a Bidirectional SISO System with Additional FPGAs for Real-time Coding

The basic single-channel configuration enables single input, single output (SISO) systems, but an additional channel can be added to address two-channel multiple input, multiple output (MIMO) use cases. Figure 7 shows an example of one of the two systems included in the bidirectional SISO configuration, with FPGA modules added for additional real-time processing.

It is common to add FPGAs to the system for increased real-time processing, for applications like a real-time 5G physical layer. For a communications link to be able to calculate data throughput, the signal must be encoded and decoded in real time, which is very processor intensive and requires additional FPGAs. Another typical addition is a timing and synchronization module which provides a trigger to synchronize multiple channels for MIMO configurations, as well as a higher quality 10 MHz clock source for better overall RF performance.

HARDWARE COMPONENTS			
PXI Baseband/IF Subsystem			
DAC	PXIe-3610	Baseband for transmitter	
ADC	PXIe-3630	Baseband for receiver	
LO and IF module	PXIe-3620	LO/IF module shared by both transmitter and receiver	
FPGA	PXIe-7902	Paired with each DAC and ADC, plus additional units for more processing	
FPGA	PXIe-7976R	For encoding/decoding; quantity depends on application	
Timing and sync	PXIe-6674T	10 MHz clock improves RF performance, triggering to synchronize MIMO configurations	
Chassis	PXIe-1085	Typically, two are needed: one for each half of the system	
Controller	PXIe-8880	One per chassis, with 8GB memory	
Radio Heads	24.25 – 33.4 GHz	37 – 42.5 GHz	110 – 170 GHz
Transmit only mmRH	mmRH 3642	mmRH 3643	Virginia Diodes, Inc. (VDI) Compact Converters or other third-party heads
Receive only mmRH	mmRH 3652	mmRH 3653	
Transceiver mmRH	mmRH 3602	mmRH 3603	
Digital Cables	785811-01	785811-01	For uni-directional system, 1 per head
	785812-01	785812-01	For bidirectional system, 1 per head

Table 1: An Overview of the PXI Modules and mmWave Radio Heads Offered by NI

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 NI Partners to obtain a turnkey system.

To learn how you can increase product quality and shorten test timelines, contact your account manager or NI at (888) 280-7645 or info@ni.com.