



Agilent PNA-X Series Microwave Network Analyzers



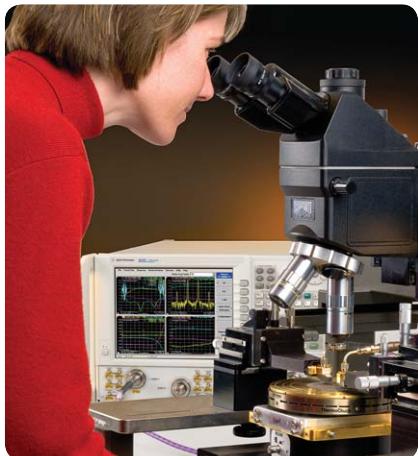
***Complete
linear and nonlinear
component characterization
in a single instrument***



Agilent Technologies

Industry's Most Advanced RF Test Solution

Complete linear
and nonlinear
characterization
in a single
instrument



All of the PNA-X's powerful measurement applications can be used for on-wafer devices.

Choose the leader in network analysis

The PNA-X Series of microwave network analyzers are the culmination of Agilent's 40-year legacy of technical leadership and innovation in radio frequency (RF) network analysis. More than just a vector network analyzer, the PNA-X is the world's most integrated and flexible microwave test engine for measuring active devices like amplifiers, mixers, and frequency converters.

The combination of two internal signal sources, a signal combiner, S-parameter and noise receivers, pulse modulators and generators, and a flexible set of switches and RF access points provide a powerful hardware core for a broad range of linear and nonlinear measurements, all with a single set of connections to your device-under-test (DUT).

World's widest range of measurement applications

PNA-X applications bring speed, accuracy, and ease-of-use to common RF measurements, in coaxial, fixtured, and on-wafer environments. Applications include:

- **S-parameters (CW and pulsed)**
- **Noise figure**
- **Gain compression**
- **Intermodulation and harmonic distortion**
- **Conversion gain/loss**
- **True-differential stimulus**
- **Nonlinear waveform and X-parameter* characterization**
- **Antenna test**

Network analysis technology down to the nanoscale

The PNA-X is also compatible with these Agilent measurement solutions:

- **Physical layer test system (PLTS) software** to calibrate, measure, and analyze linear passive interconnects, such as cables, connectors, backplanes, and printed circuit boards.
- **Materials test equipment and accessories** to help determine how your materials interact with electromagnetic fields, by calculating permittivity and permeability.
- **Award-winning scanning microwave microscope** to create a powerful and unique combination for topography measurements of calibrated capacitance and dopant densities at nanoscale dimensions.

The right frequency for your application

N5241A	10 MHz to 13.5 GHz
N5242A	10 MHz to 26.5 GHz
N5244A	10 MHz to 43.5 GHz
N5245A	10 MHz to 50 GHz
N5247A	10 MHz to 67 GHz
PNA-X with mm-wave modules	10 MHz to 1.05 THz

Build your optimal test system by selecting the frequency range for your specific device-test needs without paying for functionality you don't need.

*X-parameters is a registered trademark of Agilent Technologies. The X-parameter format and underlying equations are open and documented. For more information, visit <http://www.agilent.com/find/eesof-x-parameters-info>

Multiple measurements with a single instrument

Replace racks and stacks

With its highly integrated and versatile hardware and re-configurable measurement paths, the PNA-X replaces racks and stacks of equipment – with a single instrument. One PNA-X can take the place of the following test gear:

- Network analyzer
- Spectrum analyzer
- Two signal sources
- Noise figure meter/analyizer
- Power meters
- Switch matrix
- Digital voltmeter



Benefits of a PNA-X-based solution

• Simpler test systems for...

- ...lower hardware and software costs
- ...quicker development time and faster time to manufacturing
- ...less downtime and lower maintenance costs
- ...smaller size and lower power consumption

• Faster test times for...

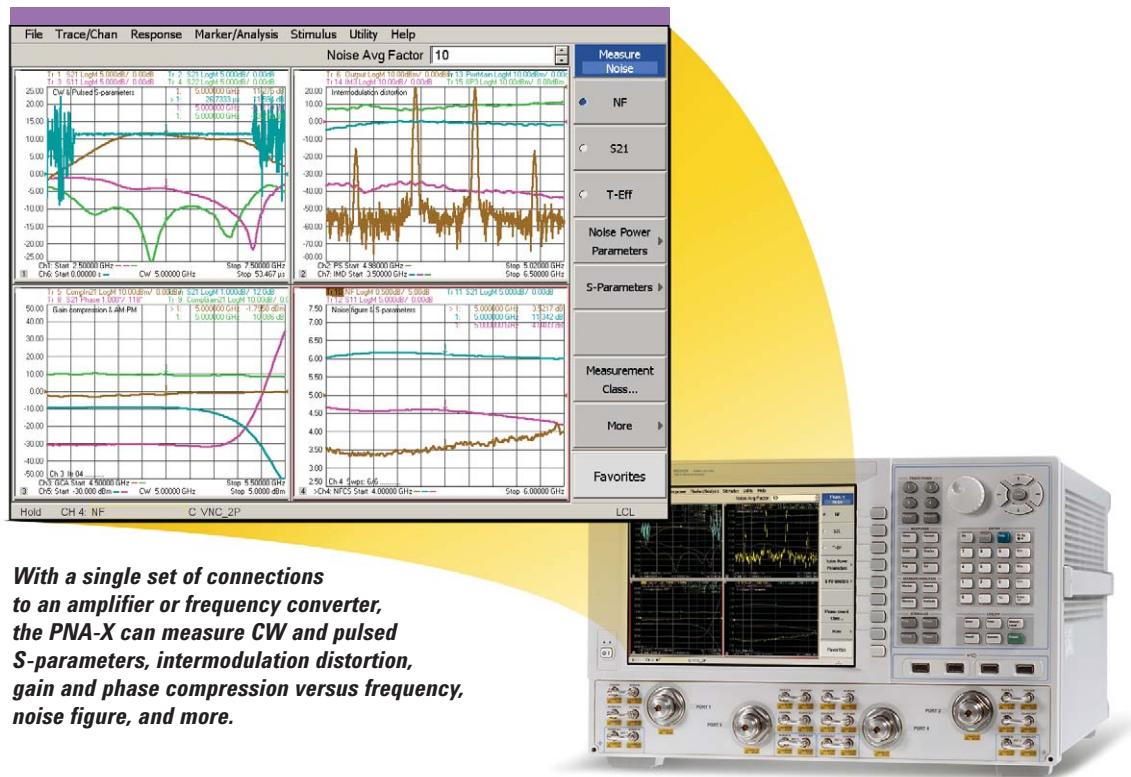
- ...improved throughput

• Higher accuracy for...

- ...better yields and better specifications

• Flexible hardware for...

- ...greater adaptability to future test requirements



With a single set of connections to an amplifier or frequency converter, the PNA-X can measure CW and pulsed S-parameters, intermodulation distortion, gain and phase compression versus frequency, noise figure, and more.

Bottom Line Results – PNA-X Case Studies

"We selected Agilent's PNA-X because it **eliminated unnecessary cable swaps** between measurements and it **makes more active measurements than any other network analyzer** out there. We used to make S-parameter, vector-signal, and noise-figure measurements with separate test equipment—and now with the PNA-X, we can **perform all of our active measurements in one box.**"

Test Engineering Manager

CASE STUDY 1

Aerospace/defense component supplier reduces test time by 95%

Challenges

This customer manufacturers over 4600 RF components, with typically 1000 devices in the manufacturing process at any given time. Devices included filters, multipliers, amplifiers, and switches, from 10 MHz to 60 GHz. They needed to simplify the test system for one particular multiport device, so they set out to develop an operator-independent automated test system (ATS). Key challenges included:

- Complicated and expensive test systems with multiple racks of equipment and miles of test cables
- Multiple cable swaps and recalibrations required with extensive operator intervention and downtime
- Significant retesting of devices and high system downtime

Results

The PNA-X's ability to incorporate more active measurements into a single instrument than any other product on the market provided:

- **Faster test times:** Reduced test times from four hours per temperature to 24 minutes when compared to the prior ATS, resulting in a test-time reduction of 95%
- **Reduced equipment count:** Replaced nine racks of equipment with three, 12-port PNA-X network analyzers
- **Increased operator productivity:** Enabled operators to monitor four test stations simultaneously and eliminated the need for single-operator test stations
- **Reduced re-testing and cable swaps**

CASE STUDY 2

Satellite designer and manufacturer reduces test time from three hours to three minutes

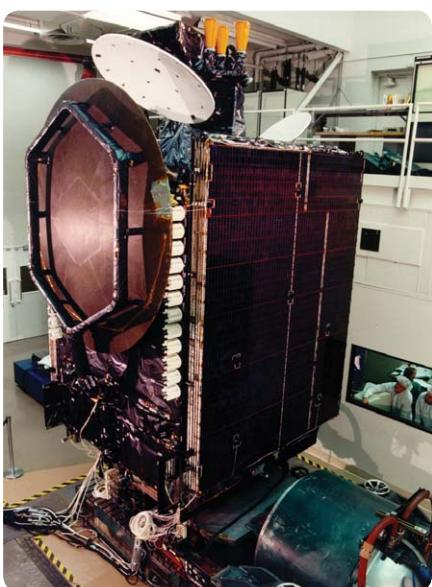
Challenges

This aerospace company was conducting a specific panel-level test and wanted to modernize its test systems and improve its test productivity and throughput. Its legacy satellite payload test systems utilized a large amount of rack and stack equipment accompanied by a big test overhead. The company was required to exert a great deal of time and effort to program and maintain the test systems.

Results

Initially the aerospace company purchased four PNA-Xs (26.5 and 50 GHz models). They were so impressed with the throughput and test productivity results, that they purchased eight more analyzers. In one test case, the level of improvement exceeded expectations—taking a 20-minute gain-transfer test to just under a minute. Replacing their test system with the PNA-X effectively modernized and simplified their test system which enabled:

- **Faster test times:** Complete test suite cut measurement times from three hours to three minutes
- **Reduced equipment count:** Replaced a two-rack payload test system with a single four-port PNA-X
- **Smaller test system:** Reduced the amount of equipment space and power consumption



CASE STUDY 3

Wireless networking systems manufacturer reduces throughput from 30 to 10 minutes

Challenges

The manufacturer was developing a new broadband wireless network system and needed a faster test system. Its existing test system consisted of two sources, a spectrum analyzer, and power meters. Using this system, they estimated their new product would take 30 minutes to test; however their speed goal was 15 minutes. In addition to needing a faster test solution, the company also needed better noise figure and distortion measurements, and it required single-connection measurements on both up and down converters.

Results

Replacing their existing multi-instrument test system with a single four-port 50 GHz PNA-X enabled the company to realize:

- **Faster test times:** Complete test suite cut test throughput from an estimated 30 minutes to under ten minutes
- **Less downtime and reduced maintenance costs:** Reducing the equipment count reduced the setup time, as well as the headaches associated with multiple equipment faults, and resulted in lowered annual calibration costs
- **Cost savings on equipment:** The cost of a four-port PNA-X was substantially less expensive than the legacy multi-instrument test system.

CASE STUDY 4

Global security company speeds test and improves measurement accuracy

Challenges

"We chose the PNA-X for its **unique single-connection, multiple-measurement capability**. The PNA-X is also the only solution we found that can make accurate nonlinear measurements by using its extended NVNA software option. This saves us an amazing amount of design time because it means we can **quickly and accurately characterize the nonlinear behavior** of our devices even at crazy high power levels."

Test Engineering Manager

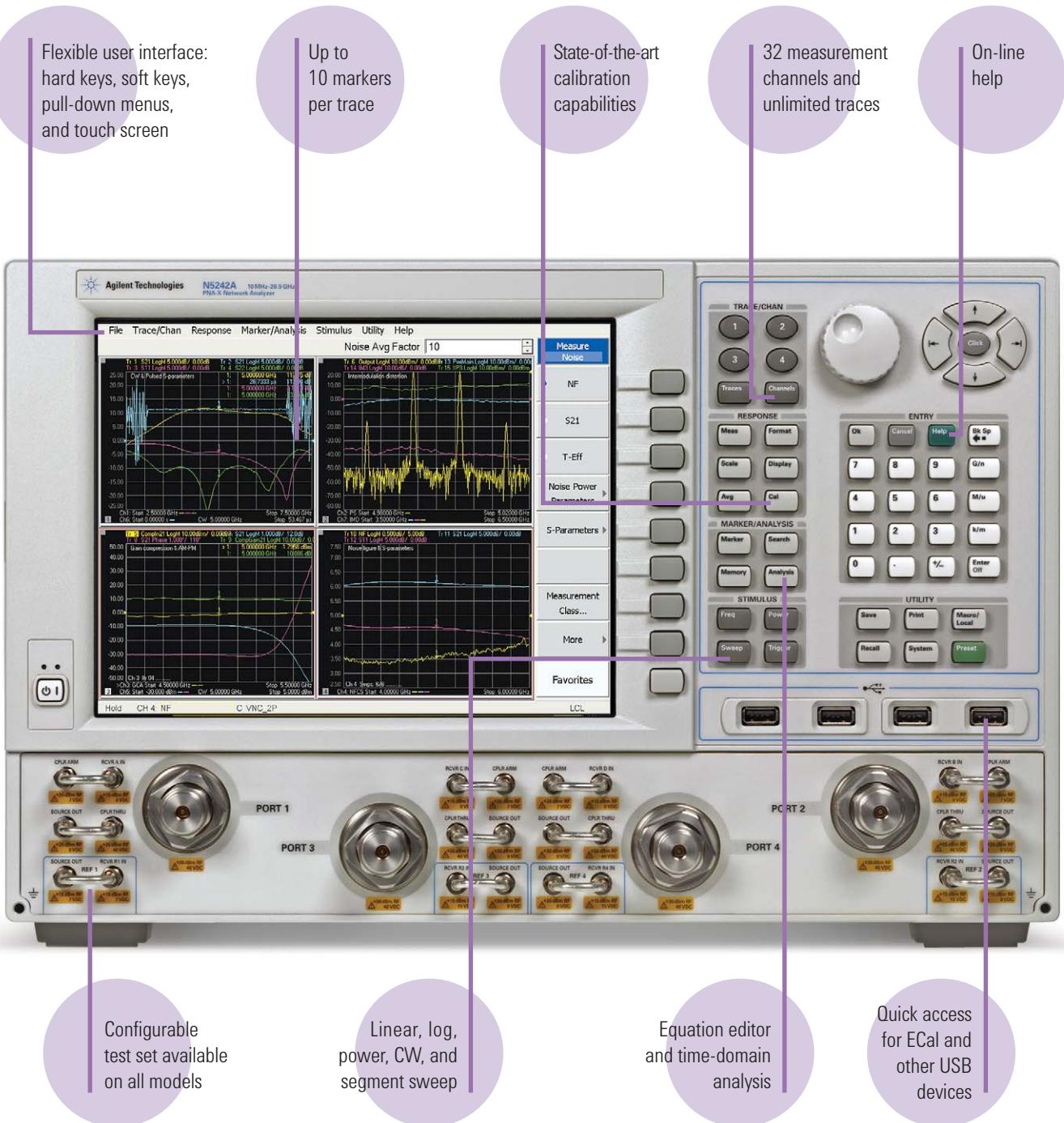
The company needed to upgrade its legacy test systems, which consisted of large switch matrices with network analyzers. They required technicians to keep connecting and disconnecting the device-under-test (DUT) to multiple instruments to make a range of different measurements. This approach was slow, costly, prone to inaccuracy, and required a good deal of user intervention and additional hardware. The company sought a solution that was easy to set up and use, decreased test time and cost, minimized measurement inaccuracy, and offered a smaller footprint

Results

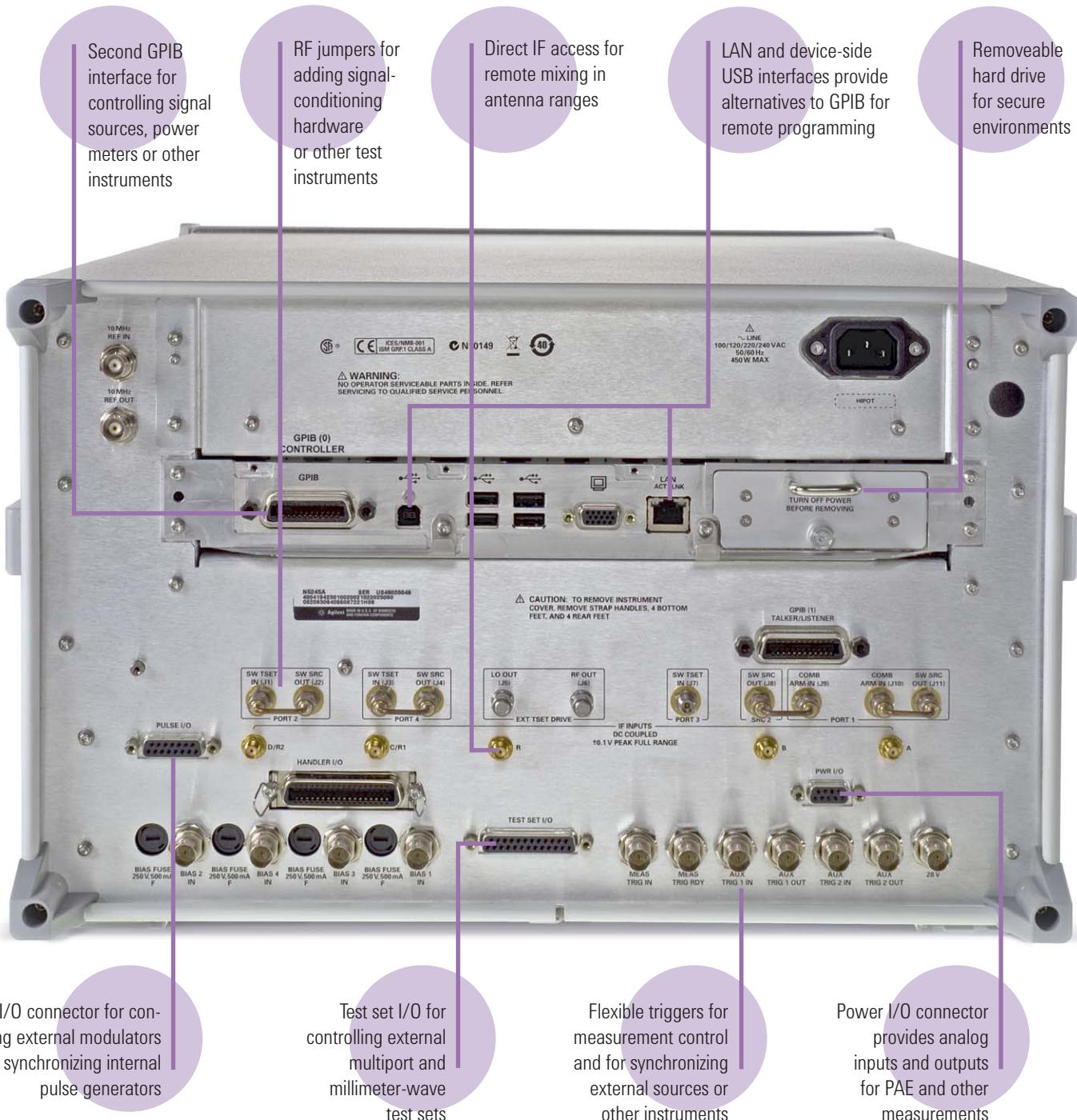
The company decided to purchase PNA-Xs rather than simply upgrade to newer, code-compatible, drop-in instruments offered by the provider of its legacy test equipment. This decision was made despite the fact that it meant significant rewrite of legacy software. The company saved time over their existing test solutions and realized:

- **Easy setup and use:** Technicians were able to easily connect to a DUT and measure all different parameters in one pass—without additional hardware
- **Faster and more accurate tests:** Using just one instrument technicians were able to conduct their required tests in significantly less time and improve accuracy
- **Smaller test system:** A single four-port PNA-X reduced their initial capital expense, equipment count, floor space, and power consumption, which resulted in lower overall test costs

Intuitive, Speed-driven Features

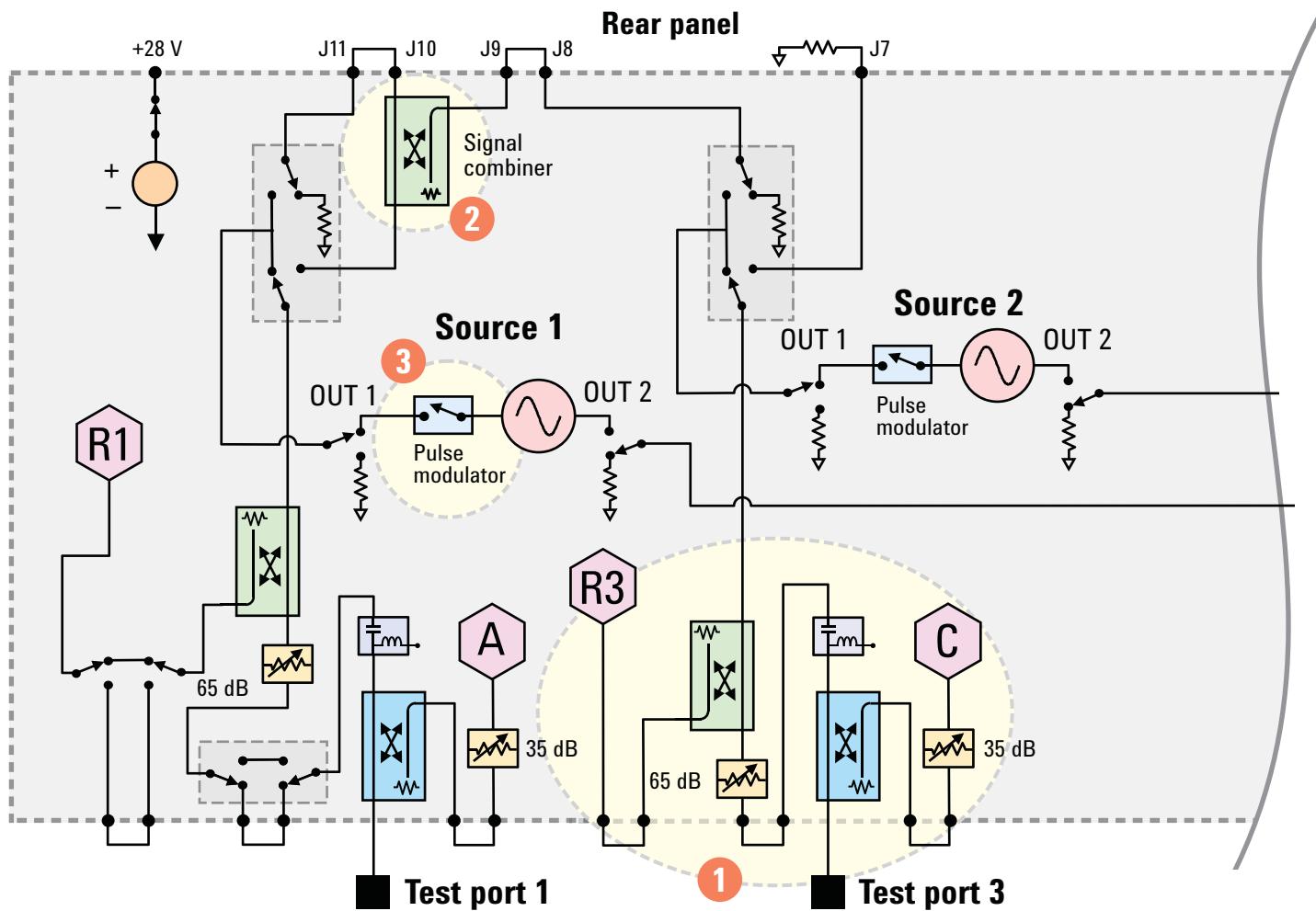


Hardware for Exceptional Flexibility

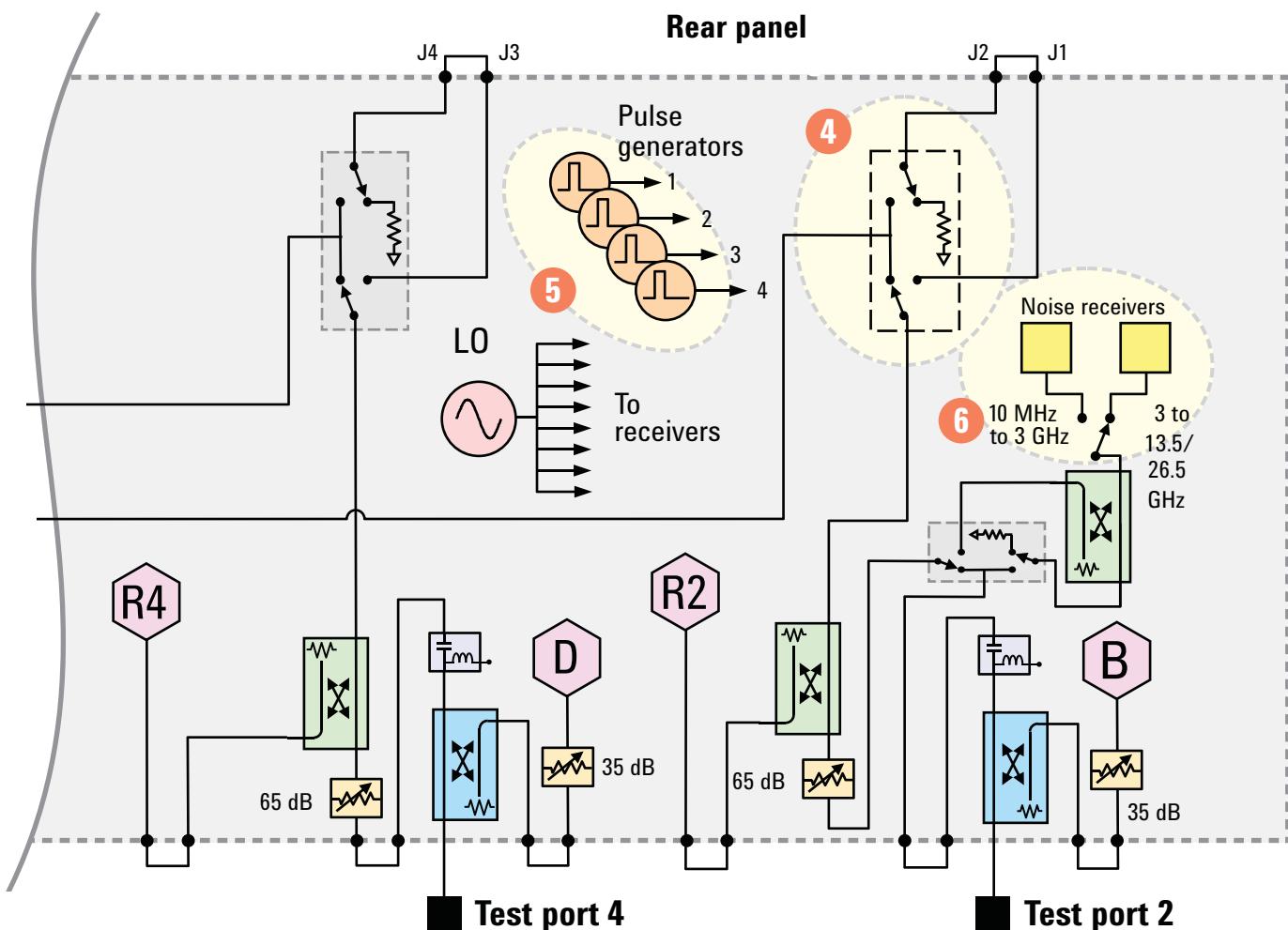


Flexible Architecture

- 1 Each test port includes test and reference couplers and receivers, source and receiver attenuators, and a bias tee, for maximum accuracy and flexibility.
- 2 The built-in signal combiner greatly simplifies the setup for intermodulation distortion and X-parameter measurements.
- 3 Internal pulse modulators enable integrated pulsed-RF testing over the full frequency range of the instrument, eliminating expensive and bulky external modulators.



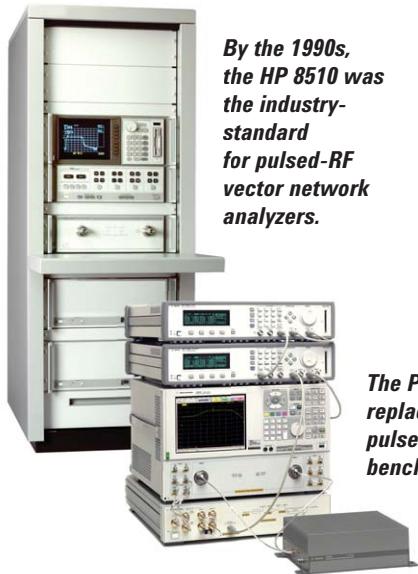
- 4** Switchable rear-panel jumpers provide the flexibility to add signal-conditioning hardware or route additional test equipment to the DUT without moving test cables.
- 5** Setting up pulse timing for the pulse modulators and internal IF gates is easy using the built-in pulse generators.
- 6** Internal low-noise receivers, along with advanced calibration and measurement algorithms, provide the industry's most accurate noise figure measurements.



Innovative Applications

Simple, fast and accurate pulsed-RF measurements

(Options 008, 021, 022, 025)



**By the 1990s,
the HP 8510 was
the industry-
standard
for pulsed-RF
vector network
analyzers.**

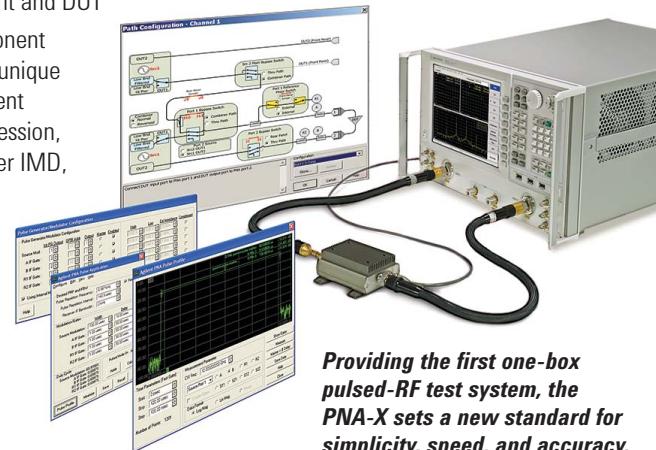
**The PNA Series
replaced the
pulsed 8510 with a
bench-top solution.**

Pulsed-RF measurement challenges

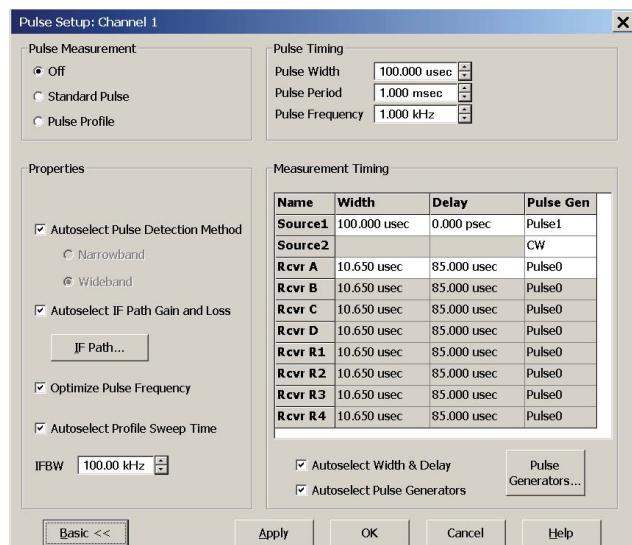
- Pulse generators and modulators required for pulsed-RF measurements add complexity in test setups
- For narrow pulses:
 - Maximum IF bandwidth of analyzer is often too small for wideband detection
 - Narrowband detection is slow, and measurements are noisy for low duty cycle pulses

PNA-X pulsed-RF measurements provide:

- A simple user interface for full control of two internal pulse modulators (Option 021 and 022), and four internal independent pulse generators (Option 025)
- Point-in-pulse measurements with 33 ns minimum pulse width, and pulse profile measurements with 16.7 ns minimum resolution (Option 008)
- Improved measurement speed and accuracy for narrowband detection using hardware filters and patented spectral-nulling and software IF-gating techniques
- Measurements using wideband detection with pulse widths as narrow as 267 ns
- Pulse I/O connector on rear panel for synchronization with external equipment and DUT
- Accurate active-component characterization using unique application measurement classes for gain compression, swept-frequency/power IMD, and noise figure



**Providing the first one-box
pulsed-RF test system, the
PNA-X sets a new standard for
simplicity, speed, and accuracy.**



Pulsed-RF measurement application automatically optimizes internal hardware configuration for specified pulse conditions to dramatically simplify test setups. Alternately, users can choose to manually set up the hardware for unique test requirements.

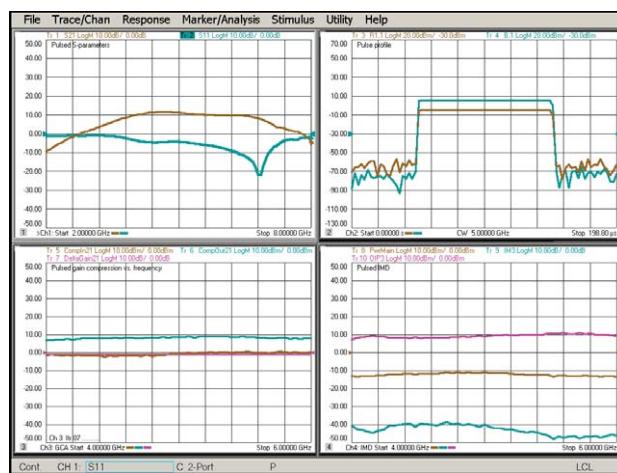
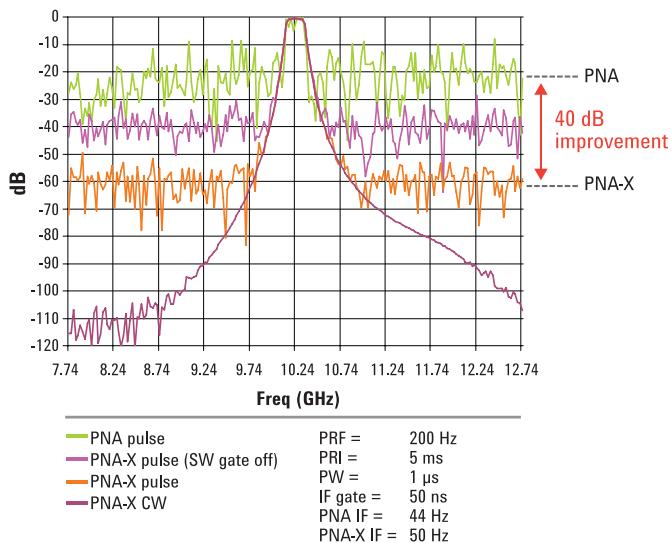
Pulse profile measurement using narrowband detection technique allows 18 measurement points within 300 ns pulse, with 16.7 ns timing resolution.

Tips from the experts

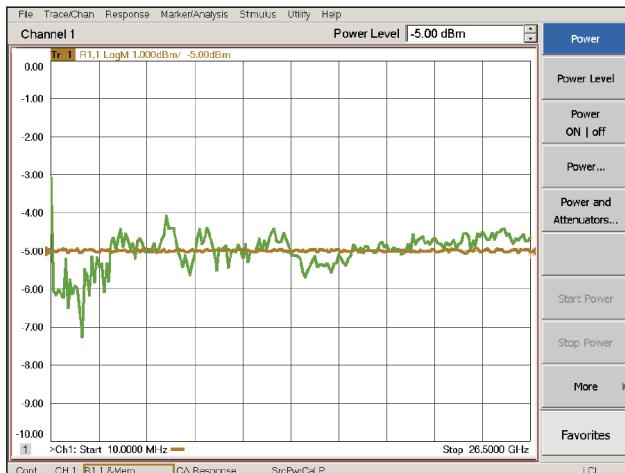
- Compared to sweep averaging, point averaging typically provides faster results when averaging is needed to lower noise and improve accuracy of measurements using wideband detection.
- During source power calibrations, power sensors read the average power, while the analyzer sets the peak power of the pulsed stimulus. To compensate for the difference between the peak and average power, use the power offset feature with the value of 10 log (duty cycle).
- The minimum pulse width for point-in-pulse measurements using wideband detection is determined by the

number of samples required for the IF bandwidth (IFBW). For example, the minimum pulse width is 267 ns with 5 MHz IFBW, 467 ns with 3 MHz IFBW, and 1.43 μ s with 1 MHz IFBW. When working at the minimum pulse width for a particular IFBW, it is important to precisely set the measurement delay (with 16.7 ns resolution) to align the pulse modulation and the data acquisition period.

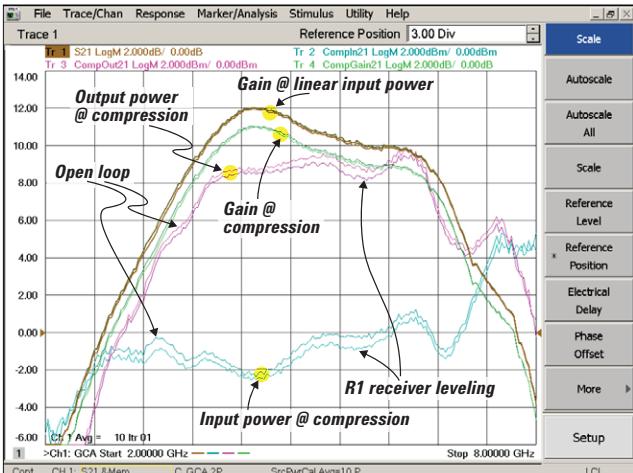
- In pulse mode, it is important to use receiver leveling to maintain power-level accuracy for power-dependent measurements, such as output power, compression, and intermodulation distortion.



The PNA-X accurately characterizes active devices under pulsed operation with a single set of connections to the DUT—pulsed S-parameters, pulse profile (input and output power in the time domain), gain compression versus frequency, and swept-frequency IMD are measured in this example.



Using receiver leveling improves the pulsed-RF power accuracy from +/- 1 dB to less than 0.05 dB.



Above measurements compare the results with and without receiver leveling in GCA measurements. Inaccurate stimulus causes large errors in power-dependent measurements such as input and output power at the compression point versus frequency.

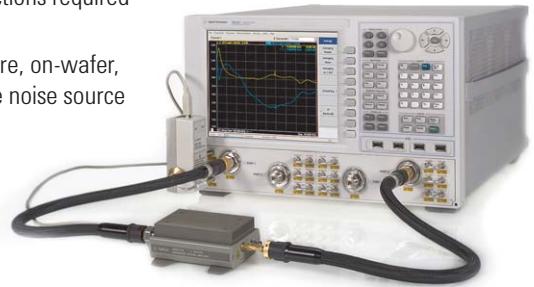
Innovative Applications

Fast and accurate noise figure measurements

(Options 028, 029, H29)

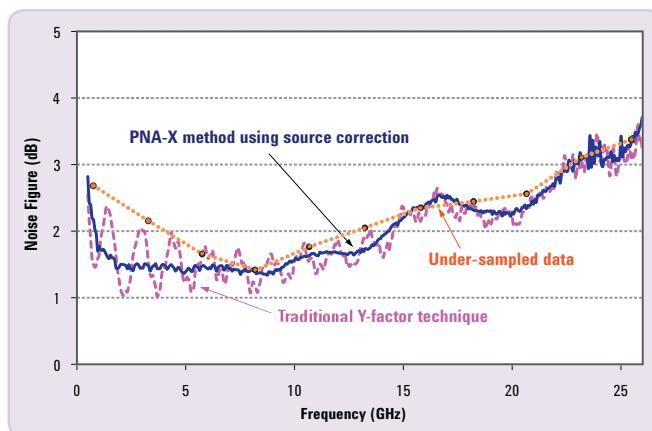
Noise figure measurement challenges with traditional, Y-factor approach

- Multiple instruments and multiple connections required to fully characterize DUT
- Measurement accuracy degrades in-fixture, on-wafer, and automated-test environments, where noise source cannot be connected directly to DUT
- Measurements are slow, often leading to fewer measured data points and misleading results due to under-sampling

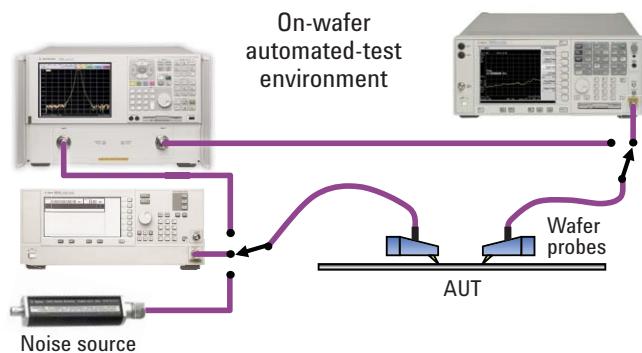


PNA-X noise figure solution provides:

- Amplifier and frequency converter measurements with the highest accuracy in the industry, using advanced error-correction methods
- Fast measurements: typically 4 to 10 times faster than Agilent's NFA Series noise figure analyzers
- Ultra-fast noise-parameter measurements when used with Maury Microwave automated tuners, giving 200 to 300 times speed improvements



For this 401 point measurement of an unmatched transistor, the PNA-X exhibits much less ripple compared to the Y-factor method. The NFA default of 11 trace points would give under-sampled and therefore misleading results of the amplifier's performance.



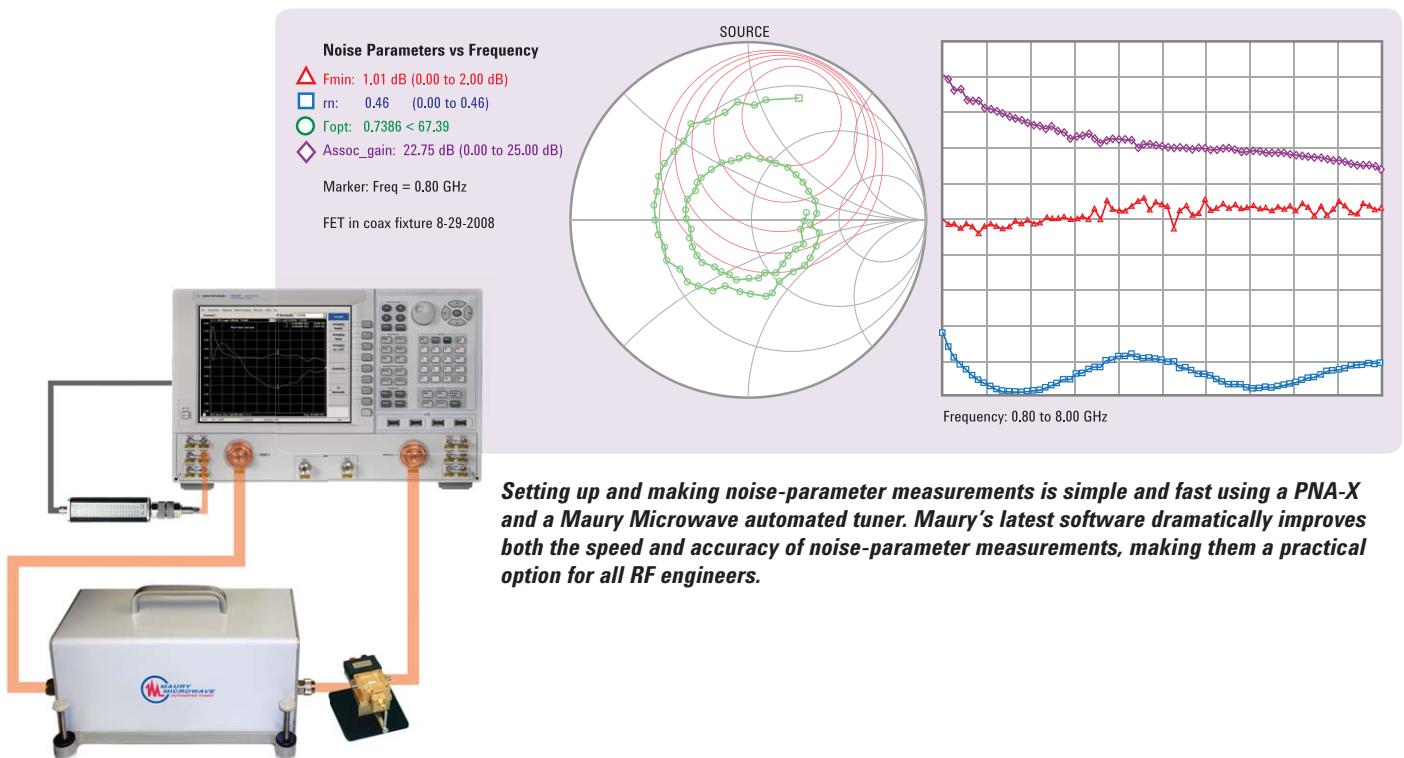
For Y-factor measurements, any electrical network connected between the noise source and the DUT, such as cables, switch matrices, and wafer probes, causes significant accuracy degradation.

"I have several instruments in my equipment pool that can measure noise figure—8970s, NFAs, and spectrum analyzers. My biggest problem for noise figure measurements was lack of correlation—I'd get different answers depending on which instrument I used. Now, with the PNA-X's high accuracy, I know I'll get the right answer every time, no matter which PNA-X I use."

Test Engineering Manager

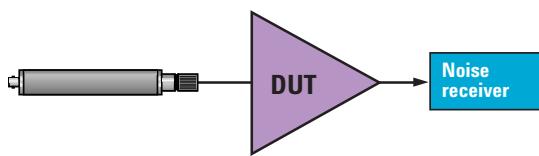


Noise-parameter measurements in minutes rather than days

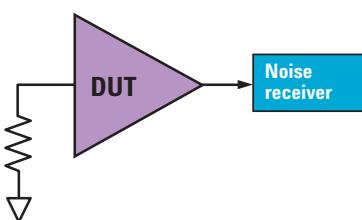


Noise figure measurement methods

Y-FACTOR: The most prevalent method for measuring noise figure is the Y-factor technique. It relies on a noise source connected to the input of the amplifier under test (AUT). When the noise source is turned off, it presents a room temperature (cold) source termination. When the noise source is turned on, it creates excess noise, equivalent to a hot source termination. Under these two conditions, noise power is measured at the output of the AUT, and the scalar gain and noise figure of the amplifier is calculated. The Y-factor method is used by Agilent's NFA Series and by spectrum analyzers with preamplifiers and a noise figure personality option.



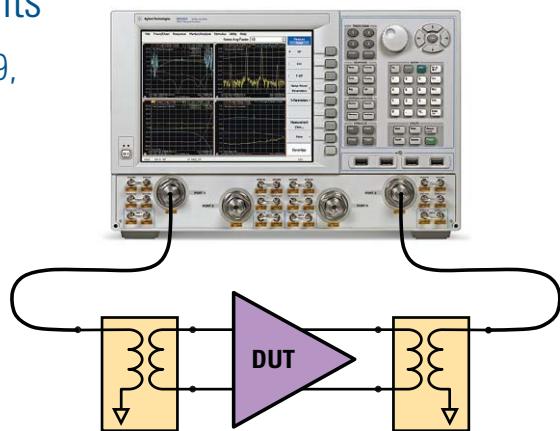
COLD SOURCE: An alternate method for measuring noise figure is the cold source or direct noise technique. With this method, only one noise power measurement is made at the output of the AUT, with the input of the amplifier terminated with a room temperature source impedance. The cold source technique requires an independent measurement of the amplifier's gain. This technique is well suited for vector network analyzers (VNAs) because VNAs can measure gain (S_{21}) extremely accurately by utilizing vector error correction. The other advantage of the cold source method is that both S-parameter and noise figure measurements can be made with a single connection to the AUT.



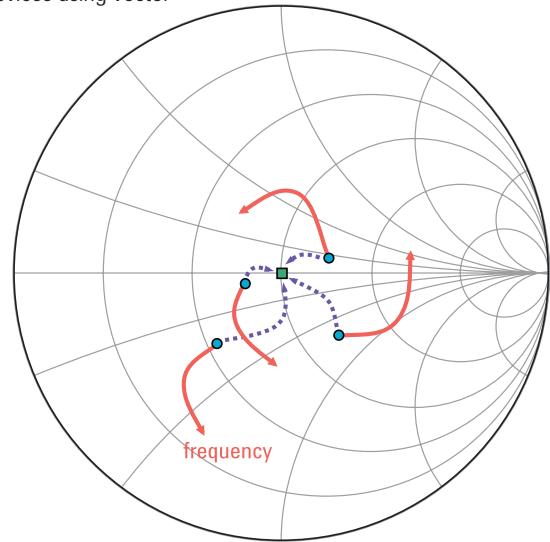
Innovative Applications

Fast and accurate noise figure measurements

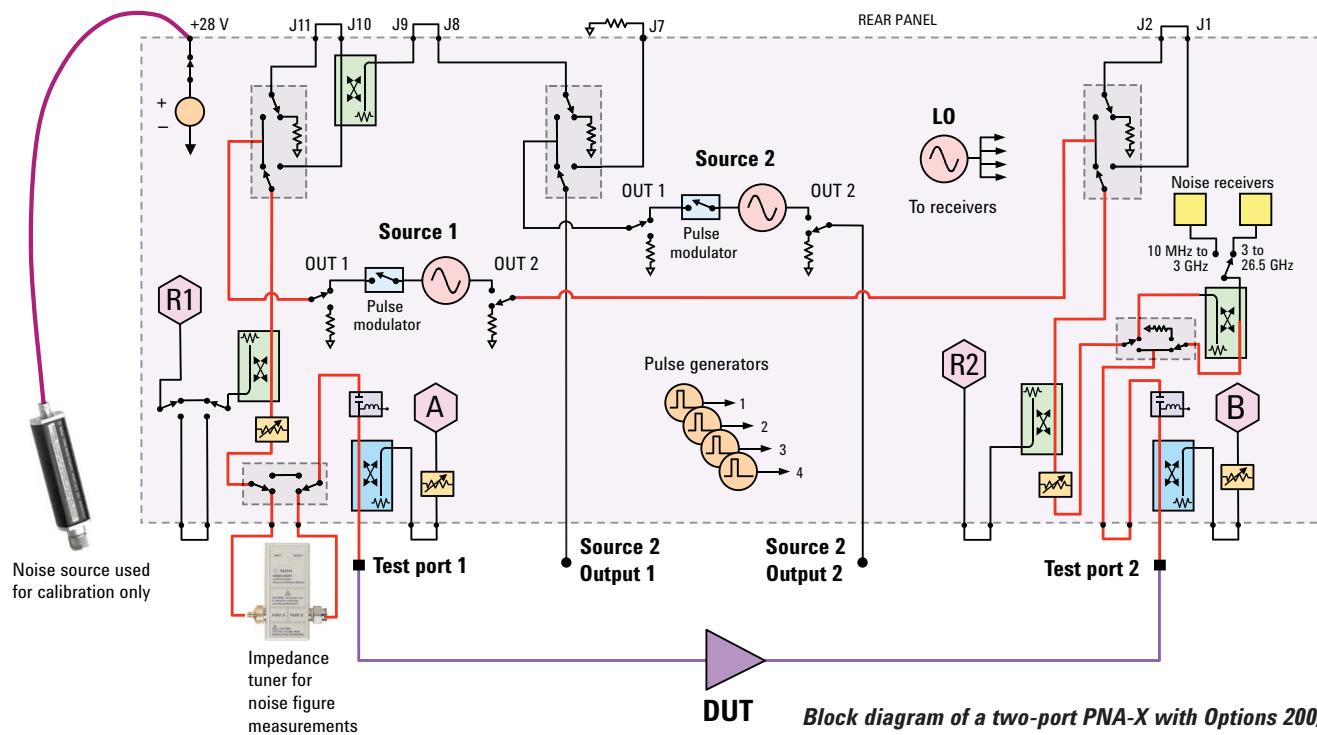
(Option 028, 029, H29) continued



Measure differential devices by deembedding baluns or hybrids.



At each test frequency, four or more noise measurements are made with known, non-50-ohm source impedances. From these measurements, 50-ohm noise figure is accurately calculated.

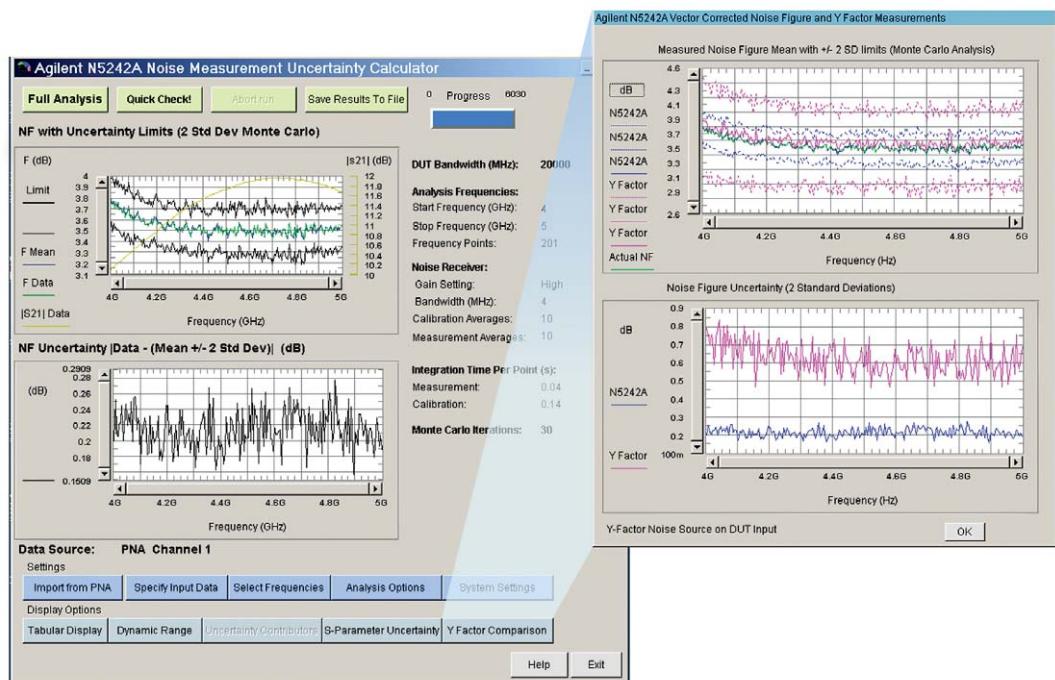


Block diagram of a two-port PNA-X with Options 200, 219, 224, and Noise Figure Option 029. A standard ECal module is used as an impedance tuner to help remove the effects of imperfect system source match.

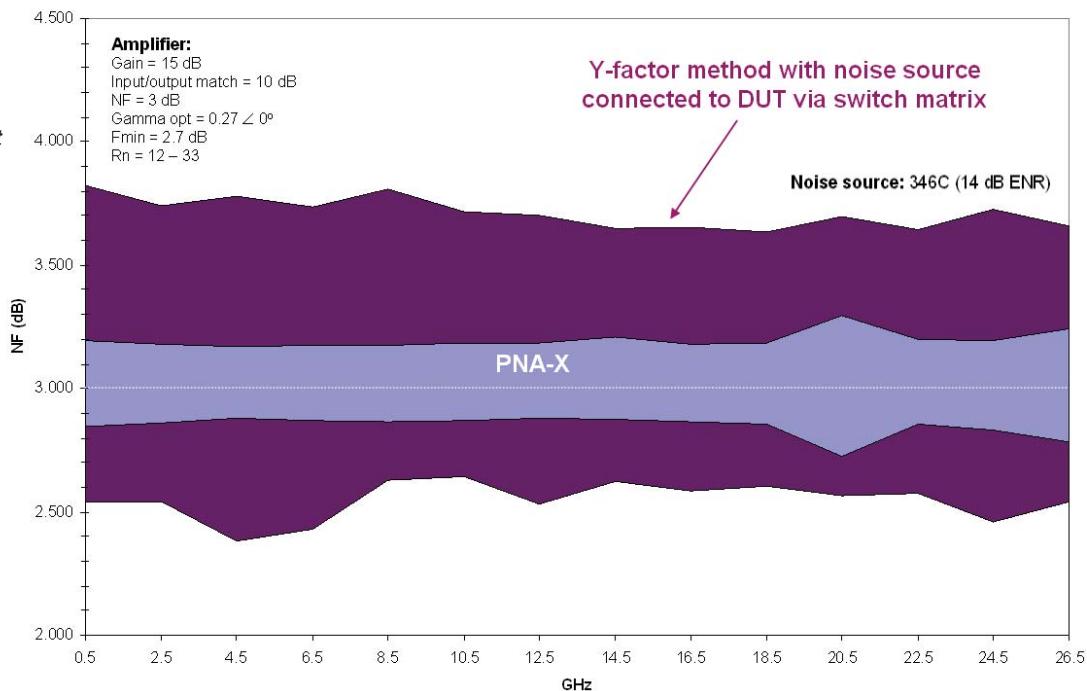
Tips from the experts

- Noise figure measurements are best done in a screen room to eliminate spurious interference from mobile phones, wireless LAN, handheld transceivers, etc.
- Batteries are sometimes used instead of mains-based power supplies to eliminate conducted interference from sensitive LNA measurements
- Overall measurement accuracy can be estimated by using Agilent's Monte-Carlo-based noise figure uncertainty calculator

Agilent's PNA-X noise figure uncertainty calculator (www.agilent.com/find/nfcalc) includes the effects of mismatch and noise-parameter-induced errors caused by imperfect system source match.



Noise figure measurement uncertainty example in an automated test environment (ATE). The PNA-X's source-corrected technique is considerably more accurate than the Y-factor method.



Innovative Applications

Fast and accurate gain compression versus frequency measurements of amplifiers and converters

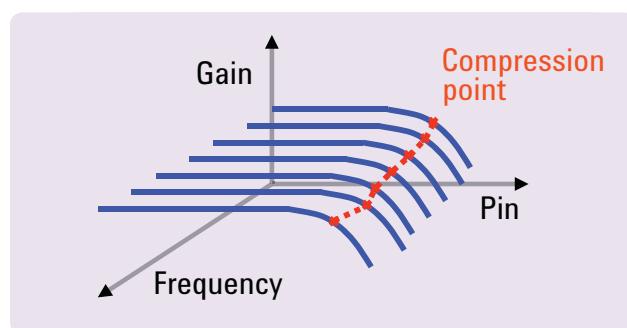
(Option 086)

Gain compression measurement challenges

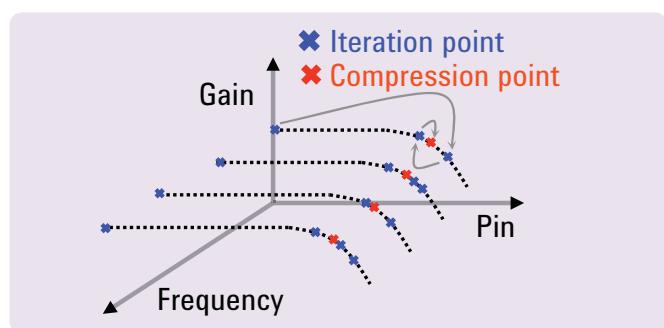
- Characterizing amplifier or frequency converter compression over its operating frequency range requires measurements at many frequency and power points, so setting up the measurements, calibration, and data manipulation takes a lot of time and effort
- A variety of errors degrade measurement accuracy, such as mismatch between the test port and the power sensor and DUT during absolute power measurements, and using linear S-parameter error correction in nonlinear compression measurements

PNA-X gain compression application (GCA) provides:

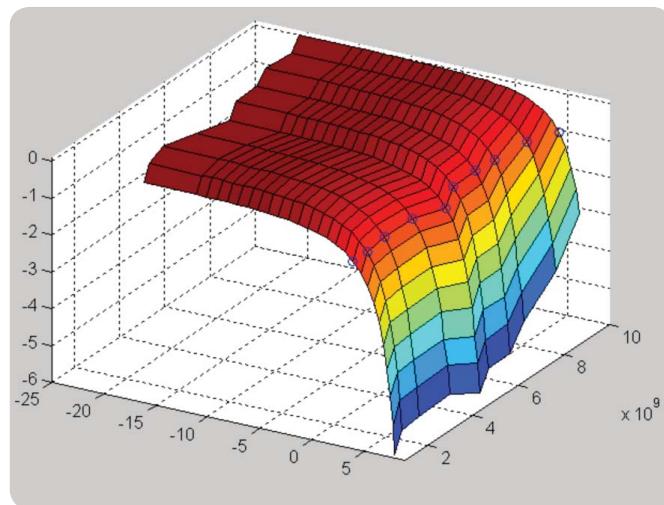
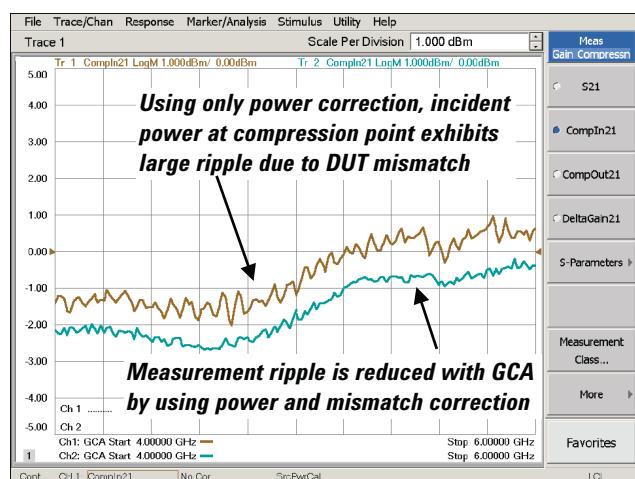
- Fast and convenient measurements with SMART Sweep
- Highly accurate results using a guided calibration that provides power and mismatch correction
- Complete device characterization with two-dimensional (2D) sweeps, with the choice of sweeping power per frequency, or sweeping frequency per power
- Flexibility with a variety of compression methods—compression from linear gain, maximum gain, X/Y compression, compression from back-off, or compression from saturation



A network analyzer is commonly used for gain compression measurements by performing power sweeps at multiple CW frequencies. The PNA-X's GCA makes it easy to characterize compression over the DUT's operating frequency range with extreme speed and accuracy, and a simple setup.



Instead of a linear power sweep with many points, GCA's SMART Sweep uses an adaptive algorithm to find the desired compression point at each frequency with just a few power measurements, thus significantly reducing test times.

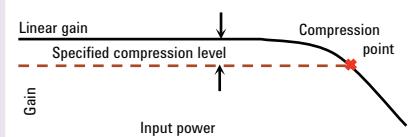


Complete device response to 2D sweeps—gain versus frequency and power—can be extracted for device modeling.

Available compression methods

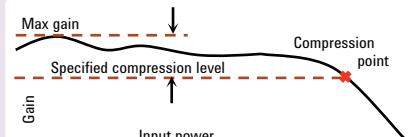
Compression from linear gain

The linear gain is measured using the specified linear (input) power level. The compression point is calculated as the linear gain minus the specified compression level.



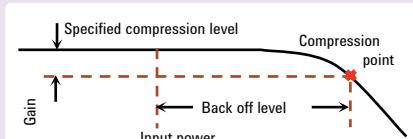
Compression from max gain

The highest gain value that is found at each frequency is used as the max gain. The compression point is calculated as the max gain minus the specified compression level.



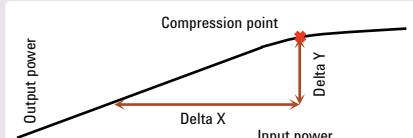
Compression from back off

The gains at two input powers that are different with the specified back off level are compared. The compression point is found as the highest input power with the gain difference of the specified compression level.



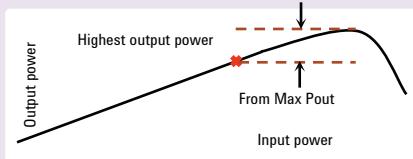
X/Y compression

The output powers at two input powers that are different with the specified delta X are compared. The compression point is found as the highest input power with the output power difference of the specified delta Y.



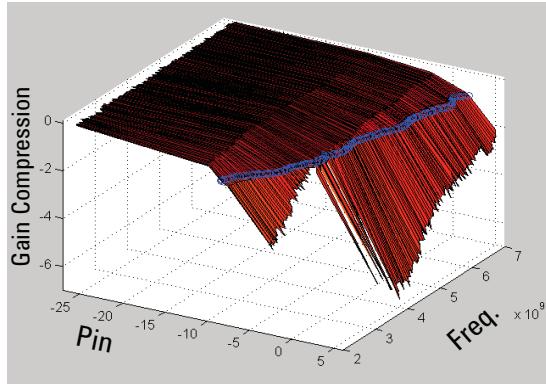
Compression from saturation

The compression point is found at the highest output power minus the value specified as "From Max Pout".

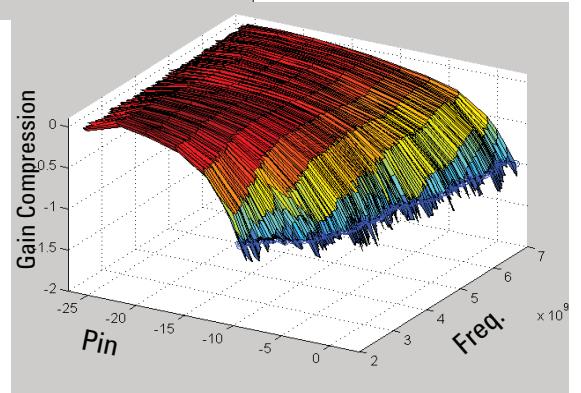


Tips from the experts

- Use the safe mode in SMART Sweep to increment the input power first with coarse and then with fine steps to prevent over driving the DUT
- When the DUT's hysteresis or thermal effects are in doubt, it is recommended to sweep frequency per power rather than power per frequency, or to add dwell time to lower the effects from previous measurements
- Compression analysis capability extracts the DUT response over the power range at a specified frequency point on any of the compression traces
- Use the CompAI1 and CompAI2 internal voltmeter readings that are synchronized to the compression point to measure power-added efficiency (PAE) at compression for each frequency



Measured background data in SMART Sweep with Safe Mode Off (above) and On (below)—more iterations are used as the gain becomes closer to the 1 dB compression point with Safe Mode On, which minimizes excess drive power.



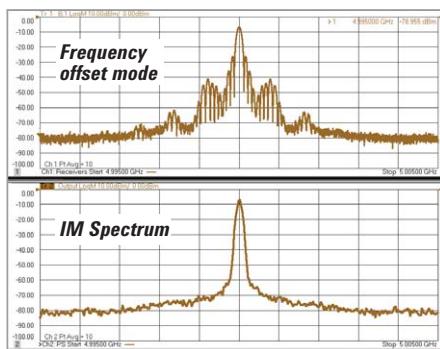
Innovative Applications

Fast two-tone intermodulation distortion (IMD) measurements with simple setup

(Option 087)



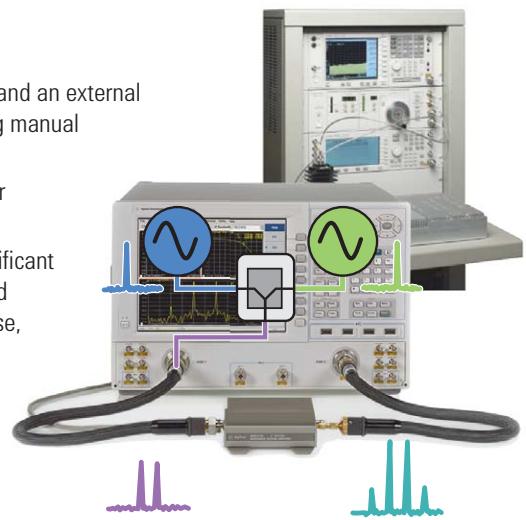
IMD application measures third order IMD and IP3 at 201 frequency (or power) points in a matter of seconds, compared to several minutes using signal generators and a spectrum analyzer.



Frequency-offset mode is commonly available in VNA's, but conventional IF filter responses exhibit high side lobes. The IM Spectrum mode employs an optimized digital IF filter and provides true spectrum measurement capability in the PNA-X.

IMD measurement challenges

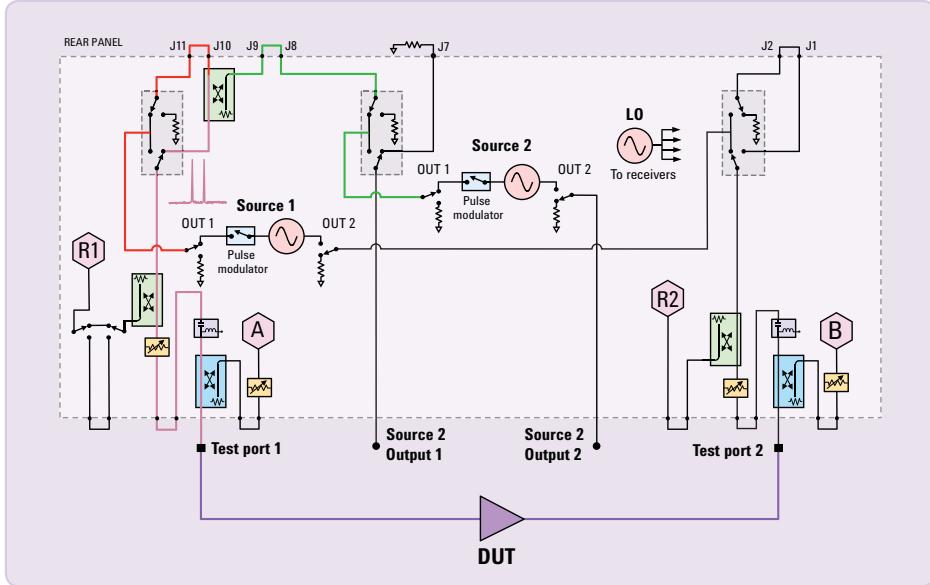
- Two signal generators, a spectrum analyzer, and an external combiner are most commonly used, requiring manual setup of all instruments and accessories
- Test times are slow when swept-frequency or swept-power IMD is measured
- Instruments and test setups often cause significant measurement errors due to source-generated harmonics, cross-modulation, and phase noise, plus receiver compression and noise floor



PNA-X with IMD application provides:

- Fast swept IMD measurements of amplifiers and frequency converters, using internal combiner and two internal sources
- Quick and easy measurements with simplified hardware setup and intuitive user interface
- Guided calibration that simplifies the calibration procedure and provides high measurement accuracy
- Spectrum analyzer mode for troubleshooting or making spurious measurements, eliminating the need for a separate spectrum analyzer
- Very clean internal sources and wide receiver dynamic range, minimizing the measurement errors caused by other instruments

The PNA-X with IMD application replaces two signal generators and a spectrum analyzer in the system rack, simplifying the system configuration and increasing test throughput.



Two internal sources with high output power, wide ALC range, -60 dBc harmonics, and a high-isolation combiner, make the PNA-X an ideal instrument to drive the DUT for two-tone IMD measurements. Wide dynamic-range receivers with high compression points enable accurate measurements of low-power IMD products while the higher power main tones are present.

Swept IMD sweep types

	Sweep fc	Sweep Delta F	Power Sweep	CW	LO Power Sweep	Segments
Center Frequency	Swept	Fixed	Fixed	Fixed	Fixed	Swept (as defined by segment table)
Tone Spacing	Fixed	Swept	Fixed	Fixed	Fixed	Fixed
Tone Powers	Fixed	Fixed	Swept (coupled or uncoupled)	Fixed	Fixed	Fixed
Diagram						

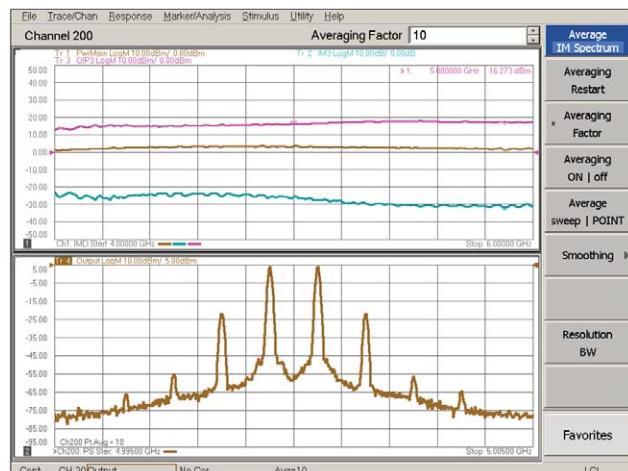
Cal all frequencies

Cal center frequencies

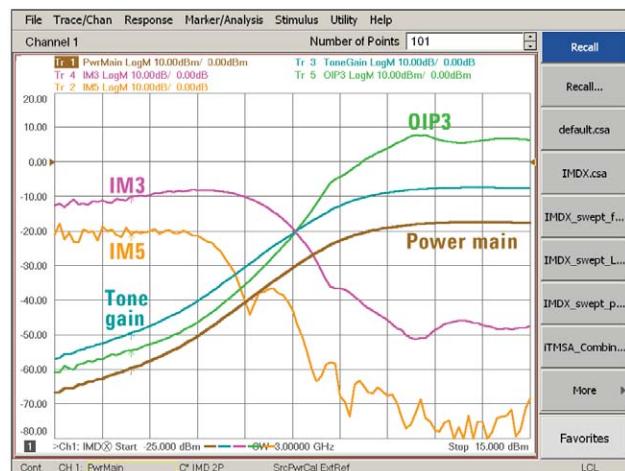
Tips from the experts

- Calibrate at all measurement frequencies or at center frequencies only, trading off productivity and accuracy
- Let the PNA-X control external signal generators to greatly simplify swept IMD measurements of mixers and converters
- Use the Marker to IM Spectrum feature to show the spectrum at a specified point on the swept IMD trace
- Use point averaging with IM Spectrum, especially when using a wide resolution bandwidth, to reduce the noise deviation of the noise floor with minimum speed impact

**Calibrating all frequencies is recommended for wide tone spacing.
Although the calibration takes longer with "all frequencies", measurement speed is not affected.**



The IM Spectrum in the lower window shows the spectrum corresponding to the Swept IMD marker at the center of the trace in the upper window. Point averaging is applied to the IM Spectrum to reduce the noise deviation.



IMD and IP3 versus LO power yields maximum IP3 with lowest possible LO drive power. This helps specify the mixer setup to achieve maximum efficiency while minimizing power consumption.

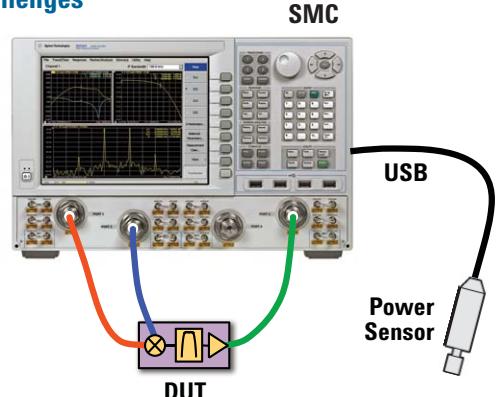
Innovative Applications

Accurate characterization of mixers and converters

(Options 082, 083, 084)

Mixer and converter measurement challenges

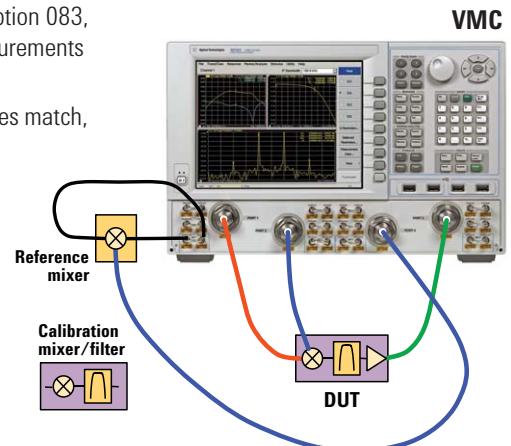
- Traditional approach with spectrum analyzer and external signal sources is cumbersome, slow, and does not provide phase or group delay information
- Conventional VNAs require an external signal source, which degrades sweep speed
- Conventional VNAs provide phase or group delay data relative to a “golden” device
- Attenuators are often used to minimize ripple due to input and output mismatch, at the expense of dynamic range and calibration stability



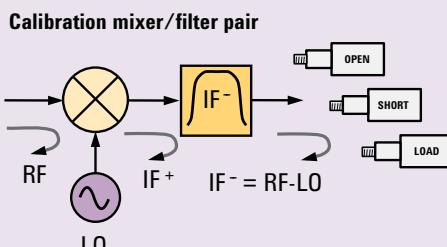
The Scalar Mixer/Converter (SMC) setup is simple and provides input and output match, and the most accurate conversion loss/gain measurements, plus calibrated absolute delay with Option 083.

PNA-X frequency converter applications provide:

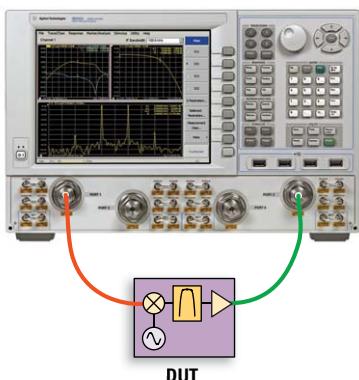
- Simple setup using internal second signal source as a local oscillator (LO) signal
- Typical measurement time improvement of 100x compared to spectrum analyzer-based approach
- High measurement accuracy using two patented techniques:
 - Scalar Mixer/Converter (SMC) provides match and most accurate conversion loss/gain measurements by combining two-port and power-meter calibrations (Option 082), and with Option 083, calibrated absolute group delay measurements without a reference mixer
 - Vector Mixer/Converter (VMC) provides match, conversion loss/gain, and low-noise measurements of phase and absolute group delay, using a vector-calibrated through mixer (Option 083)
- Input and output mismatch correction reduces ripple and eliminates the need for attenuators
- Embedded-LO feature (Option 084) extends SMC and VMC measurements to converters with embedded LOs without access to internal time bases



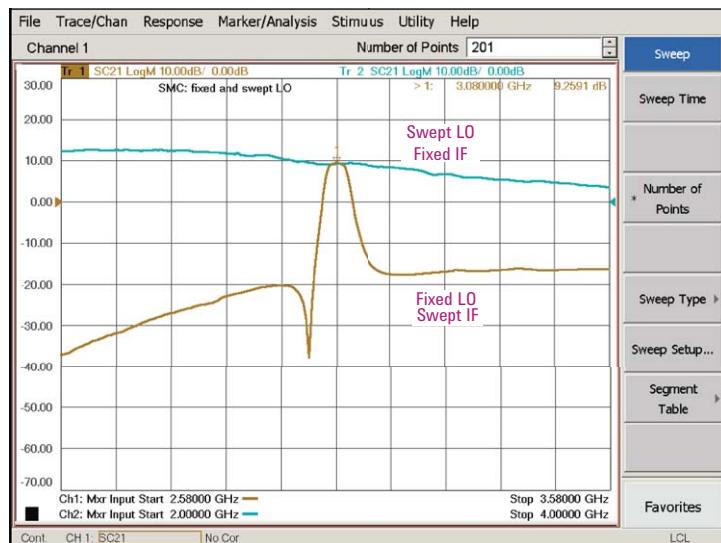
The Vector Mixer/Converter technique provides input and output match, conversion loss/gain, and low-noise measurements of phase and absolute group delay.



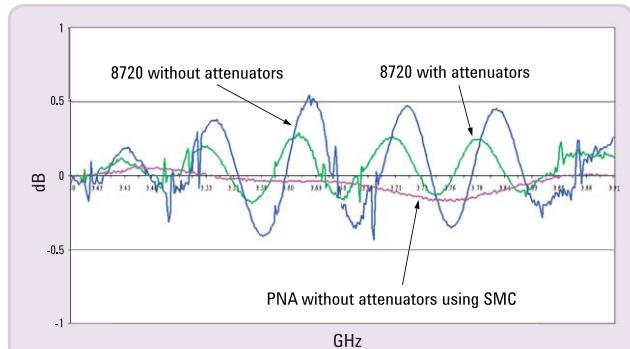
Agilent's patented Vector Mixer/Converter calibration method uses open, short, and load standards to create a characterized-mixer through standard.



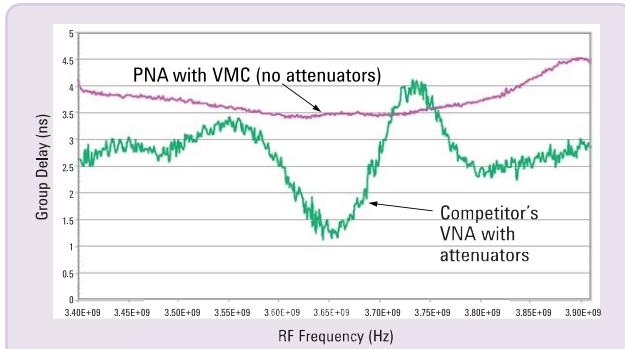
Both SMC and VMC can be used to measure converters with embedded LOs, without need for access to internal time bases.



With two internal signal sources, the PNA-X provides fast measurements of both fixed and swept IF responses.



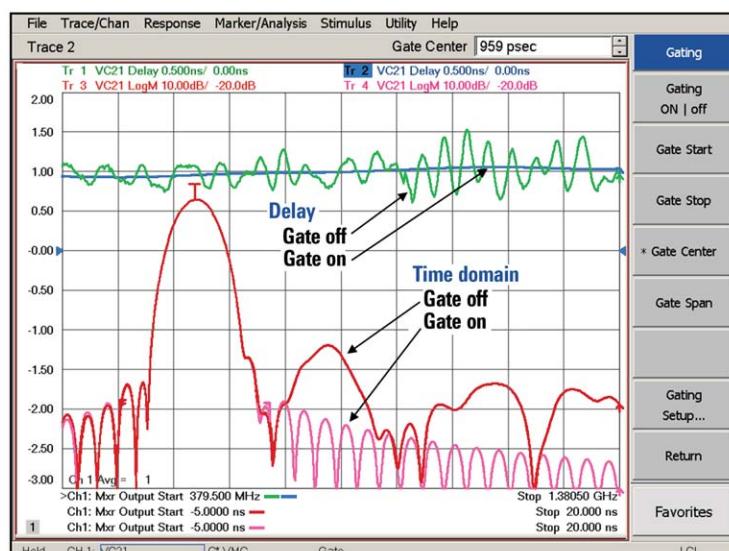
SMC's match correction greatly reduces mismatch errors in conversion loss/gain measurements, eliminating the need for attenuators at the ends of the test cables.



VMC's match correction greatly reduces mismatch errors in group delay measurements, eliminating the need for attenuators at the ends of the test cables.

Tips from the experts

- Narrowing the IF bandwidth helps eliminate spikes on the measurement trace that result from LO feed through and other spurious signals from the DUT
- To prevent source-unleveled errors when measuring devices with high-level spurious outputs (such as unfiltered mixers), it is often helpful to increase the amount of source attenuation to provide better isolation between the DUT and the PNA-X
- When making VMC measurements on multi-stage converters, it is best to create a single "meta-LO" signal that can be used to drive the reference and calibration mixers
- When measuring unfiltered mixers, time-domain gating can be a useful tool to reduce ripple by removing undesired, time-delayed responses due to spurious signals



Time-domain gating can remove ripple by removing unwanted, time-delayed responses due to spurious signals.

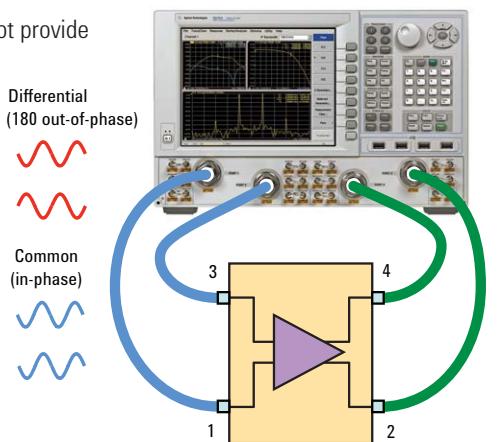
Innovative Applications

Testing differential amplifiers under real operating conditions

(Option 460)

Differential amplifier measurement challenges

- Conventional two-port VNAs with baluns do not provide common-mode, differential to common-mode, and common to differential-mode responses
- Baluns are inherently band-limited devices, which forces multiple test setups for broad frequency coverage
- Phase errors of baluns provide inaccurate differential responses
- Modern four-port VNAs provide mixed-mode S-parameter measurements with single-ended stimulus, but differential amplifiers may respond differently when in compression during real operating environments



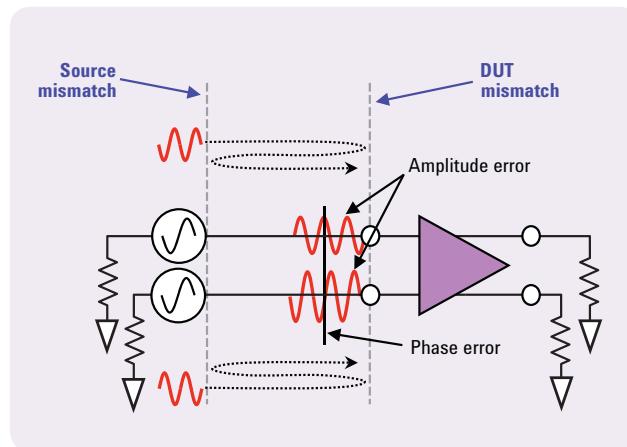
PNA-X integrated true-mode stimulus application (iTMSA) provides:

- Mixed-mode S-parameters of differential amplifiers driven by true differential and common-mode signals
- Mismatch correction at the DUT input to minimize phase errors between two sources
- Input-only drive mode that prevents damage on amplifiers caused by stimulus on the output port
- In-fixture arbitrary phase offset and phase-offset sweeps to optimize input matching network for maximum amplifier gain

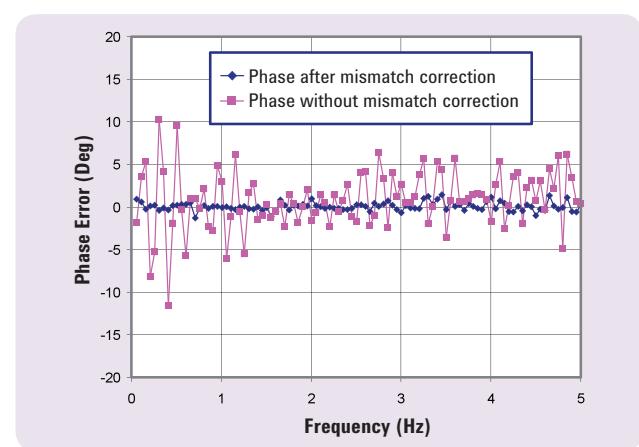
Using the PNA-X's two internal sources, iTMSA drives the differential amplifier under real world conditions, providing accurate mixed-mode S-parameters in all operating environments.

$S_{DD\ 11}$	$S_{DD\ 12}$	$S_{DC\ 11}$	$S_{DC\ 12}$
$S_{DD\ 21}$	$S_{DD\ 22}$	$S_{DC\ 21}$	$S_{DC\ 22}$
$S_{CD\ 11}$	$S_{CD\ 12}$	$S_{CC\ 11}$	$S_{CC\ 12}$
$S_{CD\ 21}$	$S_{CD\ 22}$	$S_{CC\ 21}$	$S_{CC\ 22}$

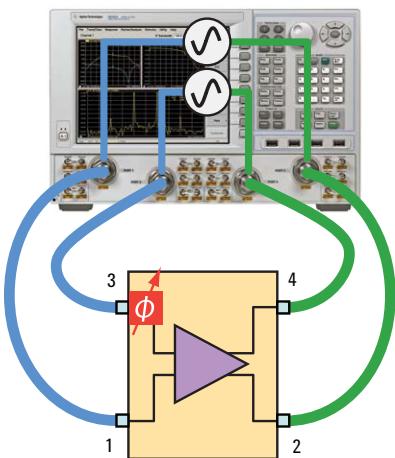
Mixed-mode S-parameters.



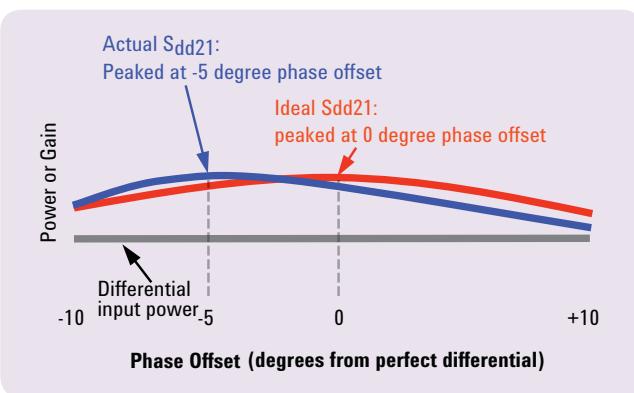
Without mismatch correction, the delivered signals to the DUT will not be truly differential due to reflection from the DUT input and the subsequent re-reflection from the sources. The reflected signals overlay the original signals, causing phase and amplitude imbalance. This effect can be corrected with mismatch correction.



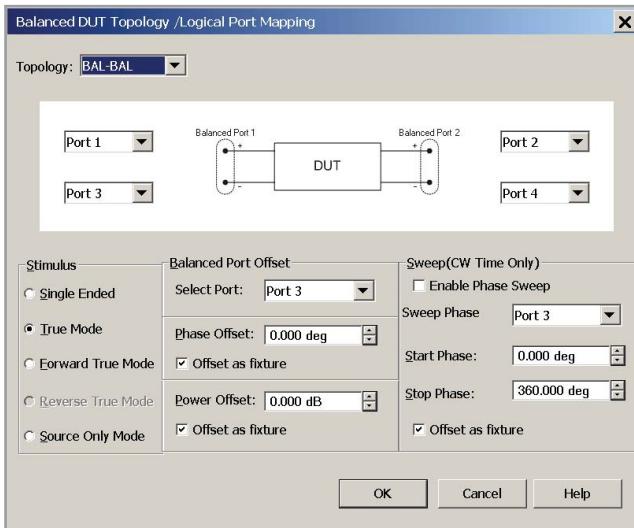
iTMSA compensates for mismatch errors by measuring the raw matches of the VNA and DUT, and precisely adjusting the amplitude and phase of the two signals at the reference plane to achieve ideal true-mode signals.



Phase-offset sweeps change the phase-offset value as if it were added in the fixture, enabling input-matching circuit validation.



In-fixture phase-offset sweeps reveal the optimal phase offset to achieve the highest amplifier gain, which is essential to the design of the input matching circuit.



Various stimulus and sweep settings are available in the Balanced DUT Topology dialog, which allow you to set the right setup for your devices characterization.

Tips from the experts

- Input-only true-mode drive assumes a perfect match between the DUT output and the VNA's test ports, which is a good assumption when the DUT's reverse isolation is high. When the reverse isolation is low, adding attenuators on the output port improves the system match and reduces mismatch errors.
- When comparing the test results between single-ended and true-mode drive conditions with the same effective delivered differential power, the individual port powers with true-differential drive must be set 6 dB lower than the port powers used with single-ended drive.

Single-ended drive

0 dBm port power = -3 dBm differential power + -3 dBm common-mode power

True differential drive

-3 dBm port power = -6 dBm port 1 single-ended power + -6 dBm port 3 single-ended power

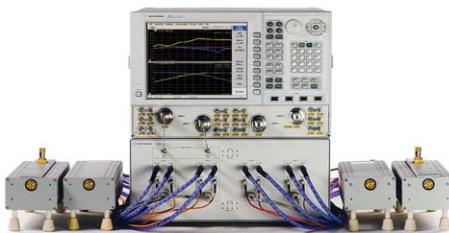
Innovative Applications

Extending the PNA-X to millimeter-wave frequencies

PNA-X's unique hardware architecture provides:

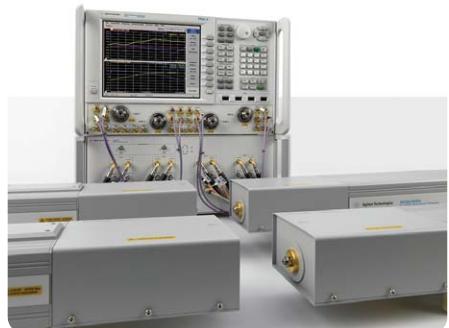
- Two- and four-port solutions for measurements on a wide variety of single-ended and balanced millimeter-wave devices
- True-mode differential measurements at millimeter-wave frequencies using two internal sources
- Fully integrated solution for millimeter-wave pulse measurements using built-in pulse modulators, pulse generators, and receiver gates
- Accurate leveled power at millimeter-wave frequencies with advanced source-power calibration methods
- Direct connection of terahertz modules driven by a 50 GHz PNA-X
- Single-sweep network analysis from 10 MHz to 110 GHz with full power-level control, using the 67 GHz PNA-X and millimeter-wave extension modules

Two- and four-port configurations



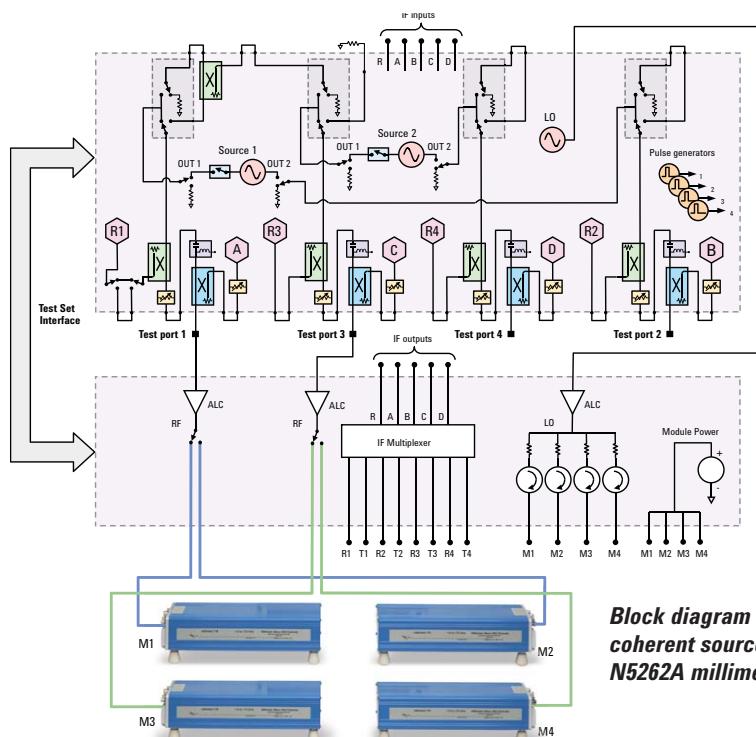
The N5262A millimeter-wave test-set controller connects four millimeter-wave test modules to the PNA-X. For two-port measurements, the N5261A millimeter-wave test-set controller is available.

Four-port single sweep 10 MHz to 110 GHz



PNA-X-based 110 GHz systems come in two- and four-port versions, with power-level control, true-differential stimulus, and the ability to measure frequency converters with SMC. These systems are table-top replacements for 8510XF systems, with superior performance.

Four-port system architecture



Block diagram of a 4-port millimeter-wave system with coherent source control of OML modules using the N5262A millimeter-wave test-set controller.

Terahertz measurements

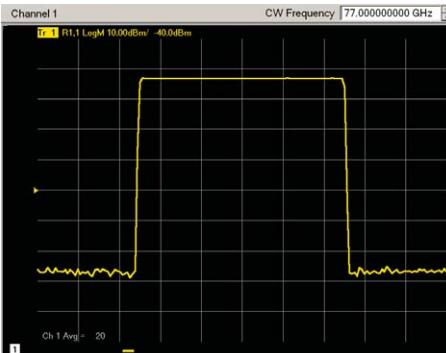


Direct connection of VDI modules to a 50 GHz PNA-X enables S-parameter measurements to 1.05 THz.

Millimeter-wave applications with the PNA-X

Integrated pulse measurements

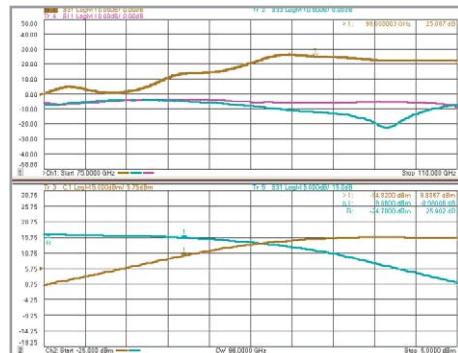
The PNA-X's internal pulse modulators create pulsed-RF signals for the millimeter-wave modules, making it easy to set up and perform pulsed millimeter-wave measurements.



Pulse profile at 77 GHz using the internal pulsed source and IF gates of the PNA-X.

Gain compression

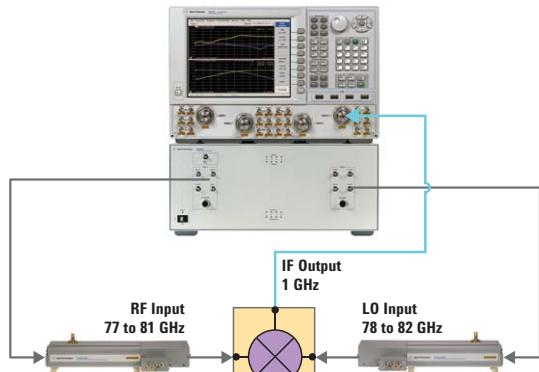
Using calibrated source-power sweeps, the PNA-X provides the most accurate millimeter-wave gain-compression measurements in the industry.



Example gain compression measurement of a 75 to 110 GHz packaged PHEMT transistor amplifier.

Scalar mixer measurements

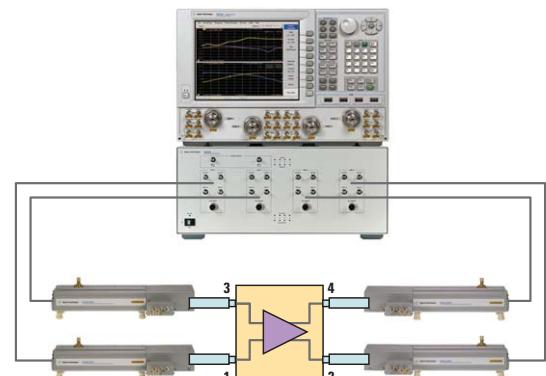
A two-module system can be used to provide fundamental RF and LO signals to a millimeter-wave mixer for conversion loss measurements.



Two-module system.

True-mode differential measurements at millimeter-wave frequencies

- Highest measurement accuracy in the industry using advanced error-correction methods
- Integrated phase sweeps with power control



True differential measurement of a balanced LNA using a PNA-X, the N5262A millimeter-wave test-set controller, and four millimeter-wave test modules.

Tips from the experts

- Use a four-port N5262A test-set controller to configure two different two-port waveguide-band setups.
- If you do not have a millimeter-wave power sensor, you can still create a power-calibration table using the PNA-X's internal reference receiver, for accurate relative source-power changes of the millimeter test modules.
- For applications that don't require a test-set controller, Agilent's downloadable macro makes it easy to configure direct-connection millimeter-wave setups.

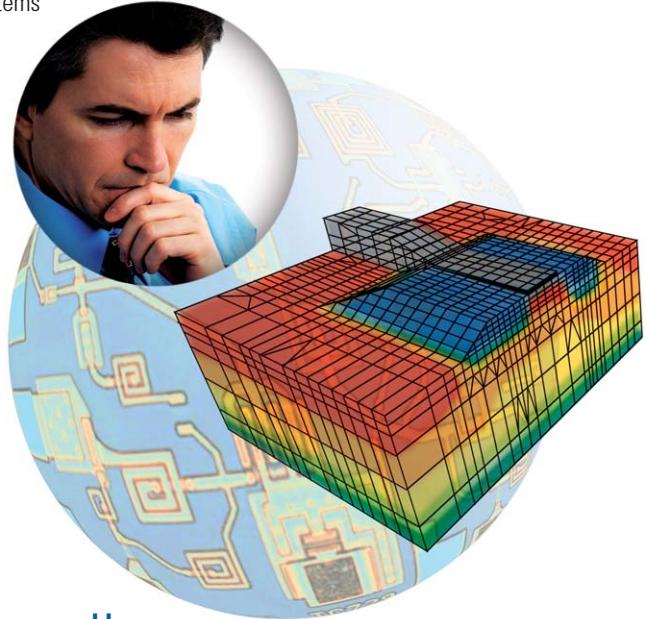
Innovative Applications

Nonlinear waveform and X-parameter characterization

(Options 510, 514, 518, and 520)

High-power design challenges

- Active devices are commonly driven into nonlinear regions, often by design to increase power efficiency, information capacity, and output power
- Under large-signal drive conditions, active devices distort time-domain waveforms, generating harmonics, intermodulation distortion, and spectral regrowth
- Current circuit simulation tools that rely on S-parameters and limited nonlinear behavioral models are no longer sufficient to fully analyze and predict nonlinear behavior of devices and systems
- Fewer design iterations are required to meet current time-to-market demands



S-parameters in a nonlinear world

In the past, when designing systems with high-power amplifiers (HPAs), designers measured amplifier S-parameters using a vector network analyzer, loaded the results into an RF simulator, added other measured or modeled circuit elements, and then ran a simulation to predict system performance such as gain and power-efficiency under various loads.

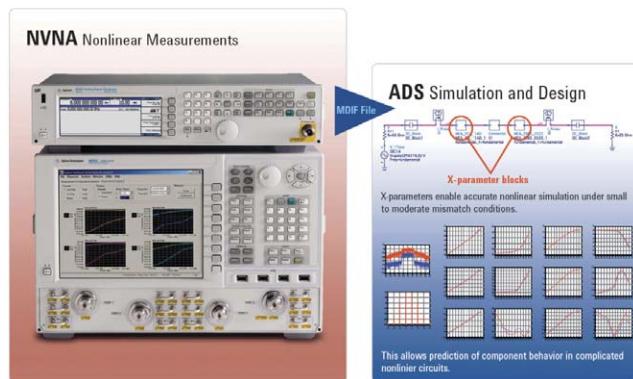
Since S-parameters assume that all elements in the system are linear, this approach does not work well when attempting to simulate performance when the amplifier is in compression or saturation, as real-world HPAs often are. The errors are particularly apparent when simulating the combined performance of two cascaded devices that exhibit nonlinear behavior. While engineers may live with this inaccuracy, it invariably results in extensive and costly empirical-based iterations of the design, adding substantial time and cost to the design and verification process.

Breakthrough technology accurately characterizes nonlinear behaviors

Testing today's high-power devices demands an alternate solution—one that quickly and accurately measures and displays the device's nonlinear behavior under large signal conditions, and provides an accurate behavioral model that can be used for linear and nonlinear circuit simulations. The Agilent nonlinear vector network analyzer (NVNA) and X-parameters* provide that solution.

Agilent's award-winning NVNA goes beyond S-parameters to:

- Efficiently and accurately analyze and design active devices and systems under real-world operating conditions, to reduce design cycles by as much as 50%
- Gain valuable insight into device behavior with full nonlinear component characterization (Option 510)
 - Display calibrated time-domain waveforms of incident, reflected, and transmitted waves of the DUT in coaxial, in-fixture, or on-wafer environments
 - Show the amplitude and phase of all harmonic and distortion spectral products to design optimal matching circuits
 - Create user-defined displays such as dynamic load lines
 - Measure with full traceability to the National Institute of Science and Technology (NIST)
- Provide fast and powerful measurements of DUT nonlinear behavior using X-parameters (Option 514)
 - Extend linear S-parameters into nonlinear operating regions for accurate predictions of cascaded nonlinear device behavior using measurement-based data
 - Easily import the NVNA's X-parameters into Agilent's Advanced Design System (ADS) to quickly and accurately simulate and design nonlinear components, modules and systems
- Measure memory effects such as self heating and signal-dependent bias changes (Option 518)
- Capture complete load-dependent nonlinear component behavior with X-parameters and external impedance tuners (Option 520)



Measure complete linear and nonlinear component behavior with the Agilent NVNA, and then accurately perform simulations and optimizations with Agilent's Advanced Design System.



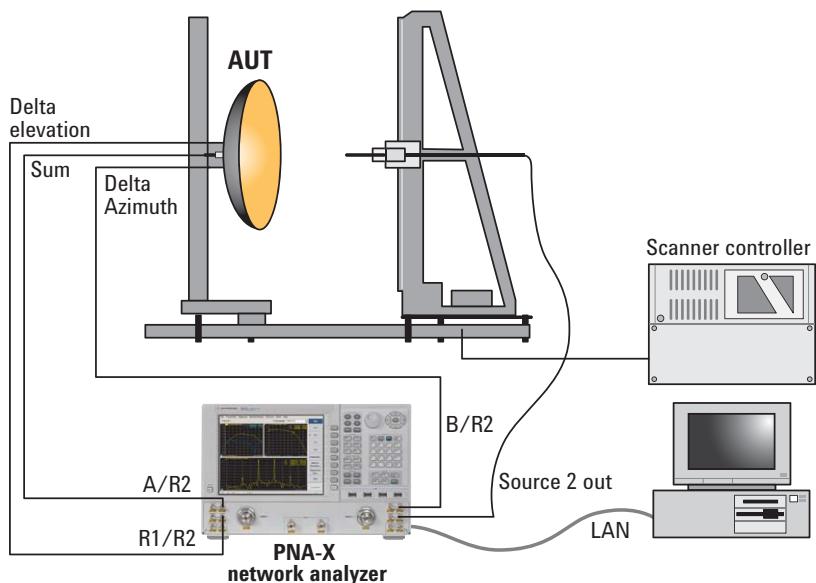
*X-parameters is a registered trademark of Agilent Technologies. The X-parameter format and underlying equations are open and documented. For more information, visit <http://www.agilent.com/find/eesof-x-parameters-info>

Agilent's NVNA software options and accessories convert an Agilent 4-port PNA-X network analyzer into a high-performance nonlinear vector network analyzer.

Innovative Applications

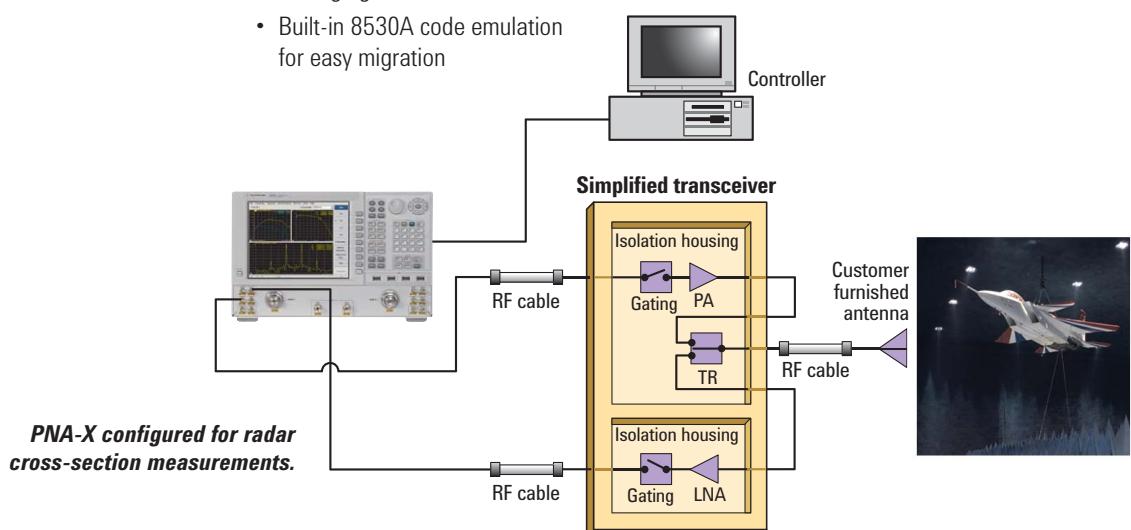
Fast and accurate RF subsystem for antenna measurements

PNA-X configured for near-field measurements.



PNA-X-based antenna solutions provide:

- Flexibility in system design: choose a standard PNA-X or an N5264A low-cost dedicated measurement receiver based on PNA-X hardware
- Fast measurements: 400,000 data points per second simultaneously on five receivers, yielding three to five times improvement in test times compared to the 8530A
- Large data collections with 500 million point circular FIFO data buffer
- Excellent measurement sensitivity via selectable IF bandwidths and point-averaging mode
- Built-in 8530A code emulation for easy migration



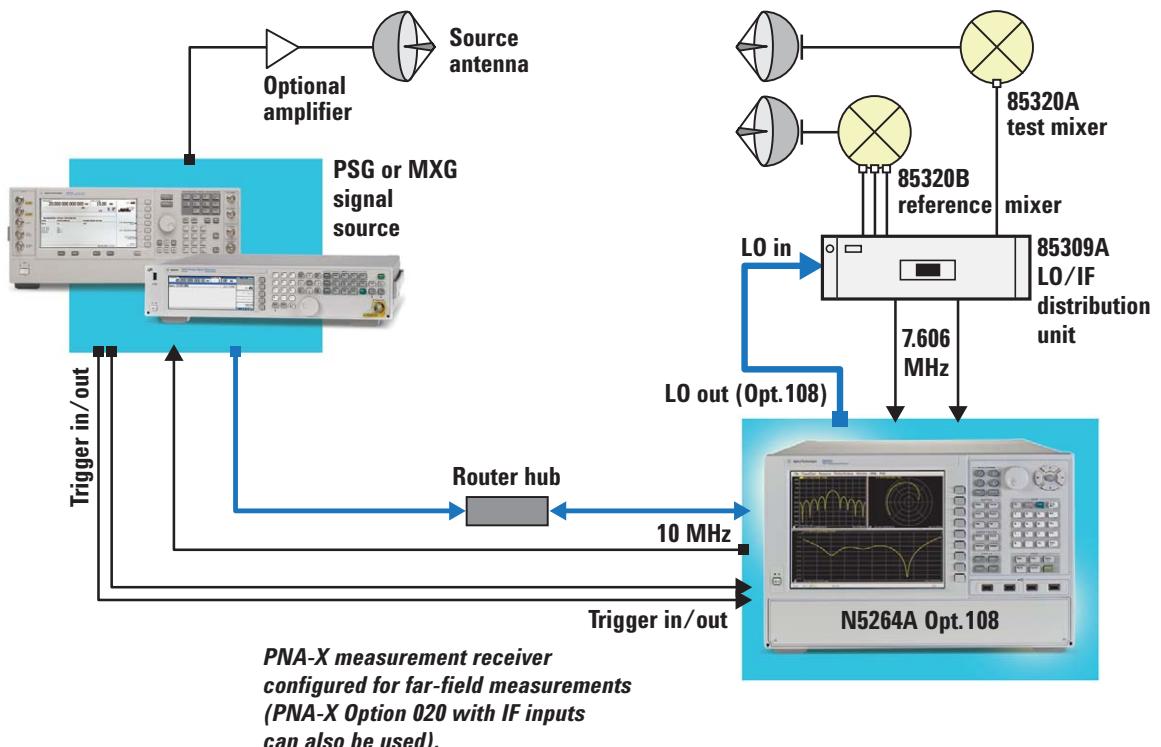
Why should I migrate my 8530A system to the new PNA-X measurement receiver?



- 8530A is no longer supported, so maintaining existing systems is getting harder and harder
- PNA-X measurement receiver...
 - Offers built-in 8530A code emulation for full reuse of existing measurement software
 - Is fully compatible with your existing 8530A system components
 - Features 80 times improvement in data acquisition time
 - Contains an optional built-in high-output power source (Option 108) that can be used as an LO for remote mixers or frequency converters

What is the best choice for an antenna receiver?

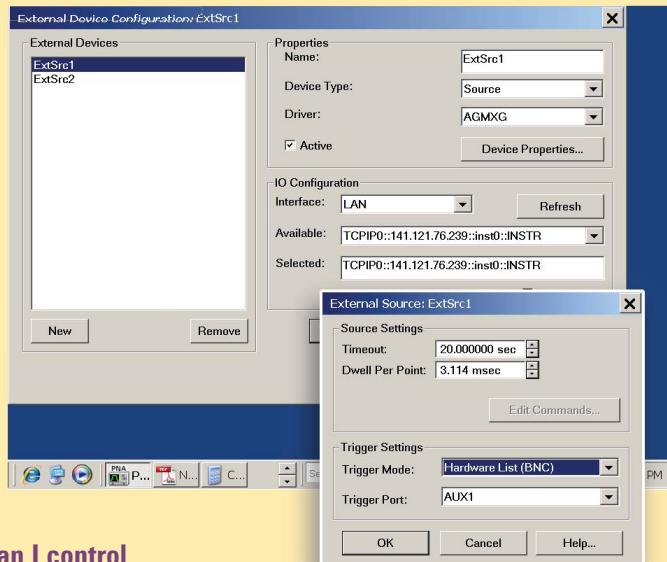
Application	N5264A measurement receiver	N524xA PNA-X	Comments
Near-field	No (requires external source)	Yes	Achieve faster measurement throughput with internal source Can use VNA for general-purpose component test
Compact range	Yes	Yes	Choice depends on the size of the antenna range
Far-field	Yes	No (higher cost)	Distributed approach increases measurement sensitivity by strategic placement of system components
Pulsed RF	No	Yes	PNA-X offers built-in pulse generators and modulators that simplify the system configuration



Innovative Applications

Fast and accurate
RF subsystem
for antenna
measurements
continued

Tips from the experts

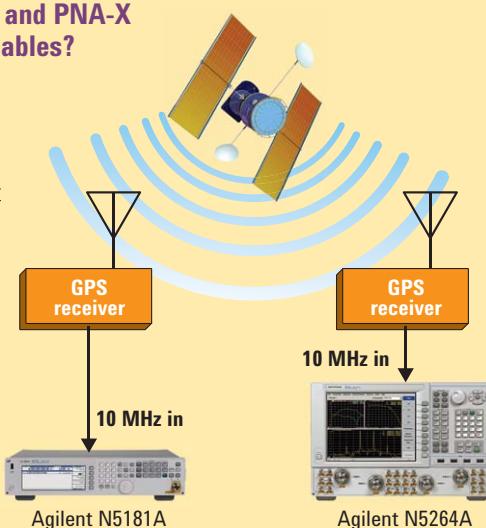


How can I control external sources?

1. Connect PNA-X to source via LAN or GPIB
2. Use External Device Configuration feature
3. Under Properties section:
 - Type name of external source, change Device Type to Source, and choose appropriate driver
 - Under Device Properties, choose between two trigger modes: Software CW (trigger cables not needed, but slow), or Hardware List (fast, but requires TTL triggers)
 - When distance between PNA-X and source is too far to use BNC trigger cables (> 40 meters), then Agilent E5818A trigger box with LAN hub offers good alternative

How do I get a common 10 MHz reference signal to my source and PNA-X when it's too far to use BNC cables?

- Use low-cost GPS-based satellite receivers to obtain high-accuracy 10 MHz reference signals
- Place a GPS receiver near transmit source, and one near the PNA-X
- This approach works for arbitrary distances, from 100's of meters to many kilometers



Outstanding Performance

Specification and Feature Comparison

	N5241A N5242A	N5244A N5245A	N5247A (<i>Preliminary</i>)
Frequency range	10 MHz to 13.5 GHz 10 MHz to 26.5 GHz	N5244A 10 MHz to 43.5 GHz N5245A 10 MHz to 50 GHz	10 MHz to 67 GHz
System dynamic range (at 20 GHz)	121 to 130 dB depends on configuration 124 to 141 dB with direct receiver access (typical)	121 to 125 dB depends on configuration 133 to 137 dB with direct receiver access (typical)	125 to 129 dB depends on configuration 136 to 140 dB with direct receiver access (typical)
Maximum output power at test port (at 20 GHz)	+13 dBm (Option 200, 400) +10 dBm (Option 219, 419) -+15 dBm (Option 224) -+10 dBm (Option 423)	+13 dBm (Option 200, 400) +10 dBm (Option 219, 419) +10 dBm (Option 224, 423)	+11 dBm (Option 200, 400) +8 dBm (Option 219, 419) +7 dBm (Option 224, 423)
Maximum power sweep range		38 dB	
Corrected specifications¹	(2-port cal, 3.5 mm) Dir 44 to 48 dB SM 31 to 40 dB LM 44 to 48 dB Refl trk +/-0.003 to 0.006 dB Trans trk +/-0.015 to 0.104 dB	(2-port cal, 2.4 mm) Dir 36 to 42 dB SM 31 to 41 dB LM 35 to 42 dB Refl trk +/-0.001 to 0.027 dB Trans trk +/-0.020 to 0.182 dB	(2-port, 1.85 mm) Dir 34 to 41 dB SM 34 to 44 dB LM 34 to 41 Refl trk 0.01 to 0.33 Trans trk 0.036 to 0.164 dB
Trace noise		0.002 dB rms (1 kHz BW)	
Harmonics 10 MHz to 2 GHz > 2 GHz		-51 dBc typical -60 dBc typical	

¹ Dir = directivity; SM = source match; LM = load match; Refl trk= reflection tracking; Trans trk = transmission tracking

PNA-X Configuration Information

PNA-X Network Analyzers

Option configurations

To add options to a product, order the corresponding item number.						
Description	N5241A 10 MHz to 13.5 GHz	N5242A 10 MHz to 26.5 GHz	N5244A 10 MHz to 43.5 GHz	N5245A 10 MHz to 50 GHz	N5247A 10 MHz to 67 GHz	Additional information
Test set						
Option 200 2-ports, single source	N5241A-200	N5242A-200	N5244A-200	N5245A-200	N5247A-200	
Option 224 2-ports, add internal 2nd source, combiner and mechanical switches	N5241A-224	N5242A-224	N5244A-224	N5245A-224	N5247A-224	Requires Options 200, one of 219 or H85, and 080
Option 400 4-ports, dual source	N5241A-400	N5242A-400	N5244A-400	N5245A-400	N5247A-400	Option 080 recommended
Option 423 4-ports, add internal combiner and mechanical switches	N5241A-423	N5242A-423	N5244A-423	N5245A-423	N5247A-423	Requires Options 400, one of 419 or H85, and 080
Power configuration						
Option 219 2-ports, extended powerrange and bias-tees	N5241A-219	N5242A-219	N5244A-219	N5245A-219	N5247A-219	
Option 419 4-ports, extended power range and bias-tees	N5241A-419	N5242A-419	N5241A-419	N5242A-419	N5247A-419	
Option H85 ¹ High power configurable (for 2- or 4-port)	N5241A-H85	N5242A-H85	N5241A-H85	N5242A-H85	N/A	
Measurement applications						
Option 010 Time-domain measurements	N5241A-010	N5242A-010	N5244A-010	N5245A-010	N5247A-010	
Option 028 ² Noise figure measurements using standard receivers	N5241A-028	N5242A-028	N5244A-028	N5245A-028	N5247A-028	Requires Option 082 or 083 for measuring frequency converters
Option 029 ² Fully-corrected noise figure measurements	N5241A-029	N5242A-029	N/A	N/A	N/A	Requires one of Options 219, 224, 419, 423, or H85, and for measuring frequency converters, requires Option 082 or 083
Option H29 ² Add 26.5 GHz noise receivers	N/A	N/A	N5244AS-H29	N5245AS-H29	N/A	Requires Option 423 and for measuring frequency converters, requires Option 082 or 083
Option 080 Frequency offset	N5241A-080	N5242A-080	N5244A-080	N5245A-080	N5247A-080	
Option 082 ³ Scalar-calibrated converter measurements	N5241A-082	N5242A-082	N5244A-082	N5245A-082	N5247A-082	Requires Option 080
Option 083 ³ Vector- and scalar-calibrated converter measurements	N5241A-083	N5242A-083	N5244A-083	N5245A-083	N5247A-083	Requires Option 080
Option 084 Embedded LO measurements	N5241A-084	N5242A-084	N5244A-084	N5245A-084	N5247A-084	Requires at least one of Options 028, 029, H29, 082, 083, 086, or 087
Option 086 Gain compression application	N5241A-086	N5242A-086	N5244A-086	N5245A-086	N5247A-086	Recommend Options 219, 419 or H85 and for measuring frequency converters, requires Option 082 or 083
Option 087 Intermodulation distortion application	N5241A-087	N5242A-087	N5244A-087	N5245A-087	N5247A-087	Requires Options 224 or 423 and for measuring frequency converters, requires Option 082 or 083
Option 460 Integrated true-mode stimulus application	N5241A-460	N5242A-460	N5244A-460	N5245A-460	N5247A-460	Requires Option 400
Option 551 ⁴ N-port capabilities	N5241A-551	N5242A-551	N5244A-551	N5245A-551	N5247A-551	
Nonlinear vector network analysis						
Option 510 Nonlinear component characterization	N5241A-510	N5242A-510	N5244A-510	N5245A-510	N/A	Requires Options 419 and 080, or 400, H85 and 080
Option 514 Nonlinear X-parameters ⁵	N5241A-514	N5242A-514	N5244A-514	N5245A-514	N/A	Requires Options 423 and 510
Option 518 Nonlinear pulse envelope domain	N5241A-518	N5242A-518	N5244A-518	N5245A-518	N/A	Requires Options 021 and 025 and either one of 510 or 514
Option 520 Arbitrary load-impedance X-parameters	N5241A-520	N5242A-520	N5244A-520	N5245A-520	N/A	Requires Option 514
Required NVNA accessories						
<ul style="list-style-type: none"> • U9391C 10 MHz to 26.5 GHz or U9391F 10 MHz to 50 GHz comb generator (two required for nonlinear measurements) • Agilent power meter and sensor or USB power sensor • Agilent calibration kit, mechanical or ECal • Agilent signal generator, MXG or PSG used for X-parameter extraction (internal 10 MHz reference output can be used for 10 MHz tone spacing applications) 						

- Order special model N524xAS instead of N524xA and add items N524xA-200 and N524xA-H85 for 2-port, extended power range, high power configuration, or items N524xA-400 and N524xAS-H85 for 4-port, extended power range, high power configuration. Order N524xA-xxx items for other standard options. Option H85 includes the extended power range of Options 219 and 419, and therefore, they cannot be ordered together.
- For source-corrected measurements, Options 028, 029, and H29 require an ECal module for use as an impedance tuner. For calibration, Options 029 and H29 also require a 346-series noise source (Agilent 346C recommended), while Option 028 requires a power meter. All options require a power meter for measuring mixers and converters.
- Option 082 is a subset of Option 083; therefore, they cannot be ordered together.
- When configured as a multiport analyzer using Option 551 and a multiport test set, the combiner feature of Option 224 or 423 is temporarily disabled. When configured as a standalone analyzer, the combiner feature is enabled. When ordering a test set, select an option to specify the appropriate interconnect jumper cable set between the analyzer and the test set.
- X-parameters is a trademark of Agilent Technologies

PNA-X Configuration Information

PNA-X Network Analyzers

Option configurations, continued

To add options to a product, order the corresponding item number.						
Description	N5241A 10 MHz to 13.5 GHz	N5242A 10 MHz to 26.5 GHz	N5244A 10 MHz to 43.5 GHz	N5245A 10 MHz to 50 GHz	N5247A 10 MHz to 67 GHz	Additional information
Pulse, antenna, mm-wave						
Option 008 Pulsed-RF measurements	N5241A-008	N5242A-008	N5244A-008	N5245A-008	N5247A-008	Requires Option 025
Option 020 Add IF inputs for antenna and mm-wave	N5241A-020	N5242A-020	N5244A-020	N5245A-020	N5247A-020	
Option 021 Add pulse modulator to internal 1st source	N5241A-021	N5242A-021	N5244A-021	N5245A-021	N5247A-021	
Option 022 Add pulse modulator to internal 2nd source	N5241A-022	N5242A-022	N5244A-022	N5245A-022	N5247A-022	Requires Option 224 or 400
Option 025 Add four internal pulsegenerators	N5241A-025	N5242A-025	N5244A-025	N5245A-025	N5247A-025	
Option 118 Fast CW sweep	N5241A-118	N5242A-118	N5244A-118	N5245A-118	N5247A-118	
Accessories						
Option 1CM Rack mount kit for use without handles	N5241A-1CM	N5242A-1CM	N5244A-1CM	N5245A-1CM	N5247A-1CM	
Option 1CP Rack mount kit for use with handles	N5241A-1CP	N5242A-1CP	N5244A-1CP	N5245A-1CP	N5247A-1CP	
Calibration software						
Option 897 ¹ Perpetual license for built-in performance test software for Agilent inclusive calibration	N5241A-897	N5242A-897	N5244A-897	N5245A-897	N5247A-897	
Option 898 ¹ Perpetual license for built-in performance test software for standards compliant calibration	N5241A-898	N5242A-898	N5244A-898	N5245A-898	N5247A-898	
Calibration documentation						
Option 1A7 ISO 17025 compliant calibration	N5241A-1A7	N5242A-1A7	N5244A-1A7	N5245A-1A7	N5247A-1A7	
Option UK6 Commercial calibration certificate with test data	N5241A-UK6	N5242A-UK6	N5244A-UK6	N5245A-UK6	N5247A-UK6	
Option A6J ANSI Z540 compliant calibration	N5241A-A6J	N5242A-A6J	N5244A-A6J	N5245A-A6J	N5247A-A6J	

1. Additional hardware required. Please refer to the analyzer's Service Guide for required service test equipment.

Additional Information

Download the latest PNA-X application notes:

Bookmark this page to download the latest PNA-X application notes to gain in-depth measurement knowledge.

High Power Amplifier Measurements
Using Agilent's Nonlinear Vector
Network Analyzer

Application Note 1408-19

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