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# 6G Sub-THz Reference Architecture

## Enabling the next generation of wireless communications

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# 6G Sub-THz Research and Validation

Whether you need to quickly take and visualize measurements or customize complex and detailed test cases, the 6G Sub-THz Reference Architecture has the tools you need to efficiently and accurately perform comprehensive sub-THz research, test, and validation.


# 6G Sub-THz Reference Architecture

## What You Need for Demanding, High-Performance, Sub-THz Test

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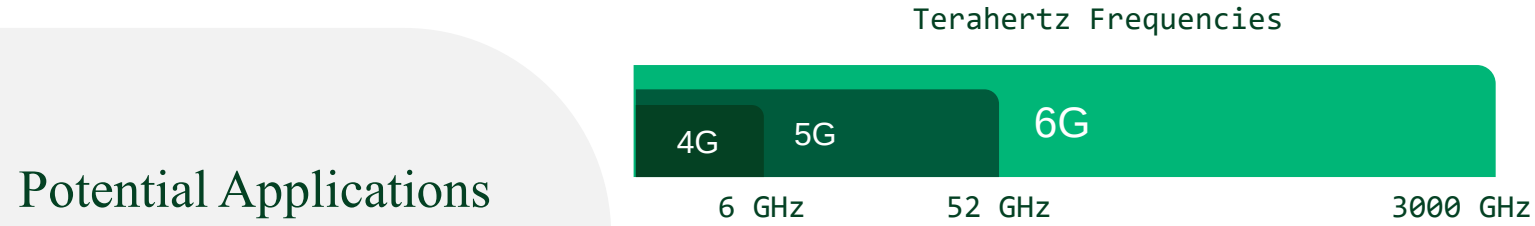
NI's 6G Sub-THz Reference Architecture is a set of interoperable hardware and software components designed to give users a platform to test and prototype the next generation wireless standards at sub-THz frequencies.

- Measurements including spectrum, power, and modulation at up to 4 GHz bandwidth
- System calibration process and correction, easy to run and built-in
- Real-time, sustained data streaming
- High-performance, open, and real-time FPGA coprocessors for data processing
- D-band frequency coverage with Virginia Diodes (VDI) frequency extensions
- Superior timing and synchronization on an integrated PXI platform
- Exceptional RF performance and dynamic range with PXI Vector Signal Transceivers
- Out-of-the-box, automated API for full control of test that is compatible with RFmx for standards-based measurements

# Why Sub-THz?

## The Future of Wireless Communication

With 5G continuing to roll out new capabilities over the next decade, followed closely by 6G, we will see many changes in wireless communications. This includes a move to much higher frequencies (sub-THz bands), to phased-array antenna solutions, to increasing bandwidths and modulation densities, and to the proliferation of new use cases in massive machine-to-machine communication and in new levels of reliability, security, and network response time.




## Potential Applications and Use-Cases for 6G:

Wireless Cognition

Wireless Sensing

Immersive XR

Device Location

Imaging & Radar

Mobile Hologram

## Enabling Technologies in 6G:

1. Extreme MIMO: new extreme and distributed MIMO techniques will require a much greater level of synchronization
2. Joint Communications and Sensing: new use cases by combining sensing and radar functions with communications channels
3. Spectrum efficiency and sharing: new and novel techniques to optimize spectrum and usage between cellular, Wi-Fi and other use-cases
4. AI and Machine Learning: native application of AI to improve techniques across all 6G—from the signal chain to the network topology
5. Non-terrestrial Networks (NTN): truly global communication will require connections to distributed satellite constellations
6. New Spectrum – FR3 (7-24 GHz) and Sub-THz (90 GHz – 300 GHz) will open more spectrum for cellular communications

# 6G Sub-THz Reference Architecture Overview

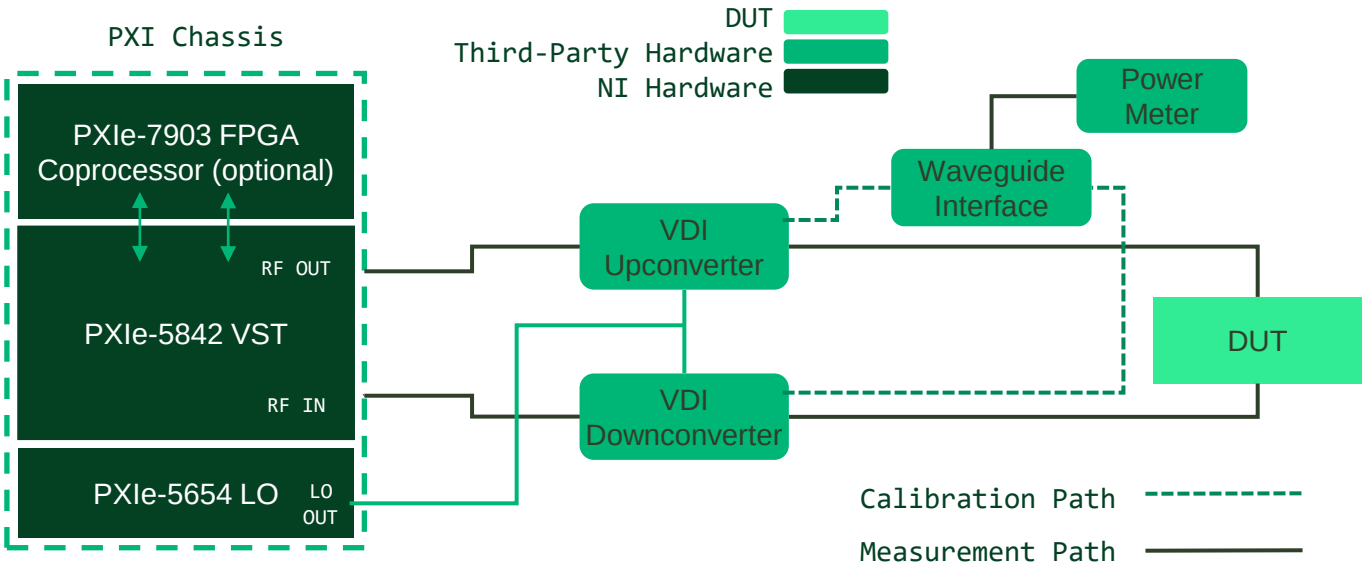



Figure 1. 6G Sub-THz Reference Architecture System Diagram

The 6G Sub-THz Reference Architecture optimizes NI and third-party hardware with easy-to-use software to bring a cost-effective, versatile, and high-performance sub-THz test system capable of a wide range of measurement options. With a high-level starting point for test configurations, quickly being taking measurements with existing software or use it as a starting point for unique test customizations with software tools built for both parametric test and prototyping applications.

Capable of up to 4 GHz instantaneous bandwidth with real-time, sustained data streaming for both signal generation and analysis, the 6G Sub-THz Reference Architecture allows for power, spectrum, modulation, and calibration measurements in the D-band with Virginia Diodes (VDI) frequency extensions.

Designed with optimized timing and synchronization in mind, NI's PXI Platform allows for sub-nanosecond synchronization between instruments, including the ability to add multiple RF channels with additional PXI VSTs for MIMO applications and the ability to add analog, DC, or digital I/O.

The 6G Sub-THz Reference Architecture is an incredibly cost-effective sub-THz test solution. It enables the unique and complex test considerations required for sub-THz research, prototyping, and validation while providing a platform that can serve as a foundation and critical tool for the continued research and innovation in wireless communication standards development.

# 6G Sub-THz Reference Architecture Features

## Real-Time, Sustained Streaming

Take advantage of the PXIe-7903 for real-time, sustained data streaming at up to 4 GHz instantaneous bandwidth. The PXIe-7903 is an FPGA coprocessor with a large, open, and high-performance FPGA that connects with the PXIe-5842 VST through four multi-gigabit (MGT) connectors through the instrument front panel capable of up to 16 Gb/s per lane (16 lanes total).

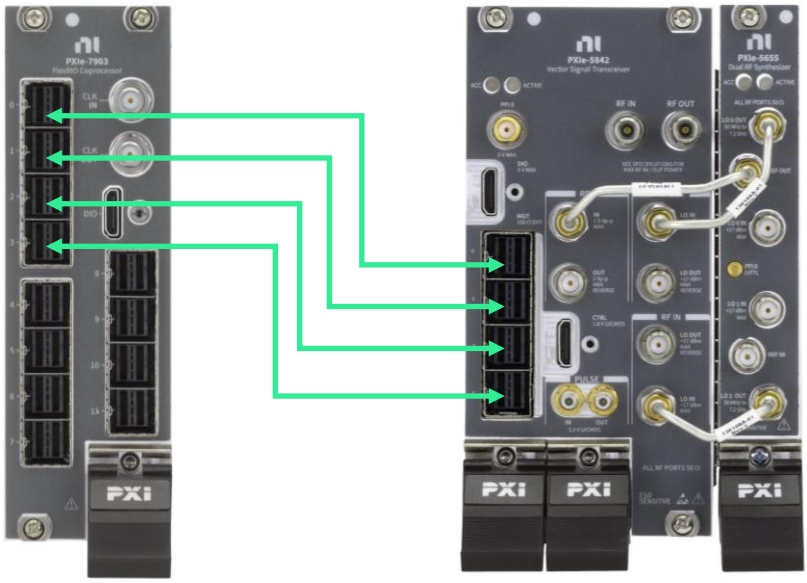


Figure 2. Using MGT Connectors with the PXIe-7903 and PXIe-5842

With the high-performance FPGA resources to process it, this enables sustained streaming at up to 4 GHz instantaneous RF bandwidth—live and in real time—enabling real-world communication system prototyping and validation.

## Sub-THz Frequency Coverage

With the VDI frequency extensions, the 6G Sub-THz Reference Architecture can provide frequency coverage from 110 to 170 GHz. Combined with a PXI-based architecture, this creates a highly synchronized interface and customizable test system, with the LO integrated into the PXI chassis alongside the VST-based IF subsystem. This means low path loss and high-performance RF measurements while maintaining an integrated and scalable test system.

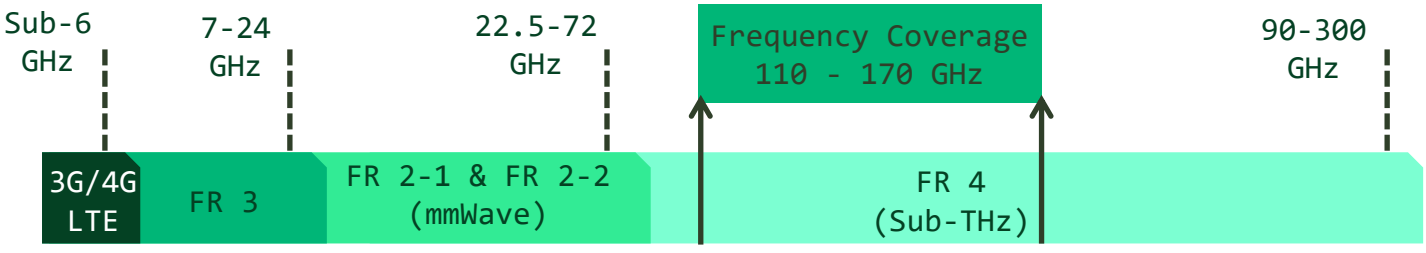
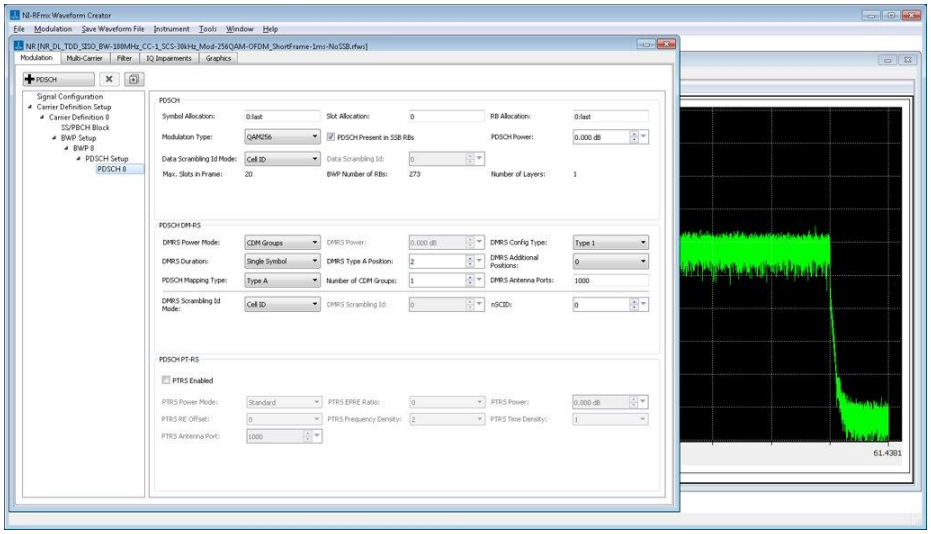



Figure 3. Frequency Coverage of the 6G Sub-THz Reference Architecture

# Waveform Generation Capabilities



The built-in waveform generation capabilities allow for quick configuration of many different 3GPP, IEEE, and custom waveforms.

With RFmx Waveform Creator, you can choose from a variety of standard modulation schemes straight out of the box.

Figure 4. Generate 3GPP, IEEE, and Custom Modulation Waveforms with the RFmx Waveform Creator

Also included is the ability to design arbitrary waveforms with external tools, allowing for complete control and customization of waveforms used.

- Manually create uplink and downlink configurations based on 3GPP standards
- Test coexistence with support for LTE-A, WLAN, and Bluetooth
- Choose from single carrier or carrier-aggregated (CA) waveforms
- Create and generate unencrypted waveforms for sharing and playing back on NI or third-party instruments
- Customize the open FPGA on the fly, and modify waveforms in real time

# Waveform Analysis Capabilities

For instantaneous bandwidth less than 2 GHz, enjoy full RFmx support, including the easy-to-use and customizable Soft Front Panel in InstrumentStudio™ software.

For large bandwidth (> 2 GHz) waveforms, capture IQ samples for offline analysis or use the RFmx Analysis Libraries or any custom analysis tool.

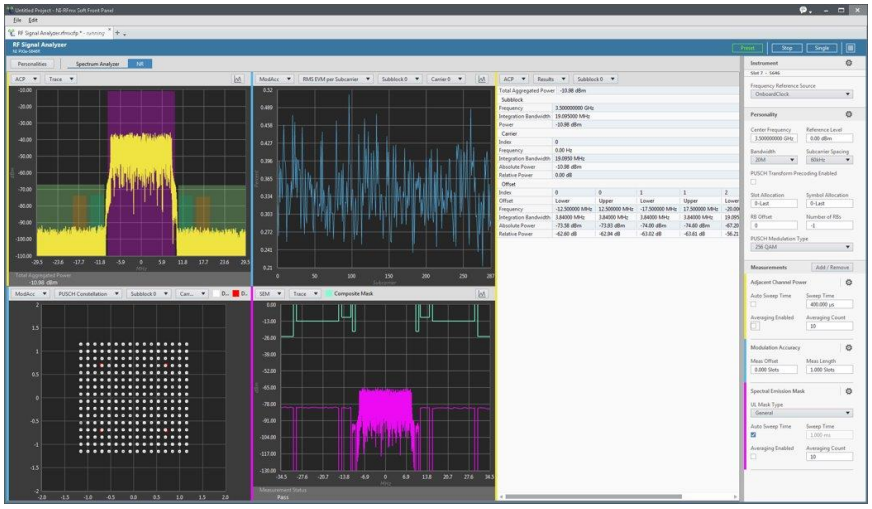


Figure 5. RFmx Soft Front Panel in InstrumentStudio

# Multichannel Synchronization

With a PXI-based architecture, all instrumentation can be highly synchronized through the same instrument backplane and interface. Configuring instruments in this way allows for sub-nanosecond synchronization among multiple instruments, all aligned on the same sample clocks and triggers.

The result is multichannel, sub-nanosecond synchronization across multiple RF channels, frequency extensions, and all other instrumentation contained within the chassis—a significant advantage when dealing with extreme high frequency and wideband sub-THz waveforms that require precise timing.

The following figure shows an example 2x2 configuration with all instruments synchronized and timed across the PXI backplane interface.

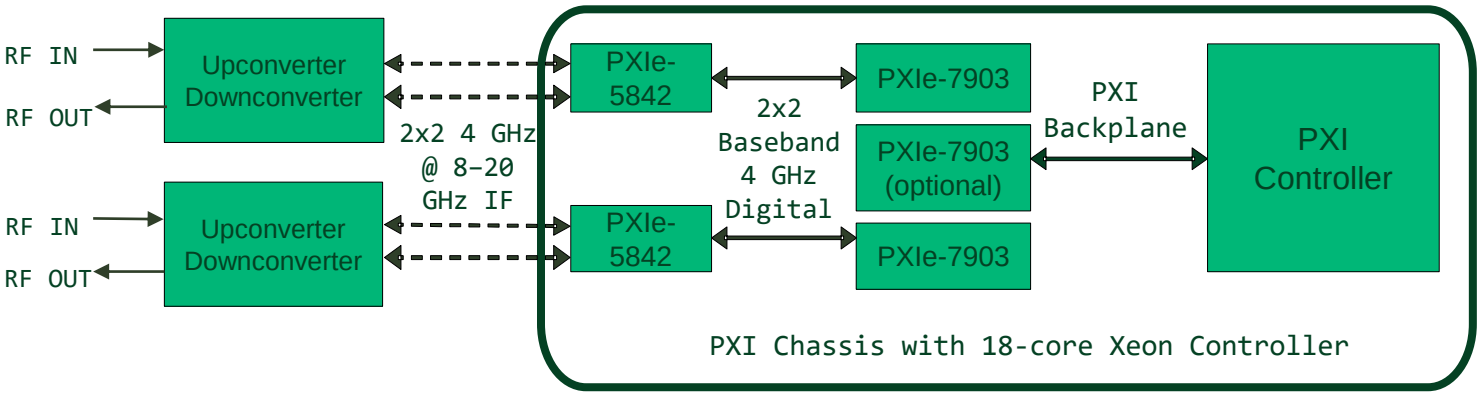



Figure 6. 6G Sub-THz Reference Architecture 2x2 MIMO Configuration Diagram

# Conducted and OTA Measurement Configurations

NI's 6G Sub-THz Reference Architecture is reconfigurable to allow for many different test cases and is designed to meet the needs of a given application. Among some of the primary options is the ability to choose between over-the-air (OTA) or conducted test. With the inclusion of the appropriate hardware, you can quickly configure OTA link or channel sounding applications with the same instrumentation and software interface.

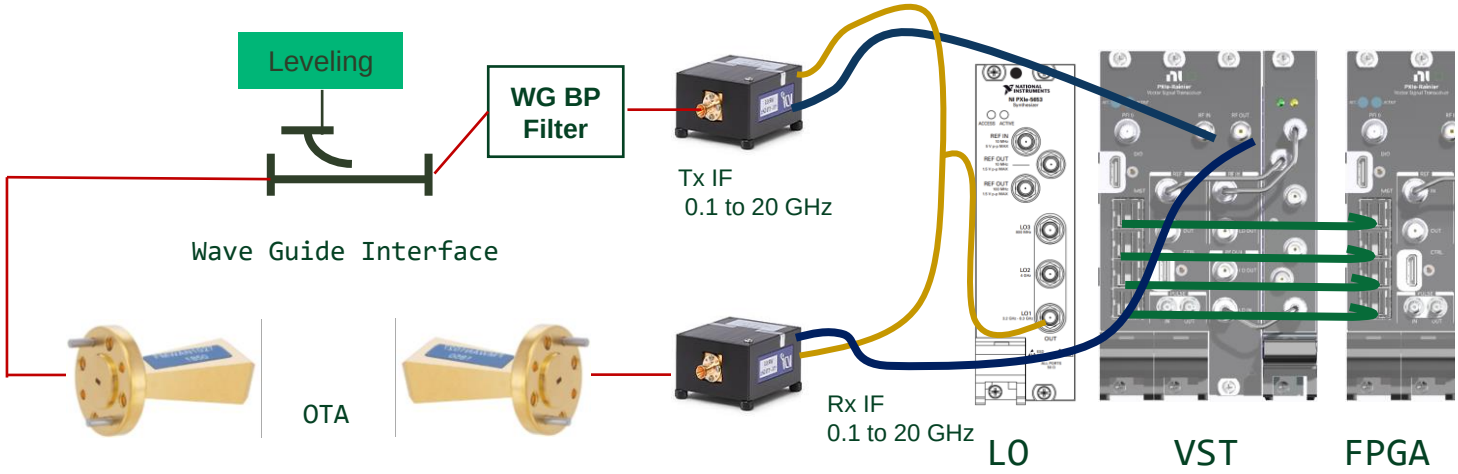



Figure 7. Over-the-air (OTA) Configuration Diagram

# Power, Spectrum, and Modulation Measurements

A wide range of measurement capabilities is important in fully characterizing sub-THz devices. With the ability to configure power, spectrum, modulation, and amplitude calibrated Tx/Rx measurements (including power/gain and flatness over bandwidth), there are built-in measurement capabilities for the many test cases encountered in sub-THz research and test.

The range of measurements included means many different use cases and DUT types can be configured and tested on the same test bench for both parametric testing and radio prototyping. A few examples of different capabilities include:

### DUT Types:

- Power Amplifier (PA)
- Low Noise Amplifier (LNA)
- Filter
- DSA
- OTA Link

### Stimulus/Response characterization of devices and systems:

- Waveform research
- Channel sounding
- CW, multi-tone

### Radio Prototyping:

- Real-time FPGA data link to FPGA coprocessor
- Open FPGA for custom signal processing, encode/decode, filtering, and more

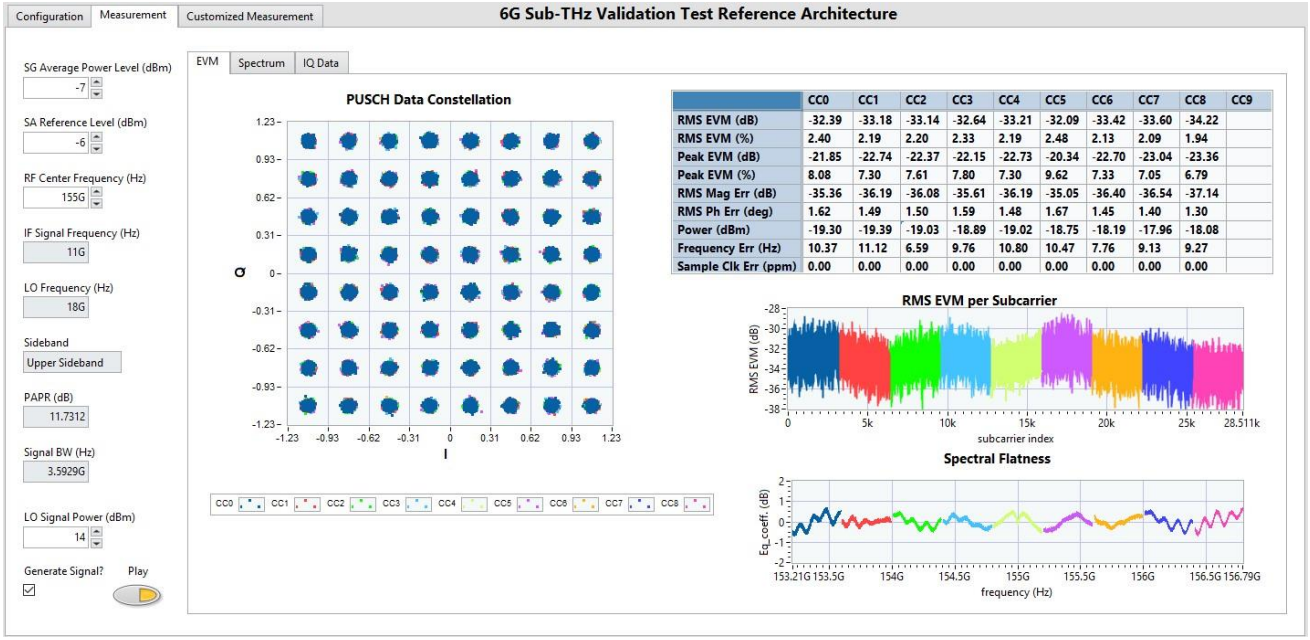



Figure 8. 6G Sub-THz Software Screenshot Showing Constellation, EVM, and Flatness

# Parametric Test and Prototyping – All in One System

The software included with the 6G Sub-THz Reference Architecture is a reference design example that allows for both parametric test and radio prototyping applications. Leverage the built-in UI for easy measurement configuration or edit the source code for custom test cases in sub-THz device characterization.

Also included is IP that allows for quick data capture and configuration of sustained data streaming, ideal for research and prototyping applications such as OTA link, channel sounding, standards-based research, and waveform characterization.

# 6G Sub-THz Hardware Components

### PXIe-5842 VST

A VST combines an RF and baseband vector signal analyzer and generator with high-speed serial interfaces for real-time signal processing. This unique variant offers 4 GHz of instantaneous bandwidth specifically for wideband sub-THz test.

### PXIe-7903 FPGA Coprocessor

FlexRIO™ instruments combine large FPGAs and high-performance analog, digital, and RF I/O. The PXIe-7903 provides real-time, full rate data streaming for sub-THz test applications.

### PXIe-5654 LO

The PXIe-5654 provides a local oscillator (LO) for the VDI frequency extensions and can be synchronized with the PXIe-5842 for superior timing and synchronization.

### PXI Chassis

PXI chassis house PXI modules and connect them with a high-performance backplane that offers timing and synchronization capabilities.

### PXI Controller

PXI controllers provide a high-performance, compact embedded computer solution for PXI Express systems and come with features such as an integrated CPU, hard drive, RAM, Ethernet, video, keyboard/mouse, serial, USB, and other peripheral I/O.

### VDI Frequency Extensions

Part of NI's 6G Sub-THz Reference Architecture is the VDI WR-6.5 providing up/down conversion in a range from 110 to 170 GHz to IF frequencies for use with PXI VSTs.

# 6G Sub-THz Configuration Options

The following part numbers are for the base configurations that provide all the hardware you need to get started, as well as optional add-ons for additional functionality.

Reference Architecture Base Configurations:

| Solution Name | Part Number | Description |
|---|---|---|
| 6G Sub-THz Test Reference Solution | 868107-01B | 6G Sub-THz, 4 GHz BW VST, RF SIGNAL GENERATOR, O-SCOPE, 18 SLOT CHASSIS, CONTROLLER |
| 6G Sub-THz Test Reference Solution (Data Streaming) | 868107-02B | 6G Sub-THz, 4 GHz BW VST, RF SIGNAL GENERATOR, O-SCOPE, 18 SLOT CHASSIS, CONTROLLER, FPGA COPROCESSOR |

Reference Architecture Optional Add-ons:

| Option Name | Part Number | Description |
|---|---|---|
| Real-time, Sustained Data Streaming | 868107-01P | FGPA Coprocessor, 28.2 Gbps, 48-Channel High-Speed Serial Instrument (PXIe-7903) |

Base configurations will offer everything you need to build a test system sub-THz test applications. All options listed will include the PXI instrumentation needed to set up a fully functioning test bench.

The PXI chassis included in bundles is the PXIe-1095 (timing and synch) and controllers included are the PXIe-8881 (8-core, Windows 10). Software is not included as part of bundles and must be purchased separately.

The 6G Sub-THz Reference Architecture requires some third-party components including:

- VDI up/downconverters
- Waveguide connected components (antenna, attenuator, etc.)
- Power meter & zero bias diode

Please contact NI for a full list of additional required components. Third-party hardware must be purchased separately. For further assistance choosing configurations, please reach out to your Account Manager, Distributor, or contact NI.

# 6G Sub-THz Software

High-level reference design starting point for quick measurements and easy test customizations ideal for research, prototyping, and validation applications.

## 6G Sub-THz Validation Test Software

Leverage a high-level reference design example code and intuitive UI to quickly being taking measurements or use the reference code as a platform to easily customize novel test cases.

The built-in streaming personality provides an easy way to acquire data for research and prototyping applications.

**Features:**

- Reference Design Example
- Calibration Software
- Real-time Tx and Rx Processing
- RFmx Analysis-Only Library

## RFmx Soft Front Panel and Waveform Creator

RFmx is a set of interoperable software applications that optimize NI RF instrumentation for general-purpose, cellular, connectivity, and aerospace/defense test applications.

For applications requiring less than 2 GHz instantaneous bandwidth, take advantage of full RFmx support, with both the Soft Front Panel and Waveform Creator.

**Features:**

- RFmx Soft Front Panel in InstrumentStudio software
- RFmx Waveform Creator
- RFmx APIs

Contact your NI product expert to get help solving your test challenges.

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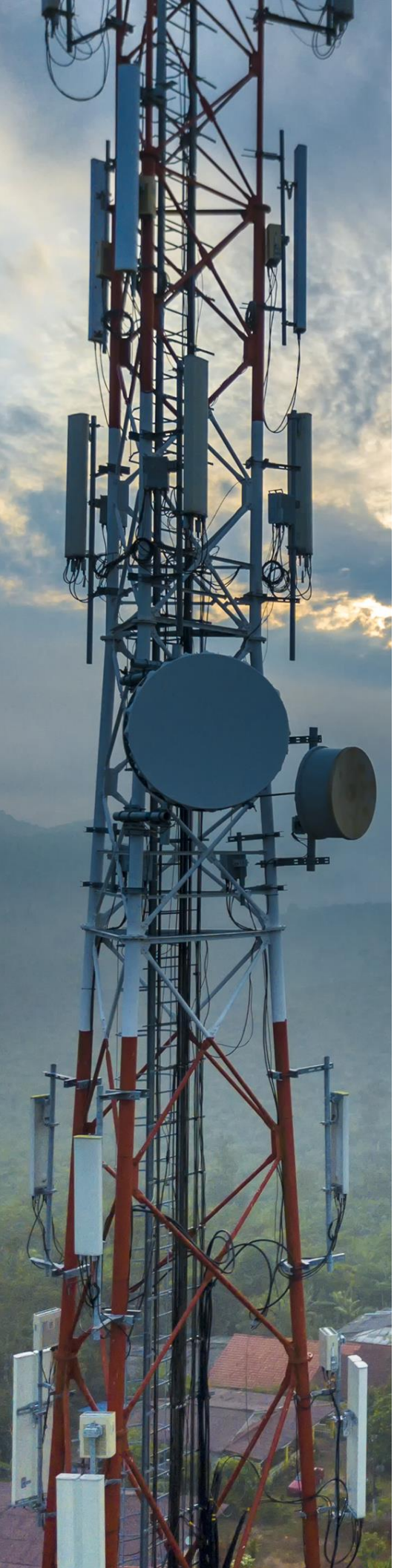

# System Integration on Your Terms

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 configure cutting-edge wireless test applications and accelerate test timelines at (888) 280-7645 or info@ni.com

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