NI CONNECT

Solving the Latest Test Challenges for Electronically Scanned Arrays Components

Julian Di Matteo

Principal Solutions Marketing Manager

Lei Song

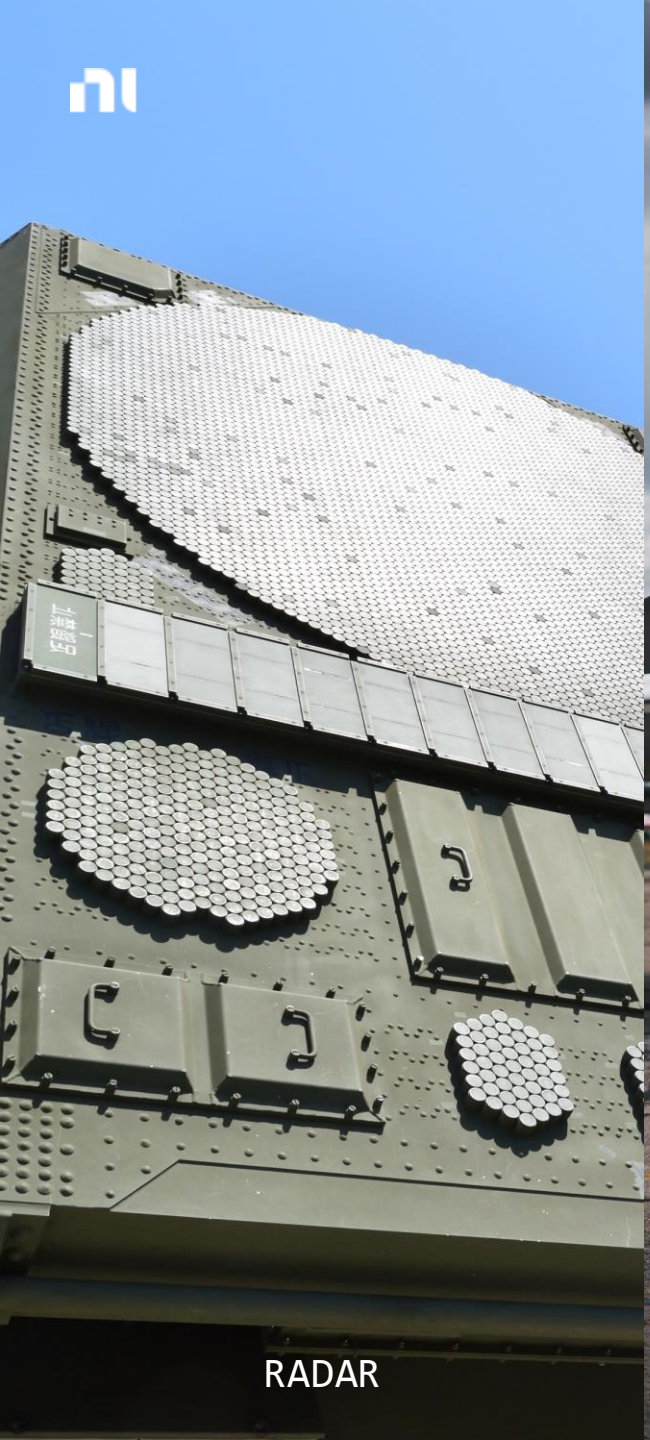
Principal Software Engineer

Agenda

Review key technology trends driving the latest generations of ESA technology

Deep-dive into NI's solution for ESA component and module characterization and test

Gain insight to future technology trends and test challenges, and learn how to prepare for those challenges today



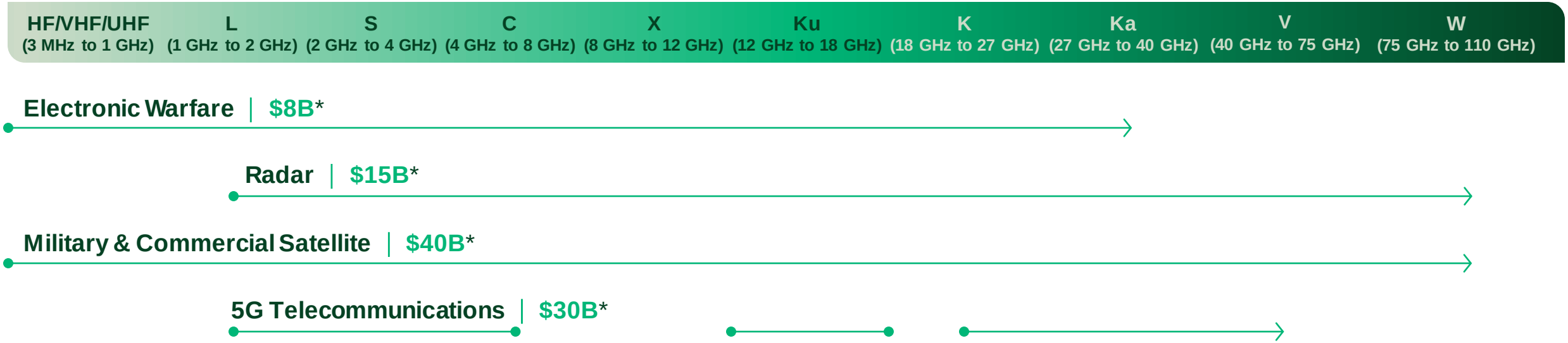
RADAR

ELECTRONIC WARFARE

CNS

SATELLITE

Market Trends and Momentum



Example Market Drivers

Continued investment in 5th generation and exploration of 6th generation fighters

- Multi-functional RF Systems (Radar + EW + Communications)

High resolution SAR payloads for terrestrial imaging and monitoring

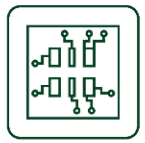
High throughput communications and convergence of Satcom and 5G

Hypersonic Intelligent weapons and next generation UAVs

Cognitive Electronic Warfare systems

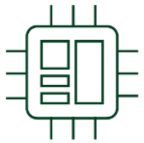
Technology Shifts and Application Evolution

Key technology shifts are leading to new mission capabilities along with new test challenges



GaN Revolution

Lower Energy Loss
Higher Voltages
More Power Per Area



Increased Integration

Integrated Digital to RF
Built in DSP
Antenna in Package

Wideband Data Converters

Increasing Bandwidths
Software Defined
Multi-Function

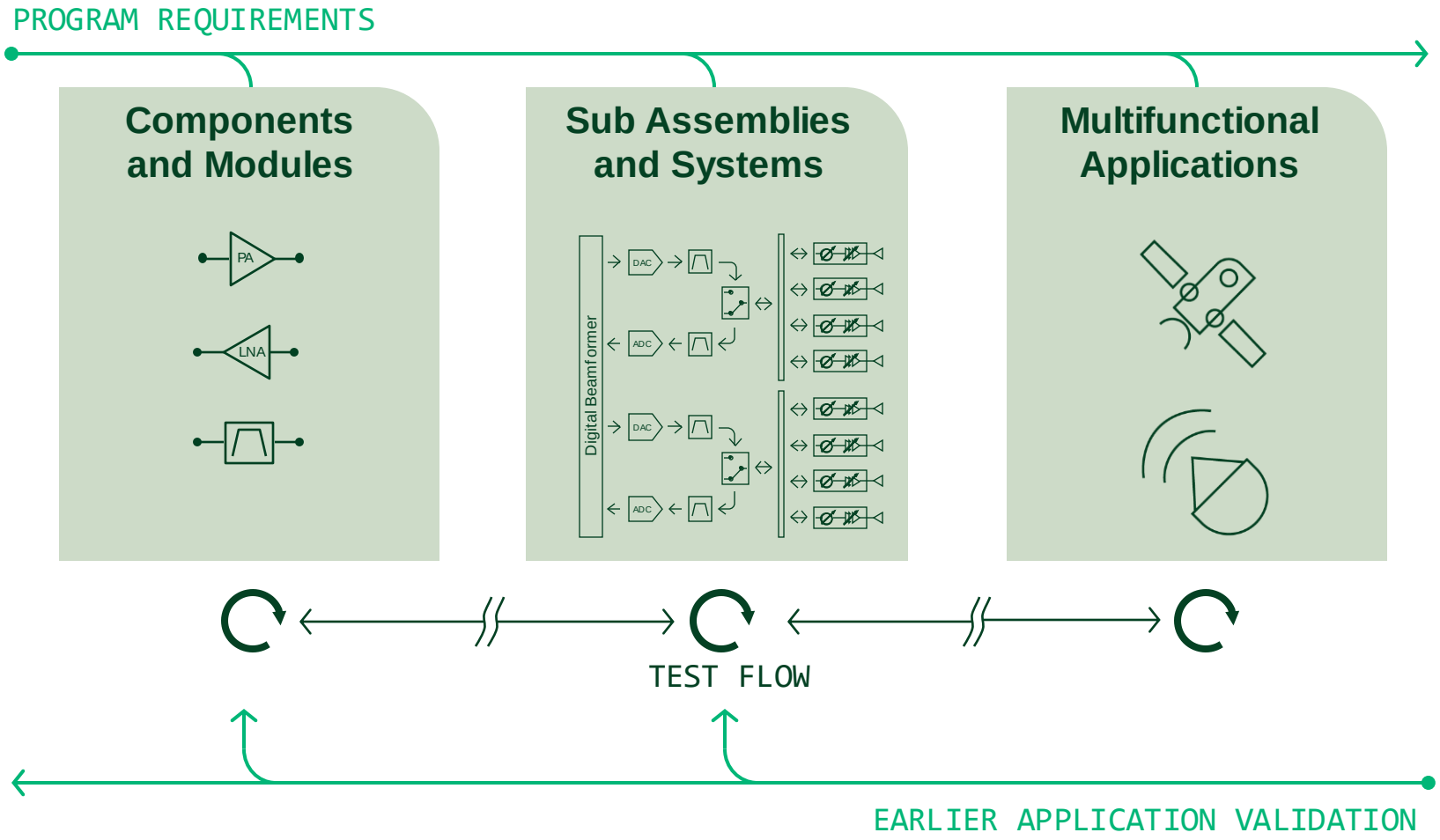
Modular, Multi-Element Antennas

1000's of Active Elements
Multiple Beams
Increased Signal Fidelity

Test Challenges for Modern ESA Applications

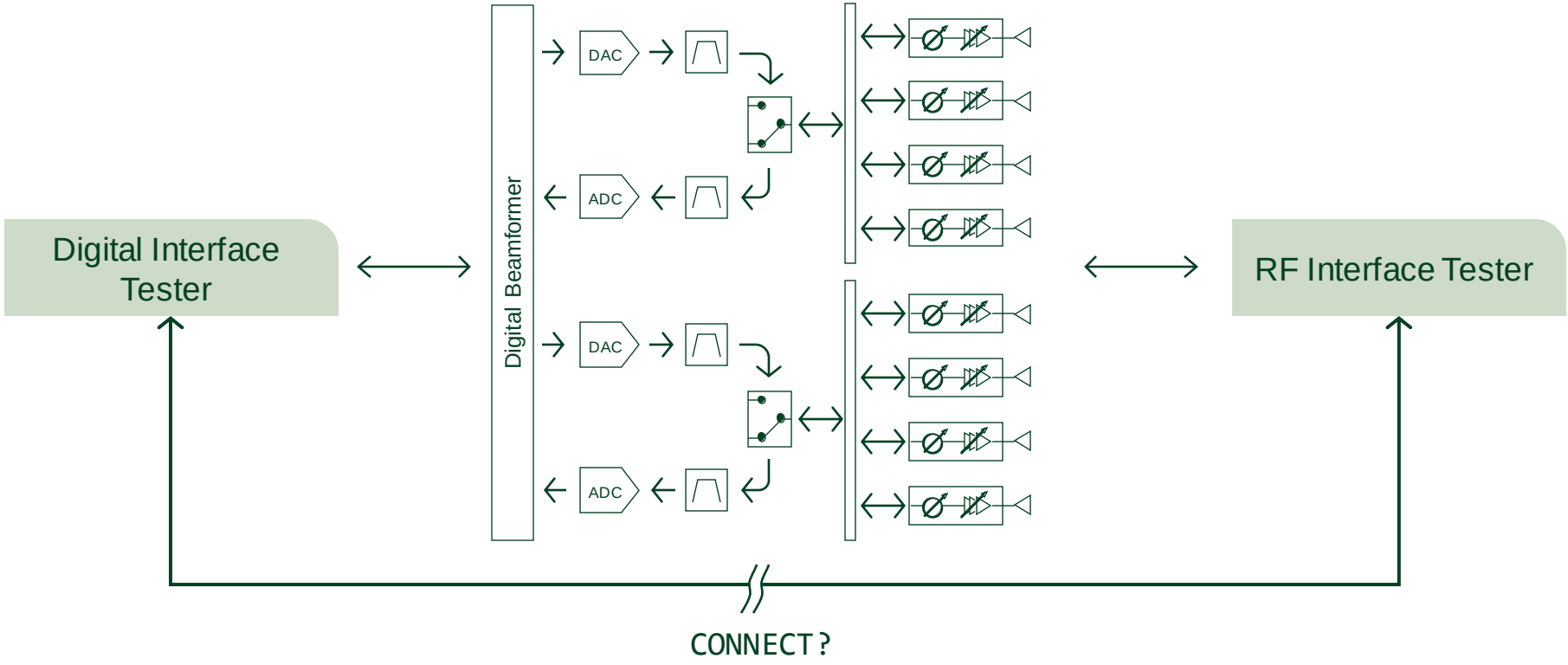
Connecting Parametric Test with System Validation

Key Test Challenge: Enable application specific validation earlier in the design and integration cycles to catch flaws sooner and reduce time to market

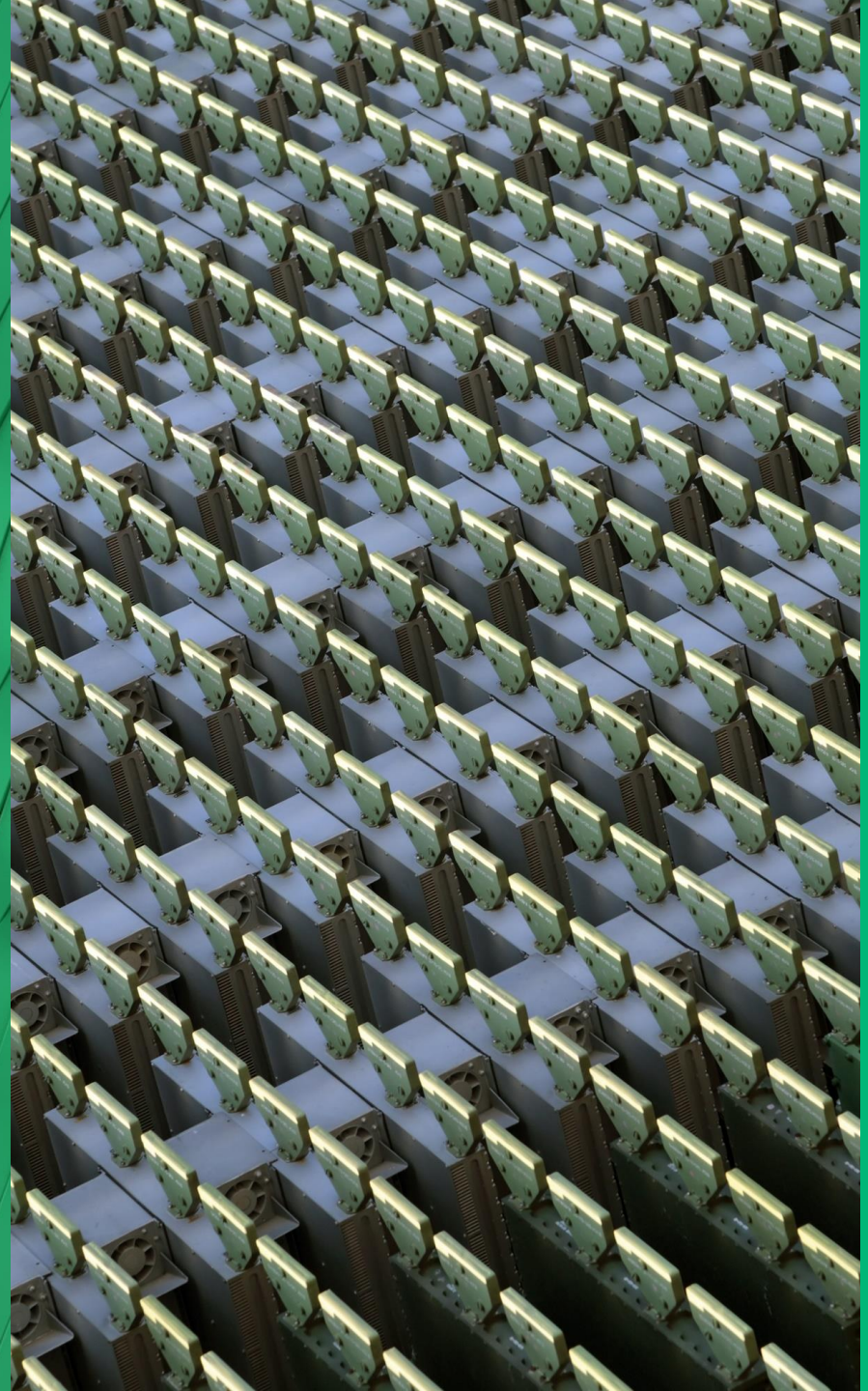


Digital Integration and the Need for Mixed I/O Test

Key Test Challenge: Provide robust and abstractable mixed I/O interfaces that can scale and adapt to evolving DUT needs while easily integrating I/O such as highspeed serial interfaces with RF instrumentation in order test functionality in an optimized and synchronous manner.



NI’s solution for ESA component and module characterization and test



FEATURES AT A GLANCE

ESA Characterization Reference Architecture

Enables Power Amplifier (PA) and Transmit Receive Module (TRM) characterization using a modular hardware platform

Interactive panels for benchtop characterization

Automatable device APIs with support for LabVIEW and C/C++

Validated system configuration with recommendations for third party accessories

System-level specifications for key measurements

Key Measurement Science:

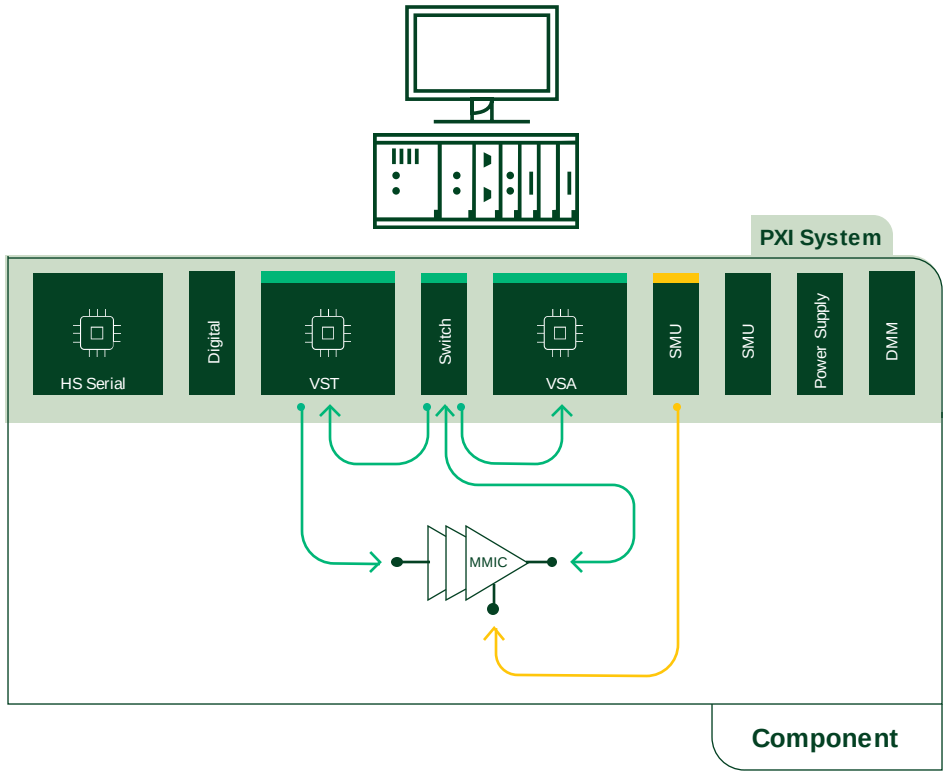
S-parameters (S11, S12, S21, S22), SOLT/SOLR calibration methods supported

Pulse Profile Measurements (Rise time, Fall time, Droop, Ripple, PRI, Duration)

Pulse Stability Measurements (Inter-pulse, Intra-pulse, Multiburst Averaging, Amplitude Stability, Phase Stability)

Power Added Efficiency (PxdB, Gain, Compression)

Modular Automated Test Bench



RF Stimulus and Response

- Vector Signal Analyzers, Generators, and Transceivers
- Up to 1 GHz of Instantaneous BW
- Software Defined with Open FPGA
- < 100psec synchronization with phase coherency

DC Source and Measure

Source Measurement Units
- Pulsed DC, up to 500W
- High Precision Sense

DMM
- 7.5 bit, 1.8MS/s

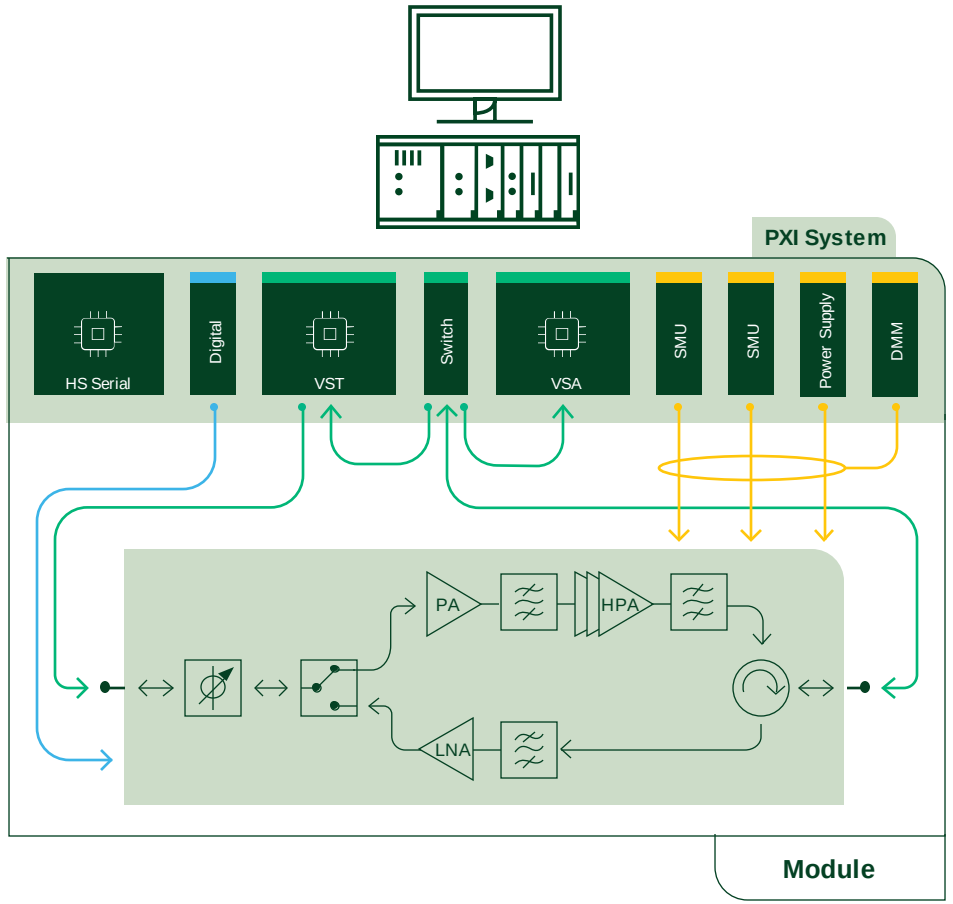
Digitizer
- 50Ω/1MΩ variable
- 8 bit to 24 bit
- Wide voltage range

Modular Automated Test Bench

Digital Control

Digital Control
- LVDS, TTL Control

Pattern Based Digital
- 100 MVectors/s
- PPMU, Voltage and Current



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- Wide voltage range

Modular Automated Test Bench

Digital Control & Highspeed Data

Digital Control
- LVDS, TTL Control

Pattern Based Digital
- 100 MVectors/s
- PPMU, Voltage and Current

Highspeed Digital Transceivers
- Up to 12.5 Gbps
- 24 TX and RX lanes

RF Stimulus and Response

- Vector Signal Analyzers, Generators, and Transceivers
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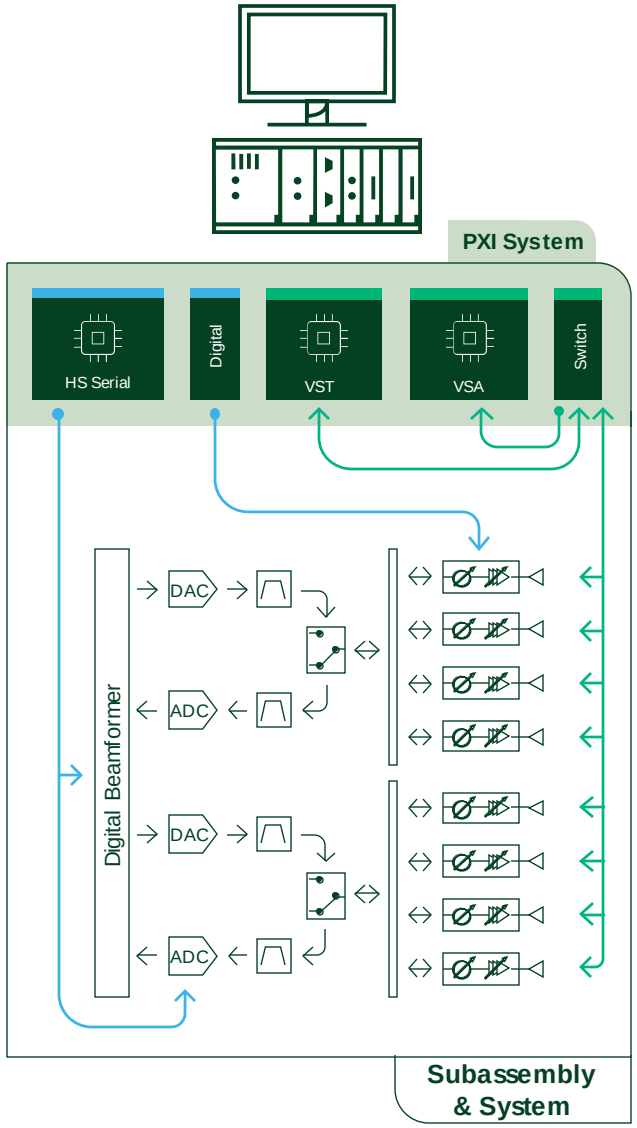
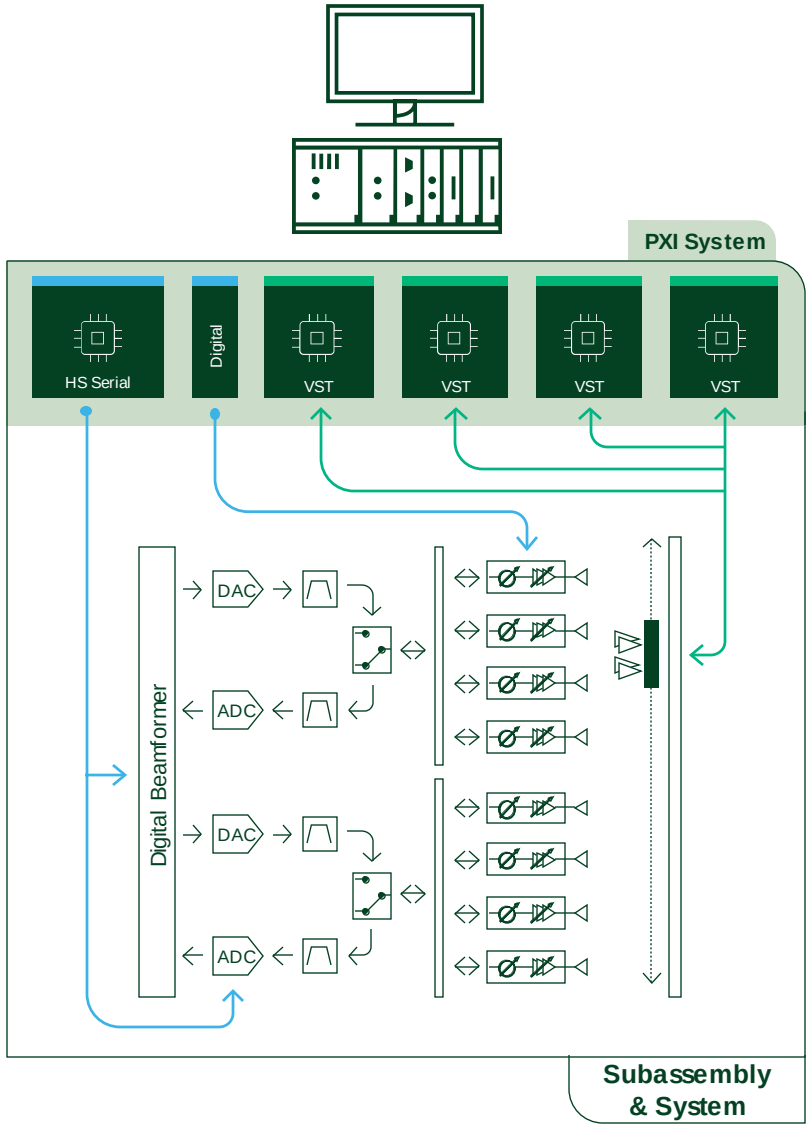
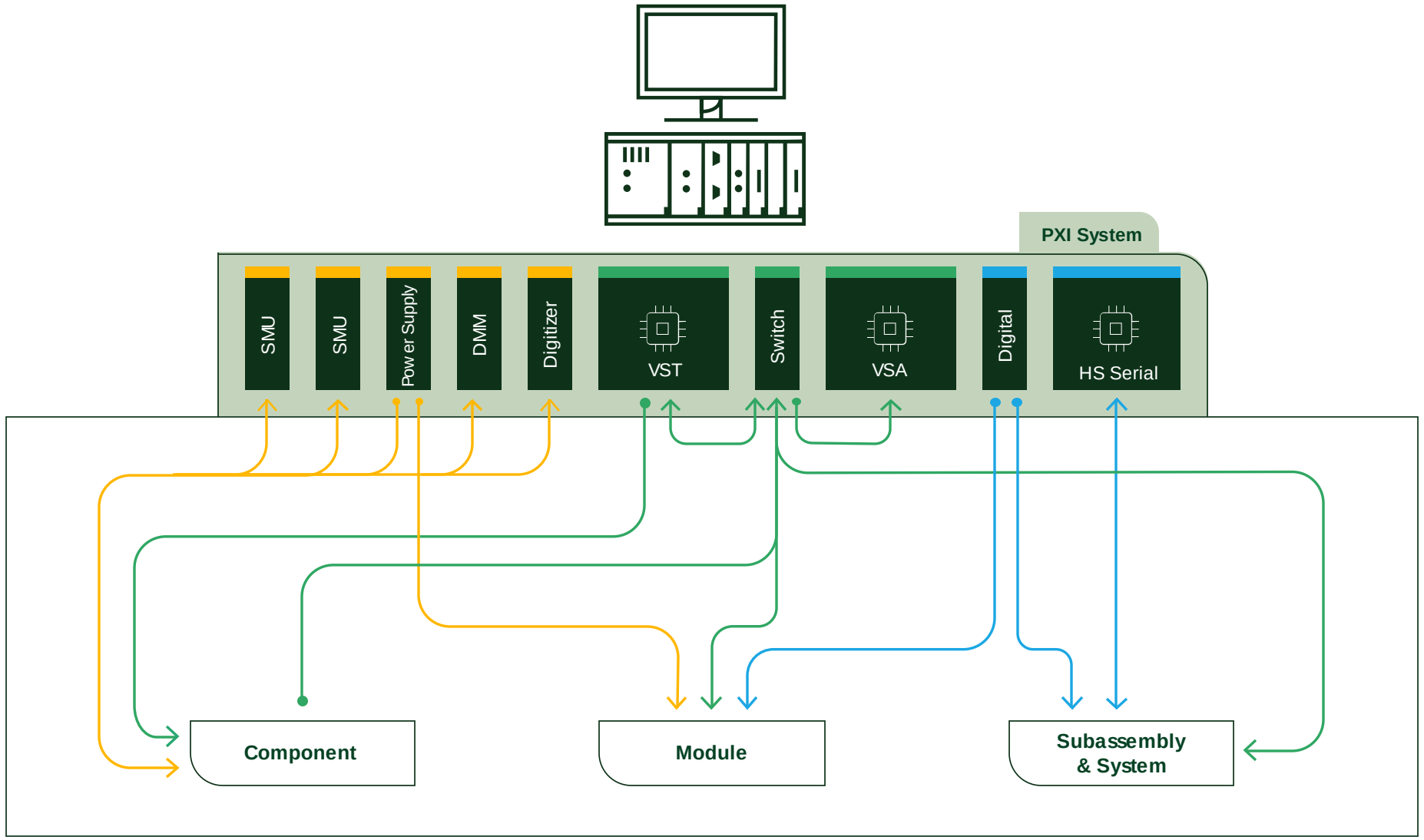




Modular Automated Test Bench



Vector Signal Transceiver

Application Coverage from Baseband to mmWave

Integrated, instrument grade VSA and VSG with up to 1 GHz of instantaneous bandwidth

Support Onboard and External LO's for phase noise optimization

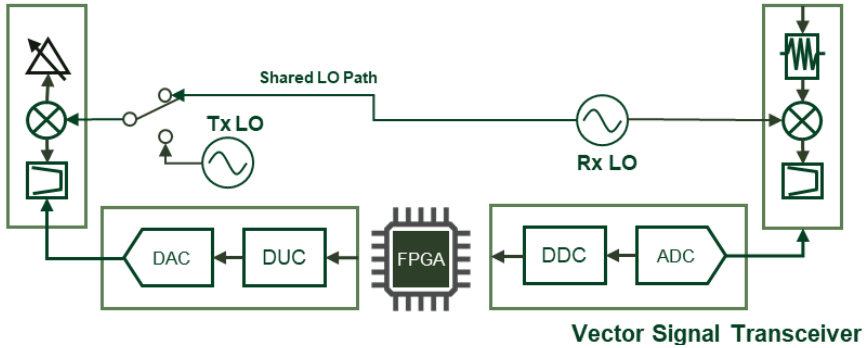
Multi-Channel Synchronization (< 1nsec) and Phase Coherent LOs

Easy SW and HW integration with mixed I/O and PXI

Optimized for automated characterization and production

Customizable firmware for deploying application IP or test speed optimization

- Onboard, open FPGA
- Full rate peer to peer streaming to FPGA coprocessors



Vector Signal Transceiver Product Family

Aerospace and Defense Application Bands

HF, VHF, UHF, L, S, C

C, X, Ku, K

K, Ka, V*

Baseband VST

9 kHz-6.5 GHz RF VST

5-21 GHz RF VST

22-45 GHz mmWave VST

High Current System SMU: PXIe-4139

IV Boundary

60 V

3 A DC (10 A Pulse)

40 W (500 W Pulse)

Sensitivity/Resolution

100 fA

100 nV

Max Speed

Sampling 1.8 MS/s

Update: 100 kS/s

NI SourceAdapt™ Technology

Extended Range Pulsing

Hardware Timing and Triggering

NI High-Speed Serial Instruments

Up to 28 Gbps

Up to 24 TX and RX lanes

Xilinx Kintex-7, Virtex-7, and Kintex Ultrascale FPGAs

Programmable in LabVIEW FPGA and Xilinx Vivado

Up to 8 GB onboard DRAM

PCI-Express Gen3 x8

Unified Software Experience

Easy, Interactive Soft Front Panels

Automatable device APIs and Measurements

Support for LabVIEW, C#/.Net, C

FPGA Development Environment

IP Libraries for Key Measurements

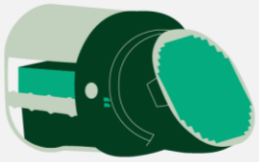
- Power Added Efficiency (PAE)
- Power and Phase Stability
- Network Analysis and S-parameters
- Pulse to Pulse Stability
- Spectral Analysis, Phase Noise

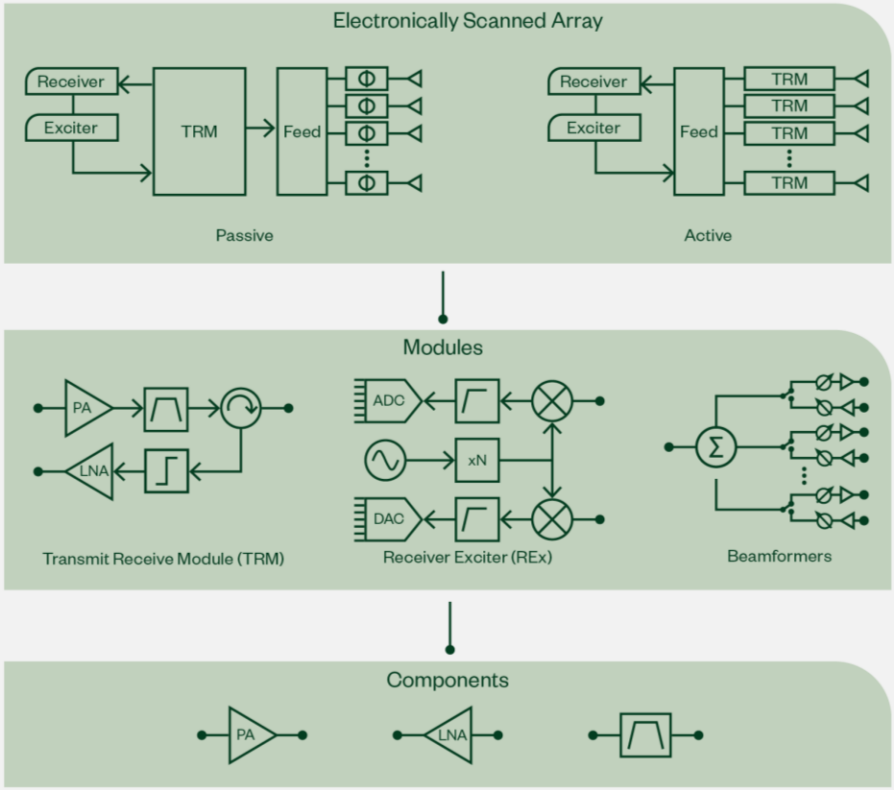
Pulsed RF Measurements Library

With easy to use, interactive interface panels for developing and debugging systems, to automatable APIs for deploying both characterization as well as production test systems, the Pulsed RF Measurements Library provides a unified software experience for testing ESA components and modules across the design cycle. In addition to easy-to-use panels, the library also includes support for several development environments including LabVIEW, C, C#, and .NET.

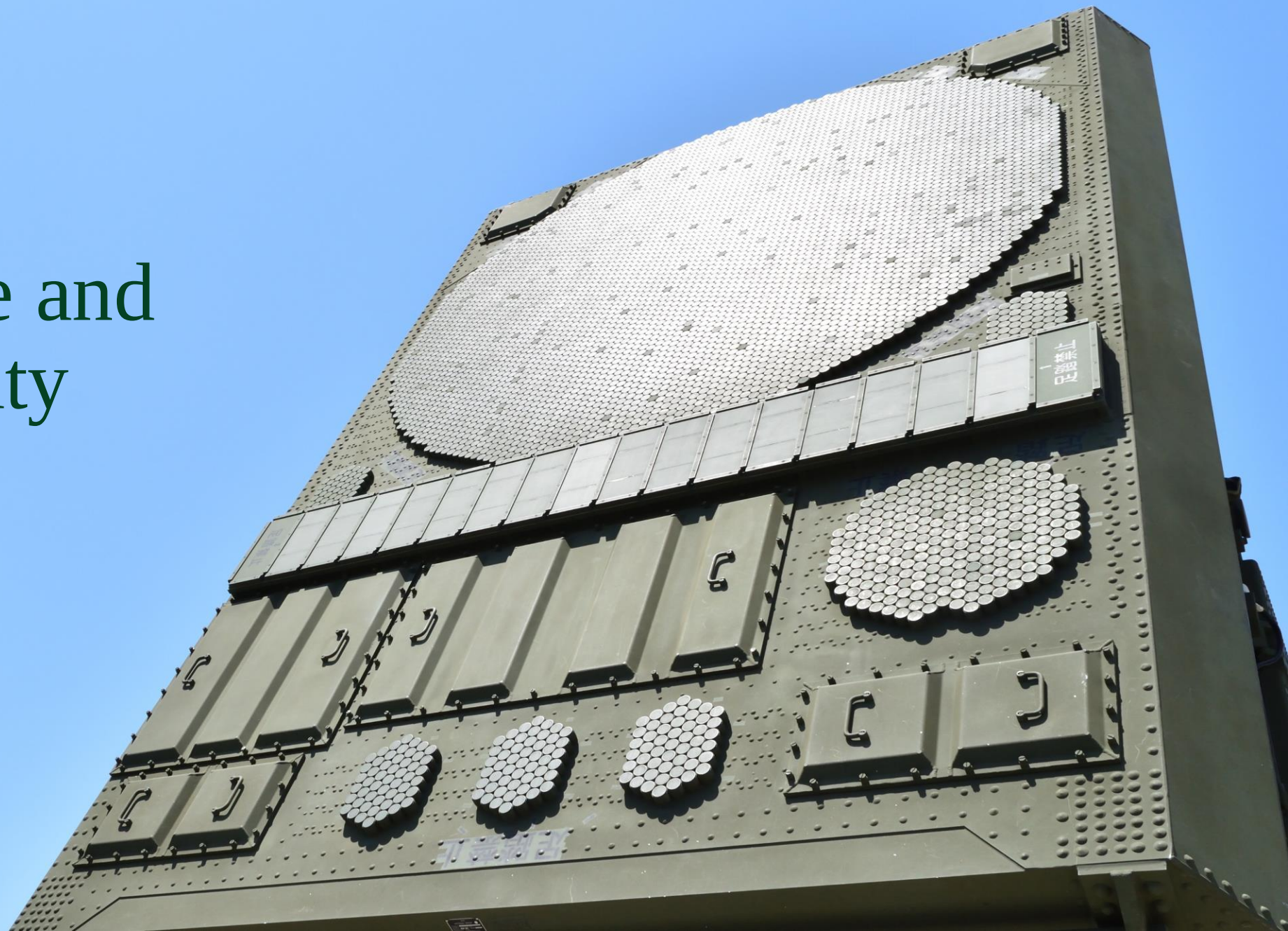
Key Measurement Capabilities

- Power and phase stability
- Network analysis and S-parameters
- Pulse profile and stability
- Power added efficiency
- Spectral analysis
- Phase noise





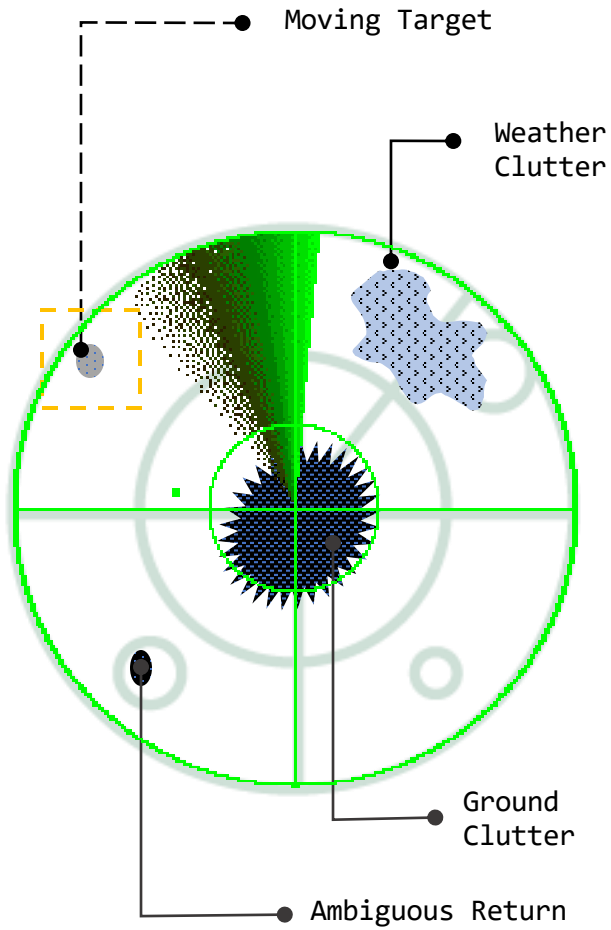
Pulse Profile and Pulse Stability



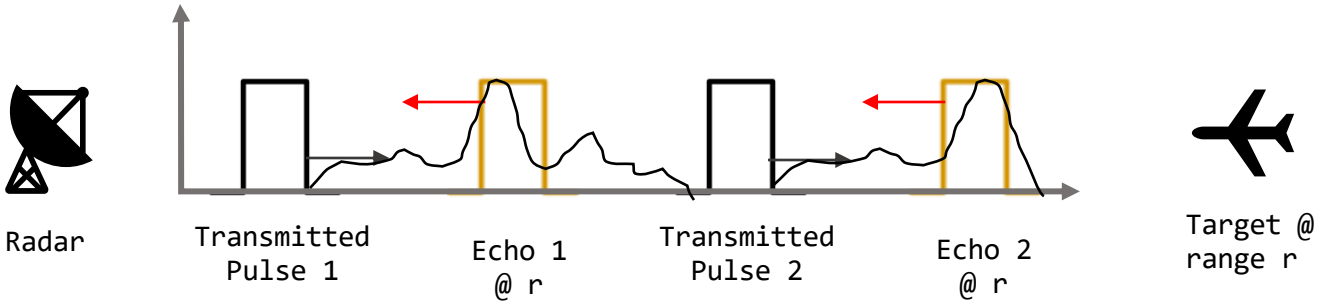
Clutter and Backscattering Impact on Radar Detection

Rain | Birds | Ground & Sea Clutter | Chaff | Interference | Shadowing | Attenuation | Reflection | Refraction

Detection Ambiguity



Target Separation Using Doppler: Moving Target Indicator



Zero Velocity Filter for Clutter Suppression

- Clutter with zero velocity will be cancelled out
- Moving targets will result in a residue

- Minimum of 2 consecutive pulses
- More pulses = higher clutter attenuation → higher MTI Improvement factor

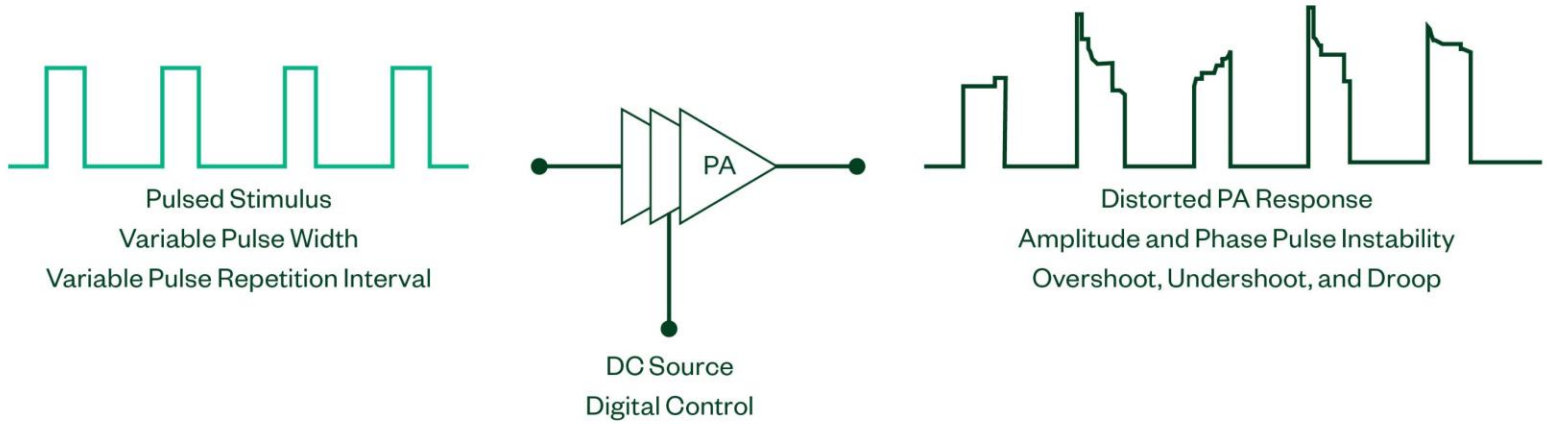
Pulse Profile and Pulse Stability

Common Test Challenges

Synchronizing RF pulsed stimulus with DUT control to accurately characterize component stability

Instrumentation phase noise negatively affects measurement accuracy

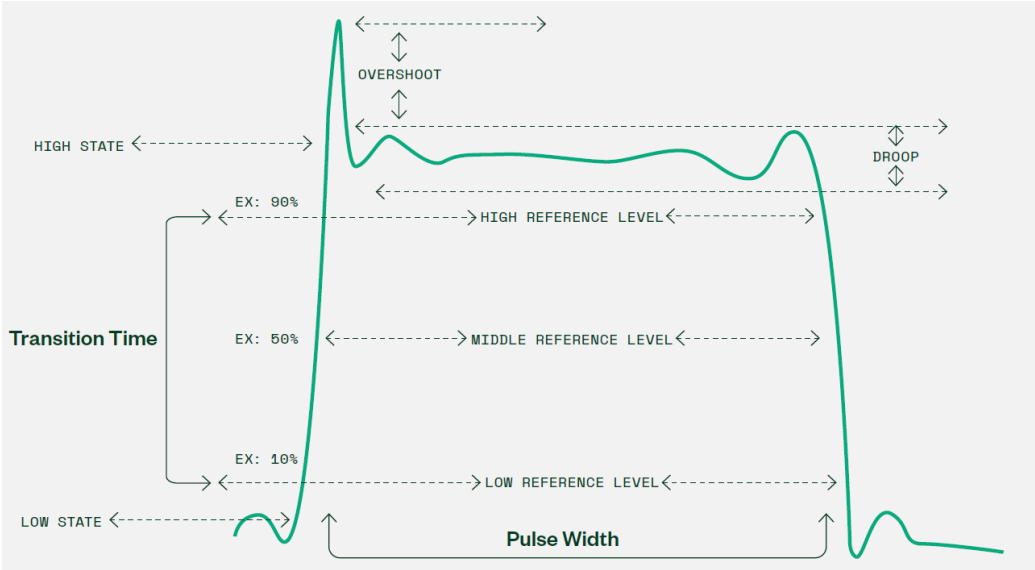
Limited RF instrumentation bandwidth reduces test coverage



Pulse Profile

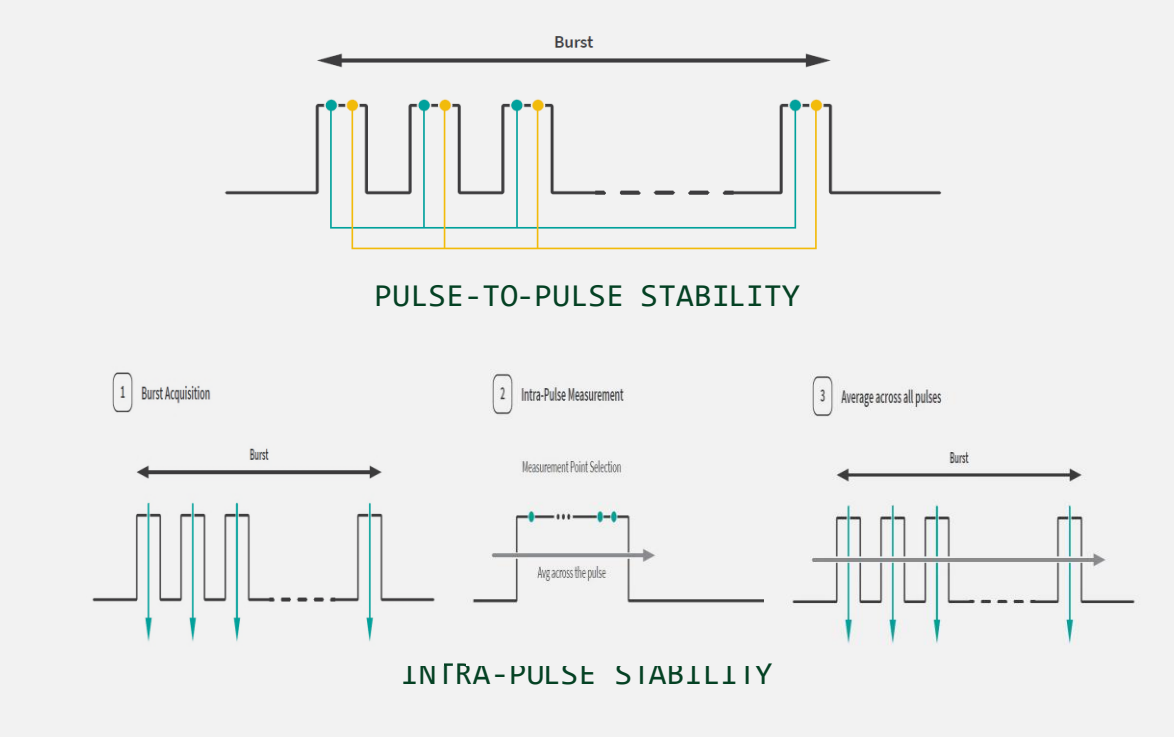
The Pulsed RF Measurements Library provides the ability to characterize pulse profile attributes defined in IEEE Std 181™-2011

Key Attributes: State Levels, Reference Levels, Transition Duration, Pulse Overshoot, Pulse Undershoot, Pulse Droop, Pulse Ripple/Ringing

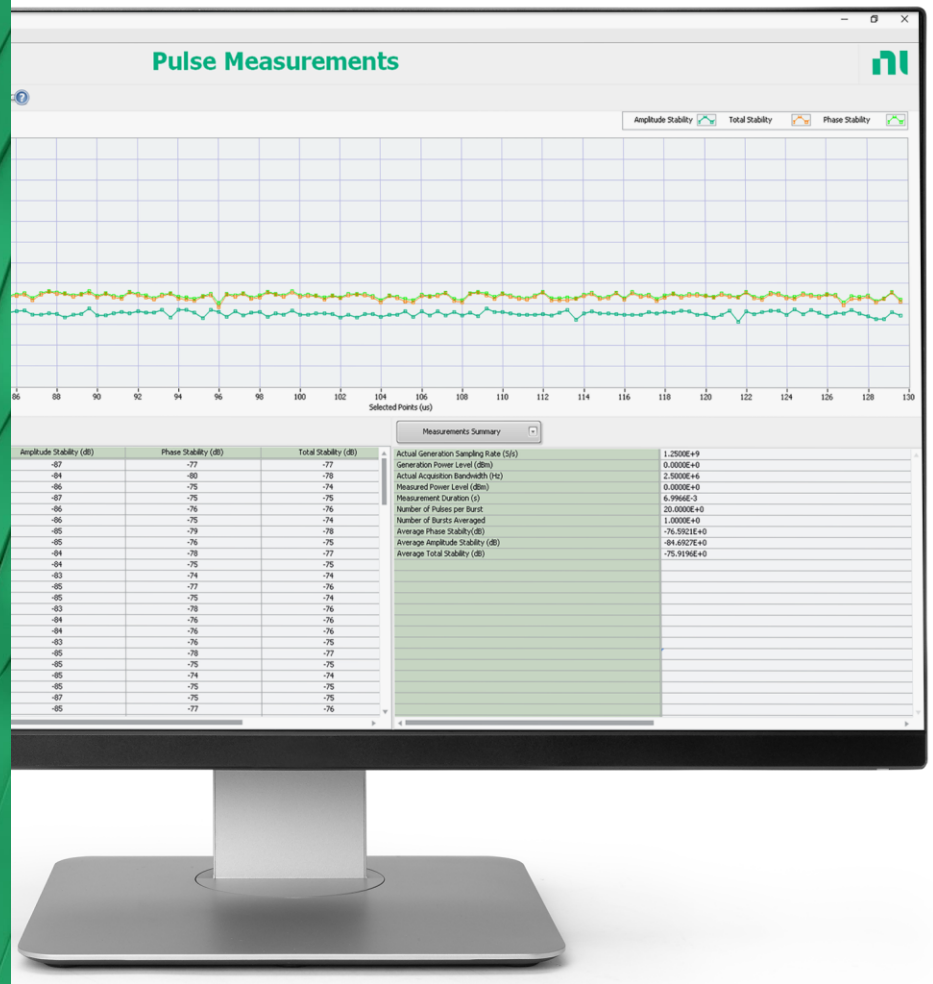


Pulse Stability

The Pulsed RF Measurements Library provides the ability to characterize pulse stability attributes defined in IEEE Std 181™-2011



INTERACTIVE MEASUREMENT PANEL INCLUDED WITH THE
NI PULSED RF MEASUREMENTS LIBRARY



Pulse Profile and Pulse Stability

Common Test Challenges

Synchronizing RF pulsed stimulus with DUT control to accurately characterize component stability

Instrumentation phase noise negatively affects measurement accuracy

Limited RF instrumentation bandwidth reduces test coverage

The NI Advantage

Wide frequency coverage from sub-L to Ka band and flexible bandwidth configuration up to 1 GHz to tailor the test system to the design.

Tight sub-nanosecond synchronization between PXI modules for synchronous RF pulsing and flexible trigger routing for DUT control.

Phase stability up to -90 dB with low phase noise impact due to shareable LO between transmit and receive.

S-Parameters

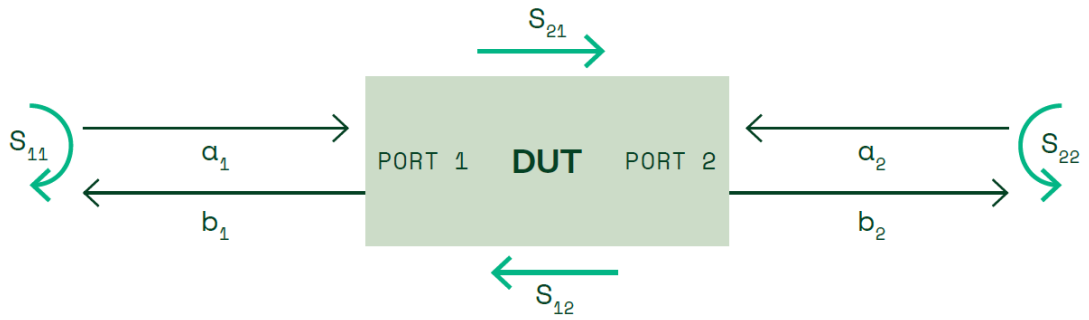
S-Parameter Measurements

Common Test Challenges

Perform flexible S-parameter measurements using CW and pulsed waveforms on the same HW as large signal analysis

Combine S-parameters with other parametric tests and simplified integration using a single reconfigurable and modular system.

Reduced overall test time and cost with unified software experience and increased hardware reuse.



$$\begin{bmatrix} b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} * \begin{bmatrix} a_1 \\ a_2 \end{bmatrix}$$

S-Parameter Measurements Using a VST

The Pulsed RF Measurements Library provides several suggested hardware configuration options to accomplish S-parameter measurements. The configuration you choose depends on your measurement accuracy, cost, and sweep speed requirements.

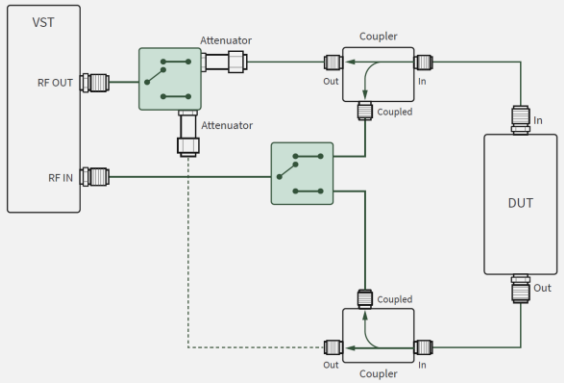
Perform flexible S-parameter measurements using CW and pulsed waveforms on the same HW as large signal analysis

Combine S-parameters with other parametric tests and simplified integration using a single reconfigurable and modular system.

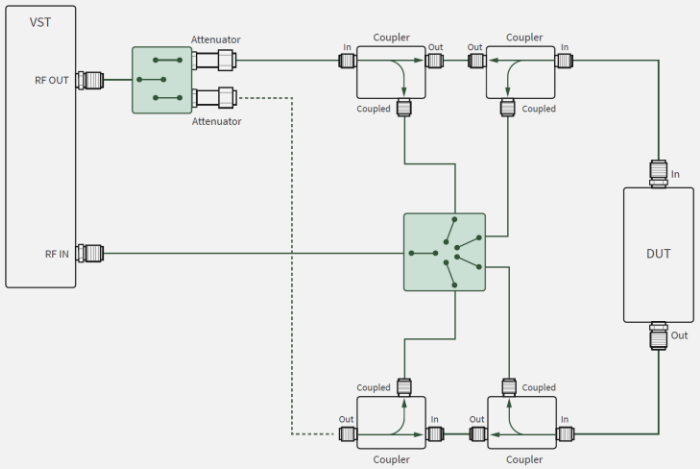
Reduced overall test time and cost with unified software experience and increased hardware reuse.

	Measurement Quality	Test Time	Cost
1 Coupler/Port, 1 VST	○	◒	●
2 Couplers/Port, 1 VST	◒	○	◒
1 Couplers/Port, 2 VSTs	◒	◒	○

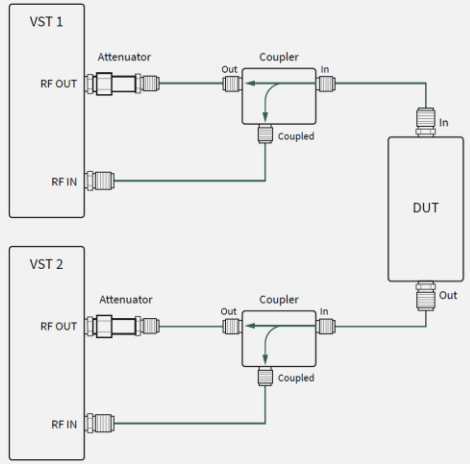
○ Good ◒ Better ● Best



1 COUPLER/PORT, 1 VST



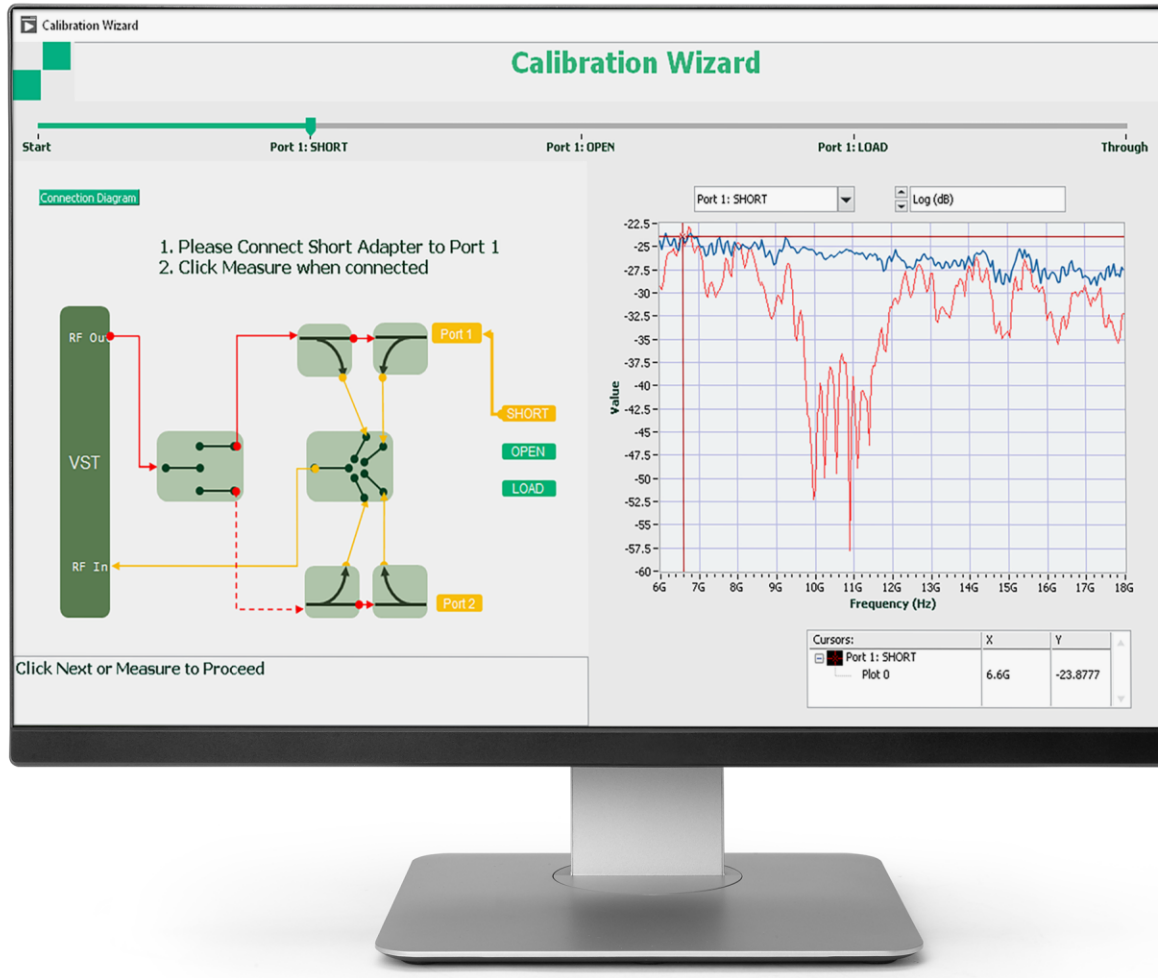
2 COUPLERS/PORT, 1 VST



1 COUPLER/PORT, 2 VSTS

S-Parameter Measurements Calibration

The NI Pulse Measurement Library includes a calibration utility to perform system calibration prior to taking your S-Parameter measurements. Options include SOLT, QSOLT, or SOLR calibration depending on your chosen hardware configuration.



INTERACTIVE MEASUREMENT PANEL INCLUDED WITH THE
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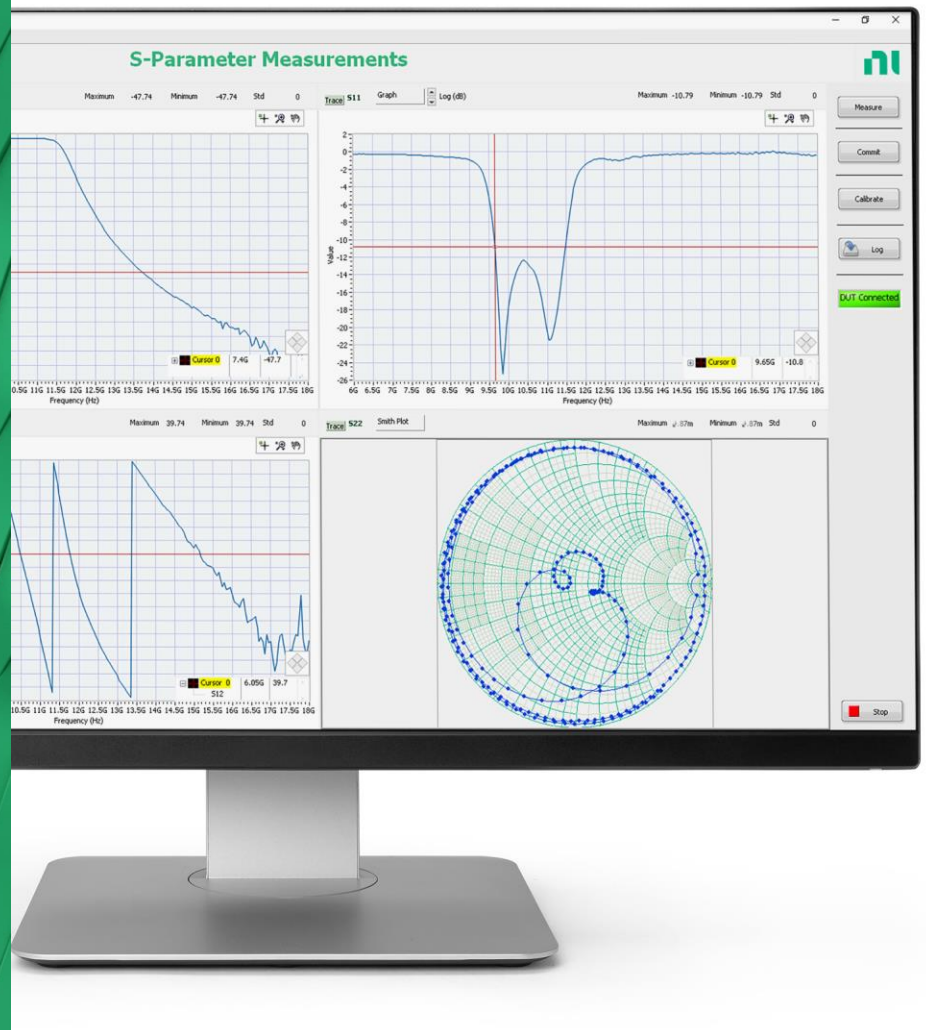


S-Parameters

Common Test Challenges

Correlation of small signal and large signal analysis due to multiple instruments

Complexity of DUT interfaces distorts built in reflectometry of VNAs

Performing fundamental RF measurements under unique application-specific stimuli

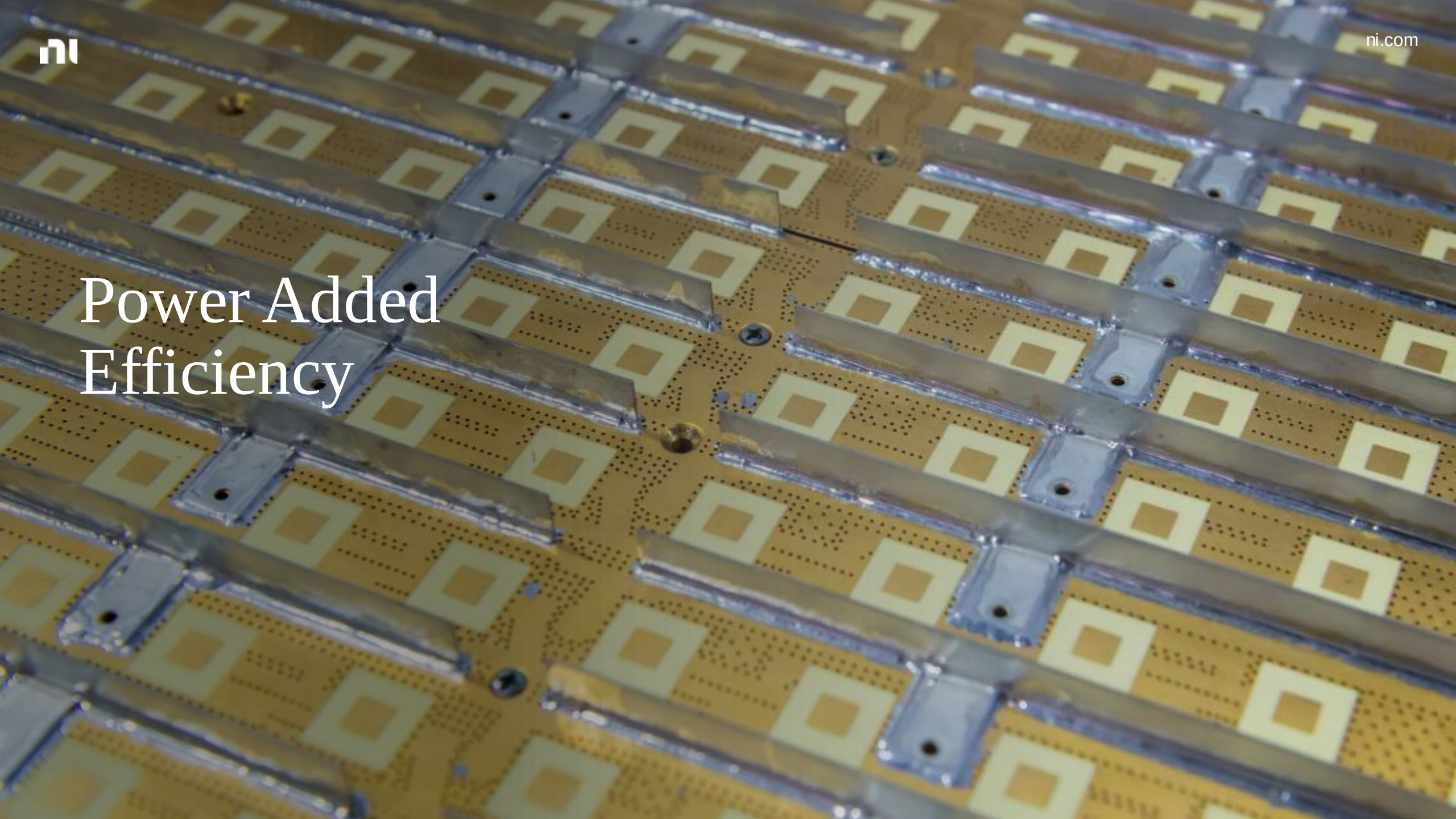
The NI Advantage

Perform flexible S-parameter measurements using CW and pulsed waveforms on the same HW as large signal analysis

Combine S-parameters with other parametric tests and simplified integration using a single reconfigurable and modular system.

Reduced overall test time and cost with unified software experience and increased hardware reuse.

Power Added Efficiency



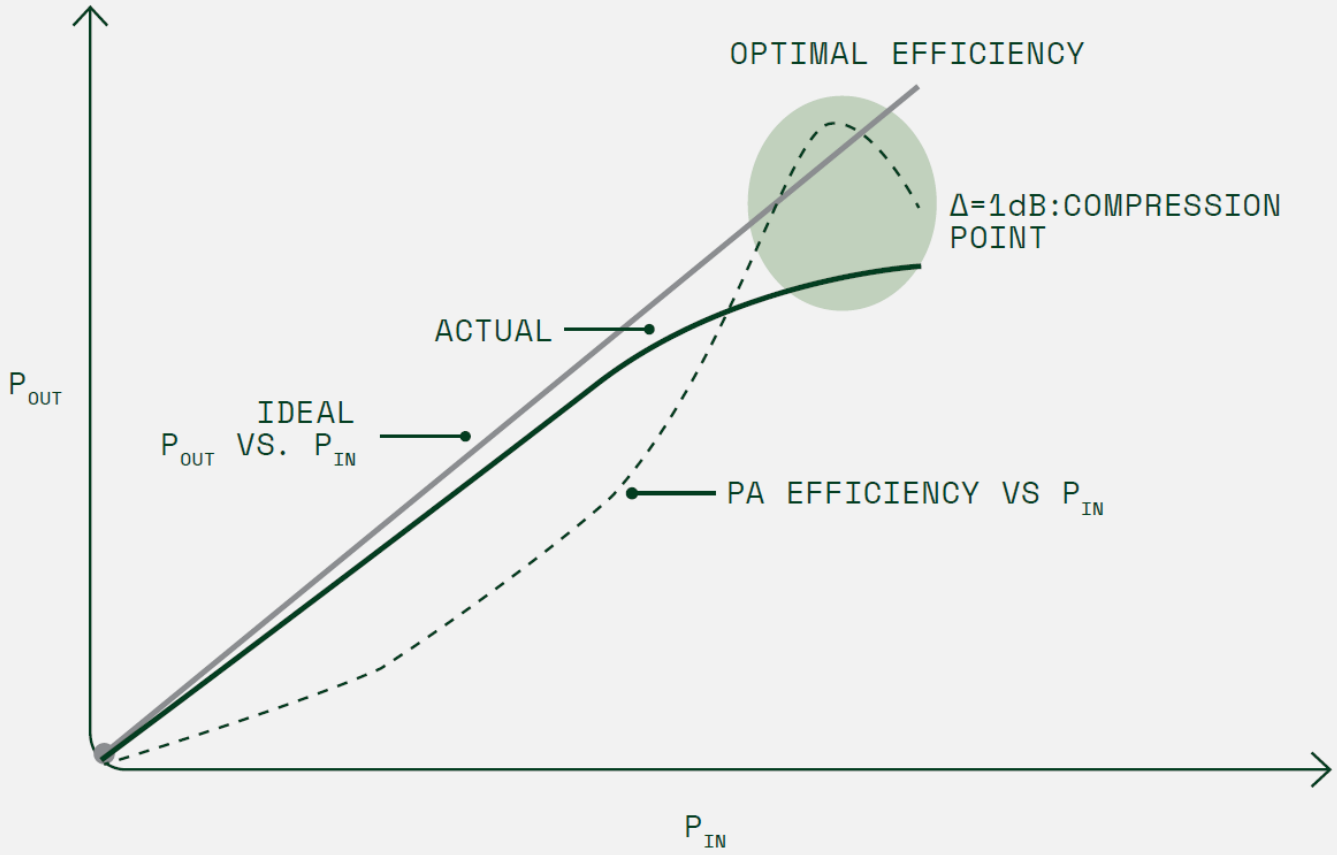
Power Added Efficiency

Common Test Challenges

Synchronization of RF and DC instrumentation for accurate measurement results

Traditional measurement setups are challenging and difficult to use

Automating sweep measurements



Power Added Efficiency

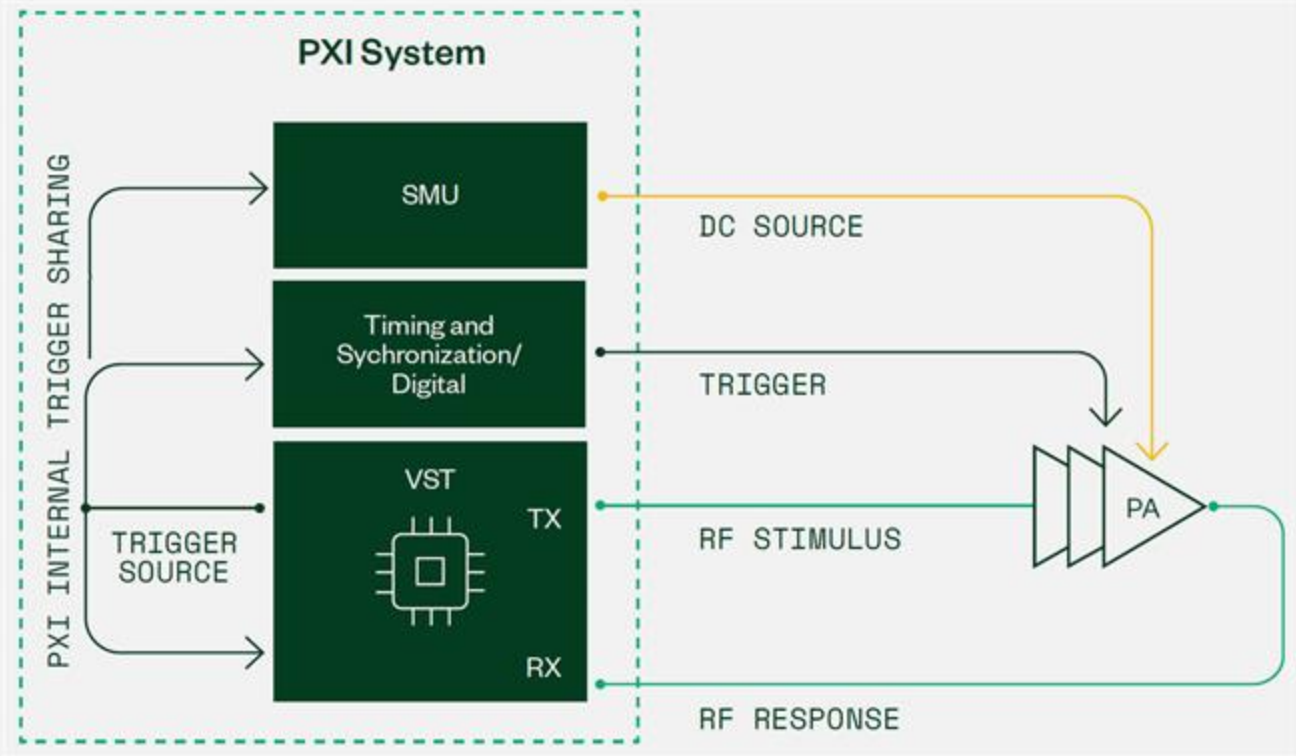
Test Setup

CW or Pulsed Stimulus/Response via the Vector Signal Transceiver (VST)

Constant/Pulsed DC supported

SMU measurement synchronized with RF measurement to ensure aligned RF/DC response

Optional triggering from PXI systems can be used to provide gate or sync to DUT



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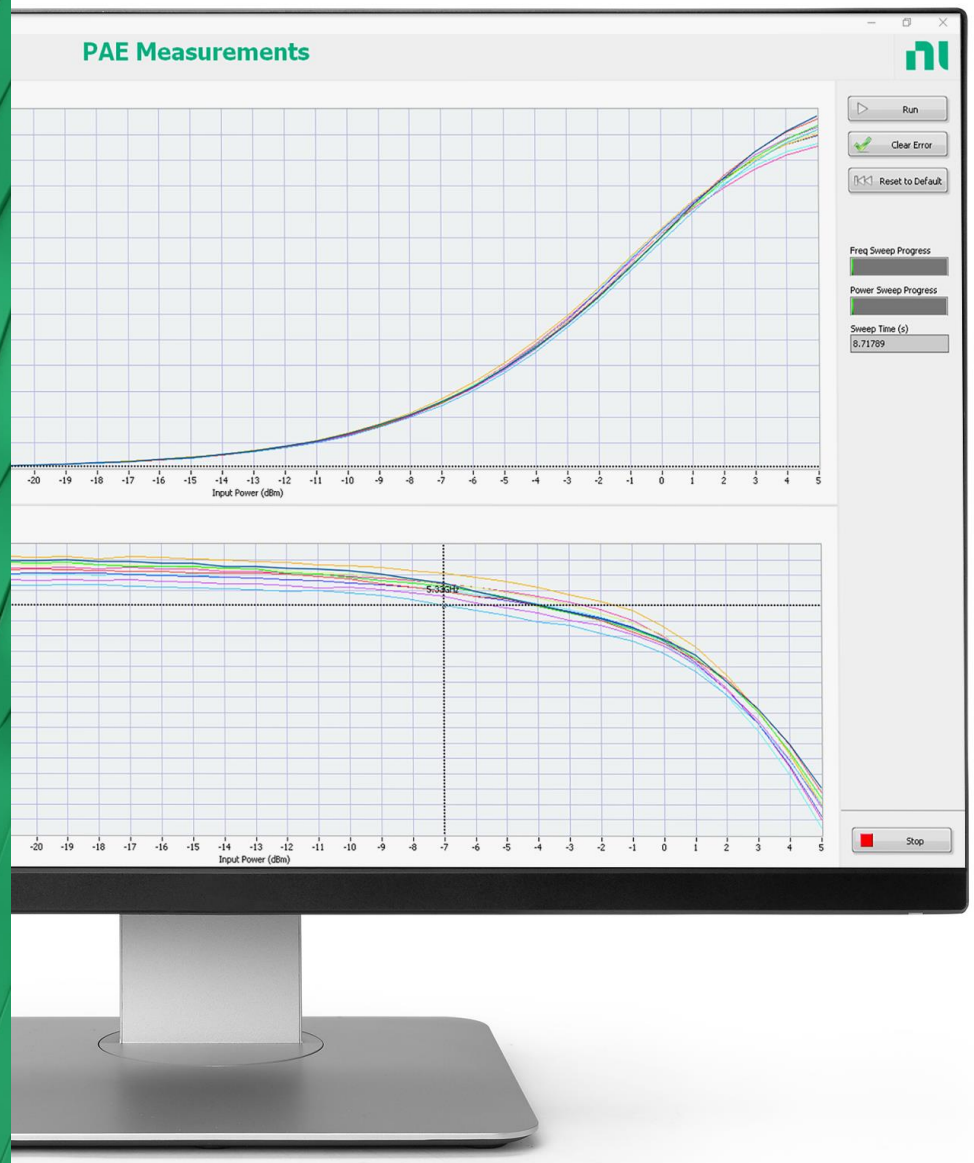


Power Added Efficiency

Common Test Challenges

Synchronization of RF and DC instrumentation for accurate measurement results

Traditional measurement setups are challenging and difficult to use

Automating sweep measurements

The NI Advantage

Easy-to-use integration of DC and RF measurements in both interactive examples and programmatic APIs

Tight sub-nanosecond synchronization between PXI modules for synchronous RF pulsing, DC triggering, and DUT control.

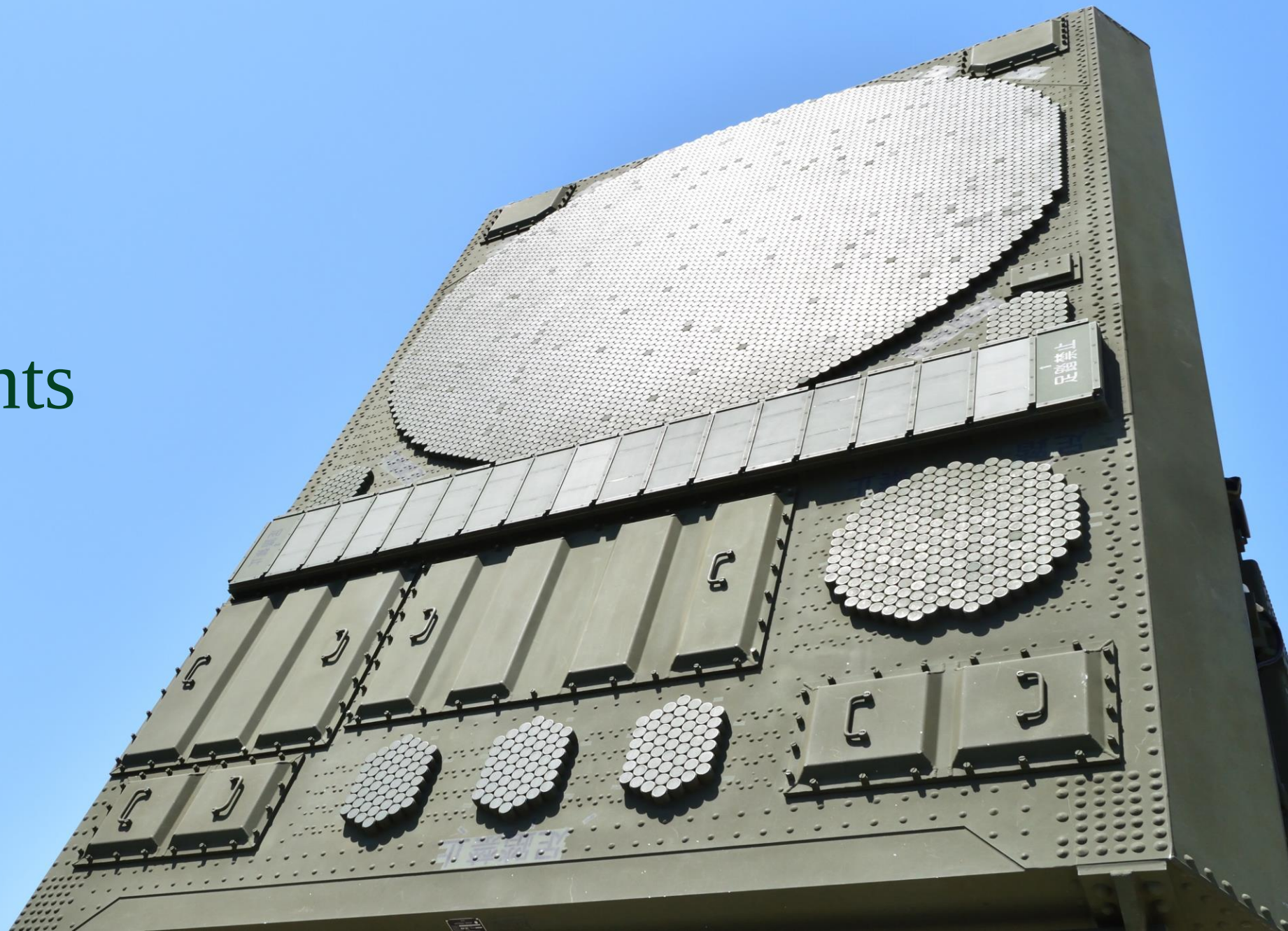
High-precision DC and RF instrumentation and scalable measurement capabilities with reduced test time for performing frequency domain and gated time domain measurements on pulsed RF signals.

References

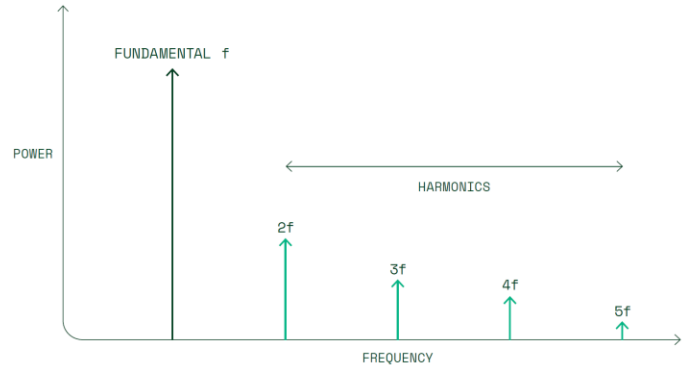
ESA Characterization Reference Architecture User Manual

ESA Characterization Reference Architecture Specifications

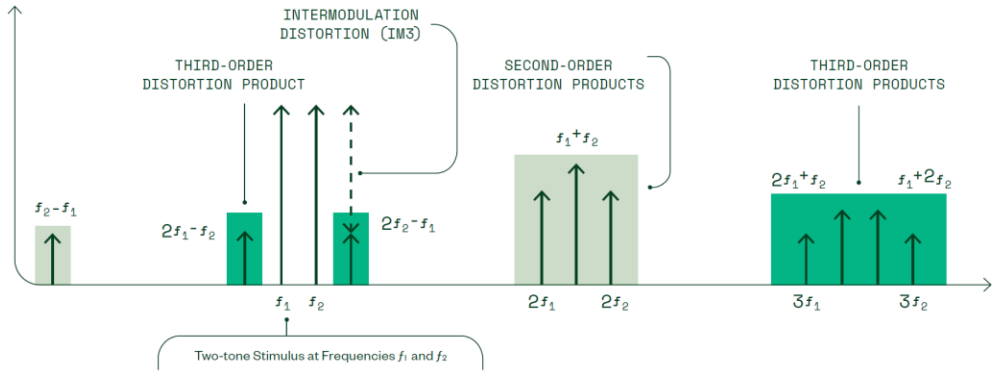
Additional Measurements



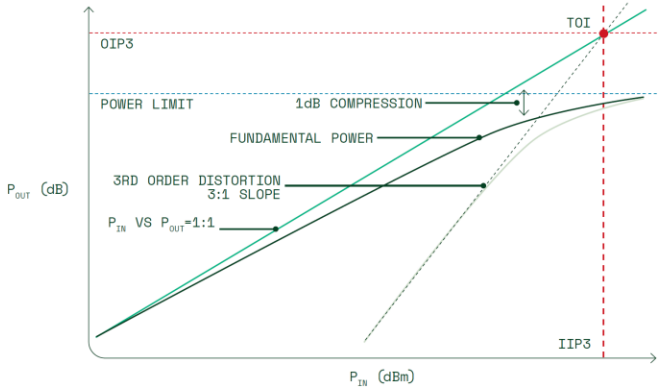
Common Spectral Measurements



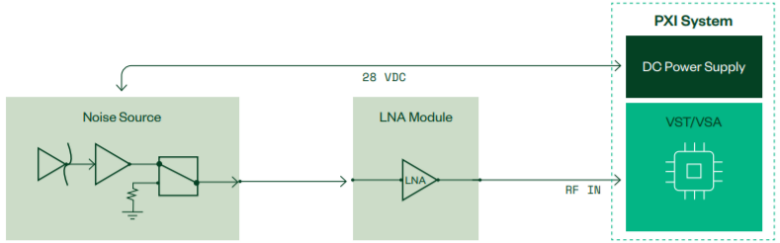
Total Harmonic Distortion



Intermodulation



Third-order Intercept



Noise Figure

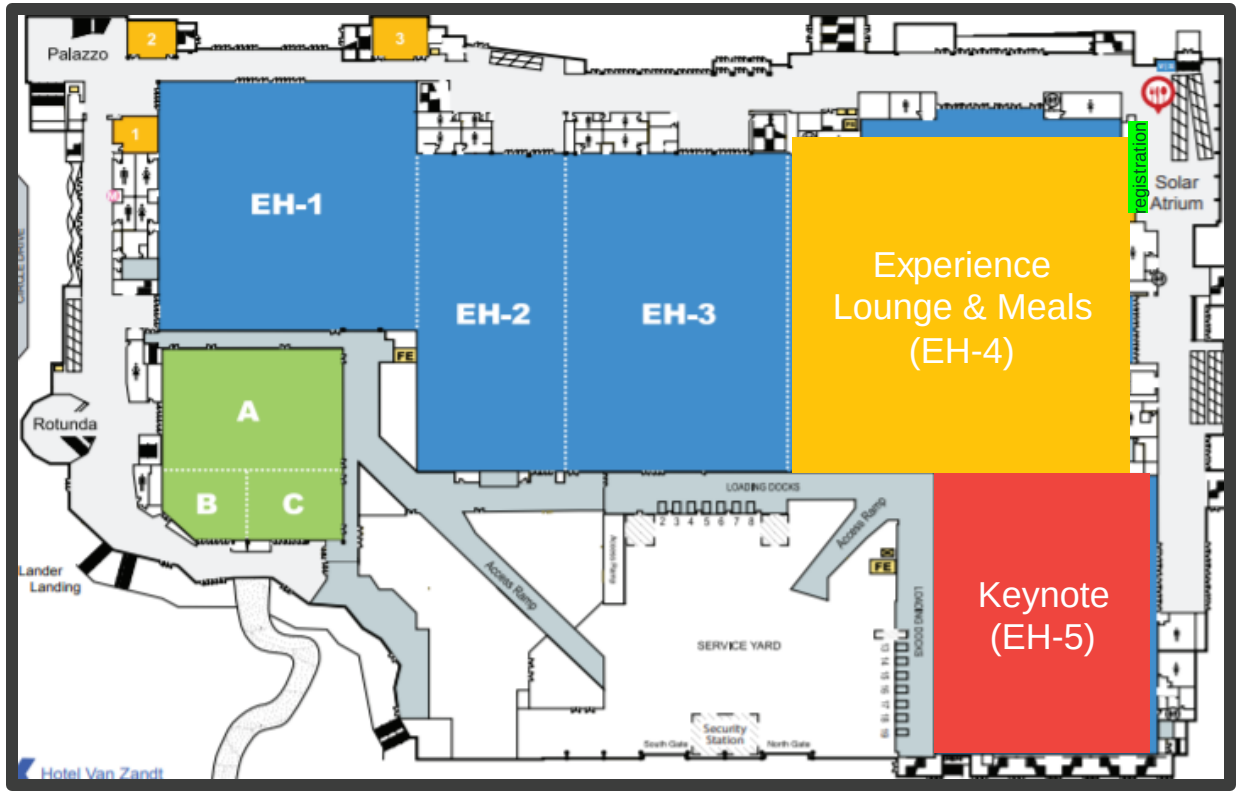
ESA Demo at the Experience Lounge

Our ESA Demo uses our VST and IP Library to perform the following measurements on ESA Components:

- Pulse Analysis
- S-Parameters
- Power Added Efficiency
- Additional key spectral measurements
- Automating common ESA measurements

Click to add text

Trinity Street



ESA Demo Setup

Looking to the Future…

Fully Digital T/R Modules

Common Test Challenges

Increased sampling rates and real-time processing

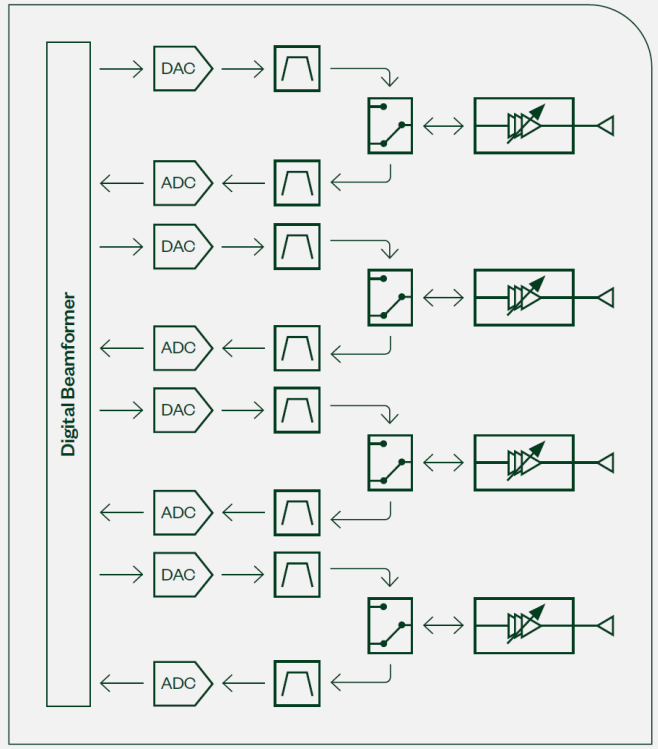
Multichannel synchronization and alignment

Calibration and de-embedding of DUT characteristics

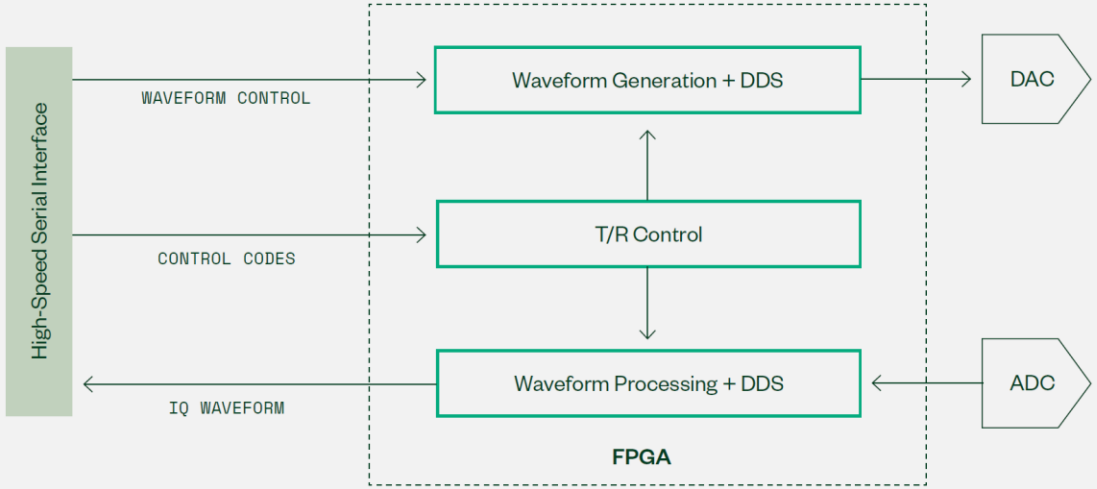
Changes in measurement scope

Diversity of operational and functional test scenarios

RF connectivity limitations



MULTICHANNEL DIGITAL T/R MODULE



DIGITAL PATH OF A DIGITAL T/R MODULE

Over the Air Testing

Common Test Challenges

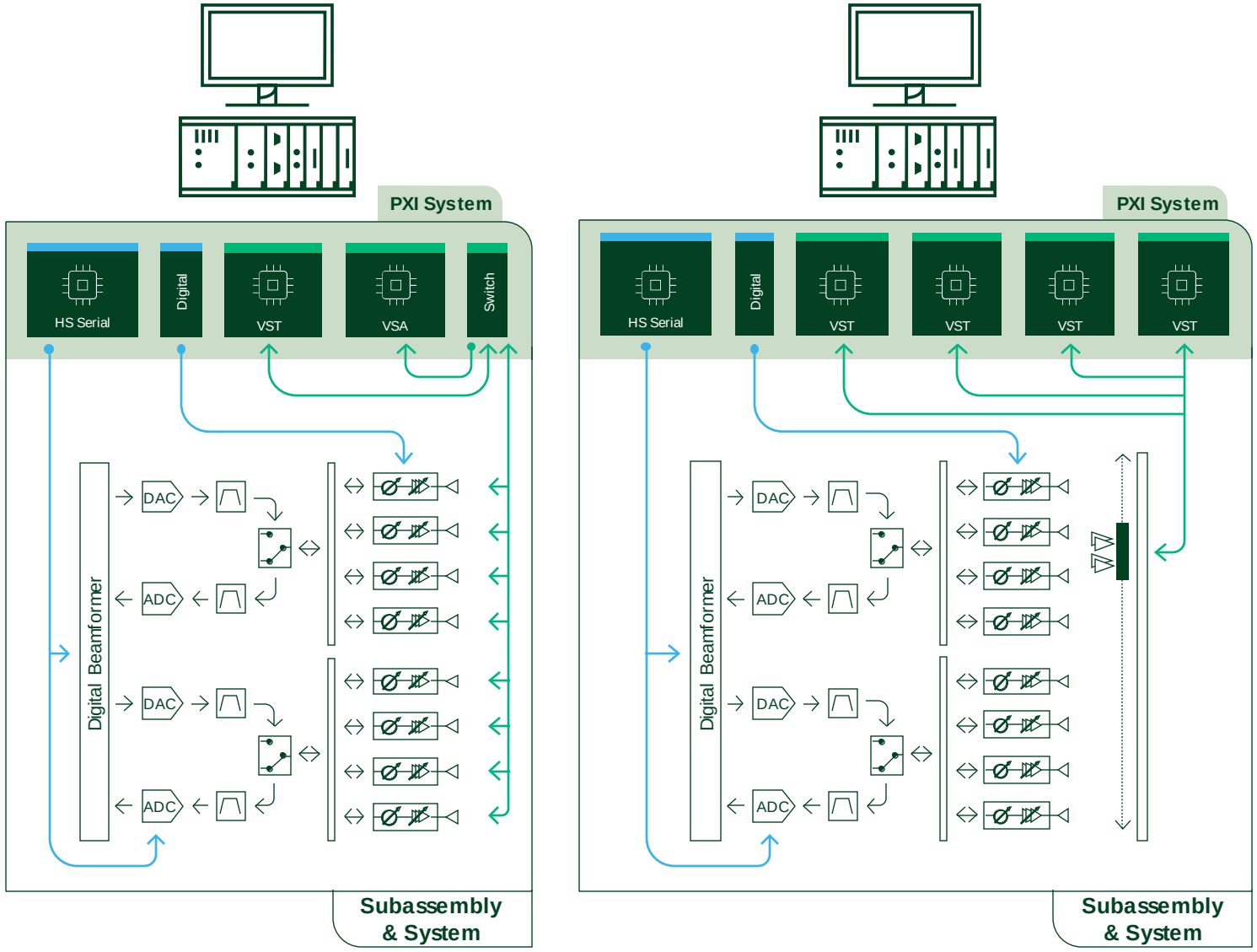
Chamber size requirements

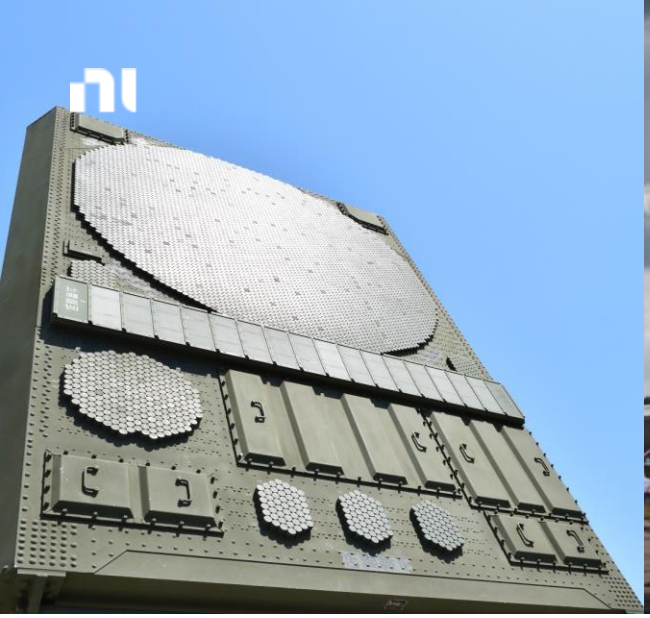
Test time and temperature

Calibration

Synchronization

Closed-loop testing






The ESA Characterization Reference Architecture enables component and module characterization using a modular hardware platform, with a focus on power amplifiers (PA) and transmit receive modules (TRM).

The Pulsed RF Measurements Library included in the reference architecture provides a unified software experience with easy-to-use interactive measurement panels and automatable device APIs for key measurement IP.

The ESA Characterization Reference Architecture includes documented measurement specifications for recommended instrumentation and system configurations.

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