Keysight Technologies
Achieving Metrology-grade Results in Vector Network Analysis at Millimeter-wave Frequencies

Application Note

For more information:

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Introduction

It's easy to underestimate the challenges that arise when working at millimeter-wave frequencies. That's why Keysight is focused on delivering easier access to accurate, repeatable measurements at ever-higher frequencies and wider bandwidths.

The ability to develop off-the-shelf tools for extremely high frequencies follows from decades of experience in measurement science and millimeter-wave technology. We capture that expertise inside our hardware and software products and put crucial capabilities at your fingertips.

To help you deliver truly competitive next-generation devices and designs, we're focused on creating innovative tools for design, simulation, test and analysis at gigahertz and terahertz frequencies. Our latest development is a pair of broadband millimeter-wave network analyzers: the N5290A (PNA) and N5291A (PNA-X). With these new solutions, you can reach for unrivalled excellence in your measurements and designs up to 120 GHz (Figure 1).
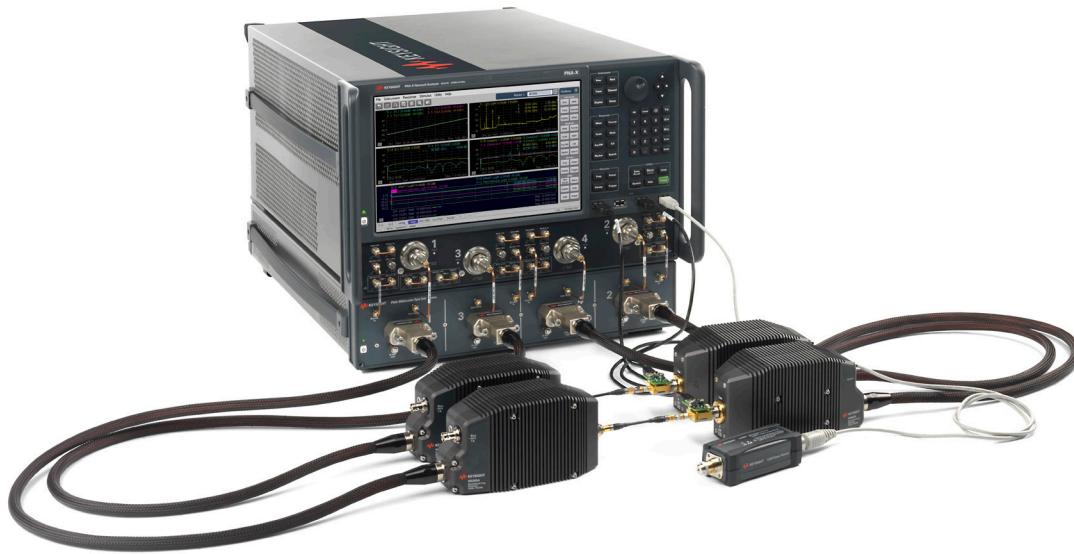
Figure 1. The N5291A four-port broadband millimeter-wave network analyzer enables you to confidently characterize your leading-edge designs.

Getting Better Results in Millimeter-wave Vector Network Analysis

Our broadband millimeter-wave solutions enhance device characterization and modeling by providing exceptional stability and accuracy for on-wafer and connectorized measurements. Leveraging our deep expertise in metrology and calibration, the N5290/91A solutions deliver traceable, metrology-grade results at millimeter-wave frequencies. Frequency range is 900 Hz to 120 GHz and the key specifications are magnitude stability of less than 0.015 dB and phase stability of less than 0.15 degrees over a 24-hour period.

The measurement platform is a PNA or PNA-X vector network analyzer (VNA) operating at a frequency of 26.5 or 67 GHz. The other core elements are a two- or four-port millimeter-wave test-set controller[1] and a set of compact frequency extenders ("smart modules"). The smart modules include ruggedized 1.0 mm connectors, convection cooling, and built-in data that enables fully calibrated port power at turn-on.

To ensure accurate and repeatable on-wafer results, the N5290/91A solution is compatible with the wafer-level measurement solution (WMS) created by Keysight and solution-partner Cascade Microtech (Figure 2). The WMS includes Cascade Microtech wafer-level probe stations, bias probes, and calibration tools combined with Keysight instrumentation and software. With these capabilities, the WMS-based solution provides accurate and repeatable wafer-level measurements that address a variety of applications: device modeling; technology development; process development and specification; process monitoring; component specification; and pilot manufacturing.
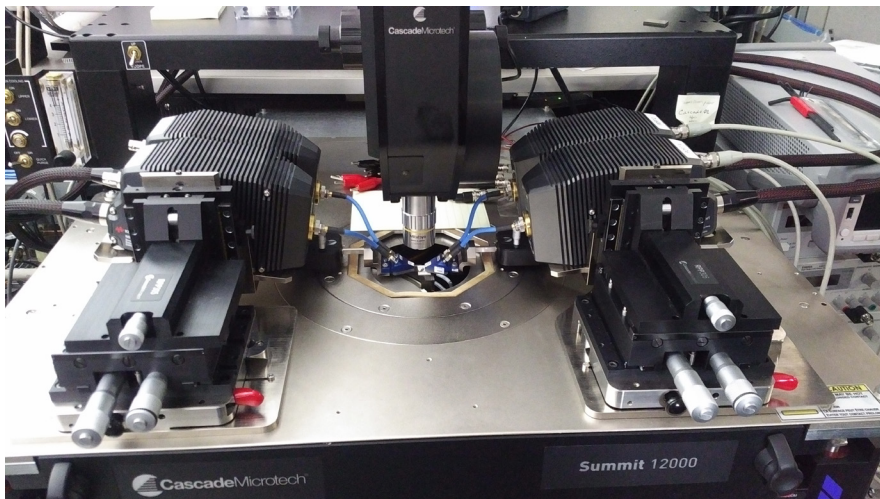

Figure 2. This WMS configuration with a four-port N5291A is being used to perform on-wafer measurements of a differential amplifier.

The new solutions also provide measurements that are traceable to national measurement institutes (NMIs). The foundation is a 1.0 mm calibration kit, and the result is traceable measurement uncertainty for key performance parameters such as residual calibration errors, system dynamic accuracy, and stability. To further enhance measurement results, you can choose to apply automatic fixture de-embedding to connectorized measurements or perform calibration at the probe tips to enhance the accuracy of on-wafer measurements.

1.   Options 200 and 400, respectively, for N5290A and N5291A

Enhancing Stability and Precision with Mechanical Innovations

At millimeter-wave frequencies, the overall performance of a measurement system also depends on its physical and mechanical design. Inside the new smart modules, we are applying our best-in-class machining capabilities to fabricate wideband coupler technology that provides exceptional stability during measurement calibration.

In the smart frequency-extender modules, the ruggedized 1.0 mm test ports ensure repeatable connections measurement to measurement, day after day. This reduces calibration uncertainty and further improves system-level measurement precision.

Testing Multiple Components in One Setup

New-generation monolithic microwave integrated circuits (MMICs) incorporate components that operate in different frequency ranges: baseband, RF, microwave and millimeter-wave. A VNA with single-sweep coverage from hertz to gigahertz enables you to test all those components with a single setup.

Wider frequency coverage also reduces the cost of your test solution. For example, a 900 Hz start frequency in a millimeter-wave network analyzer eliminates the need to purchase a dedicated low-frequency VNA. Using one analyzer also saves time and reduces complexity by streamlining development of test system software.

Greater integration inside MMICs and other wideband designs often means testing more functions per device through fewer access points. The need to connect, disconnect and reconnect the DUT to a VNA or spectrum analyzer is inconvenient and time-consuming whether done manually or automatically through a switch matrix.

The most convenient solution is a VNA with a single-connection/multiple-measurement (SCMM) architecture. As implemented in the Keysight PNA-X network analyzers, you can measure passive or active devices with one set of connections: S-parameters, noise figure, gain compression, THD, IMD, and more. For even greater measurement versatility, the SCMM capability supports the PNA family's spectrum analysis measurement application.

Simplifying Complex Tasks with Measurement Applications

To help you save time and easily configure complex tasks, Keysight offers several measurement applications that help you achieve deeper insights into device performance:

– **Scalar mixer/converter measurements:** Supports scalar characterization of mixers and frequency converters (software option S93082)

– **Gain-compression application:** Provides complete characterization of amplifiers and frequency converters (software option S93086)

– **Noise-figure measurements:** Enables further characterization of frequency converters (software option S93029)

– **Differential and I/Q devices application:** Simplifies testing of amplifiers and mixers (software option S93089)

– **Spectrum analyzer application:** Provides calibrated multi-channel spectrum analysis up to 120 GHz and beyond (software options S93093, to 120 GHz, or S93094, above 120 GHz)

These measurement applications are all touch-enabled, further simplifying complex operations and providing a more intuitive approach to investigating, characterizing, and troubleshooting broadband millimeter-wave devices.

Another key point: our approach to transportable software licensing makes it possible for you to buy one copy of a measurement application and share it between multiple instruments. This maximizes utilization by letting you and your teammates assign needed functionality to a specific instrument, when and where it's needed. It's also more cost-effective than buying a copy of the application for every instrument.

Leveraging a Common Platform for Keysight VNAs

Good usability is beneficial when performing basic measurements such as S-parameters, and it becomes essential when delving into complex tasks such as the characterization of mixers and other frequency-conversion devices. To help ensure excellent results in less time, many customers have asked us to build measurement guides into our instruments and to present those tools on the screen of the analyzer. This is an important concept, given the time pressures and design requirements most engineers face. It's also a logical and feasible idea that utilizes the processor, memory and display resources in the latest PNA and PNA-X models.

To address these needs, Keysight design engineers pursued parallel advances in measurement performance and front-panel usability. To provide a foundation for next-generation Keysight VNAs, the development team created a common platform that leverages the best attributes of our well-established VNAs.

Two guiding principles were paramount: remain familiar and comfortable for existing ENA or PNA users, and be inviting and intuitive for new users. The result is a graphical user interface (GUI) that is helpful to engineers who, from time to time, need to make a variety of measurements—simple or complex—while characterizing or troubleshooting a variety of RF components or subsystems. It is also useful to experienced users who occasionally need to make highly complex measurements and will benefit from reminders about the crucial steps and settings.

All users will appreciate the familiarity of touch-enabled UI technology similar to that used in smartphones, tablets and laptops. The updated PNA and PNA-X families include the following attributes:

– 12.1-inch widescreen display with multi-touch UI
– Easy access to frequently used functions
– Quick setups using touch-activated tabbed softkeys and dialog menus
– Intuitive single- and multi-touch gestures to drag-and-drop and magnify traces
– Versatile, touch-driven marker capabilities

For added flexibility, you can also customize the placement of traces and windows on the analyzer screen. Example capabilities include optimal arrangement of traces from multiple measurement channels and multi-page measurement displays through a "tabbed sheet" function. The N5290/91A also includes a dedicated "Millimeter Configuration" guide within the setup menus (Figure 3).
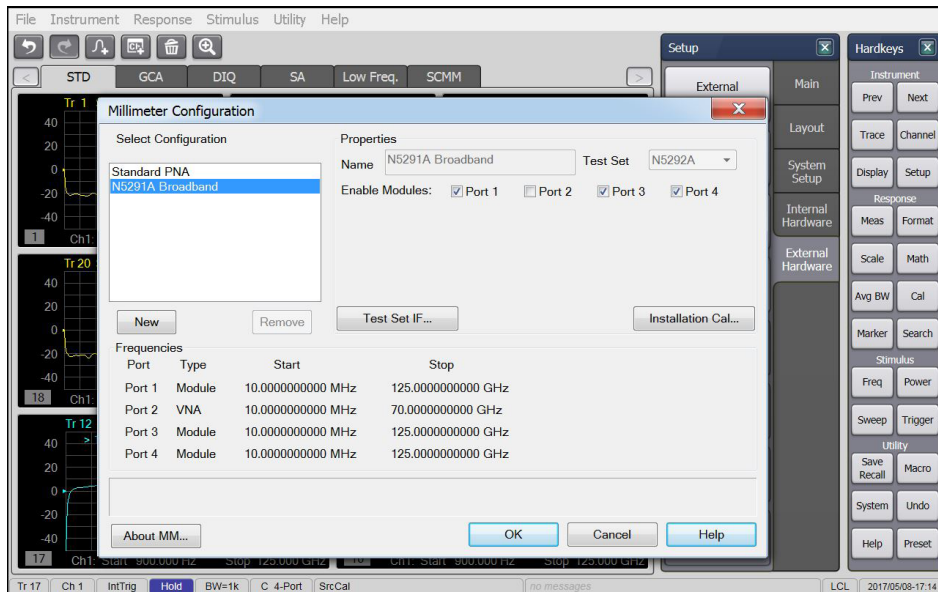

Figure 3. The new interface includes task-specific screens such as Millimeter Configuration that guide new or infrequent users and help ensure better results.

Building on our legacy of innovation

As millimeter-wave is becoming more common in commercial applications, Keysight has been advancing the learning curve for decades. Under the Hewlett-Packard brand, our earliest gigahertz products date back to 1967 and the introduction of the HP 8410 network analyzer, which reached 12 GHz and computed S-parameters. Our first millimeter-wave equipment followed in the late 1980s with signal generators that reached above 26.5 GHz with upconverters, and broadband network analyzers that covered 45 MHz to 100 GHz.

Currently, many of our signal generators, spectrum analyzers and network analyzers can cover frequencies between 50 GHz and 1.5 THz using frequency-extender products from two of our solution partners, Virginia Diode, Inc. (VDI) and OML, Inc. Working with VDI, we recently deployed a solution that includes spectrum analysis capability up to 1.5 THz.

More recently, with the broadband millimeter-wave network analyzer, the 1.0 mm calibration kit represents yet another significant contribution. For key performance parameters, the cal kit ensures measurement uncertainty that is traceable to an NMI.

Conclusion

With the N5290A and N5291A broadband millimeter-wave solutions, you can continue to depend on Keysight to provide easier access to accurate, repeatable measurements at ever-higher frequencies and wider bandwidths. Built on a foundation of electronic and mechanical innovations, the N5290A and N5291A deliver metrology-grade precision that ensures unparalleled system-level performance. As a result, you can confidently characterize and optimize new-generation devices from 900 Hz to 120 GHz.
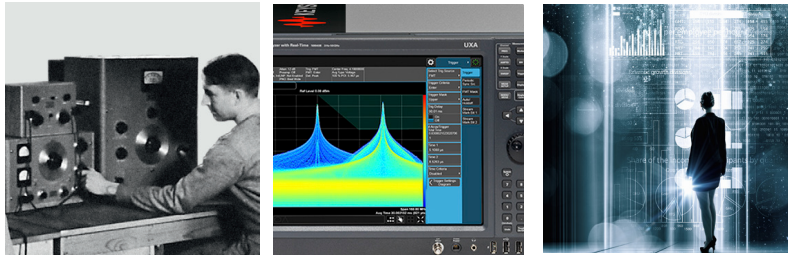
Related Information

– Configuration Guide: *Millimeter-Wave Network Analyzers (N5290A/N5291A)*, publication 5992-2179EN
– Technical Overview: *Banded Millimeter-Wave Network Analysis*, publication 5992-2177EN
– Application Note: *Optimizing On-Wafer Noise Figure Measurements up to 67 GHz*, publication 5991-2524EN
– Application Note: *Active-Device Characterization in Pulsed Operation Using the PNA-X*, publication 5990-7781EN
– Application Note: *High Accuracy Noise Figure Measurements Using the PNA-X Series Network Analyzer*, publication 5990-5800EN
– White Paper: *Accurate Spectrum Analysis up to Terahertz with Your Vector Network Analyzer*, publication 5992-1585EN
– Article Reprint: *Faster Testing with High-Performance Spectrum Analysis in a VNA*, publication 5992-0993EN
– Product Fact Sheet: *PNA and PNA-X Series Vector Network Analyzers Option 090 Spectrum Analysis*, publication 5992-0752EN
– Selection Guide: *Network Analyzer Selection Guide*, publication 5989-7603EN
– Brochure: *PNA-X Series Microwave Network Analyzers*, publication 5990-4592EN
– Brochure: *PNA and PNA-L Series Microwave Network Analyzers*, publication 5990-8290EN

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