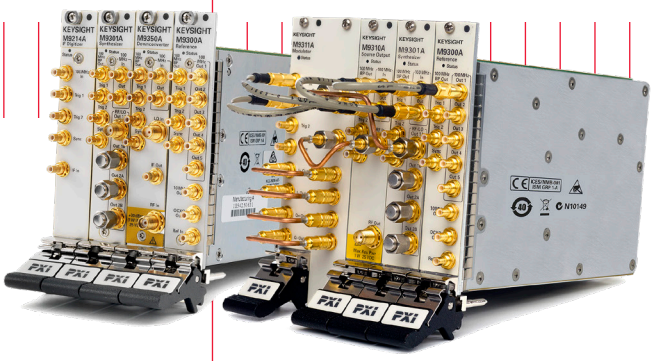
Keysight Technologies

Increase Power Amplifier Test Throughput with PXIe Vector Signal Analyzers, Vector Signal Generator and Vector Transceiver

Application Note



Accelerate power amplifier test throughput and high speed harmonic testing to achieve cost reductions, while maintaining high test quality.

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Introduction

Power amplifier designs for mobile handsets are becoming more complex, which directly impacts test demands and the cost of test. Complexity increases with the introduction of new, wider bandwidth standards and the increased number of radios to each device. At the same time, demand for improved battery life is driving efficiency improvements, such as digital pre-distortion and envelope tracking. Business issues, such as pressure to reduce prices of these devices places greater demands on engineering teams producing power amplifiers.

Engineers who test mobile power amplifiers and front end modules from design through production are looking for solutions to reduce test cost through maximizing speed and throughput while ensuring that the devices meet required performance levels.

This application note provides an overview of the key issues in a power amplifier and front end module test system related to the RF signal analyzer and generator. It then offers a PXI based hardware and software solution for achieving fast test throughput.

Key issues faced by power amplifier test engineers

This application note addresses test challenges faced by power amplifier engineers including the need to:

- Reduce test times by providing fast input power adjustment and fast power measurements.
- Assess modulation performance quickly with high quality and trusted measurements.

Figure 1 shows a simplified block diagram for the RF vector signal analyzer and signal generator in a typical power amplifier/front end module test system. Typical power amplifier modules require an input power level of 0 to + 5 dBm, digitally modulated according to communication standards such as WCDMA or LTE. The specified performance of the power amplifier or front end module is normally set at a specific output level of the DUT. If the devices have small variations in gain, it may be necessary to adjust the power level from the PXI VSG to get the correct output level of the DUT. Only after the DUT output level is set at the correct value, can the specified parameters be tested. The time spent adjusting the PXI VSG to get the correct DUT output power can be a major contributor to the test time and the overall cost of test.

The PXI VSG is connected to the DUT using a cable and switches. The switching may be used to support testing of multi-band modules or multi-site testing. The combination of the RF cables and the switching network can add several dB of loss between the output of the PXI VSG and the input of the DUT, which requires higher output levels from the PXI VSG. Since the tests are performed with a modulated signal, the PXI VSG must also have adequate modulation performance at the higher power levels.

The PXI VSA is also connected to the DUT using switches and cables. If the PXI VSA is not able to make fast and accurate power measurements, a power meter may also be required on the DUT output. The signal analyzer needs to perform measurements of power, ACPR, EVM, harmonics and other parameters. It needs to measure all of these parameters quickly and accurately and be able to switch between measurement modes in minimal time.

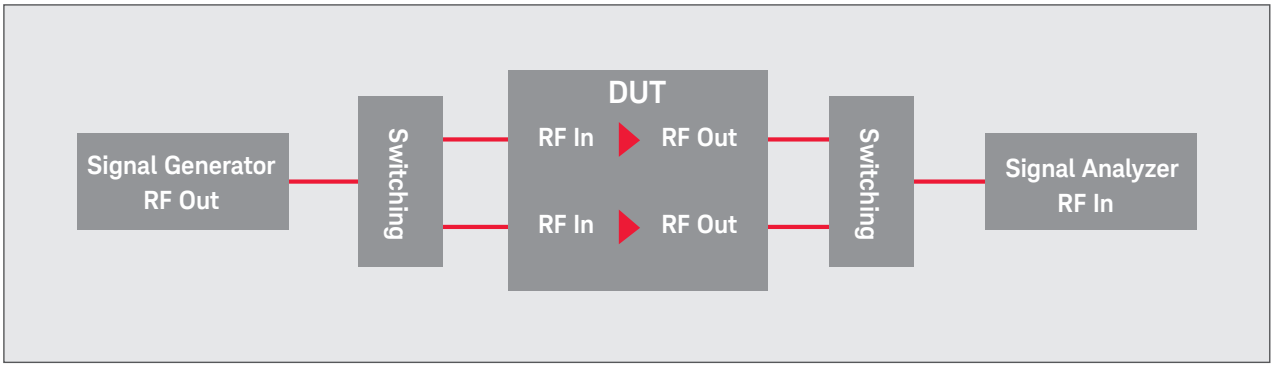

Figure 1. Typical Power Amplifier/Front End Module Test Setup

Using the PXI VSAs and VSG to increase test throughput and quality

The Keysight Technologies, Inc. M9391A and M9393A PXI VSAs and M9381A PXI VSG offer unique features that:

- Increase test throughput with fast amplitude and frequency switching as well as hardware accelerated power measurements.
- Enable synchronization with an arbitrary waveform generatorfor envelope generation to support test of envelope tracking devices.
- Provide good modulation performance, particularly at highpower levels and very linear power level changes.
- Achieve continuity of measurement results from R&D to manufacturing, as well as from previous generation test systems by using X-Series measurement applications
- Further reduces test development time through code reuse.

The M9381A PXI VSG reduces the overall switching time through a powerful, innovative tuning methodology. It further increases throughput by providing good linearity and repeatability which reduces the number of iterations required to get the DUT to the correct power output level. The PXI VSG also offers high modulation quality so you can drive amplifiers directly without having to add external amplification.

Several other vector signal generations offer amplitude and frequency switching times of less than 1 ms when used in list modes. However, since the output level of the signal generator cannot be predetermined for each test, list modes cannot be used for power amplifier testing. Other signal generators require significantly longer switching time when controlled through anormal programming interface. The PXI VSG offers the fastest switching time on the market of 250 µs from its programming interface and 10 µs in list mode, with fastune, an exclusive baseband tuning technology innovation.

The PXI VSG comes with 40 MHz bandwidth, but can be upgraded to 100 MHz or 160 MHz. The baseband frequency offset can be programmed to any offset within the purchased modulation bandwidth. For example, the 160 MHz bandwidth option allows the baseband frequency offset to be set to ±80 MHz. The baseband power offset can be set to 20 dB below the programmed RF power level and still achieves high quality modulation performance. To take advantage of this feature for power amplifier testing, engineers can set the RF frequency to the center of the band being tested and the RF power level to the maximum required for all tests. From there, baseband frequency adjustments are made to test at multiple frequencies across the band and the baseband power level is adjusted to servo the DUT output level to the correct value.

Better linearity, repeatability and resolution offered by the PXI VSG further reduces the test time by enabling the servo loop to converge in fewer steps. After the DUT output level is measured by the signal analyzer, the new value of the PXI VSG output power is calculated based on the difference between the measured power and the desired power. Then, the PXI VSG is adjusted by the amount necessary to achieve the correct DUT output power.

The PXI VSG provides high modulation quality, particularly at high output power levels. In many cases, signal levels as high as + 15 dBm may be needed to overcome the loss between the PXI VSG and the DUT input. As shown in Figure 2, the PXI VSG has excellent adjacent channel power (ACPR) at high output power levels. At + 10 dBm, there is little or no degrading of the ACPR and at + 15 dBm, the ACPR level is still near 60 dBc.

The M9391A PXI VSA reduces the overall test time through a hardware accelerated power measurement methodology. Power measurements are accumulated in real time in the digitizer, requiring only a single value to be returned to the application program and no computation of power from the IQ data in the controlling PC. In addition, the PXI VSA provides very repeatable power measurements, with acquisition times as low as 10 µs. Figure 3 shows the repeatability of the PXI VSA's power measurements with acquisition times from 10 µs to 1 ms at power levels from the expected input level to 75 dB below the expected input level. For power levels as low as 25 dB below expected input level, the PXI VSA can provide a power measurement with 0.005 dB standard deviation in a total execution time of less than 400 µs. When combined with the power level switching speed of the PXI VSG, the step time for a power servo loop can be less than 1 ms.

Power servo and ACPR measurements can be made using the hardware accelerated power measurement technique mentioned in the preceding paragraph or by using hardware accelerated FFT acquisition mode. The FFT acquisition mode offers similar accuracy and repeatability, but enables ACPR to be calculated from a single acquisition that spans all of the desired adjacent channels. By re-using the last acquisition from the power servo loop, the ACPR values can be calculated with no additional measurement time.

Emerging power efficiency technologies, such as envelope tracking, and digital pre-distortion can be supported through a configuration of PXI hardware with Signal Studio software for power amplifier test. For more information, please see the application note: Reduce Power Amplifier ET and DPD Test Times with PXIe Measurement Accelerator and Reference Solution, literature no. 5992-0883EN.

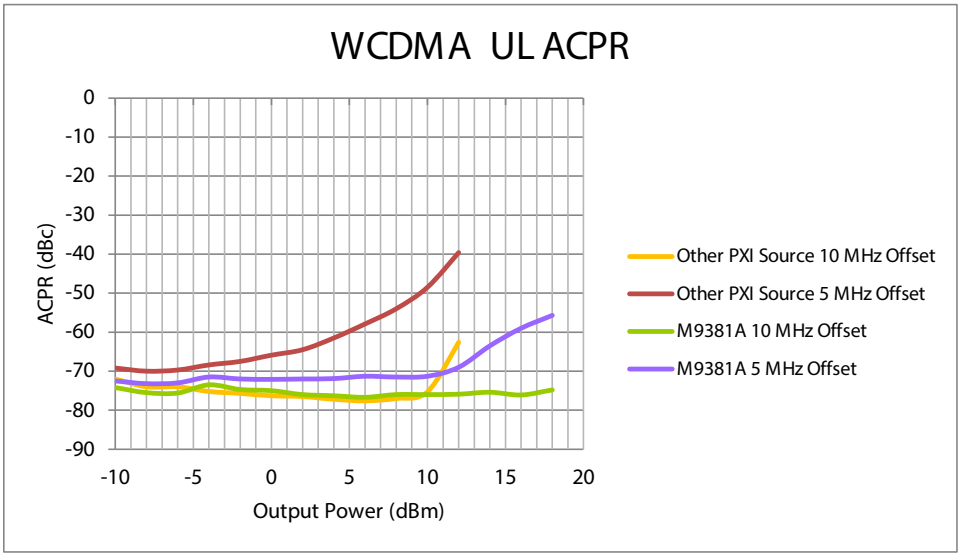

Figure 2. Note the M9381A shows little ACPR degradation below 10 dBm and is better than 60 dBc at 15 dBm.

Repeatability vs. acquisition time vs. power level					
Acquisition Time		Power Level Relative to the Expected Input Level			Test Time
		0 dB	-25 dB	-75 dB	
10 µs	Avg	1.767	-23.244	-65.047	0.0003
	Std Dev	0.033	0.032	0.550	
100 µs	Avg	1.895	-23.113	-65.073	0.0004
	Std Dev	0.007	0.005	0.168	
1 ms	Avg	1.758	-23.246	-65.059	0.0024
	Std Dev	0.003	0.001	0.0588	

Figure 3. Repeatability of power measurements using the M9391A.

Using the PXIe vector transceiver to speed test time for manufacturing

To minimize manufacturing test system development and measurement time, a calibrated PXIe vector transceiver instrument module extends the capability of the RF PA/FEM reference solution to the production floor. The vector transceiver combines vector signal generation and analysis in one 4-slot unit and aims to more than double manufacturing test throughput, while minimizing the use of valuable floor space.

Keysight's M9420A PXIe vector transceiver (VXT) is purpose-built for rapid solution creation and faster throughput in manufacturing test of wireless components and IoT devices. Up to four VXT's can be configured in a single 18-slots PXI chassis. Alternatively, a versatile single-chassis solution with one VXT, one DIO card and one of Keysight's award-winning single-slot PXI VNAs can be used for S-parameter measurements. The PXIe VXT provides frequency coverage from 60 MHz to 6 GHz and up to 160 MHz I/Q bandwidth. With a maximum of +18 dBm output power, the VXT compensates for signal losses through switch matrices.

The built-in servo routine accurately determines the final PA output power to control PA distortion. Traditional methods for power measurements have involved either swept or I/Q acquisitions followed by software processing. Though the software processing speed can scale with the capability of the processor, FPGA-based measurements have recently been utilized to further increase measurement speed. The PXIe VXT features real-time FFTs that enable high-speed measurements of signal power and adjacent-channel power ratio (ACPR), which can compress the power servo test time from 70 to 110 ms to a handful of milliseconds as shown in the table below.

Time	Swept Acquisition and Software Processing	Fast I/Q Acquisition, Mixed Hardware and Software Processing	FPGA Accelerated Processing with VXT
Power Servo WCDMA	70 ms	20 ms	5.5 ms
Power Servo FDD LTE	110 ms	20 ms	5.5 ms

Figure 4. Power servo time comparison among traditional swept acquisition, fast I/Q acquisition and FPGA accelerated processing together with PXIe VXT hardware.

Manufacturing system developers can easily create test solutions for power amplifiers (PA) and front-end modules (FEM) using the VXT's built-in software and FPGA-accelerated measurements. To reduce programming time, proven open-source example software routines are included with PA reference solution.

Harmonic Measurements

Harmonics measurements are part of the typical characterization test bench because all RF PA amplifiers exhibit harmonic distortion to some extent. Generally, a spectrum analyzer that can perform measurements with a low noise floor, minimal images, and high dynamic range is used to determine harmonic content and spurs. Since cellular and wireless connectivity applications cover up to 6 GHz, the required frequency range of the test bench's spectrum analyzer should be at least 18 GHz in order to measure the 3rd harmonic. For characterization or manufacturing, one of the main challenges is to combine these requirements with high-speed test.

Traditional spectrum analyzer designs use YIG oscillators which provide tuning sweeps generally taking tens of milliseconds, which may not be fast enough for today's throughput requirements. The M9393A PXIe performance vector signal analyzer is designed with Voltage Controlled Oscillators (VCO) instead of YIGs, combined with a stepped FFT technique. It eliminates band switching penalties and dramatically improves harmonics measurement speed. With the fast tuning LO, 160 MHz analysis bandwidth, and high speed back-end processing, the M9393A allows extremely fast "sweeps," across the entire 27 GHz frequency range, in a fraction of a second.

Because not all RF PA characterization and production test systems require harmonic test capabilities, it is important to ensure that the various PXI VSAs share common architecture to maximize test code leverage and to reduce test development time. Using the same high speed signal processing and measurement software across Agilent's line of PXIe VSAs offers consistency in measurements and programming in frequency ranges from 3 GHz to 27 GHz. The M9393A and M9391A PXIe VSAs share similar programming models and can be used with the same X-Series measurements applications without the need to purchase new software licenses.

Application Software

The PXI VSAs, VSG and VXT can be used with the same measurement applications that run on corresponding Keysight bench top instruments. Use Signal Studio software for simplifying the creation of specific test signals and X-Series measurement applications for easily trouble-shooting test setups using displays and one-button measurements. For complex signal analysis, industry-leading 89600 VSA software can be used for standards-specific demodulation analysis and advanced displays. Benefit from excellent correlation of measurement results at multiple points in your product design cycle when using Keysight software with benchtop and modular instruments, as well as the common programming interface, enabling code reuse and reduced test development time.

Ordering Information

Main Hardware Components	
M9381A	PXIe Vector Signal Generator 1 MHz to 6 GHz Includes: M9301A PXIe Synthesizer M9310A PXIe Source Output M9311A PXIe Digital Vector Modulator
M9391A	PXIe Vector Signal Analyzer 1 MHz to 6 GHz Includes: M9301A PXIe Synthesizer M9350A PXIe Downconverter M9214A PXIe IF Digitizer
M9393A	PXIe Performance Vector Signal Analyzer 9 kHz to 27 GHz Includes: M9308A PXIe Synthesizer M9365A PXIe Downconverter M9214A PXIe IF Digitizer
M9420A	PXIe Vector Transceiver 60 MHz to 6 GHz Includes: Vector generator Vector analyzer
M9300A	PXIe Frequency Reference 10 MHz to 100 MHz
M9451A-DPD	PXIe Measurement Accelerator with digital pre-distortion and envelope tracking gateware
M9195A	PXIe Digital Stimulus/Response with PMU

Recommended configuration for design validation test	
M9381A-F06	Frequency range: 1 MHz to 6 MHz
M9381A-B10	RF modulation bandwidth: 100 MHz
M9381A-M01	Memory: 32 MSa
M9381A-UNZ	Fast switching
M9391A-F06	Frequency range: 1 MHz to 6 GHz
M9391A-B10	Analysis bandwidth: 100 MHz
M9391A-M01	Memory 128 MSa
M9391A-UNZ	Fast switching
M9300A	PXIe frequency reference

Harmonic test configuration includes	
M9381A-F06	Frequency range: 1 MHz to 6 MHz
M9381A-B10	RF modulation bandwidth: 100 MHz
M9381A-M05	Memory: 512 MSa
M9381A-1EA	High output power
M9381A-UNZ	Fast switching
M9393A-F18	Frequency range: 9 kHz to 18 GHz
M9391A-B10	Analysis bandwidth: 100 MHz
M9393A-M05	Memory 512 MSa
M9393A-UNZ	Fast switching
M9300A	PXIe frequency reference

Recommended configuration for production test	
M9420A-506	Frequency range 60 MHz to 6 GHz
M9420A-B1X	RF modulation bandwidth 160 MHz
M9420A-M05	Memory 512 MSa
M9420A-1EA	High output power
M9300A	PXIe frequency reference

For more options on these configurations, or for recommended configurations for envelope tracking and/or digital pre-distortion test, please refer to the RF PA/FEM Reference Solution configuration guide, literature number 5992-0072EN.

Software Information

Supported operating systems	Microsoft Windows 7 (32/64-bit)
Standard compliant drivers	IVI-COM, IVI-C, LabVIEW, MATLAB
Supported application development environments (ADE)	VisualStudio (VB.NET, C#, C/C++), VEE, LabVIEW, LabWindows/CVI, MATLAB
Keysight IO Libraries (version 17.0 or newer)	Includes: VISA Libraries, Keysight Connection Expert, IO Monitor

Related Literature

Brochure	RF PA/FEM Characterization and Test Reference Solution (literature no. 5992-0071EN)
Configuration Guide	RF PA/FEM Characterization and Test Reference Solution (literature no. 5992-0072EN)
Application Note	Reduce Power Amplifier DPD/ET Test Times with PXIe Measurement Accelerator and Reference Solution (literature no. 5992-0883EN)

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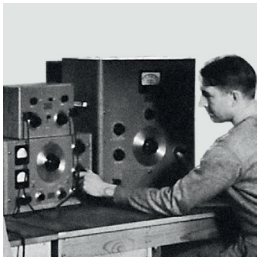

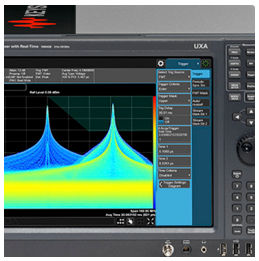

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