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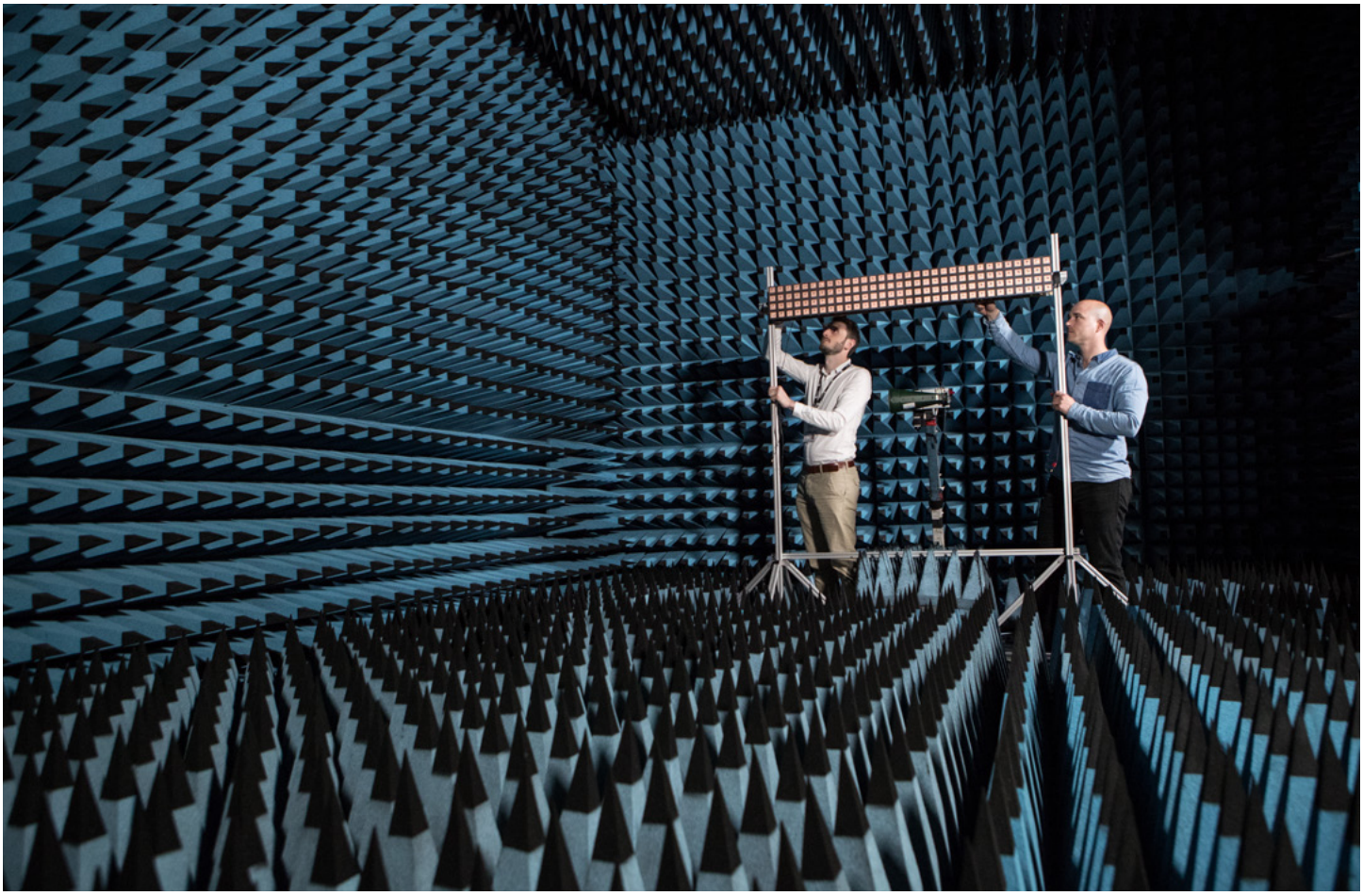
Solution Brochure

5G mmWave OTA Reference Architecture

Determine Fine Beamforming Performance Faster

Achieve Ultrafast 5G mmWave OTA Validation



5G mmWave OTA Reference Architecture Overview

The OTA Validation Reference Architecture is a set of interoperable hardware and software designed for streamlined workflows, unified control, and fast test of mmWave beamforming and AiP devices. At its core is a software application, the OTA Validation Test Software, used to set up the parameters of the spatial sweeps (frequency, power, path loss calibration, polarization, angular resolution). It also enables users to visualize the sweep results in the form of azimuth and elevation cuts, 3D patterns, polar plots, and heat maps.

Going a level deeper, the OTA reference architecture includes a plug-in for customizing device under test (DUT) control and an API for creating specific code modules. It also includes easy-to-use and easy-to-follow TestStand example sequences that automate extensive OTA testing and results reporting without having to write test software. At the hardware level, the mmWave Vector Signal Transceiver (VST) serves as a high-bandwidth waveform generator and analyzer. The VST is tightly synchronized with the DUT positioner inside the anechoic chamber to produce fast, smooth movement, and measurement results that correspond to exact coordinates in space.

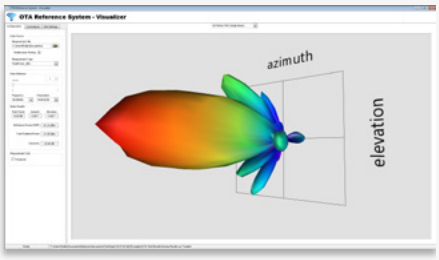
NI's 5G mmWave OTA Validation Reference Architecture can help your team:

- Cut 5G mmWave OTA test from hours to minutes
- Validate antenna-in-module (AiM) devices and reference designs of various aperture sizes over temperature
- Determine CW and high-bandwidth 5G modulated performance in 3D
- Improve measurement results and minimize OTA measurement uncertainty
- Set up integrated TX/RX benches without external switching

FIGURE 1
5G mmWave OTA Validation Reference Architecture

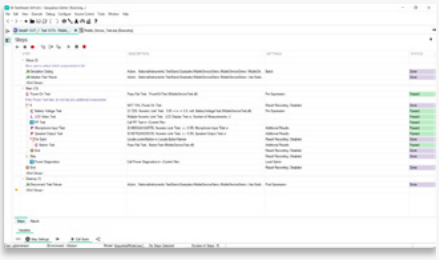
5G mmWave OTA Reference Architecture Hardware and Software Interactions

OTA Application



Interactive control and visualization of OTA test benches for sweep configuration and 3D results

OTA Measurement Programs



Flexible OTA API plug-in for customizable DUT control

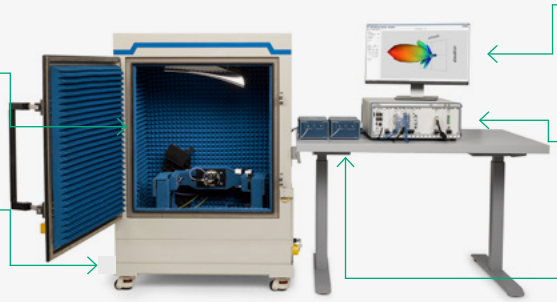
Ready-to-go sequences for fast automation

RFmx Measurement-Optimized Driver Software

OTA Hardware

DFF or CATR anechoic chamber

Built-in autonomous motion controller



PXI system with fast, multi-core processor

PXI vector signal transceiver

mmWave extensions with built-in switching

FIGURE 2

5G mmWave OTA Reference Architecture Software and Hardware Interactions

Accurate and Fast OTA Validation

Running detailed 3D over-the-air (OTA) spatial sweeps of 5G beamforming devices within a controlled RF environment in an anechoic chamber can be a very time-consuming and expensive task.

A typical move, stop, measure, point-by-point, software-controlled test system with a positioner that can rotate on two independent axes (azimuth and elevation), produces only a handful of RF measurements per second. However, engineers need to measure and validate antenna performance by scanning hundreds or even thousands of points in space. The finer the 3D sampling grid (smaller distance between measurement points), the higher the test times, but the lower the measurement uncertainty. Conversely, a 3D grid that is too sparse can give faster results but introduce significant measurement error.

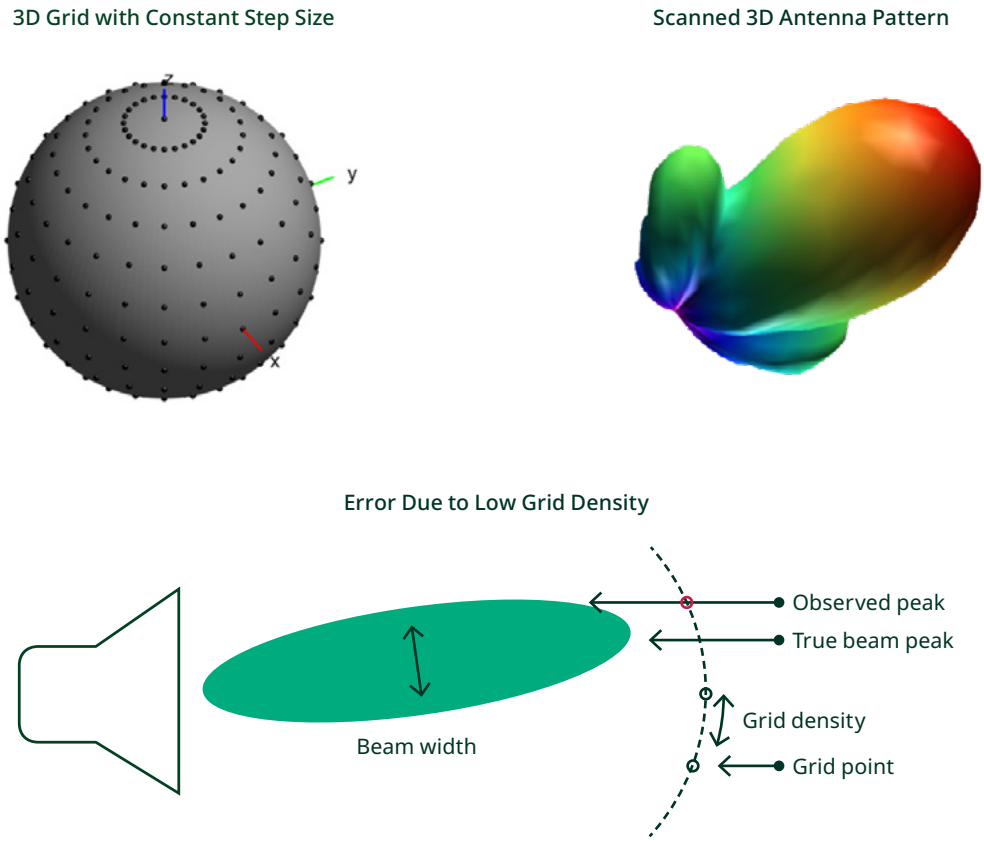


FIGURE 3

Finer 3D Sampling Grids Lead to More Accurate Results with Longer Times

Continuous Motion for Rapid 3D Results

To help engineers in charge of validation of beamforming devices reduce test times without compromising accuracy, NI developed the 5G mmWave OTA Validation Reference Architecture.

The mmWave OTA Validation Reference Architecture integrates NI's real-time motion control, data acquisition, and PXI triggering and synchronization to take fast, high-bandwidth RF measurements synchronized with the instantaneous (φ, θ) coordinates of the positioner's motors. Unlike traditional OTA test solutions, NI's approach moves the DUT in a smooth and continuous motion across the 3D space while the RF engine takes rapid measurements.

This eliminates the time waste of moving discretely from point to point. As a result, engineers can perform 3D spatial sweeps with thousands of points that execute in a fraction of the time, all the while reducing measurement uncertainty and error.

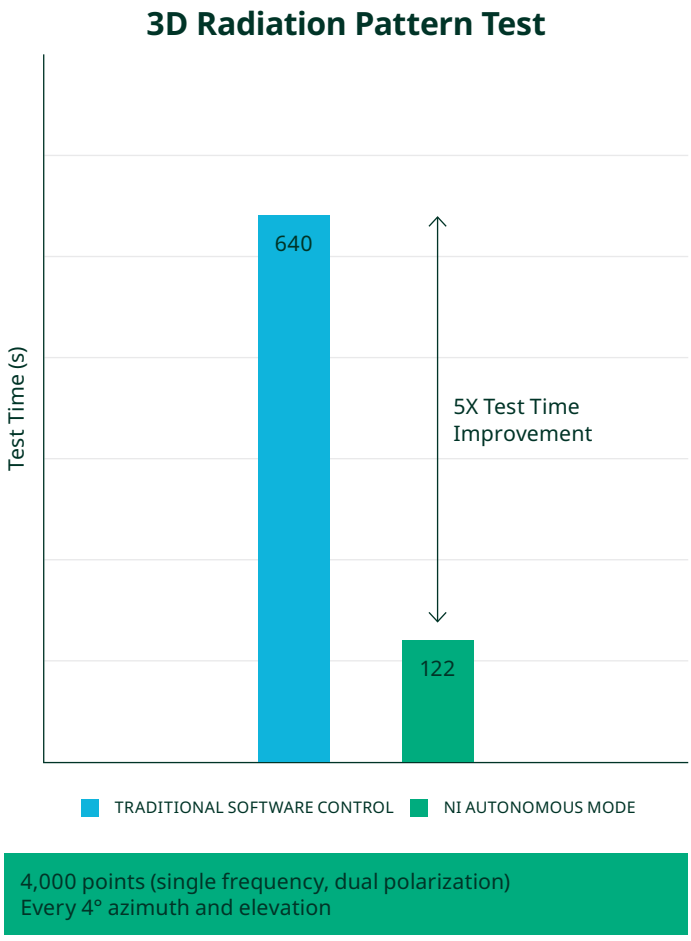


FIGURE 4
Enabling Fast Test Times

CW and 5G NR Modulated Measurements

NI's mmWave VST, the RF instrument at the heart of the OTA Validation Reference Architecture, uses narrowband CW signals to determine the radiation pattern, the coordinates of maximum directivity, beam characteristics, EIRP, and TRP of the DUT.

Additionally, thanks to its high instantaneous bandwidth, the mmWave VST can generate and analyze 5G NR signals to give users detailed 3D information on CHP, ACLR, OBW, and SEM. Furthermore, NI's software supports fast, on-the-fly demodulation of the 5G NR signal to present a complete 3D picture of the device's error vector magnitude (EVM).

CW Signals for 3D Radiation Pattern

Wideband 5G NR Signals for 3D ACLR, EVM Pattern

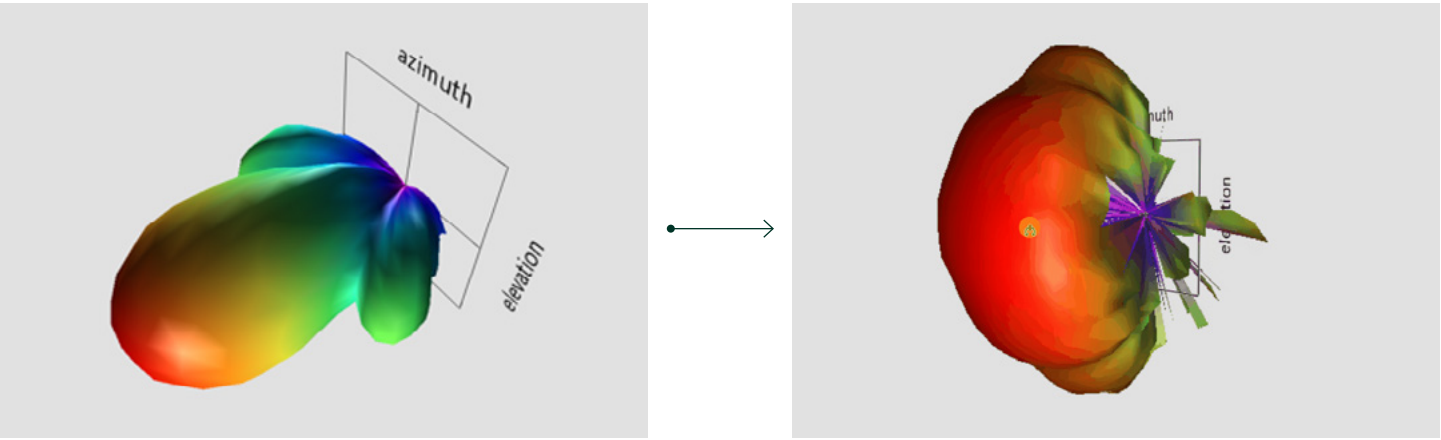


FIGURE 5
Spatial Visualization of CW and Modulated Measurements

Super-Fast CHP, ACLR, EVM, SEM Results in 3D

Thanks to advanced measurement algorithms and a multi-threaded processing approach, the NI mmWave OTA Validation Reference Architecture completes the computation of CHP, ACLR, OBW, EVM, and SEM over thousands of points just a few seconds after finishing the 3D sweep.

This gives engineers quick visibility into the spatial performance of their device with high-bandwidth signals.

Type	Resolution	Points	Measurement Time(s)
5G NR 100 MHz	4° steps	4583	140
Single Tone	4° steps	4583	122

TABLE 1
Measurement Times for Single Tone and Modulated Spatial Parameters

Validate Small and Large Devices with DFF and IFF (CATR) Measurements in the Same Chamber

Antenna-in-module (AiM) devices with just a few elements and antenna apertures smaller than 5 cm benefit from a direct far-field (DFF) approach that preserves link budget and helps ensure testing with greater signal-to-noise ratios.

However, testing system-level designs with a larger number of antenna elements and antenna apertures larger than 5 cm requires an indirect far-field (IFF) approach that produces a high-quality quiet zone (QZ) with minimal phase and amplitude variation, following the 3GPP specifications for IFF testing.

The NI 5G mmWave OTA Validation Reference Architecture offers both DFF and IFF testing in the same chamber, thanks to a premium mmWave reflector and intelligent chamber design. Engineers can reduce cost and complexity and move through the product design cycle more easily by using the DFF approach for validation of the antenna modules. They can also reuse the same test bench in IFF configuration for validation of system-level designs—no need for additional, large anechoic chambers.

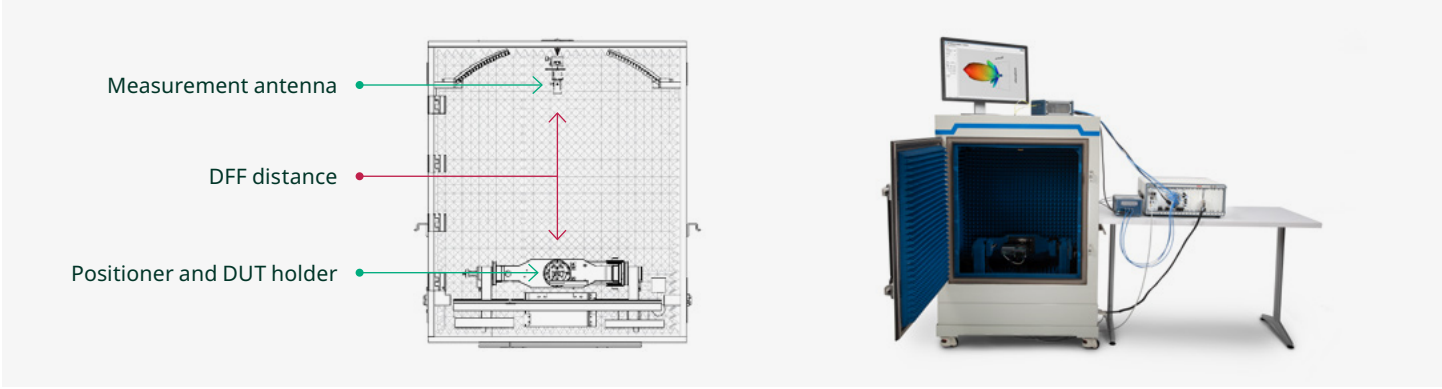


FIGURE 6

DFF Configuration Test Setup
Take advantage of a direct far-field (DFF) configuration for greater link budget and SNR.

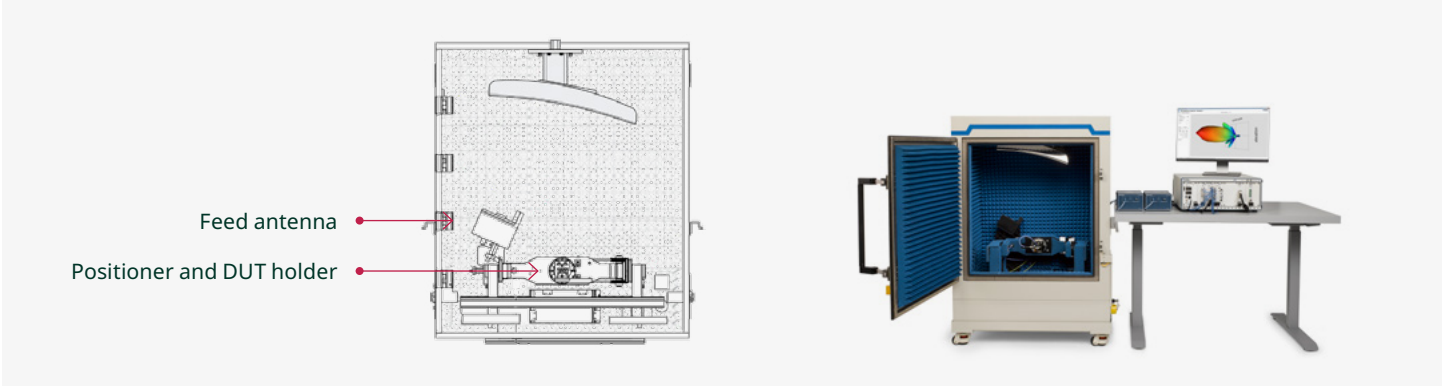


FIGURE 7

CATR Configuration Test Setup
Validate larger devices with an indirect far-field configuration in the same chamber. Streamline the OTA lab with a single setup.

Validate Device Performance over Temperature

Instead of the slow, tedious, and risky process of trying to control the temperature of the whole volume inside the anechoic chamber, take advantage of NI's thermal dome mounted on the DUT positioner to create a small enclosure that is easy to chill and heat up while preserving the complete 3D range of motion. Using RF-transparent material, the NI thermal dome lets users characterize and validate the DUT's beamforming performance from -40 °C to +85 °C.

FAST TEMPERATURE CONTROL

01

TRP/EIRP up to +/-90 elevation and +/-180 azimuth (Full 3D pattern)

02

Small volume allows for stable and quick temperature control

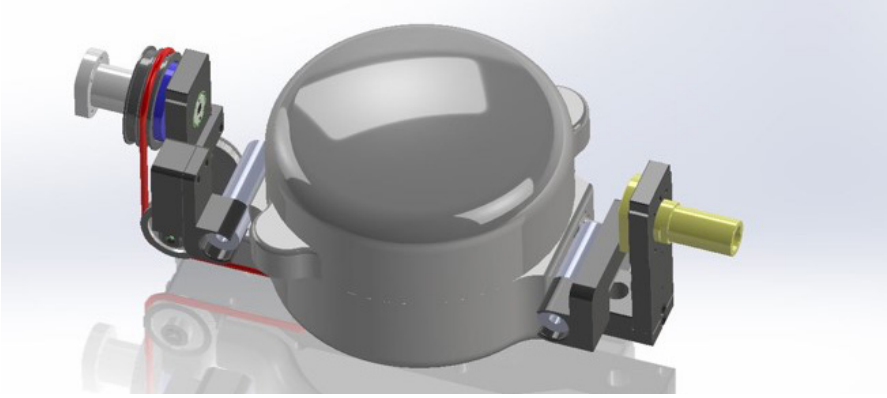


FIGURE 8
Rendering of Thermal Chamber

IF-RF and RF-RF Measurements with PXI VSTs

NI's PXI mmWave VSTs combine a mmWave vector signal generator (VSG) and vector signal analyzer (VSA) into one module. These PXI instruments uses external mmWave heads that cover the 5G FR2 bands. These heads get placed right next to the anechoic chamber to minimize signal losses through the cables. Additionally, each mmWave head has two bidirectional (TX/RX) RF ports.

The mmWave VSTs also have calibrated intermediate frequency ports providing test coverage for multi-band IF-to-RF DUTs.

PXIe-5831 mmWave VST Specifications	
Frequency Range	22.5 GHz–44 GHz
Bandwidth	1 GHz
Amplitude Accuracy	±0.25 dB
Max. Output Power	+17 dBm
5G NR EVM	<1%
Direct Ports	2

FIGURE 9

PXIe-5831 (refer to specs for more details)

PXIe-5842 with 54 GHz Frequency Extension Specifications	
RF I/O Frequency Range	22.5 GHz–54 GHz
IF I/O Frequency Range	200 MHz–23 GHz
Bandwidth	2 GHz
RF IN/OUT Absolute Accuracy @ 39 GHz	±1.0 dB
Max. Output Power	+13 dBm
5G NR EVM, 100 MHz BW	-43 dB @ 47 GHz
Bidirectional Ports	2

FIGURE 10

PXIe-5842 with 54 GHz Frequency Extension
(refer to specs for more details)

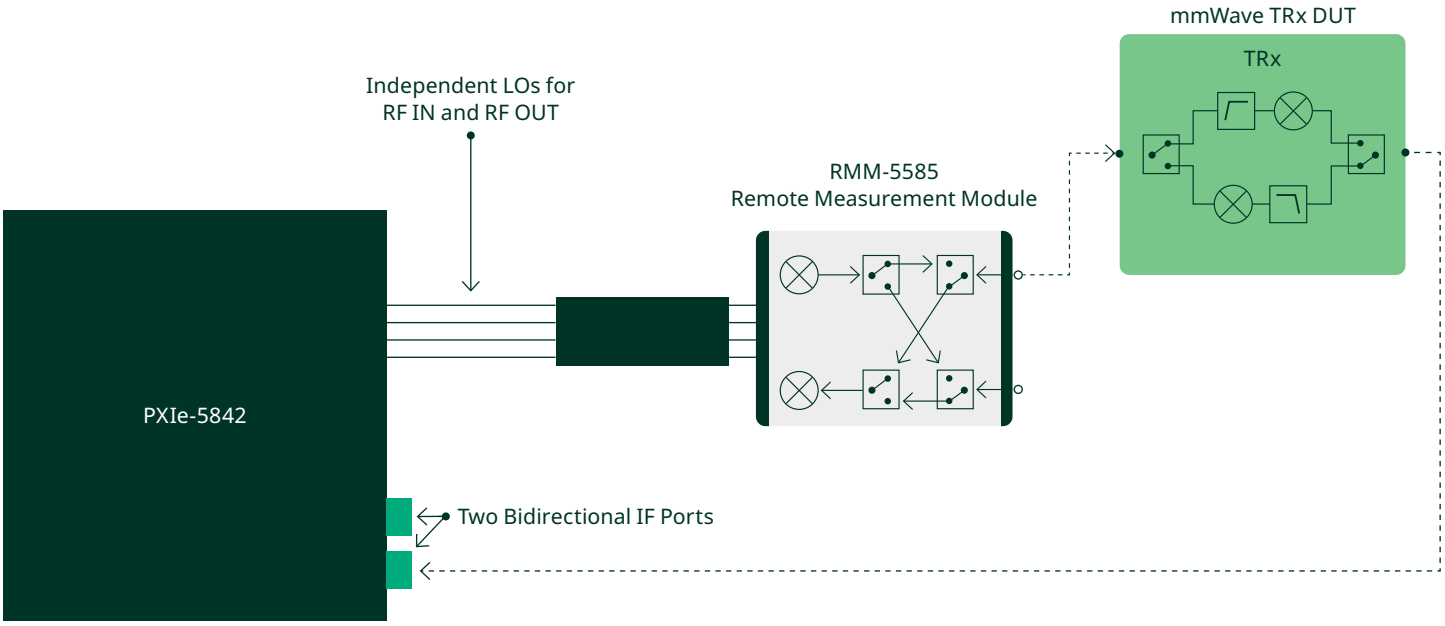


FIGURE 11

RF to IF Bidirectional Test Setup with One Remote Measurement Module

Built-in Switches for TX and RX Test

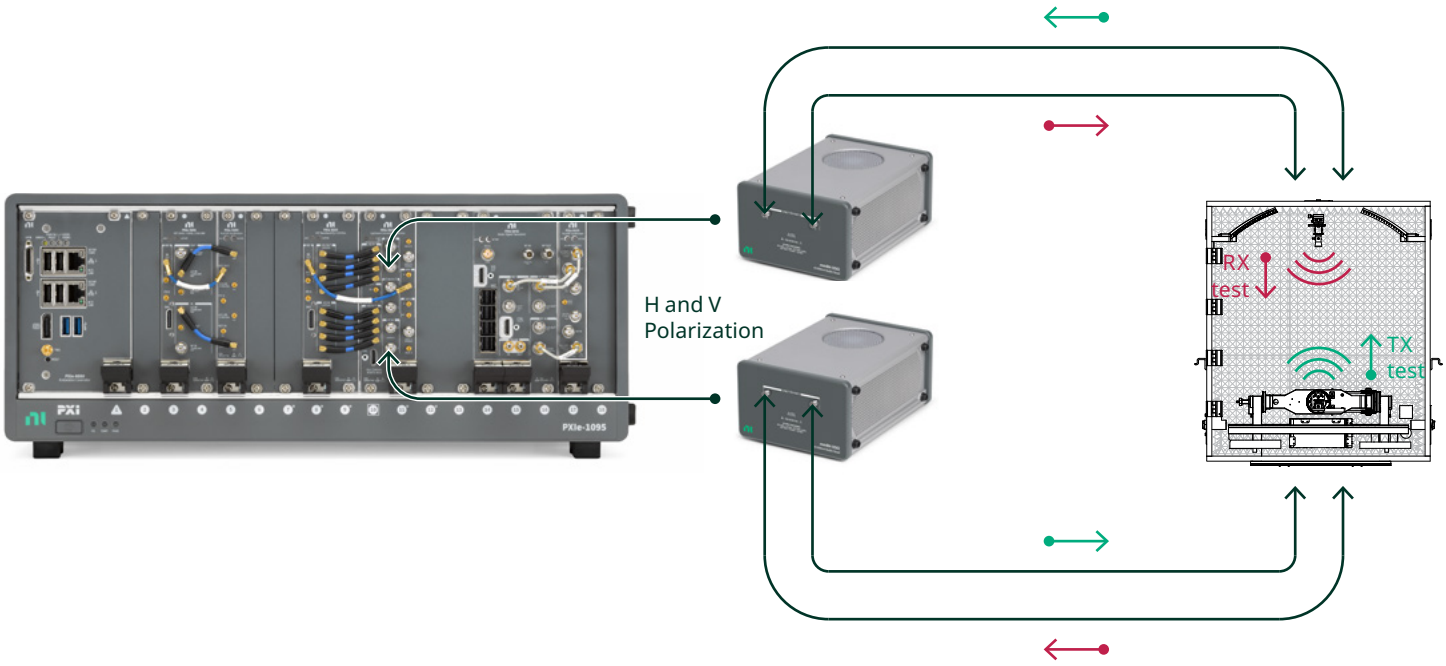


FIGURE 12

PXIe-5842 (refer to specs for more details)

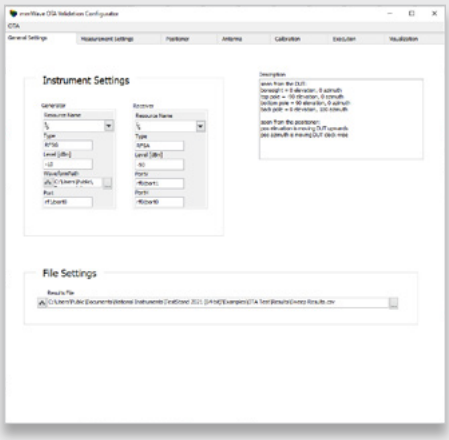
Simplified Measurement Configurations

NI's 5G mmWave OTA Validation Reference Architecture has the flexibility to use different PXI VSTs. For simplified hardware configurations and bidirectional test ports, leverage the bandwidth, flexibility, and simplicity of the PXIe-5842 with 54 GHz Frequency Extension.

FIGURE 13

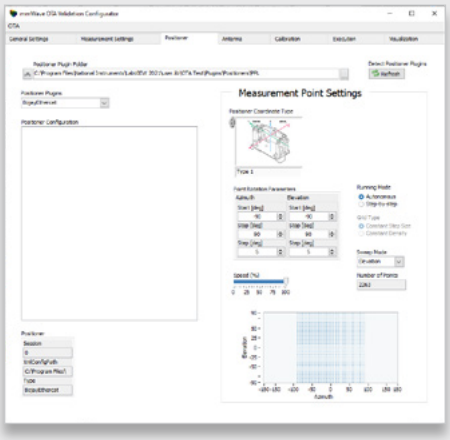
PXIe-5842 with 54 GHz Frequency Extension (refer to specs for more details)

Smooth Workflow with the OTA Validation Software



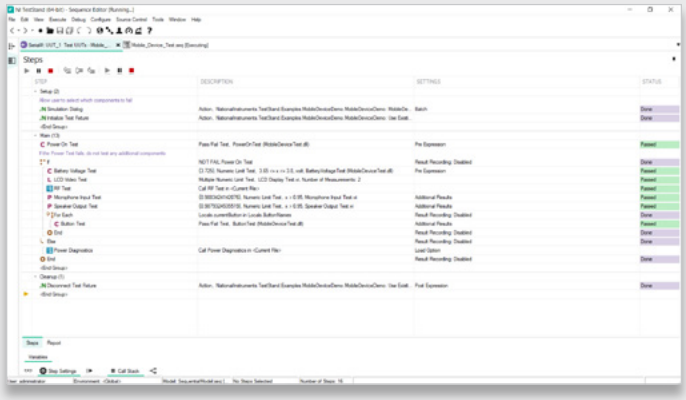
01

Determine all IF and RF path losses with the RF system calibration utility.



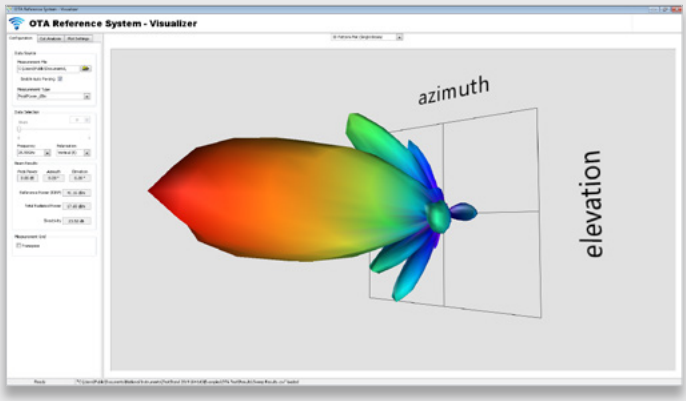
02

Configure 3D grid size, frequency, power level, desired measurements, file locations, and other measurement settings.



03

Launch one of the included automated sequences, looping over multiple parameters, and producing valuable reports.



04

Visualize DUT performance with a variety of plots.

OTA Results Visualization and Analysis

Engineers can use the mmWave OTA Test Visualizer to invoke different results visualizations and analyze antenna-specific measurements and patterns.

The mmWave OTA Test Visualizer takes in measurement results as comma-separated values (.CSV) files and displays the data onscreen. Users can select various data sources and types of plots, as depicted in the following figures.

FIGURE 14

3D Antenna Pattern for Single and Multiple Beams

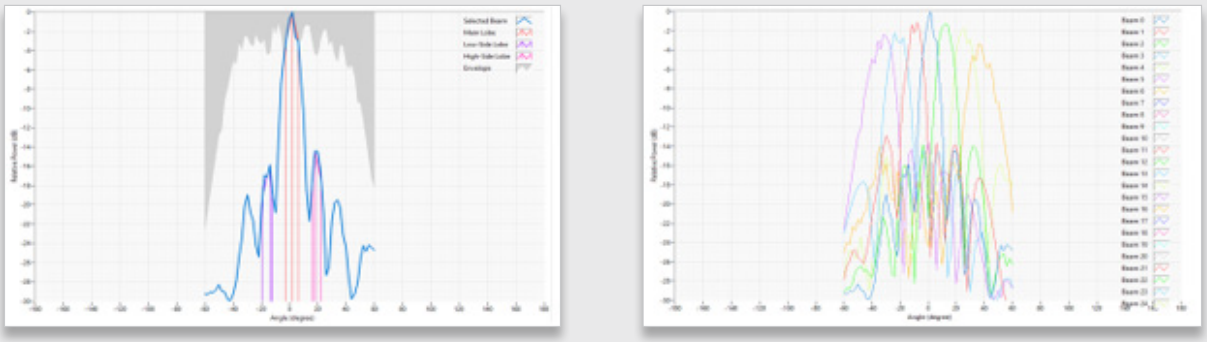


FIGURE 15

Antenna Cut Analysis, Single Beam, and Multiple Beams

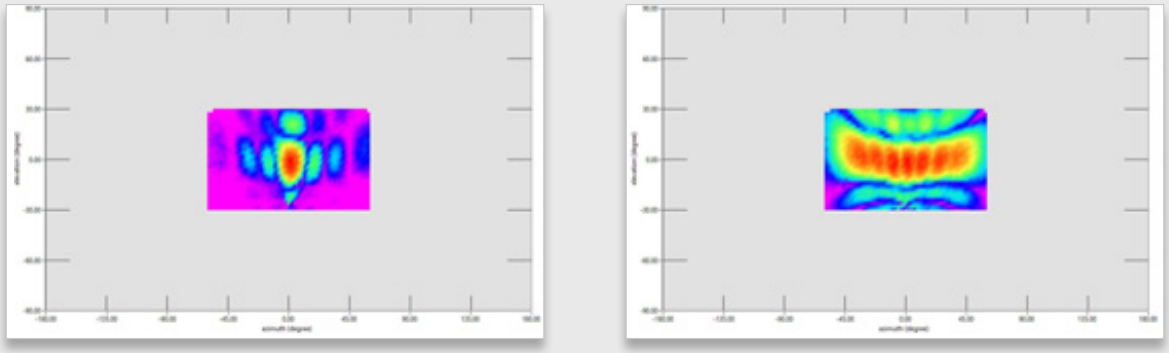


FIGURE 16

Heat Map Plot for Single and Multiple Beams

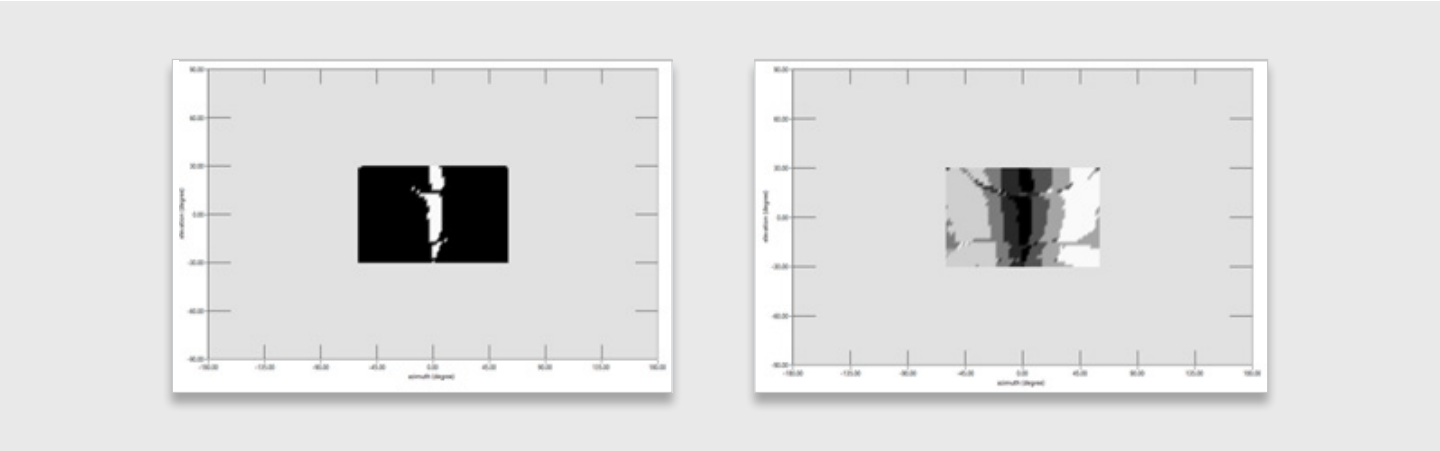


FIGURE 17
Best Beam Index for Single and Multiple Beams

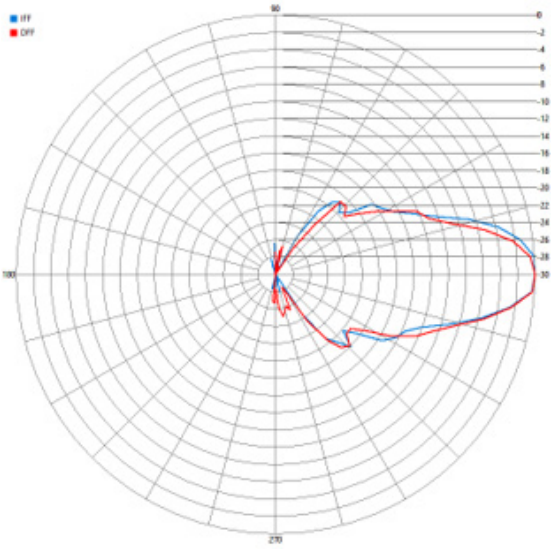


FIGURE 18
Polar Plot

5G mmWave OTA Validation Configuration Options

The 5G mmWave OTA Validation Reference Architecture includes various bundles for an easy experience when getting started. All base configurations contain everything you need to get started testing. There are also optional add-ons for additional functionality.

Reference Solution Base Configurations

Solution Name	Part Number	Description
54 GHz IF-RF mmWave Test Reference Solution	868109-01B	mmWave, 200 MHz–54 GHz VST, 2 GHz BW, 18-slot chassis, controller
54 GHz RF-RF mmWave Test Reference Solution	868109-02B	mmWave, 200 MHz–54 GHZ VST (x2), 2 GHz BW, 18-slot chassis, controller
44 GHz RF-RF mmWave Test Reference Solution	868109-03B	mmWave, 5 GHz–44 GHz VST (two heads), 1 GHz BW, 18-slot chassis, controller
44 GHz IF-RF mmWave Test Reference Solution	868109-04B	mmWave, 5 GHz–44 GHz VST (one head), 1 GHz BW, 18-slot chassis, controller
54 GHz IF-RF mmWave Test Reference Solution (Remote Control)	868109-05B	mmWave, 200 MHz–54 GHz VST, 2 GHz BW, 18-slot chassis, PXI Remote Control Module
54 GHz RF-RF mmWave Test Reference Solution (Remote Control)	868109-06B	mmWave, 200 MHz–54 GHz VST (x2), 2 GHz BW, 18-Slot chassis, PXI Remote Control Module
44 GHz RF-RF mmWave Test Reference Solution (Remote Control)	868109-07B	mmWave, 5 GHz–44 GHz VST (two heads), 1 GHz BW, 18-slot chassis, PXI Remote Control Module
44 GHz IF-RF mmWave Test Reference Solution (Remote Control)	868109-08B	mmWave, 5 GHz–44 GHz VST (one head), 1 GHz BW, 18-slot chassis, PXI Remote Control Module

TABLE 2

Reference Solution Base Configurations

Notes:

- 50 GHz antenna upgrade is only available with base configurations using the PXIe-5842 with 54 GHz frequency extension, for frequency coverage up to 50 GHz
- Customers can choose to upgrade from a DFF to CATR configuration, or purchase a CATR configuration initially
- The PXI chassis included in bundles is the PXIe-1095 (timing and sync) and controllers included are the PXIe-8881 (8-core, Windows 10) or PXIe-8398 MXI Controller (remote control options)
- For CATR configurations, use base part numbers that include the PXIe-5831 VST (44 GHz options)

Reference Solution Optional Add-Ons

Option Name	Part Number	Description
OTA Anechoic Chamber: DFF	868109-04P	mmWave OTA Anechoic Chamber Rev B, mmWave OTA Accessory Kit
OTA Anechoic Chamber: CATR*	868109-05P	mmWave OTA Anechoic Chamber Rev B, mmWave OTA Accessory Kit, DFF to CATR Conversion Kit
DFF to CATR Conversion Kit*	868109-06P	DFF to CATR Conversion Kit
Thermal Enclosure	868109-07P	mmWave OTA Validation Thermal Option
50 GHz Antenna Upgrade	868109-08P	mmWave Validation 50 GHz Measurement Antenna

TABLE 3
Reference Solution Optional Add-Ons

*CATR configurations only available with the PXIe-5831 VST (44 GHz Base Configurations)

Software

Part Number	Description
784584-35	LabVIEW Professional
Free	RFmx Spectrum Analysis
788024-35	RFmx Digital Modulation
788018-35	RFmx Analog Modulation
788033-35	RFmx Cellular Bundle
788036-35	RFmx NR
Free	Third-Party Licensing and Activation Toolkit
Free	NI Modulation Toolkit
788372-35	TestStand
787917-35	RFIC Test Software Professional (includes RFmx PA)
788590-35	mmWave OTA Validation Test Software

TABLE 4
Software

Software is not included as part of bundles and must be purchased separately.

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.

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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