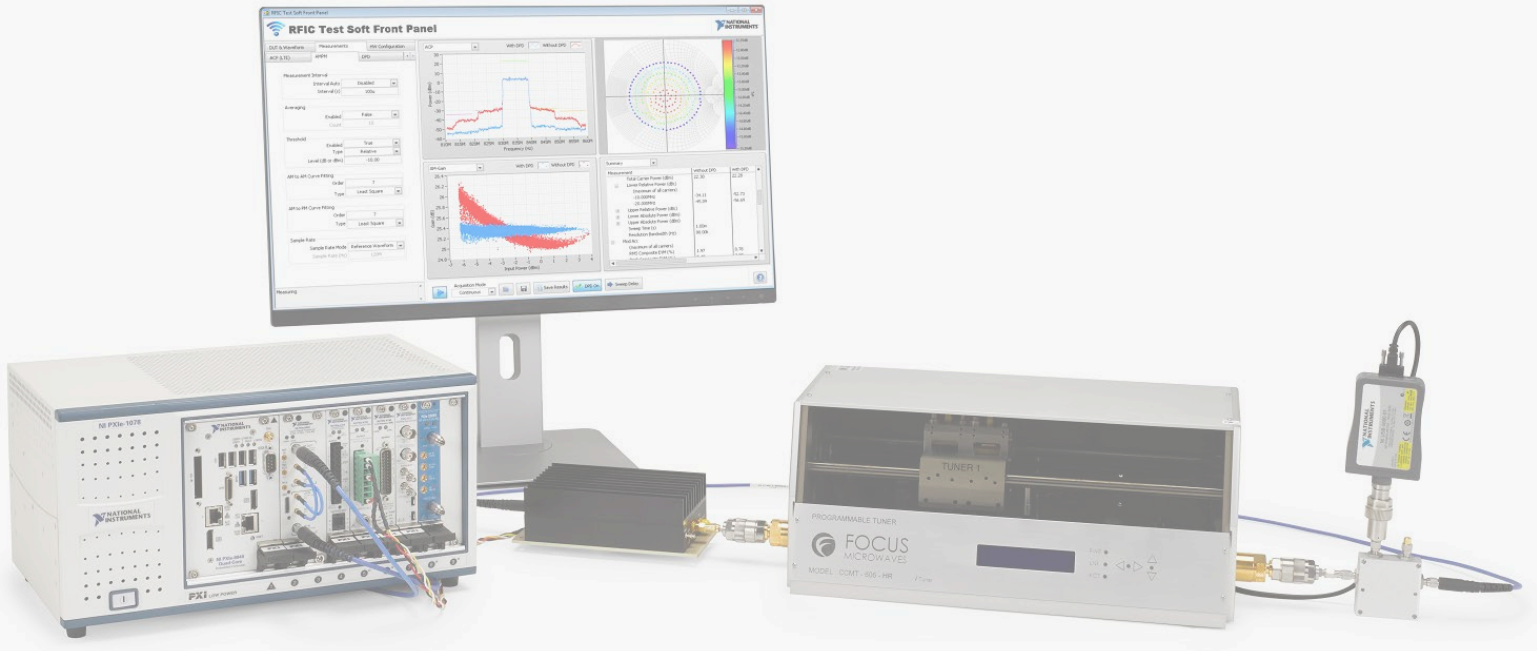
RFFE Validation

Determine RFFE Design Performance Faster – from Interactive Bring-up to Automated Validation



NI's RFFE Validation reference architecture can help your team:

- Quickly bring up new designs of the latest 5G NR and Wi-Fi RF Front-ends
- Determine key RF performance metrics in 50 and non-50 Ω environments
- Explore best-in-class PA linearization with state-of-the-art DPD algorithms
- Configure extensive parameter sweeps with industry-leading speed
- Achieve accurate measurements with S-parameter calibration/de-embedding
- Lower the cost of test with integrated, modular benches

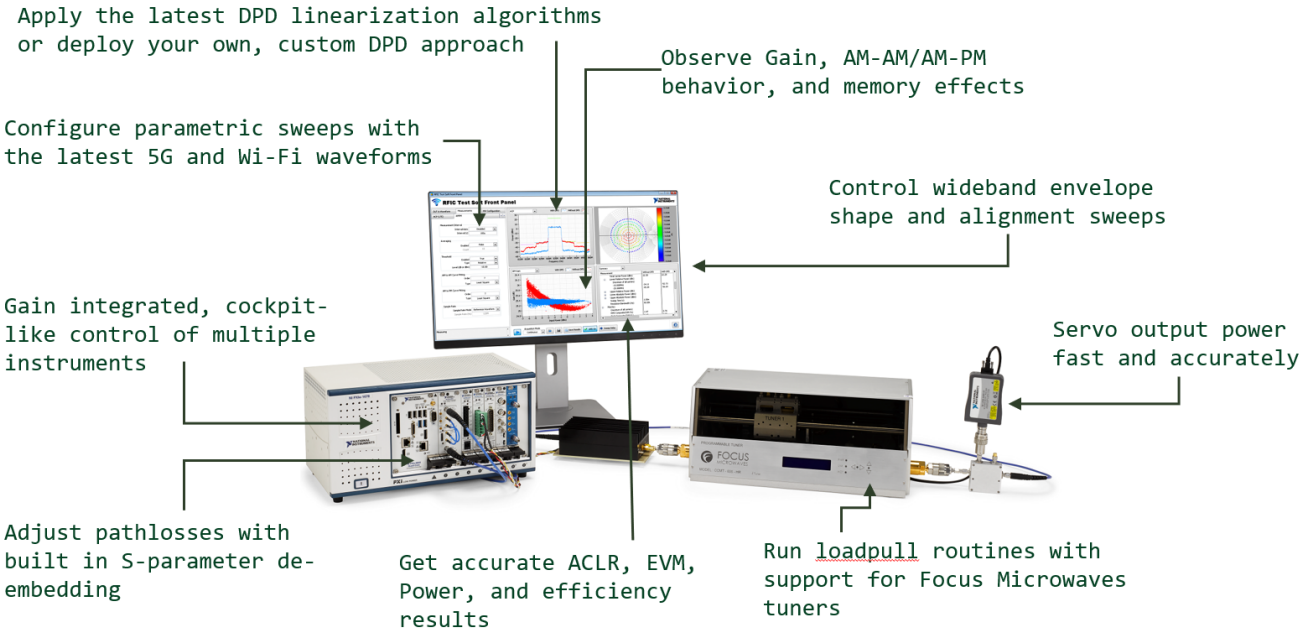
RFFE Validation Reference Architecture

The number of supported frequency bands and test cases for new wideband wireless standards, such as 5G New Radio and Wi-Fi 6 (802.11ax), continues to grow. Simultaneously, the need for power amplifier design tradeoffs between greater power efficiency and higher linearity keeps driving exploration of novel linearization and envelope tracking (ET) techniques.

NI's RF Front-end validation reference architecture simplifies the workflow of engineers in charge of the validation of wideband RF power amplifiers (PAs) for demanding applications, like 5G and Wi-Fi 6.

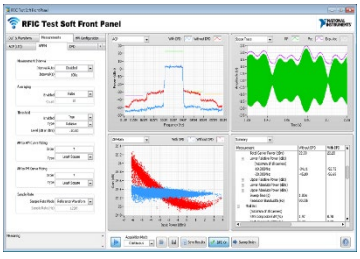
On the hardware side, NI's portfolio of lab-grade instrumentation and Focus Microwave wideband tuners deliver modular and tightly integrated validation benches.

Thanks to the latest NI RFIC Test Software 20.5, optimized for wideband wireless standards, engineers enjoy cockpit-like control of their validation bench and detailed results visualization for a streamlined workflow. The RFIC Test Software makes it easy to bring-up new DUTs, to interact manually to validate DUT performance, and to automate extensive device characterization routines.



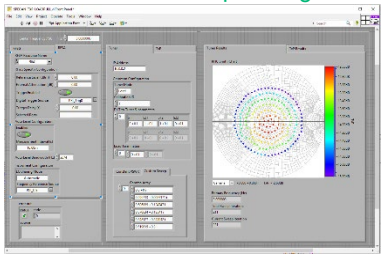
Easy-to-Use RFIC Test Software

RFIC Test Software GUI



Interactively characterize PAs with ET and DPD. Run parametric sweeps of frequency, power, and load

Customizable Example Programs



Customize your RFIC test system more quickly by modifying ready-to-run example programs.

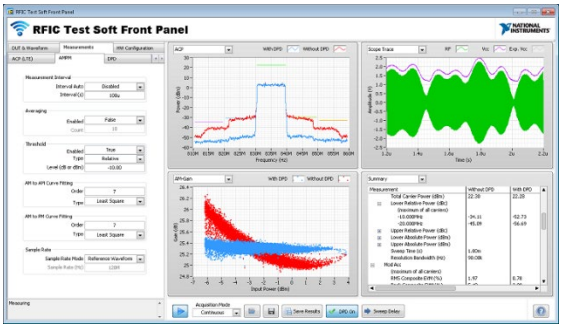
Ready-to-run Sequences

Transition test plans from initial design to automated characterization using TestStand example sequences.

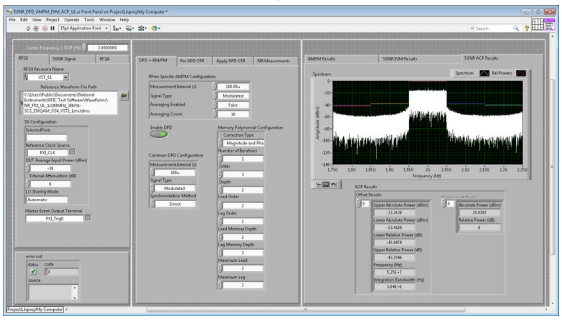
RFFE Validation Reference Architecture – A more streamlined validation workflow:

1. Configure a cost-optimized, modular bench with a combination of DC,AWGs, Scopes, Digital, and RF. Expand your bench later, if your application demands it.

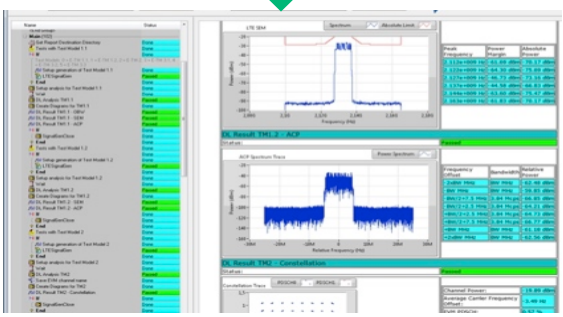
2. Control your bench from the intuitive RFIC Test Software for fast, manual and interactive bring-up of RF Front-ends – No coding necessary.



3. Launch the Test Automation Wizard and instantly create easy-to-read and easy-to-use code modules with NI's RF Reference Design Libraries in LabVIEW and .NET

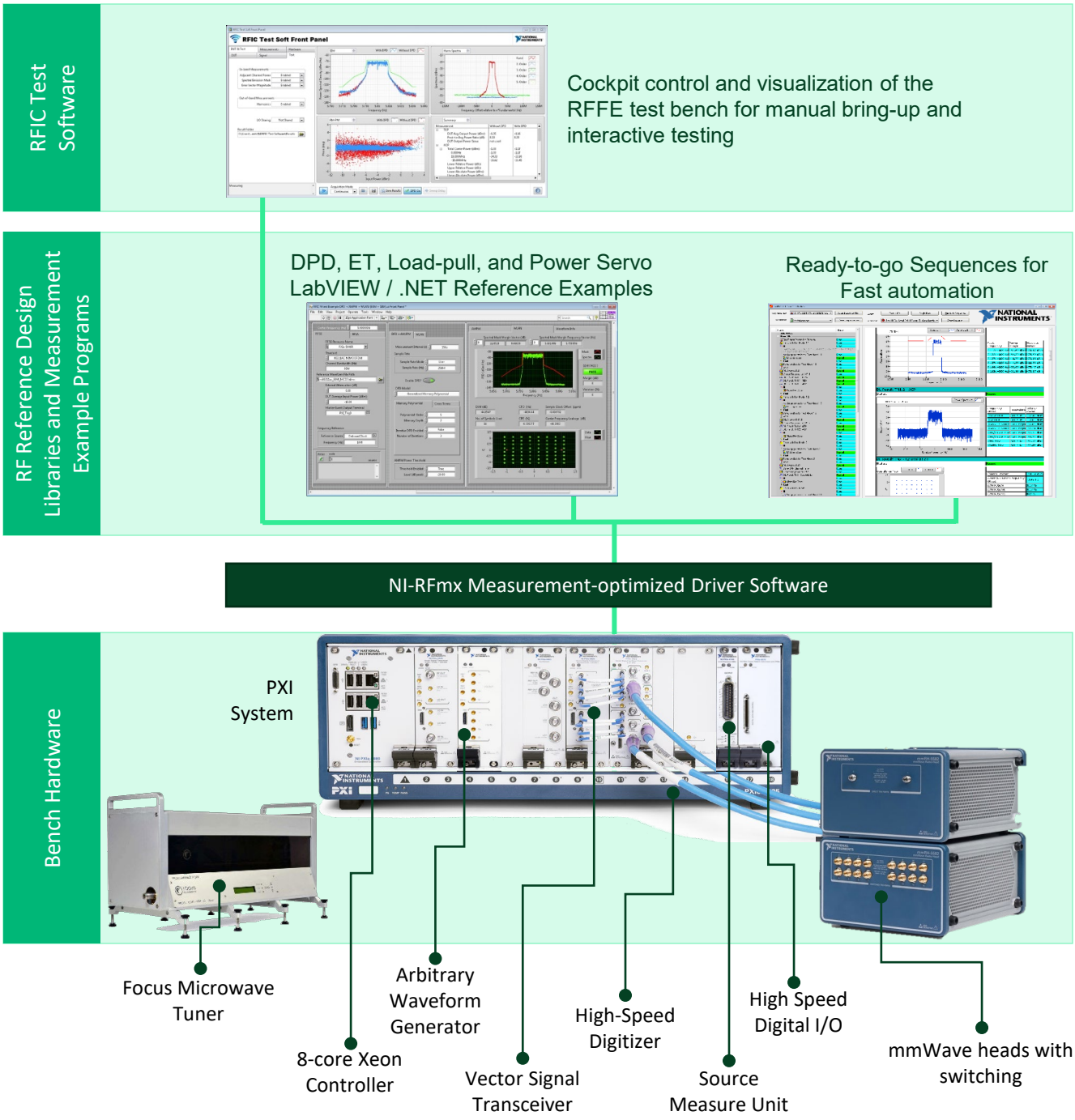


4. Transition to extensive automated characterization with included sample sequences, looping over multiple parameters, and producing valuable results reports.



System Architecture

NI's RFFE Validation reference architecture gives engineers fine control of modular PXI test bench hardware through powerful software.
At the top level, the RFIC Test Software acts as a visualization and control cockpit for fast bring-up and manual interaction with the RF DUT.
Going a level deeper, the RFFE validation reference architecture includes an automation wizard with easy-to-use and easy-to-follow reference design libraries (RDLs) – and an array of code examples in LabVIEW and .NET – to empower engineers to run quick, automated tests on their DUTs.
In addition, the Automation Wizard creates NI TestStand example sequences that use these code modules to automate extensive PA testing and results reporting, looping through multiple nested parameters without having to write complicated test software.



Linearization and DPD Overview

Linearization of wideband RF power amplifiers with digital pre-distortion (DPD) is a popular technique to correct for higher-order non-linearities, minimizing spectral regrowth and improving EVM. The RFFE Validation reference architecture performs all four key DPD operations: characterizing device behavior, model extraction, model inversion, and application of predistortion to baseband IQ samples.

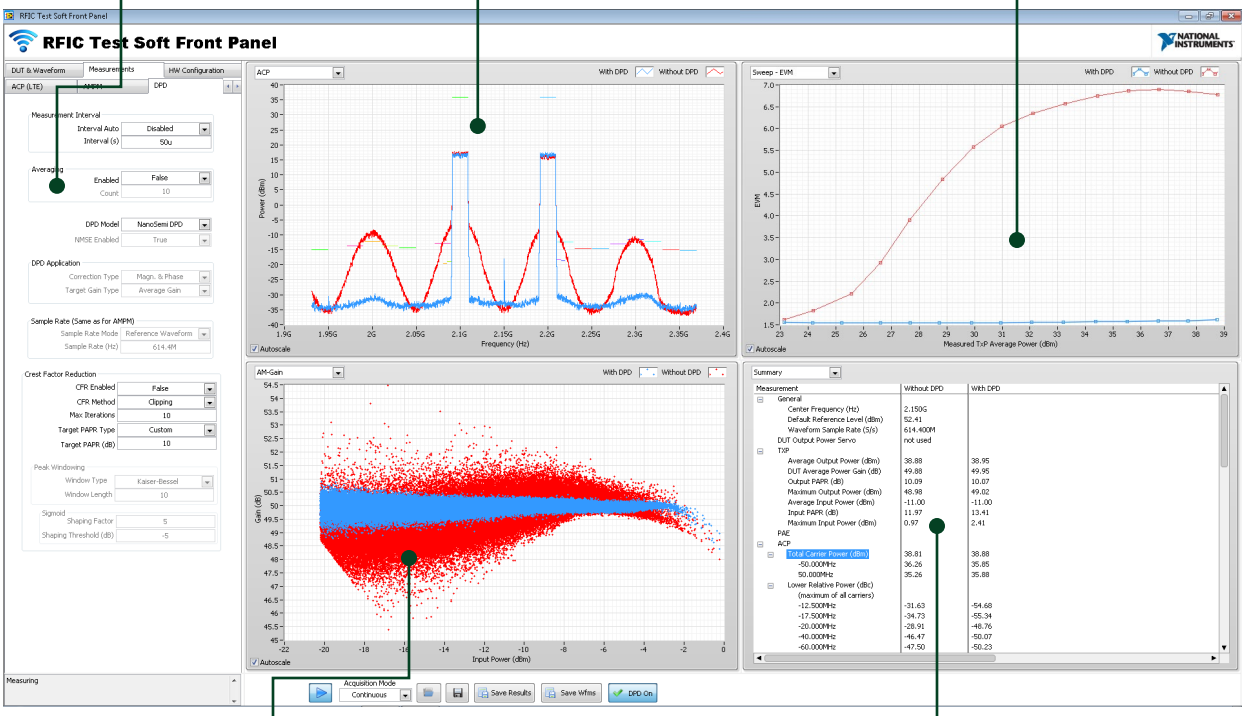
The RFIC Test Software allows you to apply DPD models and observe device behavior interactively. This solution supports both well-known DPD algorithms –lookup table (LUT), Memory Polynomial Model (MPM), and Generalized Memory Polynomial (GMP) – and new, state-of-the-art DPD models, such as custom Matlab algorithms, and Maxlinear's (NanoSemi's) dual-band algorithms.

The included code examples empower engineers to automate device validation with DPD. Because these example programs use the same underlying measurement IP as the RFIC Test Software, users can more readily correlate results from the interactive and automated use cases.

Linearization Algorithms
Select from traditional or new, state-of-the-art linearization implementations

Performance Visualization
Observe single- and dual-band DPD improvements in ACLR and modulation quality in real time

Sweep Results
Configure frequency, power, and load sweeps to characterize DPD performance as conditions change



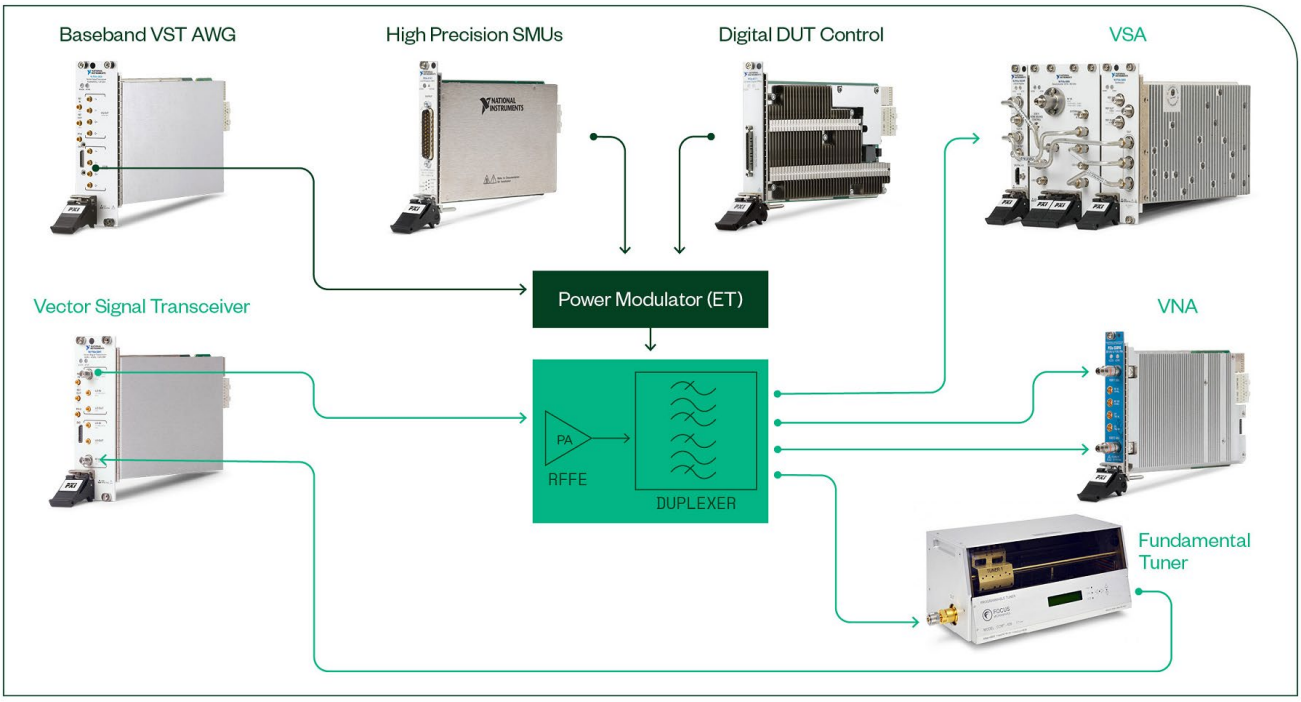
PA Linearity Measurements
Observe Gain, AM-AM and AM-PM response of the PA with and without DPD.

PA Performance Metrics
Live, numerical results as ACLR, EVM, power, PAE and RMS memory to characterize PA performance.

Hardware Configuration

For DPD testing, the RFFE Validation reference architecture combines multiple instruments into a unified measurement experience that controls the NI vector signal transceiver (VST), precision Source Measure Units (SMU), and high-speed digital I/O for DUT control. The VST is a key element of the measurement configuration and combines a wideband RF signal generator and RF signal analyzer into one module. Tight synchronization between RF generator and analyzer enables accurate measurements of gain and AM-AM/PM using modulated waveforms.

The PXI platform takes advantage of the latest multicore processors to speed up processing of mathematically complex DPD algorithms.



DPD Solution Features and Specifications

DPD Models

- NanoSemi single-band and dual-band DPD
- Custom Matlab algorithms
- Memoryless AM-AM/PM LUT
- Memory Polynomial Model
- Generalized Memory Polynomial

Measurements

- AM-AM/PM
- RF Power and Gain
- EVM
- ACLR
- SEM
- RMS Memory (Phase)
- Harmonics
- Power Added Efficiency

Supported Signal Types

- 5G NR: Single carrier and carrier-aggregated signals
- 2G to 4G
- The latest Wi-Fi 6 and legacy Wi-Fi (802.11 a,b,g,n,ac)

Load-Pull Overview

NI has partnered with Focus Microwaves to integrate control of their passive load tuners as part of the RFFE Validation reference architecture. All Focus tuners use extremely efficient calibration and tuning algorithms to produce consistent measurement results sweep after sweep.

Users can interactively adjust and sweep the reflection factor (complex Gamma) of their tuner directly from the RFIC Test Software, as they visualize the performance of the amplifier with the changing impedance.

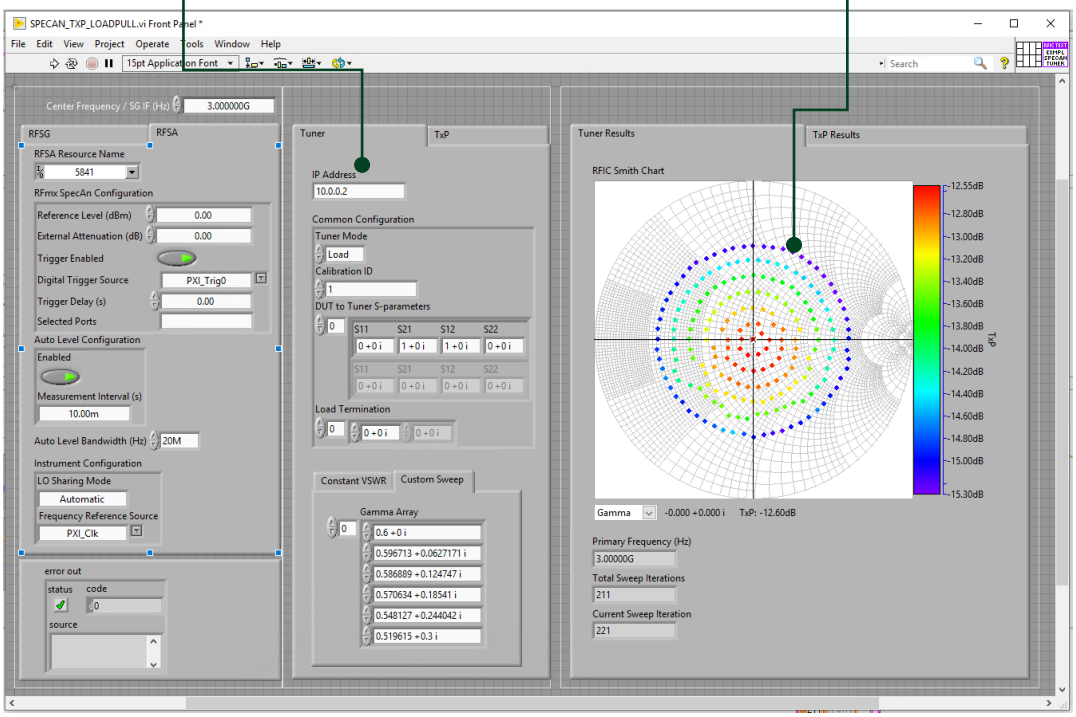
Additionally, users can automate their impedance sweeps and measurements from the code and test sequence examples included with the Automation Wizard.

Sweep Impedance

Configure detailed impedance sweeps to characterize power amplifier performance as conditions change, with and without DPD

Performance Visualization

Observe RF power amplifier performance in real time using CW and wideband signals



Load-pull Solution Features & Specifications

- Scalar, pre-calibrated load pulling for highly repeatable generation of complex reflection factors
- Integrated control of various Focus Microwaves wideband, fundamental, passive tuners via Ethernet (TCP/IP) connection
- Multiple tuner impedance setting modes: motor position, gamma, VSWR
- Smith chart and numerical visualization, and results logging.
- Integration of bench calibration S-parameters

Envelope Tracking Overview

Envelope tracking (ET) for wideband power amplifiers relies on an ET Power Supply (ETPS) to vary the DC power supply dynamically in conjunction with the amplitude of a modulated wireless signal. Envelope tracking keeps a PA near compression as often as possible – thus improving overall efficiency.

For ET testing, the NI RFFE Validation reference architecture transforms multiple instruments into an easy to configure, unified measurement experience that simplifies control and synchronization of the VST, a high-bandwidth arbitrary waveform generator (AWG), and high-speed digitizer.

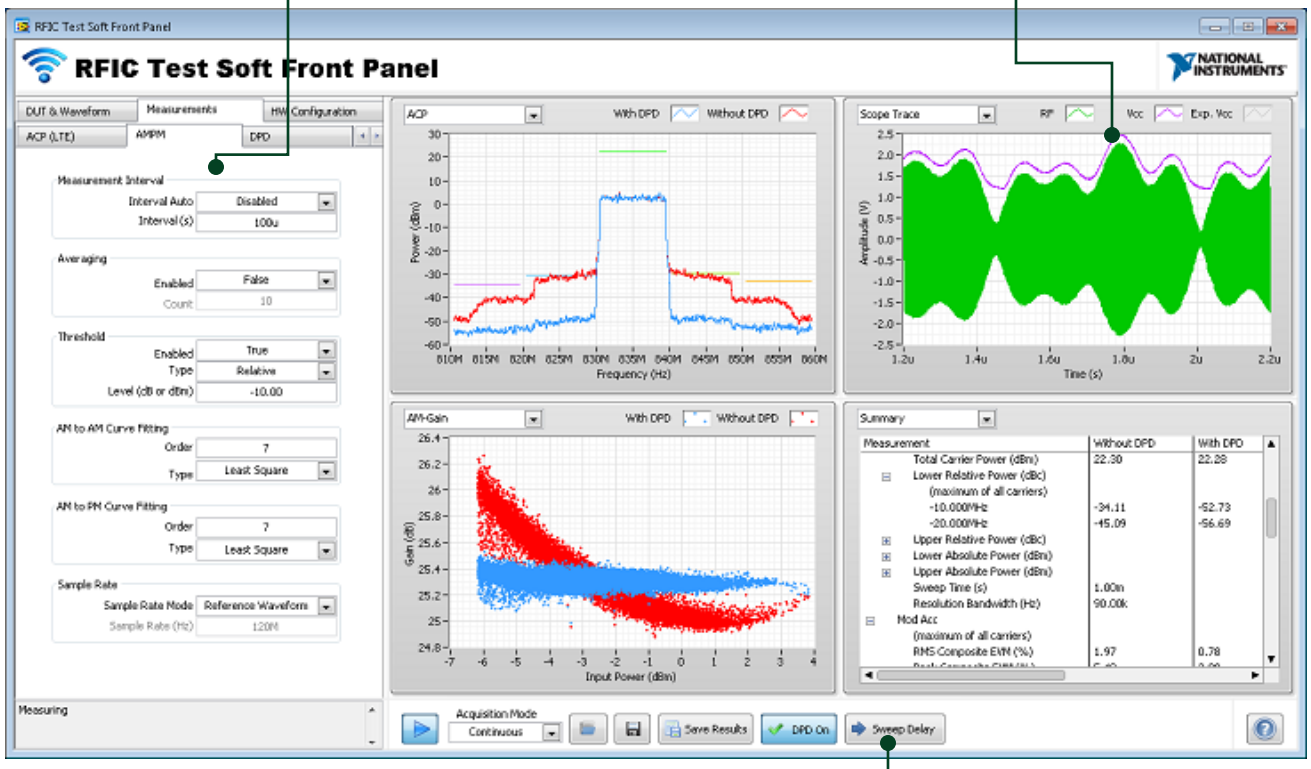
The RFFE validation reference architecture also features LabVIEW and .NET example code and ready-to-run automated test sequences that you can customize for extensive automated validation applications.

Integrated bench control

Simplify configuration of SMUs, AWG, oscilloscope, and RF instrumentation

Envelope control

Apply envelope shaping and real-time control of VSG-to-AWG delay.

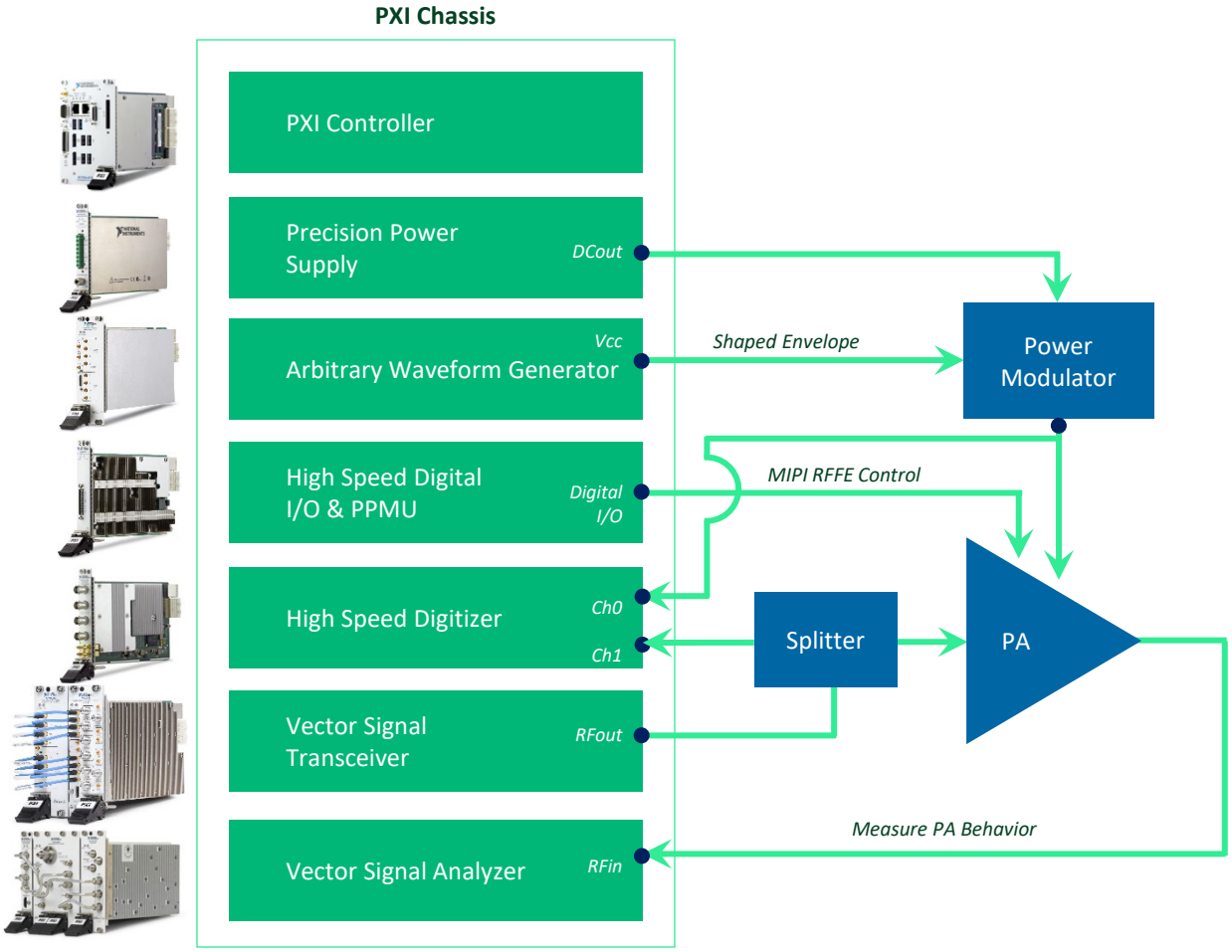


Sweep and adjust delays

Take advantage of sub-nanosecond synchronization between instruments to sweep the envelope delay and find the best timing settings

Envelope Tracking Hardware Configuration

A critical challenge for ET PA Testing is synchronization and stable alignment of RF and Vcc signals supplied by a vector signal generator (VSG) and arbitrary waveform generator (AWG). The RFFE Validation reference architecture is based on NI PXI instrumentation and features shared trigger and timing bus resources. This implementation minimizes synchronization jitter between RF and Vcc signals to less than 20 ps. In addition, by routing timing signals on the PXI backplane, these results are stable and repeatable. The software includes the NI Fast ET Align measurement which rapidly estimates RF and Vcc alignment. Finally, the envelope tracking software can simultaneously apply DPD to the stimulus signal.



Envelope Tracking Solution Features & Specifications

Synchronization

- AWG-to-VSG Jitter: < 20 ps
- AWG-to-VSG skew resolution: 1 ns

Supported Signal Types

- 5G New Radio
- 2G to 4G
- Wi-Fi 6 and legacy Wi-Fi

Accelerated Test Times

The evolution of wideband wireless technologies and multi-mode power amplifiers is increasing the demands on automated validation and characterization of power amplifiers. Combining high-performance modular instruments with fast and reliable measurement software, the RFFE Validation reference architecture delivers accurate RF results with test times that are typically 5 to 10 times faster than traditional instruments.

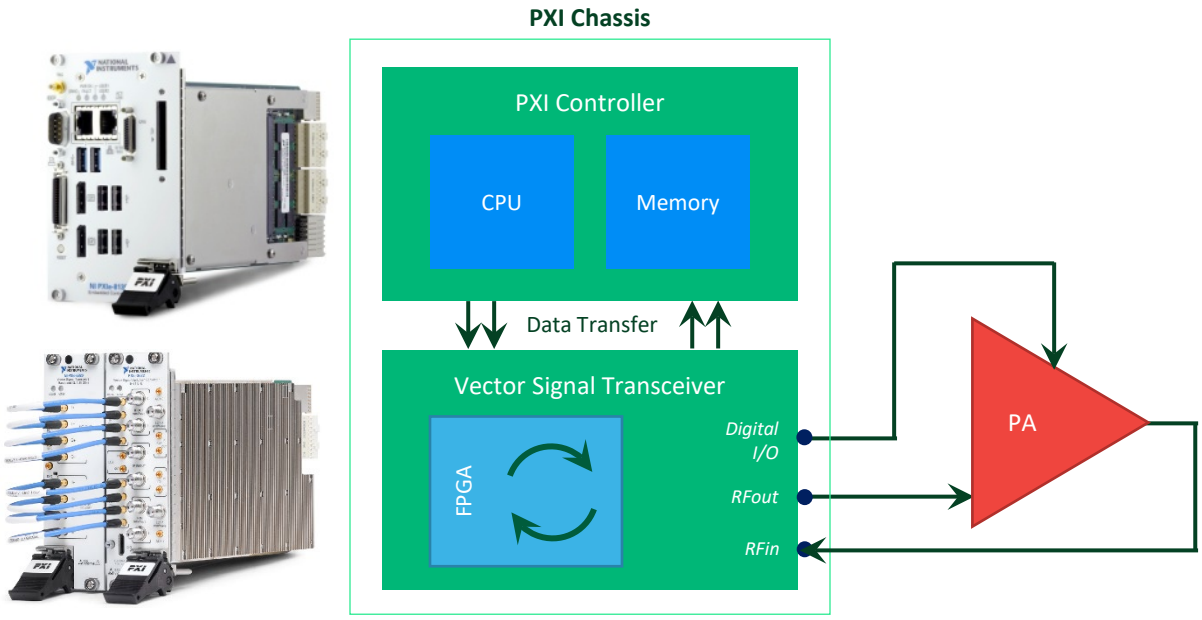
Reliable Path Loss and Fixture Calibration with S-parameters

The RFIC Test Software includes support for S-parameter calibration files, extracting magnitude and phase information to correct for path losses through every cable, fixture, and other signal paths.

Fast Power Level Servo Technology

A unique benefit of the NI RFFE approach is the super-fast FPGA-based power level servo using the NI VST. By performing the control loop entirely on the instrument FPGA, engineers can achieve very fast power level convergence. By decoupling the power level servo algorithm from the embedded controller and performing it on an FPGA, engineers can achieve significant reductions in validation time and cost.

The RFIC Test Software also supports output power servo routines using USB power sensors coupled to the output load. The software automatically reads the power sensor and adjusts the level of the generated waveform to achieve the desired output power set point.



From Characterization to Production Test

The openness and flexibility of the NI RFFE Validation reference architecture empowers engineering teams to transition test systems from the R&D lab to the manufacturing floor, leveraging the initial engineering investment, using the same type of instrumentation and measurement science for production test, and reducing the correlation efforts. NI's combination of fast measurement speed and small physical footprint make it an ideal test solution for high-volume, high-throughput environments.

R&D Test Bench	Device Characterization	Production Test
Quickly validate PA behavior using instrument soft front panels or reference examples.	Automate PA/FEM characterization through easy-to-use example code and sequences	Re-use test equipment and characterization software in manufacturing test.

Deploying PXI in Manufacturing Test

You can deploy PXI for manufacturing test either as a stand-alone system or as part of the NI Semiconductor Test System (STS). The STS combines the NI PXI platform with NI's speed-optimized test software for high test throughput inside a fully enclosed test head suited for production environments.

PXI Chassis and Controller

PXI RF and Modular Instrumentation

NI RFmx Measurement Science and NI TestStand (Test Management)

STS Standardized Docking and Cabling Interface

NI PXI

ATE Core configurations

NI STS T4

The STS enclosure houses all the key components of a production tester including test instruments, device under test (DUT) interfacing, and device handler/prober docking mechanics. With the open, modular STS design, you can take advantage of the latest industry-standard PXI modules for more instrumentation and computing power to lower the overall cost of RFFE production test.

Hardware Specifications

Engineers can specify a modular combination of PXI instruments to complete their NI RFFE Validation reference architecture, going from the most basic, to more comprehensive setups with multiple, synchronized instruments.

Simpler measurements of the most basic RF parameters might require only a PXI chassis, controller, and VST, while other configurations for envelope tracking call for additional instruments like arbitrary waveform generators, scopes, and SMUs.

PXIe-5841 VST Specifications	
Frequency Range	65 MHz – 6 GHz
Bandwidth	1000 MHz
Amplitude Accuracy	+/- 0.25 dB
Maximum Output Power	+20 dBm
Channel flatness	< 0.5 dB
Average Noise Floor	SSB phase noise < -130 dBc/Hz at 2.4 GHz (10 kHz offset)
Wi-Fi 6 EVM (MCS 11)	< -50 dB

Refer to PXIe-5841 Specifications Document for more details

Vector Signal Transceivers

NI's VSTs combine an RF vector signal generator (VSG) and RF vector signal analyzer (VSA) into one module. The combination of wide bandwidth and high-quality RF measurement performance makes the NI VSTs an ideal solution for RF power amplifier testing of sub-6 GHz and mmWave Front-end modules.

NI PXIe-5831 mmWave Vector Signal Transceiver

PXIe-5831 mmWave VST Specifications	
Frequency Range	24 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
Switched ports	(8+1) or (8+8)

Refer to PXIe-5831 Specifications Document for more details

Hardware Specifications (Continued)

NI PXIe-5668R Vector Signal Transceiver

PXIe-5668 Specifications	
Frequency Range	20 Hz – 26.5 GHz
Bandwidth	Up to 765 MHz
Phase Noise, Typ	-129 dBm/Hz (1GHz)
Amplitude Accuracy	+/- 0.25 dB
Average Noise Floor	-167 dBM/Hz (1 GHz) with pre-amp
Tuning Speed	3 ms (1 GHz step)
Third Order Intercept	+25 dBm (1 GHz)

Refer to PXIe-5668R Specifications Document for more details

PXIe-5820 Arbitrary Waveform Generator Specifications	
Max Sample Rate	1.25 GS/s
Bandwidth	1 GHz
Common-mode accuracy	±2mV

PXIe-4147 Precision Source Measure Unit Specifications	
No. Channels	4
Max Continuous Power	±8V, 3A, 24 W
Transient Response	< 50 µs

Hardware Specifications (Continued)

PXIe-5162 10-Bit Digitizer Specifications	
Max Sample Rate	5 GS/s
Bandwidth (3 dB)	1.5 GHz
Max Channels	4

PXIe-6571 High Speed Digital Specifications	
Data Rate	200 Mb/s
Pattern Timing	39.0625 ps placement
Voltage Ranges	-2 V to 7 V

PXIe-1095 Chassis Specifications	
PXI Express Slots	18
Total System Bandwidth	24 GB/s
Total Power Rating	1644 W (dual supply)

PXIe-8880 Embedded Controller Specifications	
Processor	Xeon Octal Core
CPU Clock Rate	2.3 GHz
Memory	Up to 24 GB

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.