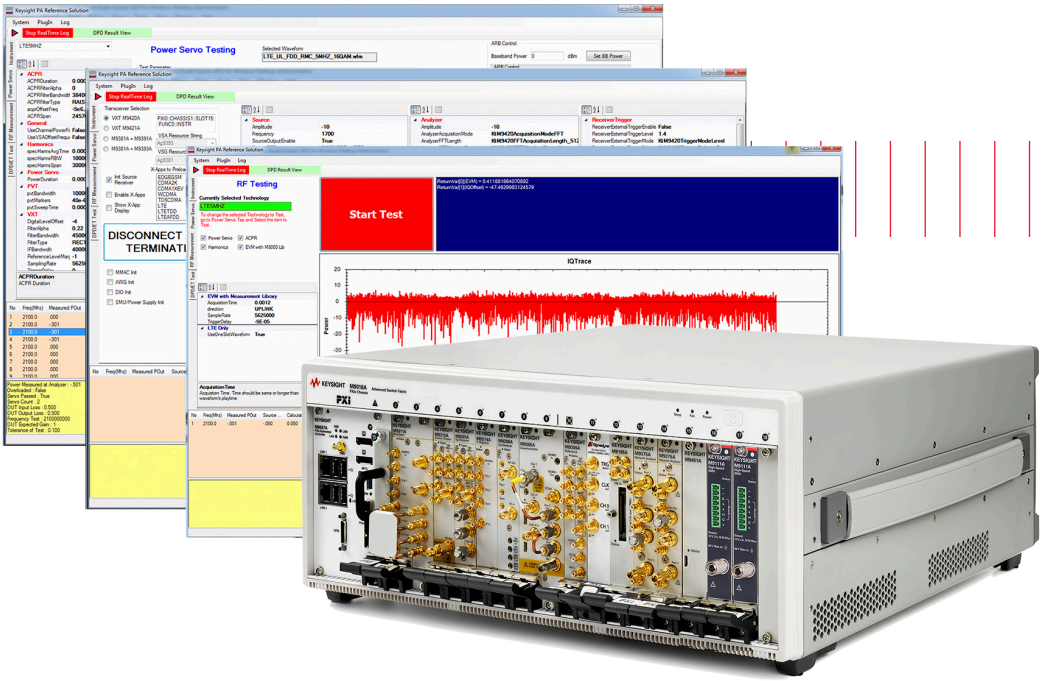
Keysight Technologies
RF PA/FEM Characterization & Test, Reference Solution

Solution Brochure



KEYSIGHT TECHNOLOGIES

Unlocking Measurement Insights

This Reference Solution provides high throughput, measurement quality, and performance for design validation and production test of next generation power amplifiers/front end modules (PA/FEM) supporting cellular and wireless connectivity formats.

Next generation RF PA/FEM characterization and test challenges

Wireless mobile device manufacturers continue to look for ways to drive down cost while improving performance of their devices. To support this trend, power amplifier duplex (PAD) devices are an increasingly popular alternative to the more traditional PA architecture. These smaller, highly integrated devices allow designers to optimize space by replacing multiple, discrete components with a single, compact module while lowering power consumption and increasing performance.

With device complexity and performance requirements increasing, the amount and type of testing continues to grow while price pressures simultaneously drive the need for higher throughput.

Testing next generation RF PAs brings new challenges:

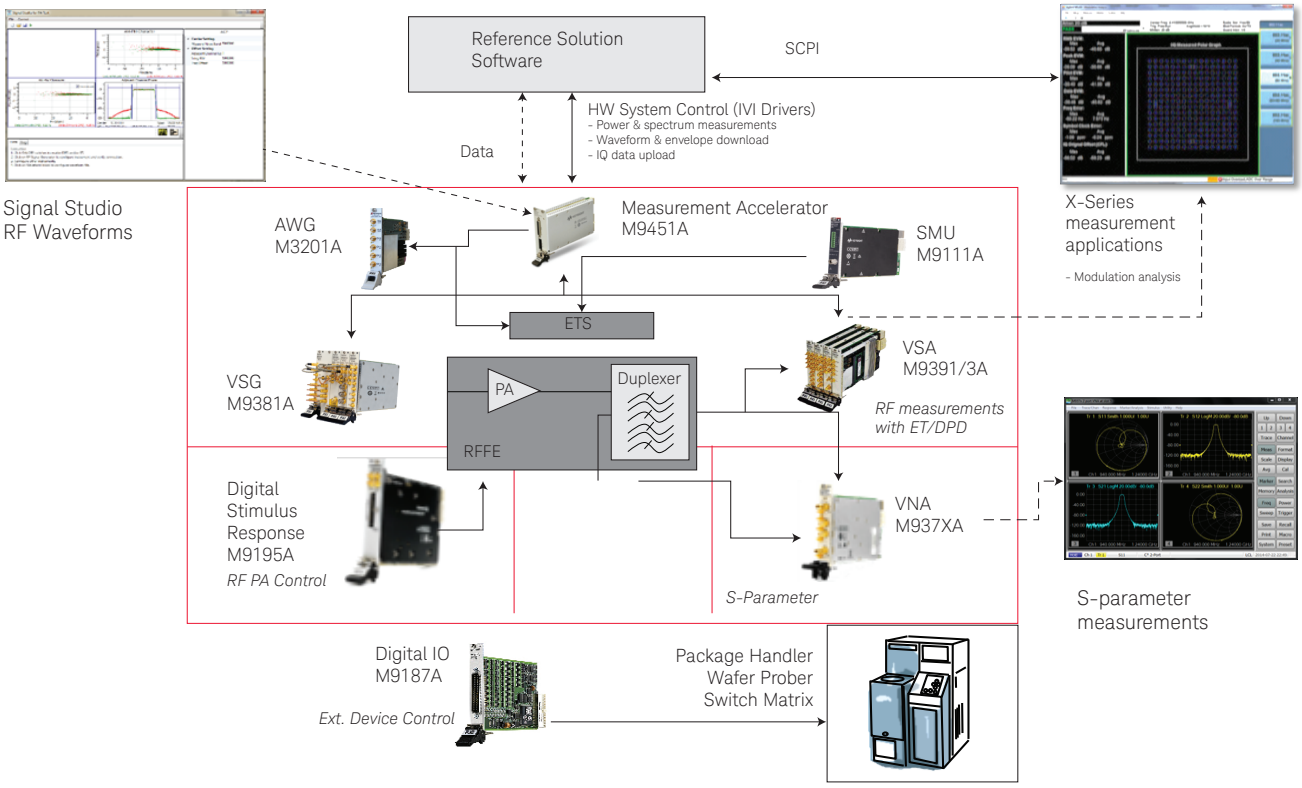
- Passive components integrated onto PAD-type devices must be tested in addition to the PA
- Envelope tracking and digital pre-distortion to overcome efficiency issues caused by high peak-to-average ratio modulation formats
- Higher number of bands and modulation formats requiring additional test conditions

Using a Reference Solution to address PA/FEM test challenges

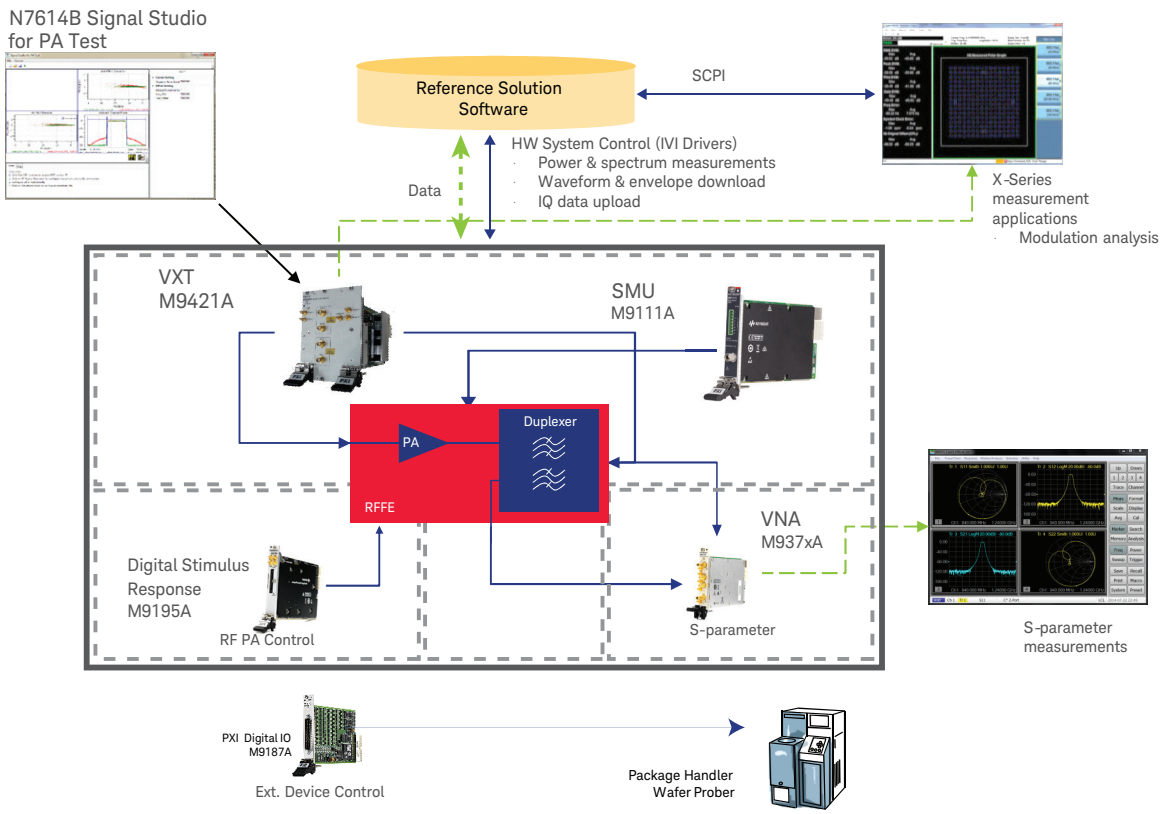
RF PA/FEM characterization and test, Reference Solution enables rapid, full characterization of next-generation power amplifier modules such as PAD devices, including S-parameter, demodulation, power, adjacent channel power and harmonic distortion measurements. Digital pre-distortion (DPD) and envelope tracking signal generation and analysis are enabled by Keysight's N7614B Signal Studio for Power Amplifier Test software. Closed/open loop DPD and envelope tracking measurements can be made in tens of milliseconds with the M9451A PXIe measurement accelerator. The Reference Solution control software enables tight synchronization between the signal source and the arbitrary waveform generator (AWG), resulting in optimal alignment between input signal and envelope.

To facilitate evaluation and integration into your test environment, you can use supplied test code examples that have been designed to optimize test throughput without compromising performance.

Reference Solution Architecture for Design Validation Test



Reference Solution Architecture for Production Test



Hardware - Solution Features & Benefits

Feature	Benefit
Integration with N7614B Signal Studio for PA Test	Automated DPD & ET for fast design and characterization (with M9381A, M9391A or M9393A)
High performance VSA	Wide dynamic range and frequency coverage for harmonic distortion (only with M9393A)
Vector transceiver VXT	Combined VSG and VSA in a single, 4-slot PXIe module
Real-time signal processing	Fast measurements
Adjustable RF signal/ envelope skew to ± 1 ps resolution over 250 ns range	Tight synchronization between RF signal and envelope
X-series measurement applications for modular instrument	Measurement correlation to bench top instruments
High-speed source/measure unit	Stable, glitch-free sourcing, sinking, and high accuracy measurements with PXIe module
True multiport VNA with N-port correction capability	No degradation in performance (i.e. dynamic range, trace noise, directivity, stability)
Solution measurement speed	
EVM measurement speed	< 20 ms, nominal for LTE 10 MHz BW
ACPR measurement speed	0 ms, after a power servo loop
Servo loop time	< 3 ms, nominal
DPD model extraction and application speed with M9451A PXIe measurement acceleration module	< 70 ms, nominal for LTE 20 MHz BW
Tuning speed	150 us, nominal
Full 2-port S-parameter measurement speed	28-33 msec across 401 points

Hardware - Key Specifications & Characteristics

M9381A PXIe Vector Signal Generator	
Frequency range	1 MHz to 3, 6 GHz
Modulation bandwidth	Up to 160 MHz
Output power	+20 dBm
M9391A PXIe Vector Signal Analyzer	
Frequency range	1 MHz to 3, 6 GHz
Analysis bandwidth	Up to 160 MHz
Absolute amplitude accuracy	± 0.45 dB, typical
M9393A PXIe Performance Vector Signal Analyzer	
Frequency range	9 kHz to 8.4, 14, 18, 27 GHz
Analysis bandwidth	Up to 160 MHz
Absolute amplitude accuracy	± 0.15 dB, nominal
M9420A/M9421A PXIe VXT Vector Transceiver	
Frequency range	60 MHz to 3.8 or 6 GHz
Modulation and analysis bandwidth	Up to 160 MHz
Output power	Up to +20 dBm
Absolute amplitude accuracy	± 0.20 dB typical
M3201A PXIe Arbitrary Waveform Generator	
Real-time bandwidth	200 MHz
Maximum sample rate	500 MSPS per channel
M937xA PXIe Vector Network Analyzer	
Frequency range	300 kHz to 4, 6.5, 9, 14, 20, 26.5 GHz
Dynamic range	≥ 122 dBrms, typical (IFBW = 10 Hz)
Trace noise	< 0.001 dB, typical (IFBW = 1 kHz)
M9485A PXIe Multiport Vector Network Analyzer	
Frequency range	1 MHz to 9 GHz
Dynamic range	≥ 142 dB, typical (standard test set, IFBW = 10 Hz)
Trace noise	< 0.001 dBrms, typical (IFBW = 10 kHz)
M9195A Digital Stimulus and Response with PMU	
Per pin functionality	Logic level, edge placement, delay, PMU, timing
Max pattern and DUT clock rate	250 MHz
Site (test sequences) per module	1 or 4, selectable
M9451A-DPD Measurement Accelerator with Digital Pre-Distortion & Envelope Tracking Gateware	
Bus interface and compatibility	PXI Express peripheral module (x1, x4, x8 PCIe® specification v2.1)
FPGA	Altera Stratix V A7 (5SGXMA7K3F40C2)
Memory	4 GB DDR3 memory – 2 independent DDR3 banks@ 1200 MT/s, 600 MHz each
M9111A PXIe High-Speed Source/Measure Unit	
Measurement accuracy:	
Current, 3 A range	0.05% + 300 uA
Current, 1 mA range	0.05% + 100 nA
Current, 100 uA range	0.05% + 10 nA
Voltage, 13 V and 6 V ranges	0.05% + 1 mV

Hardware – Instruments

M9381A PXIe Vector Signal Generator

www.keysight.com/find/m9381a

Designed for fast data interfaces and high-speed automated test systems, the M9381A generates RF signals up to 6 GHz with 160 MHz bandwidth. The M9381A is compatible with the full range of Signal Studio communications applications. A typical M9381A configuration includes 4 individual PXIe modules – M9311A digital vector modulator, M9310A source output, M9301A synthesizer and M9300A frequency reference (may be shared with other signal generators and analyzers in the same chassis).

M9391A PXIe Vector Signal Analyzer, 1 MHz to 6 GHz
M9393A PXIe Vector Signal Analyzer, 9 kHz to 8.4/14/18/27 GHz

www.keysight.com/find/m9391a
www.keysight.com/find/m9393a

Designed for fast power and demodulation measurements in high-speed automated test systems, the M9391A and M9393A analyze signals with 160 MHz bandwidth. Perform power measurements quickly with real-time signal processing and analyze harmonic distortion. The M9391A and M9393A are compatible with the full range of X-Series Measurement Applications for signal analysis. A typical M9391A configuration includes 4 individual PXIe modules: M9301A synthesizer, M9214A digitizer, M9350A downconverter and M9300A frequency reference. A typical M9393A configuration includes: 4 individual PXIe modules – M9308A synthesizer, M9214A digitizer, M9365A downconverter and M9300A frequency reference. The M9300A may be shared with other signal generators and analyzers in the same chassis.

M9420A, M9421A PXIe Vector Transceiver (VXT), 60 Mhz to 6 GHz

www.keysight.com/find/vxt

The M9420A and M9421A PXIe VXT vector transceiver are purpose-built for rapid solution creation and faster throughput in manufacturing test of wireless components and IoT devices. The module combines both vector signal generation and signal analysis with frequency range from 60 MHz to 6 GHz and bandwidth up to 160 MHz in only four PXIe slots With FPGA-accelerated measurements and deep software, the ready-to-run VXT lets you start closer to your finish line. Additionally, a comprehensive self-calibration routine enables extremely accurate, repeatable results on the VXT. This results in tighter test margins and better pass/fail results.

The M9420A addresses manufacturing test of a broad range of wireless components and devices. New to the VXT family, the M9421A is optimized for PA/FEM test, offering improved EVM measurements for WLAN PAs and noise figure measurements for LNA-integrated FEMs, when used with the N9069A X-Series measurement application for noise figure.

M9195A PXIe Digital Stimulus/Response

www.keysight.com/find/m9195a

Designed for IC design validation and production test environments, the M9195A can easily emulate standard serial interfaces like the MIPI™ RF front-dnd interface for DUT (PA) control. The 16-channel, single slot PXI module utilizes a high performance pattern cyclizer for powerful pattern creation and per-vector timing changes. It supports multiple drive edges per cycle for flexible edge placement. It can also support up to four independent multi-sites for quick test development with multiple test fixtures. Software tools included with the M9195A allow the user to modify vector and pattern parameters without requiring the user to recompile and download tests. It includes ATE features such as: deep vector memory, per pin programming of voltage levels, real time compare, parametric measurement unit (PMU), response delay cable compensation, and a high speed pattern application rate up to 250 MHz.

M9451A-DPD PXIe Measurement Accelerator with Digital Pre-Distortion & Envelope Tracking Gateway

www.keysight.com/find/m9451a

With the M9451A-DPD, closed/open loop digital pre-distortion (DPD) and envelope tracking (ET) measurements can be made in tens of milliseconds, reducing overall test time to <100 msec. The measurement accelerator module uses an Altera Stratix V "A7" FPGA with 4 GB DDR3 memory and trusted DPD/ET algorithms built on years of close cooperation with leading wireless manufacturing customers. Peer to peer connectivity with the M9381A PXIe Vector Signal Generator, M9391A PXIe Vector Signal Analyzer, and M9393A PXIe Performance Vector Signal Analyzer, achieves fast PA/FEM test times without sacrificing performance.

M9111A PXIe High-Speed Source/Measure Unit (SMU)

www.keysight.com/find/m9111a

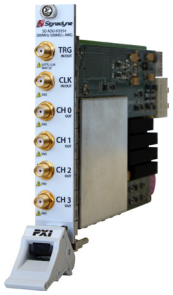
The M9111A is a 1-slot, 2-quadrant PXIe SMU that combines the capabilities of a voltage source, a current source, an ammeter and a voltmeter to provide stable, glitch-free sourcing, sinking, and high accuracy measurements. With output ratings up to 13 V, ±1 A (or up to 6 V, ±3 A, 18 W), the SMU also provides up to 20X faster than previous generation Keysight SMUs. By offering superior transient performance, the SMU dramatically reduces the transient voltage drop due to pulsed loading and recovers quickly to its program voltage.

N6700B Mainframe and N6782A Source/Measure Unit (SMU)

www.keysight.com/find/n6700b

For PA/FEM measurements that require the DC power synchronized with the PA's burst signal, the N6782A 2-quadrant SMU with the N6700B system mainframe is the solution. Designed for glitch-free operation the N6782A with the N6700B ensures safe usage with the DUT during output and measurement range changes, even with capacitances of up to 150 uF. The N6700B is a 1U high modular power mainframe that accepts the N6782A SMU designed for precision sourcing and measurement.

M3201A PXIe Arbitrary Waveform Generator [1]



Designed for high-speed waveform generation, the single-slot M3201A enables fast envelope generation for use in high-speed automated test applications. Combine with the M9381A PXIe Vector Signal Generator for synchronized RF and envelope signals. Adjust synchronization at 1 ps resolution.

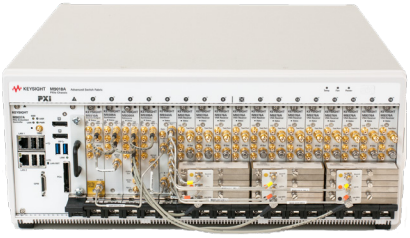
M937XA PXIe Vector Network Analyzer, 300 kHz to 4/6.5/9/14/20/26.5 GHz

www.keysight.com/find/pxivna

Designed for fast S-parameter measurements in high-speed automated test systems, the M937XA series analyzes signals up to 26.5 GHz. This single-slot, full 2-port VNA enables multiport/multi-site capability in a very small package. Excellent total performance including the dynamic rage of typically 122 dB ensures reliable testing of general multiport devices. Easily add or subtract VNA modules based on the needs of your test station. The full N-port correction capability allows for complete and accurate characterization of multiport devices.

M9485A PXIe Multiport Vector Network Analyzer, 1 MHz to 9 GHz

www.keysight.com/find/pxivna



The M9485A is the high-performance PXIe multiport network analyzer that provides unparalleled speed and performance for S-parameter measurements of multiport devices. An extremely wide dynamic range of typically 142 dB enables fast testing of FEMs with high-rejection SAW/BAW filters. The full N-port correction capability allows for complete and accurate characterization of multiport devices. The M9485A multiport network analyzer consists of the source modules, the distributor module, the receiver modules (1 slot/port), and other accessories. You can configure up to 12 ports with one chassis, and up to 24 ports with two chassis.

1. Previously the Signadyne AWG-H3353. For more information, visit http://www.signadyne.com/en/products/hardware/generators-digitizers/awgs/sd-awg-h3353--arbitrary-waveform-generator

Software

Common application software, usable with both modular and benchtop instruments, provides users with the same measurement routines, user interfaces and programming models on both benchtop and modular solutions. The RF PA/FEM Characterization & Test, Reference Solution includes measurement applications that can be used with benchtop and modular instruments: Signal Studio for signal creation, X-Series measurement applications for demodulation and PNA-X-based software for S-parameter measurements

Software – Signal creation

The RF PA/FEM characterization and test, Reference Solution enables multiple ways to create the RF signal. A range of standard waveforms generated with the Keysight Signal Studio software applications are included for demonstration. The Reference Solution software and the M9381A PXIe VSG or M9420A PXIe VXT programming interface supports importing customer supplied waveforms, as well.

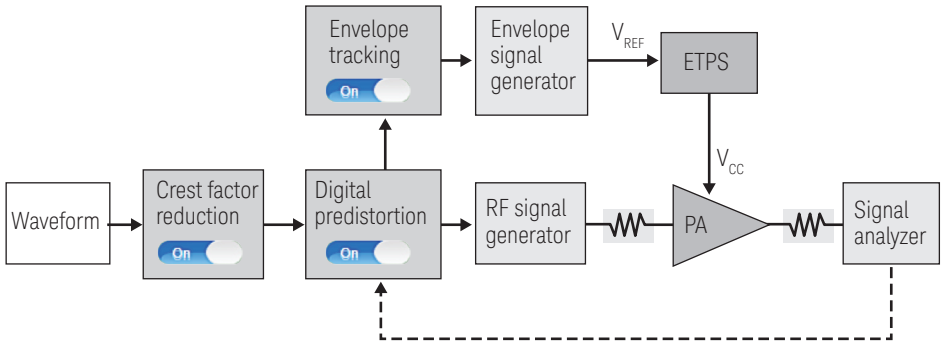
Signal Studio

Keysight Signal Studio software is a flexible test suite of signal-creation and measurement tools that will reduce the time you spend on signal simulation.

Signal Studio's basic capabilities use waveform playback mode to create and customize waveform files needed to test components and transmitters.

With the N7614B power amplifier test software, Signal Studio's performance-optimized test flow – validated by Keysight – enhances the characterization and verification of your devices.

Crest factor reduction, envelope tracking and digital pre-distortion, the three main PA test methods that have been introduced, are undergoing research aimed at achieving these goals. All of these methods are supported by the N7614B Signal Studio for power amplifier test software.



Signal Studio's ET and DPD test flow allows the envelope calculation to be performed using a non-pre-distorted signal, a pre-distorted DPD signal, or an user-specified envelope waveform

Waveform Creator

The M9099A Waveform Creator is a powerful software application for creating more complex signal creations. The M9099 enables easy development and re-use of complex baseband and vector signals used to validate and test digital communications products. Its "drag and drop" graphical user interface allows quick development of multi-format, multi-track waveforms with waveform segments displayed in frequency and time.

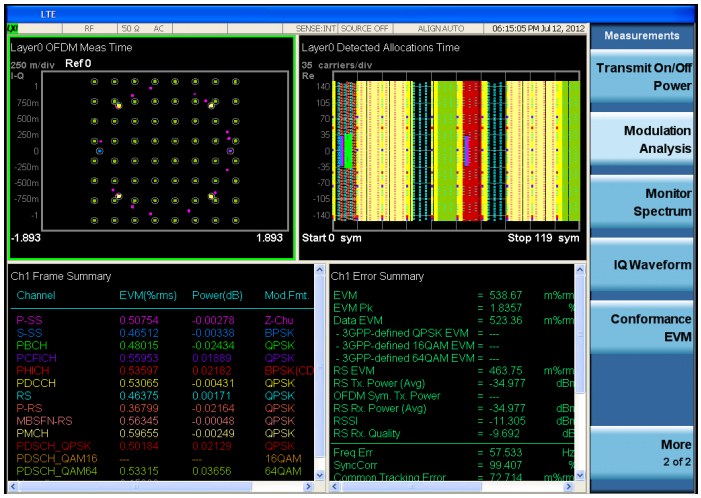
Software – Signal Analysis

X-Series measurements applications for modular instruments

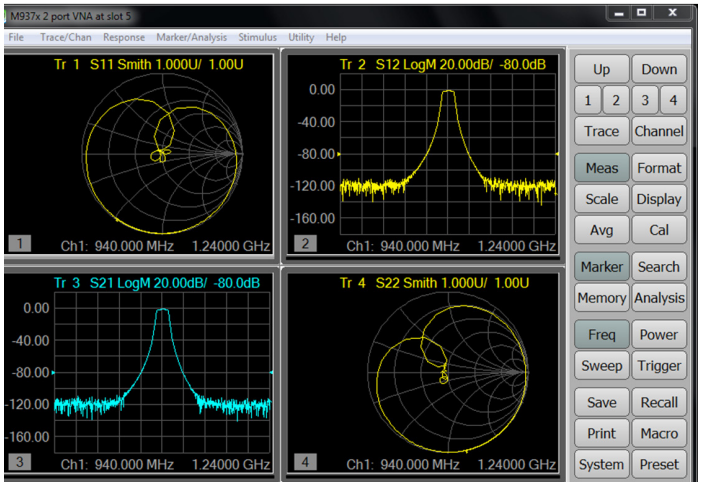
The X-Series measurement applications for modular instruments transform PXI vector signal analyzers into standards-based RF transmitter testers. Fast RF conformance measurements help you evaluate and manufacture your devices and equipment.

S-parameter measurements

The PXI VNA extends Keysight's expertise in measurement and metrology into the modular PXI form factor. It provides the same quality results you have come to expect in our benchtop VNAs. The graphical user interface guides test engineers using a similar look and feel as Keysight's popular PNA family of network analyzers.



X-Series measurement applications for modular instruments



S-parameter measurements using PXI VNA

Software – Test Automation

This Reference Solution includes a C# test code example that optimizes speed without compromising performance and repeatability. To accelerate test development and facilitate the integration in your test environment, the source code of the test automation software is also provided.

Instrument control

Power amplifier measurement libraries

The power amplifier measurement libraries include the main functions to interface with the test instruments and the PA control through the MIPI RFFE interface. Hardware controls are provided to optimize test time and synchronization.

The primary function of the power amplifier measurement library is to use the IVI drivers for the PXI instruments and VNA measurement application; and the SCPI interface for the X-Series measurement applications to setup and make the required measurements for testing of power amplifiers (PA) and front end modules (FEM). This library includes PA test functions that leverage from the PXI VSA's or VXT's high speed embedded measurement capabilities. For example, the same embedded FFT measurements can be used for both servo loops and ACPR, reducing test times.

Test functions include: Load waveforms, power servo loops, Pout, harmonics and ACPR measurements, modulation analysis and S-parameters.

Digital pre-distortion and envelope tracking

Examples are provided that use the programming API to the N7614B Signal Studio for PA Test application as a signal generation and analysis library while using the IVI drivers to control the PXI VSG, VSA and AWG. These examples include:

- Generating and loading IQ and envelope waveforms generated from N7614B into the PXI VSG and AWG
- Capturing IQ data from the PA output with the VSA and then using this IQ data to perform the digital pre-distortion model extraction with N7614B
- Performing AM/AM and AM/PM analysis from N7614B using the IQ data captured from the PA output, as well as ACPR, efficiency and modulation analysis measurements with the pre-distorted waveforms applied to the PA input.

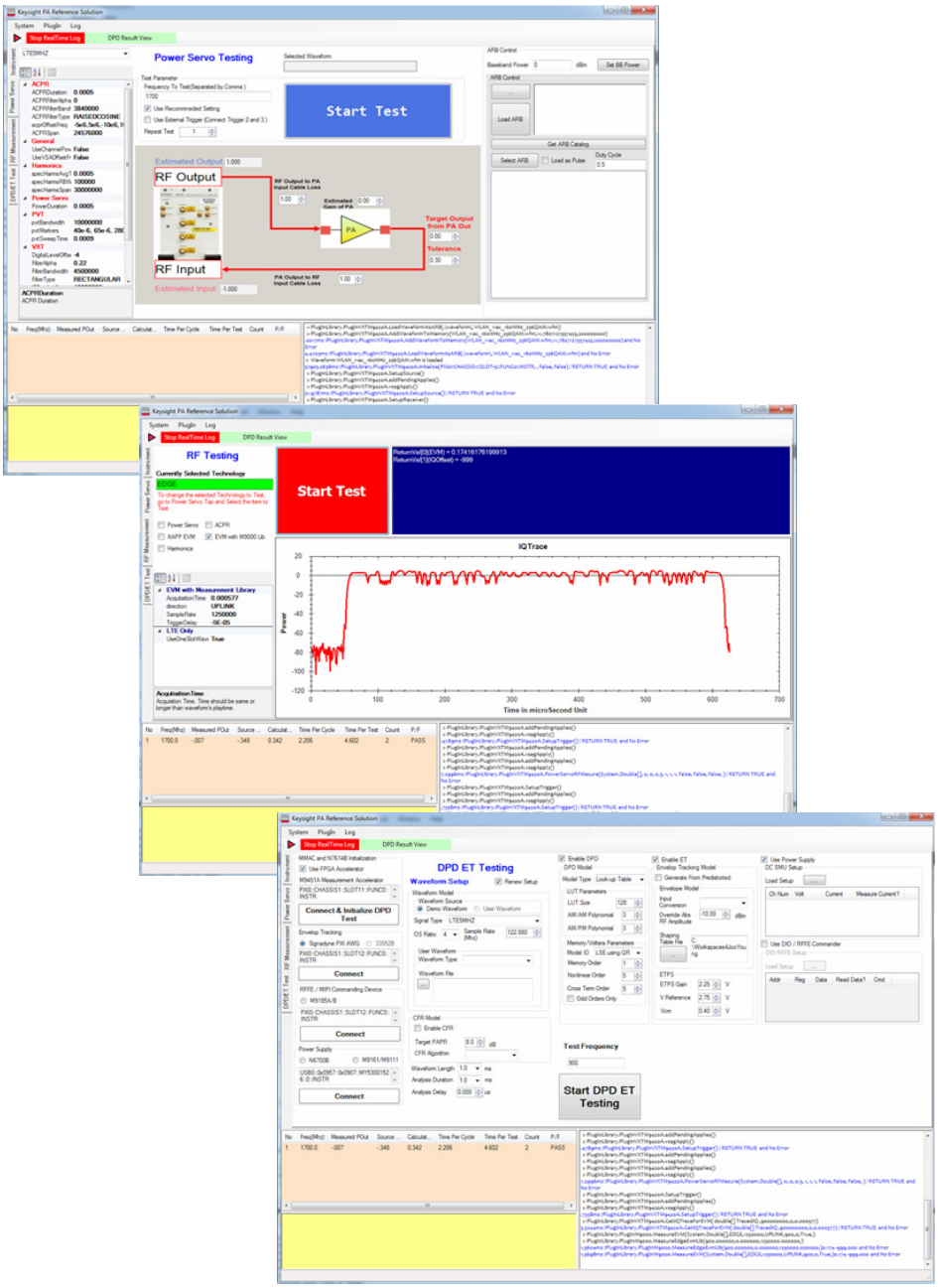
Test program examples

Included in this Reference Solution are test program examples for standards, including W-CDMA, LTE (5, 10, and 20 MHz), GSM, 1xEV-DO, WLAN. These examples leverage from the PA measurement library as well as X-Series measurement applications.

Measurements include EVM, ACPR, SEM, power, harmonics, and S-parameters, as well as data logging and test times as shown in the figures below. It also includes dynamic EVM measurements for WLAN applications. The new PA reference demo program revision 4.0 includes example source codes that enable improved EVM measurement speed by using the new measurement libraries.

Demonstration and evaluation GUI

To help you quickly and easily evaluate this Reference Solution, a demo program integrates all the features described in this brochure. Configure the GUI to test your own devices without writing software.



Test program – instruments and measurements supported

Instruments supported
M9381A VSG + M9391A VSA
M9381A VSG + M9393A VSA
M9420A or M9421A VXT
M9195A DSR
M9451A Accelerator
M3201A AWG
M937xA VNA or M9485A Multiport VNA
M9111A or N6700 SMU
Measurements supported
Power servo (including ACPR and harmonics)
EVM
SEM
PvT
DPD / ET (with M9381A VSG + M9391A/93A VSA)
S-parameter (with M937xA or M9485A VNA)
DC current

Support

Support		
Core exchange program	Keysight's replacement core exchange program allows fast and easy module repairs. A replacement core assembly is a fully functioning pre-calibrated module replacement that is updated with the defective module serial number, allowing the replacement module to retain the original serial number.	For qualified self-maintainers in US only
Self-test utility	A self-test utility runs a set of internal tests which verifies the health of the modules and reports their status.	Included in base configuration

Recommended reference solution configuration for design validation test [1]

Model	Description
M9381A	PXIe vector signal generator
M9381A-F06	1 MHz – 6 GHz frequency range
M9381A-B10	100 MHz modulation bandwidth
M9381A-M01	32 MSa memory
M9381A-UNZ	Fast switching
M9393A	PXIe vector signal analyzer
M9393A-F08	9 kHz – 8.4 GHz
M9393A-B10	100 MHz analysis bandwidth
M9393A-M01	128 MSa memory
M9393A-UNZ	Fast tuning
M9300A	PXIe frequency reference
M9195A	PXIe digital stimulus/response with PMU
M9451A	PXIe measurement accelerator
M9451A-DPD	PXIe measurement accelerator with digital pre-distortion and envelope tracking gateware
M3201A	PXIe arbitrary waveform generator, 500 MSPS, 16 bits
M3201A-CH2	Two channels
M3201A-CLV	Variable sampling clock
M3201A-M20	Memory 2 GB, 1 GSamples
M9111A	PXIe high-speed source/measure unit
U2004A	USB power sensor
PXIe Chassis and Controllers	
M9018A	PXIe 18-slot chassis
M9037A	PXIe embedded controller
Application Software	
M907x/8x	X-Series measurement application for modular instruments
N76xx	Signal Studio
N7614B	Signal Studio for Power Amplifier Test (for DPD and ET)

Recommended reference solution configuration for production test [1]

Model	Description
M9421A	PXIe vector transceiver
M9421A-506	60 MHz to 6 GHz frequency range
M9421A-B1X	160 MHz modulation bandwidth
M9421A-1EA	High output power
M9421A-M05	512 MSa memory
M9300A	PXIe frequency reference
M9195A	PXIe digital stimulus/response with PMU
M9111A	PXIe high-speed source/measure unit
U2004A	USB power sensor
PXIe Chassis and Controllers	
M9018A	PXIe 18-slot chassis
M9037A	PXIe embedded controller
Application Software	
N907x/8x	X-Series measurement applications
N7650B	Signal Studio waveform licenses

1. For a more complete set of configuration options, please refer to the *RF PA/FEM Characterization and Test, Reference Solution* configuration guide, literature number 5992-0072EN

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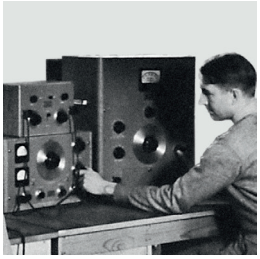

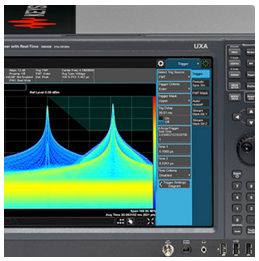

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Published in USA, December 1, 2017
5992-0071EN
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