5G mmWave Over-the-Air (OTA) Validation

Determine Fine Beamforming Performance Faster

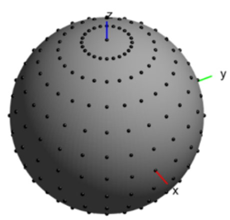
NI's 5G mmWave OTA Validation reference architecture can help your team:

- Speed up 5G mmWave OTA test from hours to minutes
- Validate Antenna-in-module (AiM) devices and reference designs of various aperture sizes
- 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

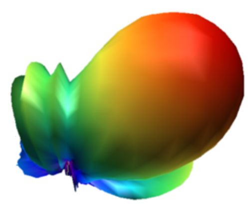
Accurate and Much Faster OTA Validation

Running detailed 3D Over-the-Air spatial sweeps of 5G beamforming devices within a carefully controlled RF environment in an anechoic chamber can be a very time-consuming and expensive task.

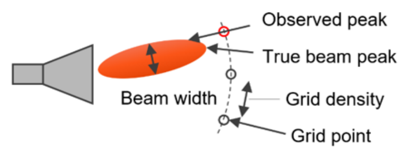
A typical move → stop → measure, point-by-point, software-controlled test system with a positioner that can rotate in two independent axes (azimuth and elevation), produces only a handful of RF measurements per second. However, engineers need to measure and validate antenna performance by scanning hundreds 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.



3D grid with constant step size



Scanned 3D antenna pattern



Error due to low grid density

Continuous Motion for Rapid 3D Results

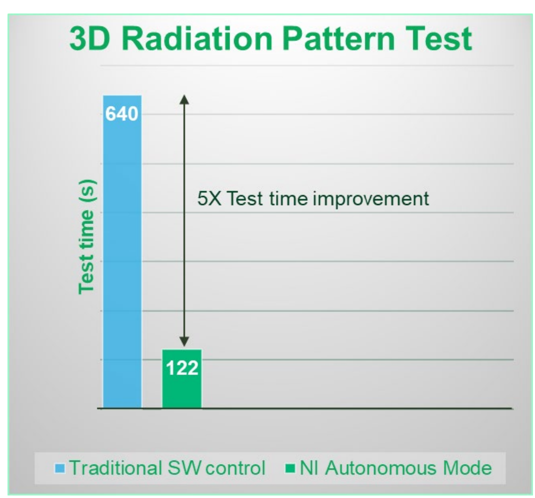
To help engineers in charge of validation of beamforming devices reduce test times without compromising accuracy, NI developed the **5G mmWave OTA Validation reference architecture**.

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 Device Under Test (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.

4000 points
(single frequency, dual polarization)

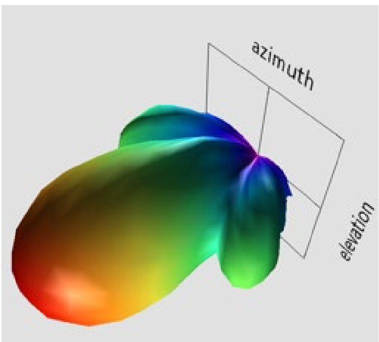
Every 4° azimuth and elevation



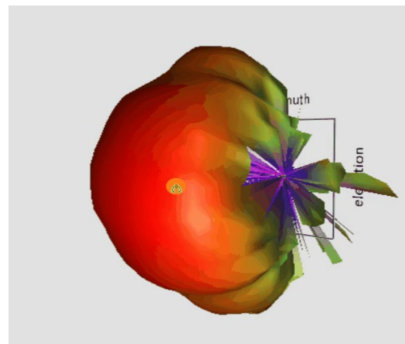
CW and 5G NR Modulated Measurements

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 Device Under Test.

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

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.

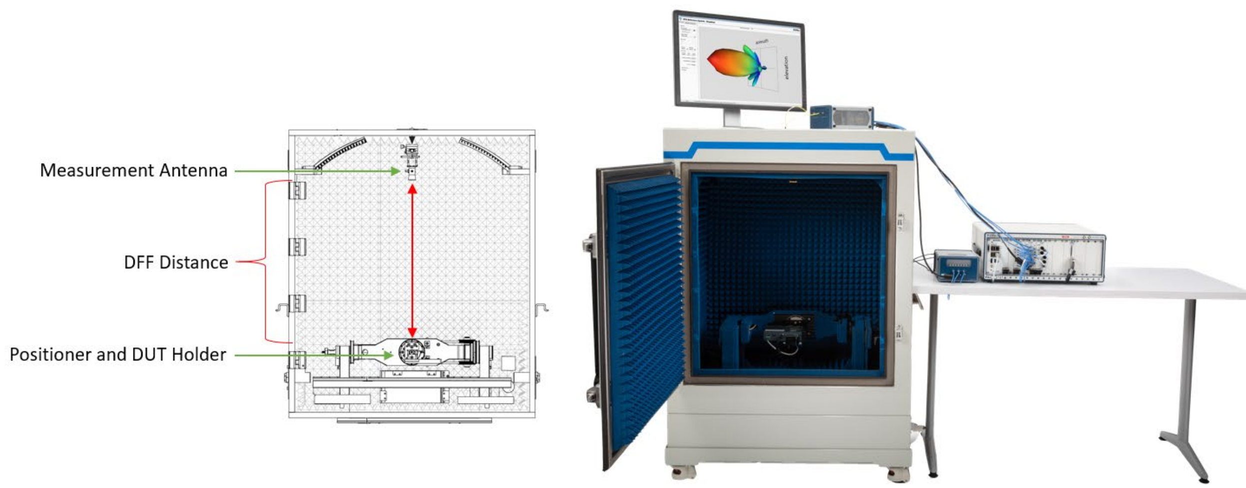
Type	Resolution	Points	Measurement Time (s)
5G NR – 100MHz	4° steps	4583	**140**
Single Tone	4° steps	4583	122

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

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

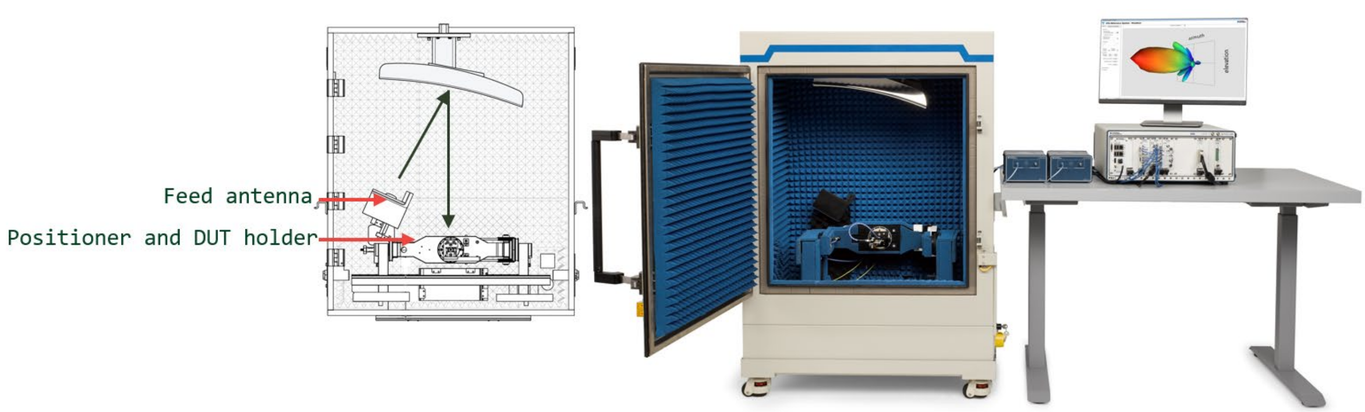
However, testing system-level designs with a larger number of antenna elements and antenna apertures above 5 cm requires an indirect far-field (IFF) approach that produces a high-quality Quiet Zone (QZ) with minimal phase and amplitude variation, following the 3GPP specifications for IFF testing.

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.



Antenna-in-Module Testing

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



System-level Testing

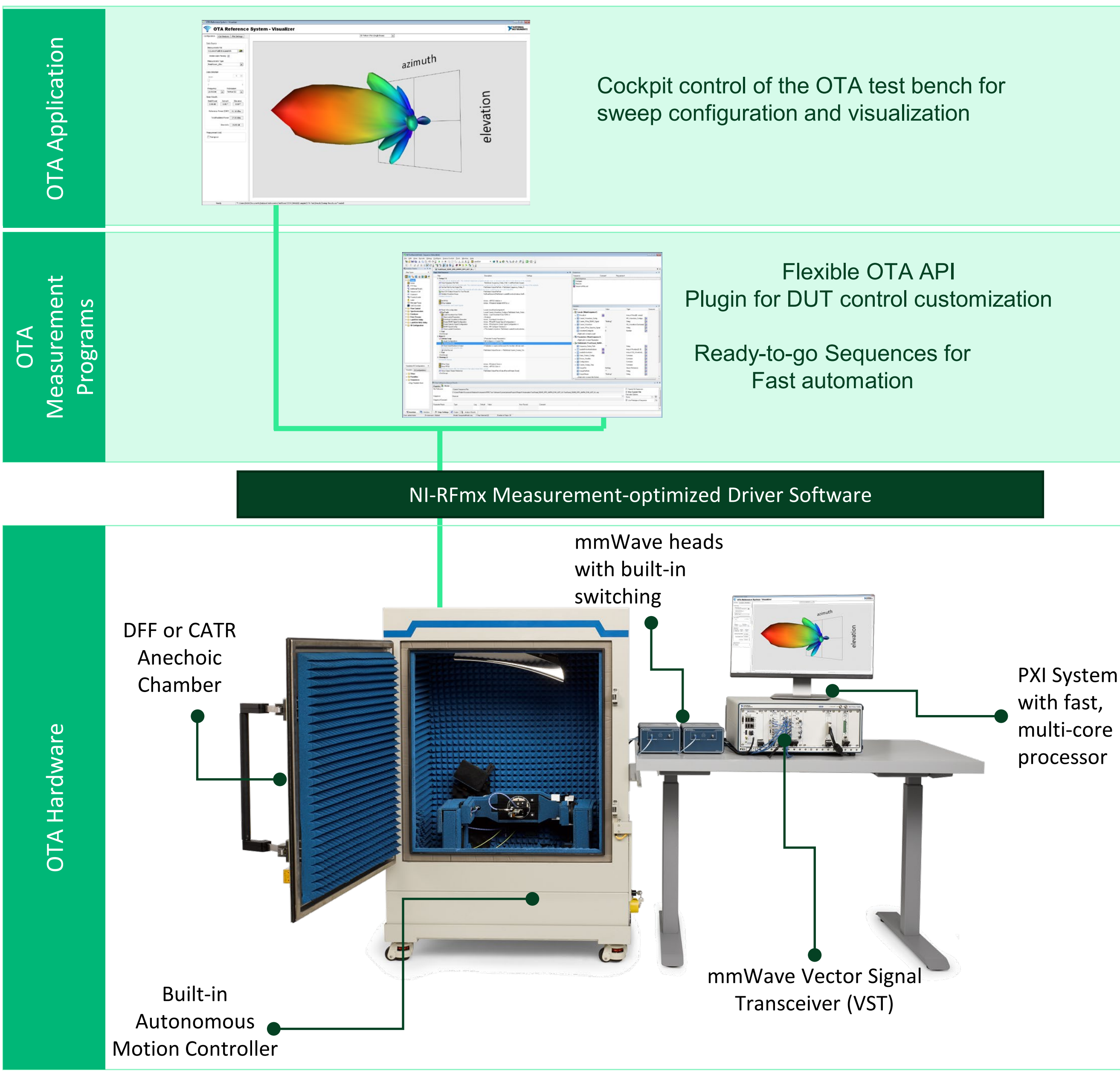
Validate larger devices with an indirect far-field configuration in the same chamber. Streamline the OTA lab with a single setup.

NI 5G mmWave OTA Validation Architecture

At the top level, the OTA software application acts as a configuration control cockpit 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 plugin for customizing DUT control, an API for creating specific code modules, and 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.



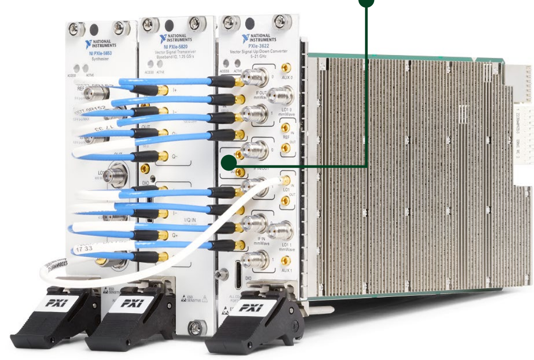
IF-to-RF and RF-to-RF Measurements with the mmWave VST

NI's PXI mmWave VST combines a mmWave vector signal generator (VSG) and vector signal analyzer (VSA) into one module. This PXI instrument uses external mmWave heads that cover the 5G frequency range 2 (FR 2) bands. These heads get placed right next to the anechoic chamber to minimize signal losses through the cables. Additionally, each mmWave head has two bi-directional (TX/RX) RF ports that can provide up to 17 dBm of power.

The mmWave VST also has calibrated intermediate frequency ports (IF: 5-21 GHz), providing test coverage for up/downconverting IF-to-RF DUTs.

mmWave Heads with bi-directional ports
Improve power budget with 17 dBm output power and short cable lengths

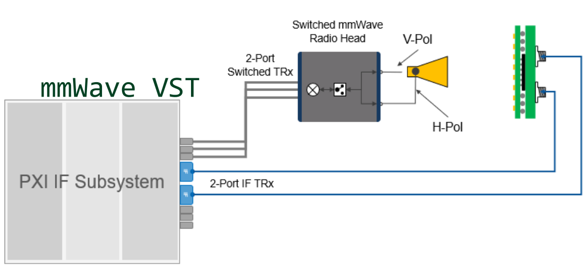
IF bi-directional ports
Coverage for up/downconverting devices



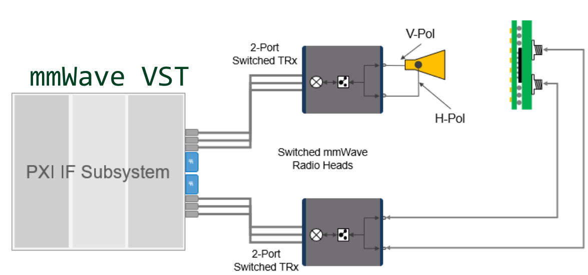
PXIe-5831 mmWave VST Specifications	
Frequency Range	22.5 GHz – 44 GHz
Bandwidth	1 GHz
Amplitude Accuracy	+/- 0.25 dB
Max. Output Power	+17 dBm
EVM (5G NR 256 QAM)	<1%
Direct ports	2

Refer to PXIe-5831 Specifications Document for more details

Setup for IF-to-RF beamformers:



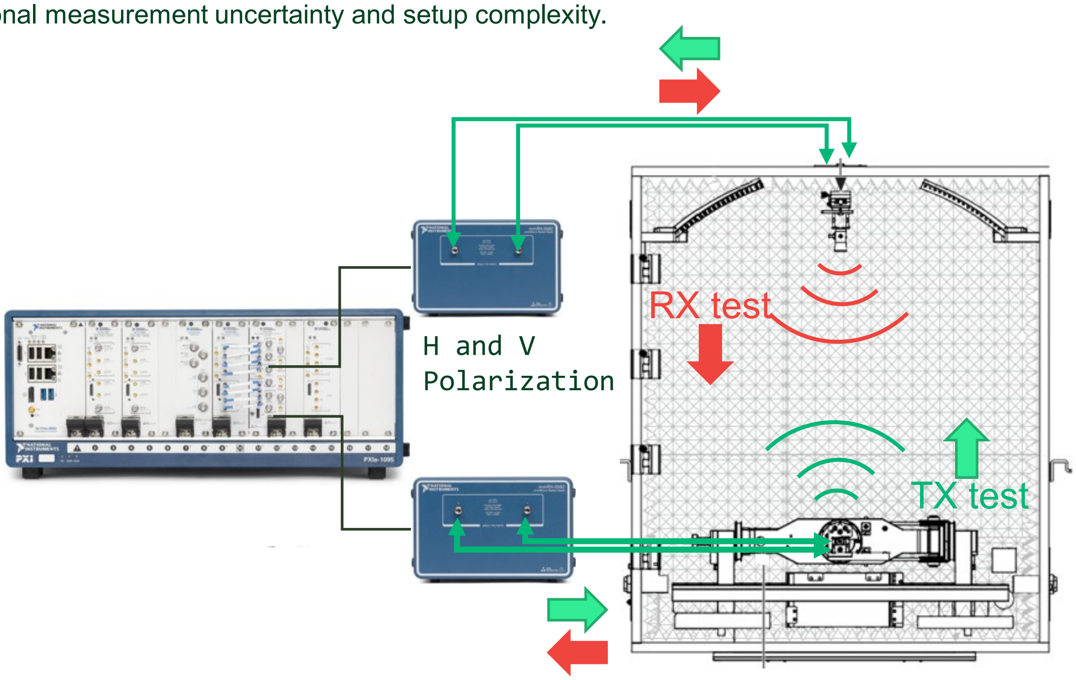
Setup for RF-to-RF beamformers:



Built-in Switches for TX and RX Test

NI's 5G mmWave OTA Validation reference architecture takes advantage of the bi-directional, dual-port design of the mmWave heads attached to the mmWave VST. That way, users don't have to change connections to test a DUT in transmit or receive mode.

As an additional benefit, users can altogether avoid external switching configurations, eliminating additional measurement uncertainty and setup complexity.

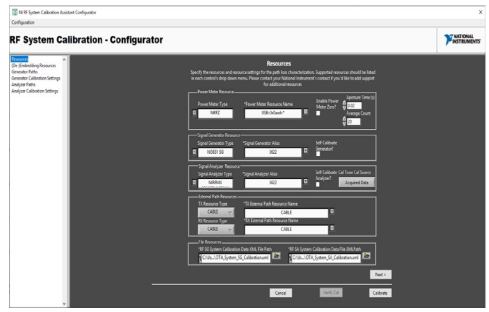


Smooth Workflow with the OTA Validation Software

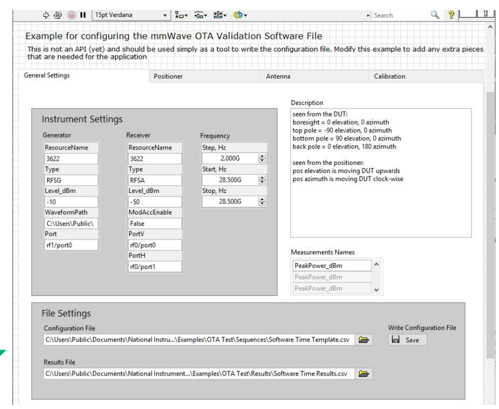
The mmWave OTA Validation software helps engineers quickly configure extensive spatial sweeps to characterize their device's antenna patterns, while they produce, visualize, store, or distribute detailed parametric results. Users can take advantage of the Software as a complete test framework for OTA validation, incorporate some of its components into their existing test framework or use the separate components as stand-alone utilities.

The following steps describe the workflow for getting accurate OTA measurements much faster:

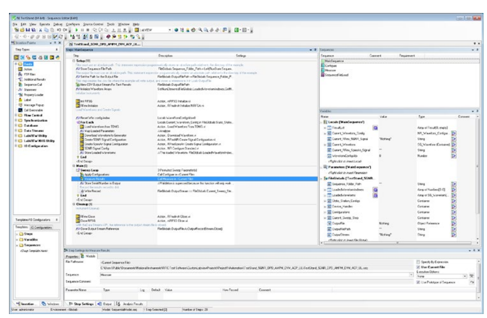
1 Determine all IF and RF path losses with the RF system calibration utility



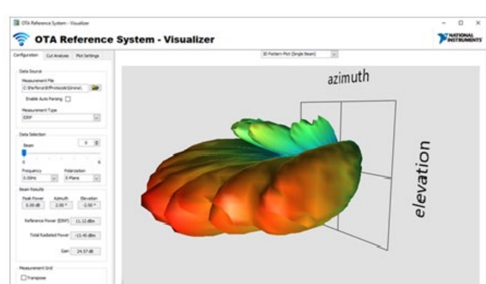
2 Configure 3D grid size, frequency, power level, desired measurements, file locations, and other measurement settings



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



4 Visualize DUT performance with a variety of plots

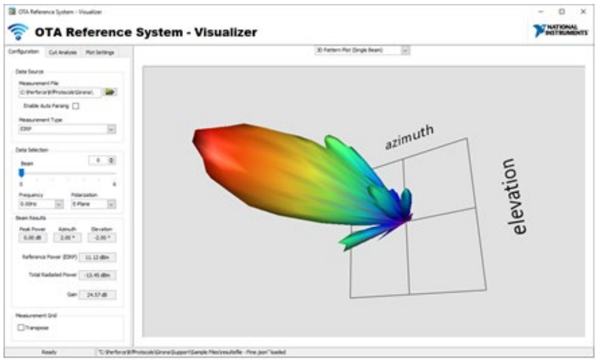


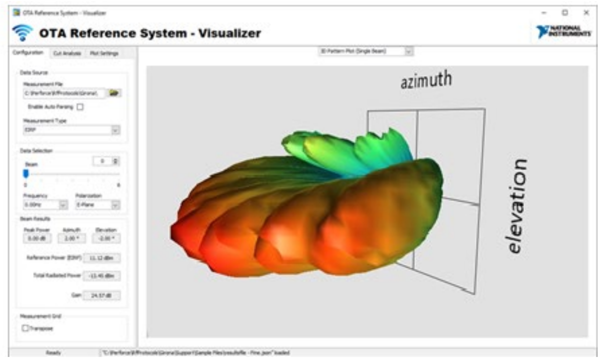
OTA Results Visualization and Analysis

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

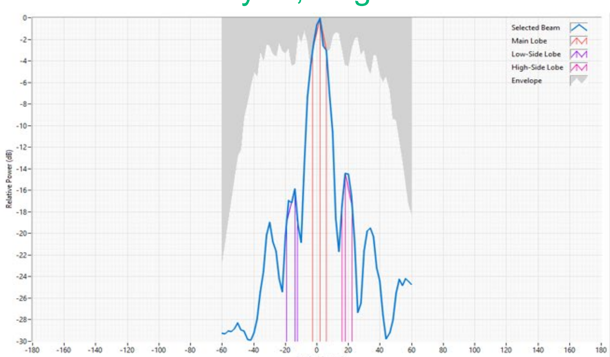
The mmWave OTA Test Visualizer takes in measurement results as comma-separated values (CSV) files and displays the data on-screen. Users can select various data sources and types of plots, as illustrated below:

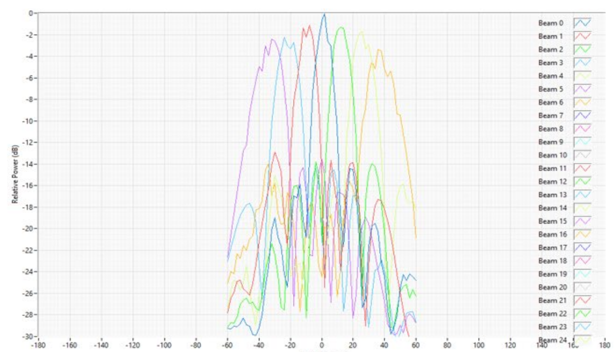
3D Antenna Pattern for single and multiple beams



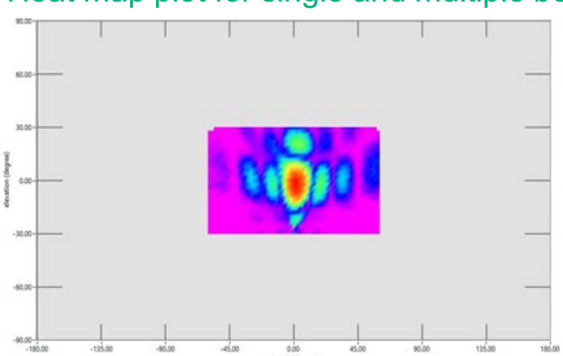


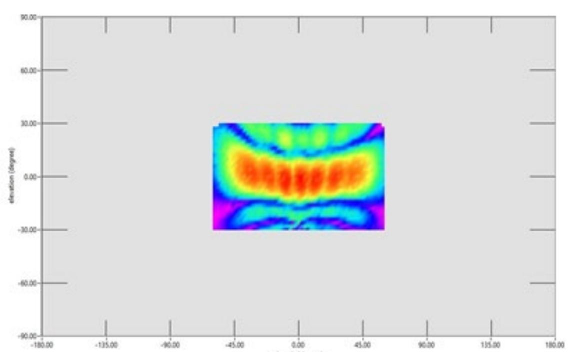
Antenna cut analysis, single beam and multiple beams



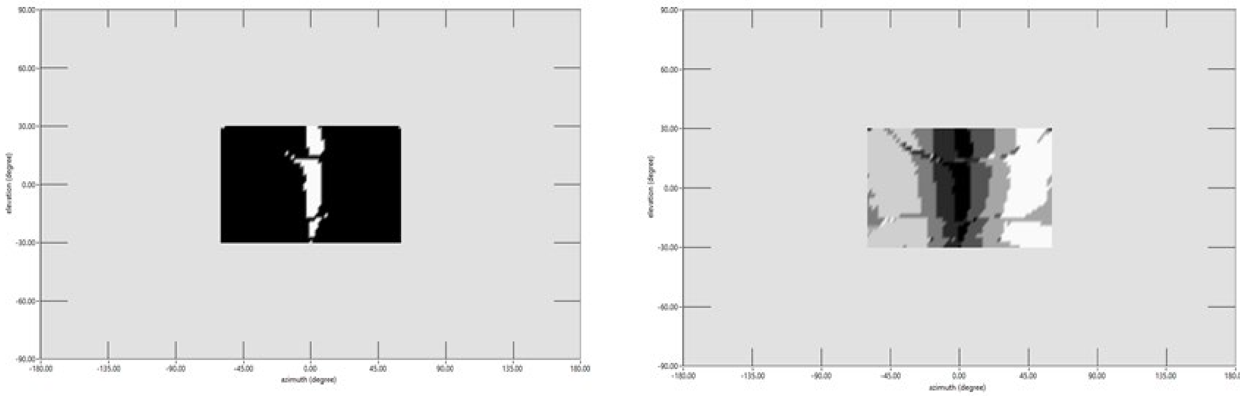


Heat map plot for single and multiple beams

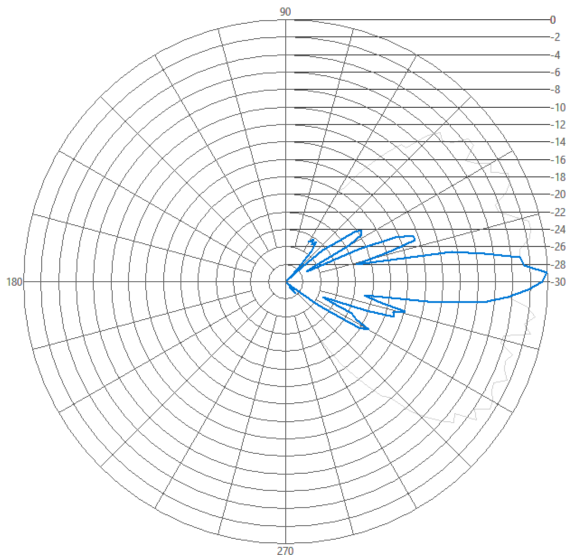




Best beam index for single and multiple beams



Polar plot



Solution Services

Implementing reliable mmWave OTA validation test setups can be a very complex task with several risk factors. Some of the more common ones include measurement uncertainty due to mechanical placement of the DUTs, in-chamber reflections, and system calibration.

As a trusted advisor, NI complements its mmWave OTA Validation reference architecture with services from experts around the globe to help users achieve their OTA test goals. Whether the OTA challenges are simple or complex, you can maximize productivity and reduce costs with NI OTA test setup installation, training, technical support, consulting and integration, and hardware services.

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. 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.