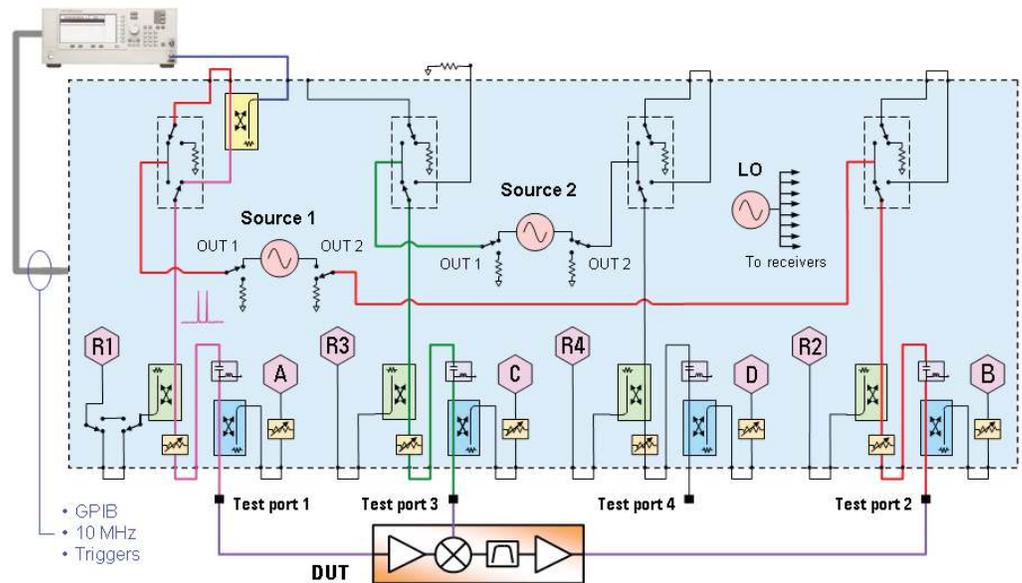


Keysight Technologies

Solutions for Active Device Test

Using Modern VNAs to Automate
Traditional Multi-instrument RF Test Systems

Application
Note



Introduction

Overview

Designing test systems is a complex task, especially when those systems are intended to test active devices used in the aerospace & defense and wireless communications arenas. Here, stringent requirements and continually changing standards stress an already challenging test process. Traditionally, multi-instrument RF test systems have been created to meet these challenges. Along with the test hardware, test system designers typically employ software to automate the test process. Automation provides increased speed and therefore higher test throughput, convenience in terms of data collection and reduced operator error, and synchronized measurements for triggering between multiple instruments and/or control of the device under test (DUT).

While Automated Test Equipment (ATE) offers a number of highly appealing benefits to the test system designer, it also presents its own unique set of challenges and constraints. Test system designers always strive to offer better measurements in terms of speed and accuracy. They must also optimize the test system by reducing its development time, size and power consumption, while making it easier to calibrate and use. And finally, test system designers attempt to lower the overall cost of test system ownership by minimizing initial development costs, keeping maintenance costs for calibration and repair to a minimum, and by planning for future upgrades.

Problem

It is not an easy task to design an optimized RF test system to test S-parameters, compression, intermodulation distortion (IMD), spurs, and noise figure that not only features faster and more accurate measurements, but also lowers the cost of ownership. Traditional “rack and stack” RF test systems are comprised of multiple instruments. A network analyzer, spectrum analyzer, multiple signal generators, and power meter are required for core RF tests, while a noise figure analyzer or noise-figure option to the spectrum analyzer is required for testing low-noise amplifiers. A switch matrix interfaces these instruments to the DUT. Low frequency test equipment (e.g., oscilloscopes and digital voltmeters), DC power supplies and extra signal conditioning hardware are also commonly included in RF test systems. Unfortunately, the complexity of such multi-instrument solutions run counter to the simplicity offered by ATE and as a result, test system designers now demand an alternative to the traditional “rack and stack” approach for RF test systems.

Solution

Modern vector network analyzers (VNAs) have evolved considerably over the past few years and now offer a cost effective, ATE-system-friendly replacement to traditional multi-instrument RF test systems. They contain more sophisticated hardware with improved specifications, and can perform a broad suite of RF measurements beyond just S-parameters and compression, with great speed and accuracy. Their internal switches provide much more flexibility for test setups, simplifying test systems by eliminating the need for a switch matrix and enabling more complicated test systems.

Using the modern VNA as the core RF measurement engine for automated test systems, the test system designer can realize a number of significant benefits, including:

- Simpler test systems, which translates into faster, more cost-effective development time and faster time to manufacturing. In addition to being smaller and consuming less power, modern VNAs contain fewer parts than traditional RF test systems and therefore experience less downtime and lower maintenance costs. Less instruments also mean test systems that are easier to use.
- Faster test times that improve test throughput.
- Higher accuracy which enables better yields and specifications.
- Flexible hardware which offers adaptability for future test requirements.

The Keysight Technologies, Inc. PNA-X Series network analyzer is a modern VNA that can be used in place of a traditional RF test system to test components from 10 MHz to 26.5 GHz. This 2- or 4-port network analyzer offers a unique single-connection multiple-measurement solution for CW and pulsed S-parameter, compression, IMD, and noise-figure measurements. An integrated second source, signal combining network, noise receivers, and internal pulse generators and modulators transform it from a pure network analyzer to an RF measurement hub for amplifiers and frequency converters.

Figure 1 depicts a block diagram of a 4-port PNA-X. Each circled block represents a key element that makes this VNA an ideal alternative to “rack and stack” RF test systems and underscores its advantages over ordinary VNAs. For example, a second RF signal source (Source 2) can be used for two-tone testing or as an LO for converter tests. An internal signal combiner can be switched in to route the two-tone stimulus out of test port 1 to the input of the DUT, allowing IMD measurements to be made over

the full frequency range of the instrument without any additional hardware. Source 1 and 2 contain built-in pulse modulators for bi-directional measurements of pulsed S-parameters.

Internal pulse generators drive the pulse modulators and internal IF gates (used during narrowband detection), simplifying pulsed S-parameter measurement setup and eliminating the need for external hardware. Switches and associated rear-panel jumpers allow other test instruments and signal conditioning hardware to be added to the test setup, while maintaining a single connection to the DUT. Finally, the optional noise receivers add noise figure measurements to the suite of possible RF tests.

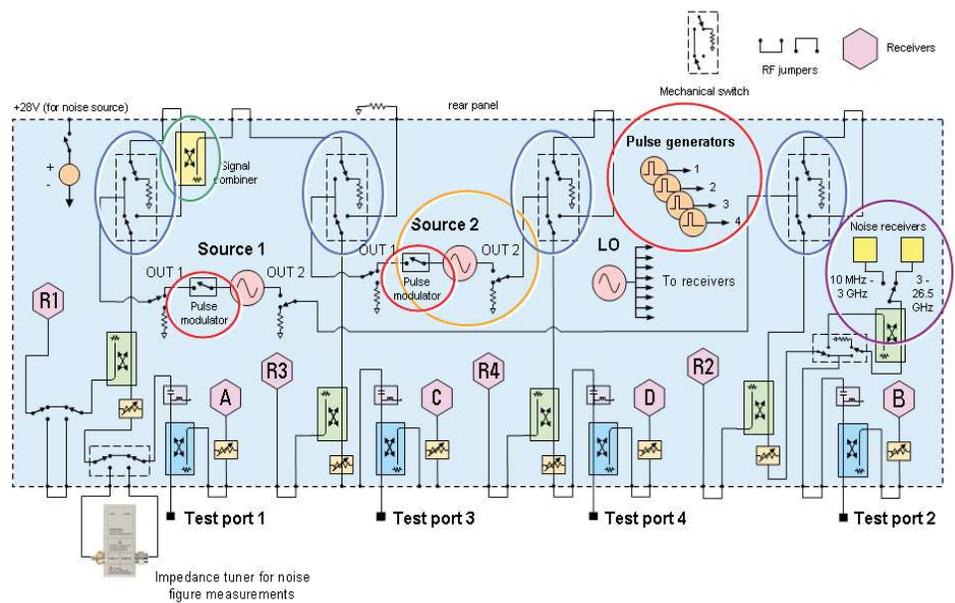


Figure 1: Block diagram of a modern VNA—the PNA-X.

The PNA-X supports a wide range of one- and two-source RF measurements with a single connection to the DUT. One-source measurements include CW and pulsed S-parameters, gain compression, AM-to-PM conversion, harmonics, and noise figure. Two-source measurements include IMD, Hot-S22, phase versus drive, true-mode stimulus, and conversion loss/gain. The test system designer can extend this range of measurements by switching in a signal generator such as the MXG signal generator, and a spectrum analyzer such as Keysight's MXA spectrum analyzer (Figure 2). Doing so enables digitally modulated RF carrier tests like adjacent-channel power ratio to be easily performed. All tests involving the MXG or MXA are done while maintaining a single connection to the DUT.

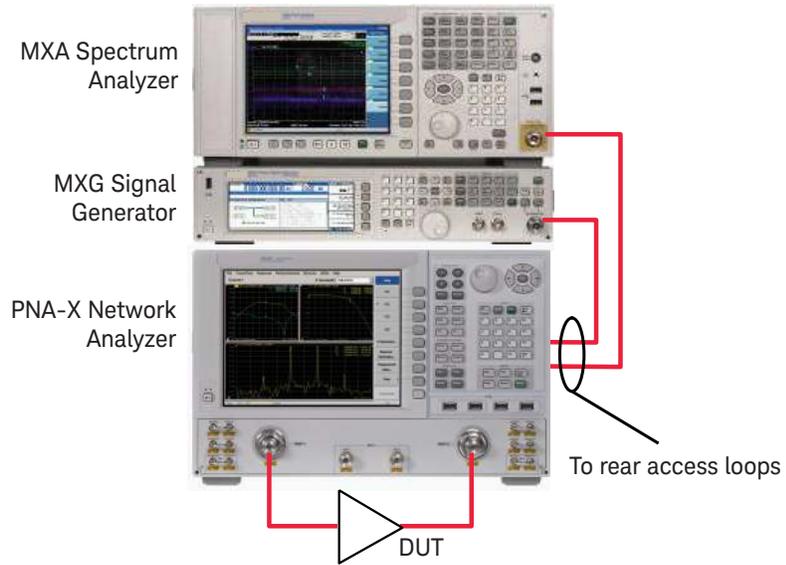


Figure 2: Switches route the MXG to the input of the DUT and the output of the DUT to the MXA. An external directional coupler couples the signal into the PNA-X while preserving the path through the internal combiner for the two internal sources—a configuration used for IMD measurements.

Converter IMD Measurements Example

IMD measurements of frequency converters require two sources for input signals and one for the LO. To make these measurements, the Keysight MXG signal generator is added to the PNA-X according to the setup in Figure 3. Here, the external source serves as an input signal so that the speed of Source 2 can be used for conversion gain and LO match measurements. The external source can also be used as the LO signal, with the two internal sources acting as input signals.

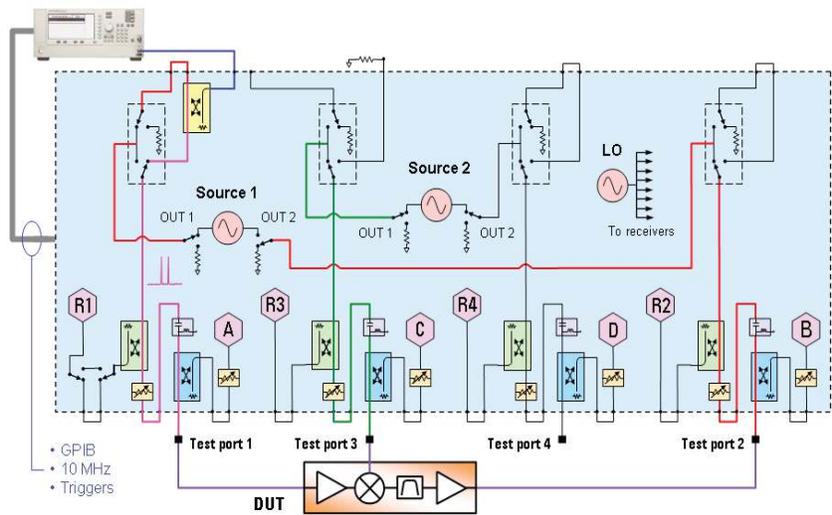


Figure 3: One possible configuration of the PNA-X for IMD measurements of converters. The external source is programmed by GPIB and the 10 MHz references are tied together to ensure the PNA-X tunes to the correct frequency of interest.

Noise Figure Measurements Example

Noise figure measurements are critical for characterizing low noise amplifiers. A source-corrected noise figure option is added to the PNA-X to make these measurements. It contains additional hardware and firmware, including an off-the-shelf ECal module used as an impedance tuner (Figure 4). A second ECal module or mechanical cal kit is required for system calibration, along with a noise source for calibrating the internal noise receivers. With this option, the PNA-X makes the industry's most accurate noise figure measurements, at a speed that is typically 4 to 10 times faster than a noise figure analyzer (Figure 5).



Keysight's unique noise-figure-calibration technique uses an ECal module as an impedance tuner to remove the effects of imperfect system source match

Figure 4: The source-corrected noise figure option extends the single-connection multiple-measurement capability of the PNA-X.

Summary of Results

The traditional multi-instrument "rack and stack" approach to creating RF test systems fails to provide the benefits of better measurements or lower cost of ownership that test system designers now demand. A modern VNA like the PNA-X Series network analyzer, with its flexibility, optimized hardware and ability to perform a broad range of measurements with high speed and accuracy, and a single connection to the DUT, offers the ideal replacement to legacy RF test systems. By employing this solution, test system designers can now design simpler test systems with the lowest overall cost of ownership.

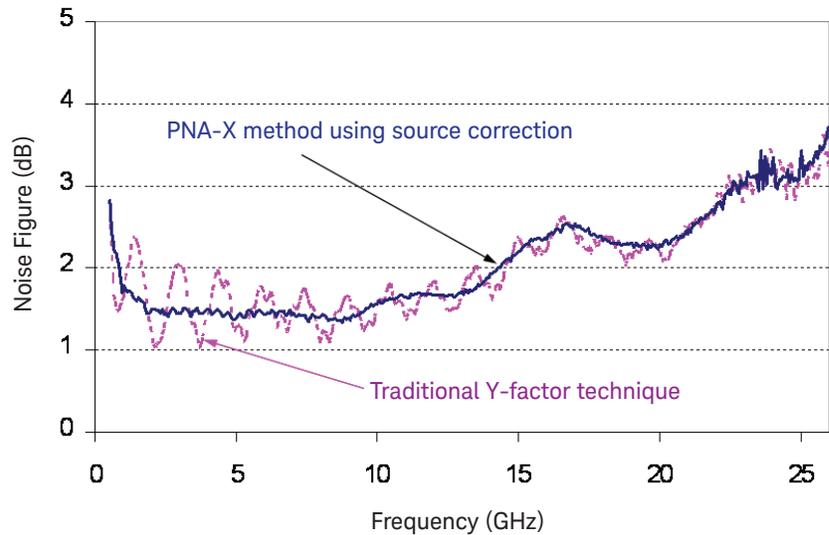


Figure 5: An example of an actual broadband measurement of a packaged low-noise transistor, comparing the source-corrected measurement method with the Y-factor method. The PNA-X, with its lower ripple and therefore higher measurement accuracy, gives a truer picture of the device's noise figure.

The Power of X

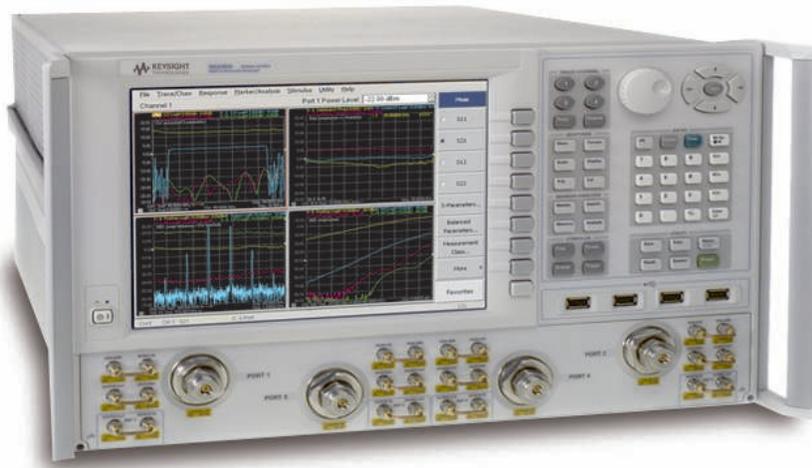
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PNA-X Microwave Network Analyzer

Related Applications

- Time domain measurements
- True-mode stimulus
- Nonlinear component characterization:
 - Time and frequency domain analysis
 - X-parameters
 - Arbitrary load impedance X-parameters
 - Pulse envelope domain

Related Keysight Products

- PNA-X Microwave Network Analyzer
- N5181A MXG Analog Signal Generator
- N5182A MXG Vector Signal Generator
- PNA-X Active Device Test Applications:
 - Source-Corrected Noise Figure Measurement (Option 029)
 - Frequency Converter Application (Option 083)
 - Embedded LO Measurement (Option 084)
 - Gain Compression Application (GCA) (Option 086)
 - Intermodulation Distortion (IMD) Application (Option 087)
 - N-Port Calibrated Measurements (Option 551)
 - Pulsed-RF Measurement Capability (Option H08)



N5181A MXG Analog Signal Generator
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