Maury Microwave and Keysight Technologies

SOLUTION PARTNER BROCHURE / 5G-001



"Alone we can do so little; together we can do so much." – Helen Keller

I started working with Maury Microwave in 2005 and one of the things that has always impressed me was Maury's presence in the microwave and RF community, as a pioneer and innovator since its inception in 1957.

Our history is full of firsts: the first commercial connector gage kit, the first 40 GHz mode-free coaxial connector, the first VNA calibration kit, the first manual slide-screw impedance tuner, the first commercial automated slide-screw impedance tuner, and the first non-50 Ω device characterization software, just to name a few.

But as much as we accomplished ourselves, it has been through partnerships that we have been able to best support our customers with the largest offering of validated turnkey solutions. With our partners, we have launched the industry's first and widest assortment of commercial vector-receiver load pull systems, open-loop active and hybrid-active load pull systems, mixed-signal active load pull systems, compact model extraction and refinement systems, sub-THz active load pull systems, and the list goes on!

Partnerships are and remain a cornerstone of our strategy, and as Helen Keller said, "alone we can do so little; together we can do so much." With that, I would like to introduce you to a selection of our best-in-class solutions that have been made possible through intimate relationships with our partners.

Finally, I would like to extend an invitation to visit Maury Microwave and witness our best-in-class solutions in person. We hope to see you soon!

Michael Howo, CEO

Impedance Matching with Vector-Receiver Load Pull

Keysight Technologies and Maury Microwave

Improve the performance of your amplifiers with fast, accurate impedance matching

Load pull is the technique used to determine the ideal matching impedances required to maximize power transfer, output power, gain and efficiency in amplifier designs. With vector-receiver load pull, the scalar measurement instruments traditionally used are replaced by a vector network analyzer. Vector-receiver load pull allows you to make faster, more accurate assessments of the optimum matching impedances required for your amplifier designs.

The signal path in a traditional load pull system consists of a signal source and amplifier, source and load impedance tuners, a power meter and, optionally, a spectrum analyzer. If the scalar measurement instruments are replaced by a vector network analyzer the signals can be analyzed on a per-frequency basis. Each frequency component is accurately separated and can be used to calculate independent fundamental and harmonic powers. Additionally, a network analyzer is inherently a more accurate tool for measuring power than a power meter or spectrum analyzer.

In a vector-receiver load pull system measurements are made in real time at the device-under-test (DUT) reference plane. Instead of measuring power parameters, the actual DUT a- and b-waves are measured, allowing a more complete set of parameters to be analyzed. Parameters include large signal input impedance, which is used to determine delivered input power, power gain and power added efficiency, AM-PM, and harmonic measurements.

Using a vector-receiver load pull system eliminates the necessity for multiple load-pull source-pull iterations thereby saving time, it reduces errors cause by de-embedding through tuners at higher gammas and it improves the overall accuracy by measuring at the DUT reference plane.

- Load pull measurements using vector network analyzer
- Provides faster and more accurate impedance matching
- Allows measurements on per frequency basis
- Measurements made at DUT reference plane
- Separates fundamental and harmonic measurements
- Eliminates load-pull source-pull iterations
- Uses Keysight PNA-X analyzers





Impedance Matching with Vector-Receiver Load Pull

Maury Microwave provides a full range of passive, active, hybrid-active and vector-receiver fundamental and harmonic load pull solutions. All of these solutions are designed around the Keysight Technologies PNA-X Series of microwave network analyzers.

The PNA-X has wide power range, fast and accurate control of source phase, clean harmonics, wide frequency coverage from 10 MHz to 67 GHz and a flexible test set to allow the connection of ancillary components.

With a vector-receiver load pull solution from Maury and Keysight you can reduce the time and improve the accuracy of your load pull measurements allowing you to optimize the performance of your amplifier designs



System Components

Keysight Technologies

PNA	
N522xB	PNA network analyzer
N522xB-401, 417 or 419	4-port with configurable test set
PNA-X	
N524xB	PNA-X network analyzer
N524xB-4xx	4-port, dual source

Other options are available; contact your local Keysight sales engineer for more details

Maury Microwave

MT98x	Automated impedance tuner
MT930A	IVCAD base application
MT930B	IVCAD visualization
MT930C	IVCAD vector-receiver load pull

To learn how this solution
can address your specific needs
please contact
Keysight's solutions partner,
Maury Microwave
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Keysight and its Solutions Partners work together to help customers meet their unique challenges, in design, manufacturing, installation or support. To learn more about the program, our partners and solutions go to

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Maury Microwave has been in business for 50+ years and has become the world's leading manufacturer of laboratory devices and system components, with an emphasis on device characterization and automated tuning systems.

www.maurymw.com

For information on Keysight Technologies' products, applications and services, go to

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Impedance Matching for High Power Devices

Keysight Technologies and Maury Microwave

Impedance match your high power devices with active and hybrid load pull

Load pull measurements are used to study the response of a device-under-test (DUT) under multiple source and load impedances. By using these techniques designers can develop impedance matching networks for high power, non-linear devices, maximizing their power transfer, output power, gain and efficiency over a broad range of frequencies.

Traditional load pull measurements utilize a passive mechanical tuner to vary the impedance seen by the DUT. Mechanical tuners are simple, low cost and can handle high power. However they may be relatively slow to use, especially when multiple frequencies are to be investigated, and are intrinsically limited due to the losses incurred in the signal path. Since they can be physically large they may also be more difficult to integrate with on-wafer measurement systems.

Active load pull measurements use an external signal source to inject a signal into the output of the DUT in order to emulate the effect of a reflected signal. The system overcomes the problems encountered with mechanical tuners. However, these advantages come with a cost penalty due to the need for high power amplifiers in the tuning chain.

The solution is to use a combination of the two techniques, or hybrid load pull. A mechanical tuner is used to handle the high power levels at the fundamental frequency while active devices are used for the lower power harmonics.

Maury Microwave provides a range of passive, active and hybrid load pull solutions that utilize test instruments from Keysight Technologies, including the PNA-X microwave network analyzer. The PNA-X has wide power range, fast and accurate control of source phase,

- Impedance match for optimum device performance
- Use load pull for impedance matching high power devices
- Overcome limitations of traditional load pull techniques
- Combine active and passive techniques in hybrid load pull
- Uses Keysight PNA-X network analyzer and Maury tuners
- Develop impedance matching networks for high power, large signal devices





Impedance Matching for High Power Devices

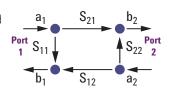
clean harmonics, wide frequency coverage from 10 MHz to 50 GHz and a flexible test set to allow the connection of ancillary components.

By utilizing the advanced features of the Keysight PNA-X, Maury Microwave can provide cost-effective active and hybrid load pull systems to allow you to optimize the performance of your large signal, high power devices.



Impedance Measurements

The impedance presented at a DUT can be stated in various formats: ZL, VSWR and reflection coefficient, Γ_{L} . In the case of a two port device the magnitude of the reflection coefficient, Γ_{L} , is given by the ratio of the forward to the reflected travelling wave at port 2 (a2/b2).



Two-port scattering parameter model

With a passive load pull system the losses incurred in the mechanical tuner mean that the reflection coefficients that can be measured will always be less than 1 and typically in the range 0.8 and 0.92. An active load pull system overcomes this issue since the reflected signal is injected directly into the return path at point a2. As a result reflection coefficients of unity (and theoretically greater than unity) can be achieved.

System Components

Keysight Technologies

PNA	
N522xB	PNA network analyzer
N522xB-401, 417 or 419	4-port with configurable test set
PNA-X	
N524xB	PNA-X network analyzer
N524xB-4xx	4-port, dual source
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Other options are available; contact your local Keysight sales engineer for more details

Maury Microwave

MT98x	Automated Impedance Tuner (0.227 MHz to 65 GHz coaxial)
MT930x	IVCAD measurement and modeling device characterization software



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Reducing the Cost of Load Pull Measurements

Keysight Technologies and Maury Microwave

Achieve high accuracy non-50Ω load pull measurements at lower cost

A load pull system is used to study the behavior of a device-under-test (DUT) when presented with varying source and/or load impedances at one or more frequencies in a controlled manner.

For transistor designers, load pull is an essential tool to characterize and model transistor technologies and designs. For amplifier and circuit designers, load pull is helpful in determining the ideal impedance match for maximum performance under application-specific conditions. For system engineers, load pull can be used to test the robustness of a system under mismatched conditions.

Modern load pull solutions based on vector-receivers such as those found in commercial network analyzers allow for the direct measurement of calibrated a- and b-waves at the DUT reference plane. From these waves, it is possible to directly measure large signal input and output impedances as well as calculate available and delivered input power, output power, transducer and power gain, drain and power added efficiencies, and vector-parameters such as AM/PM and droop.

As Keysight's highest performance mid-range VNA, the N523xA PNA-L is ideally suited for lower cost vector-receiver load pull when combined with Maury Microwave's LXI-certified automated impedance tuners and IVCAD measurement and modeling device characterization software.

With this solution, Keysight's benchtop instruments are now viable for lower cost device characterization in the same way as its higher cost ultra-performance products.

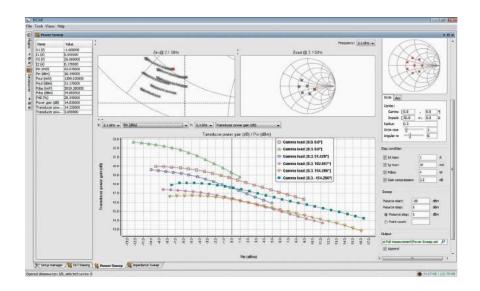
Add-ons are available from Maury Microwave to extend the solution's capabilities to include pulsed-RF, pulsed-bias, active- and hybrid-active tuning, and harmonic load pull.

- Load pull measurements using lower cost Keysight PNA-L VNAs
- Provides accurate measurement of vector a- and b-waves and Sparameters
- Measure input and output fundamental and harmonic powers, gain, efficiency, AM/PM and more
- Sweep impedance, power, bias, frequency
- Measurements de-embedded to DUT reference plane
- Automate measurements for advanced sweep plans





Reducing the Cost of Load Pull Measurements



System Components

Keysight Technologies

N523xA-216	PNA-L, 2 ports, configurable test, source attenuators
N523xA-080	Optional frequency offset
N99XXX	USB power sensor
N46XXX	E-cal

Maury Microwave

MT98x	Automated impedance tuner
MT930A	IVCAD base application
MT930B	IVCAD visualization
MT930C	IVCAD vector-receiver load pull

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High-Speed Impedance Matching with Modular PXI

Keysight Technologies and Maury Microwave

Characterize your devices with PXI-based load pull and gain-compression testing

'Load pull' involves the systematic varying of the impedances presented to a device under test while measuring the device's performance. For R&D applications, load pull is an essential characterization tool that allows designers to understand better the capability of their devices, to model the performance of their devices, and to design ideal matching networks. For pre-production and production applications, load pull is useful in determining a device's robustness and resilience to mismatch and high-VS-WR conditions

Modern load pull solutions based on vector-receivers such as those found in commercial network analyzers allow for the direct measurement of calibrated a- and b-waves at the DUT reference plane. From these waves, it is possible to directly measure large signal input and output impedances as well as calculate available and delivered input power, output power, transducer and power gain, drain and power added efficiencies, and vector-parameters such as AM/PM and droop.

When combined with Maury Microwave's LXI-certified automated impedance tuners

and IVCAD measurement and modeling device characterization software, Keysight Technologies' M9485A PXIe multiport vector network analyzer with direct receiver access becomes the first commercially available modular solution for high-frequency load pull characterization for R&D, pre-production and production applications.

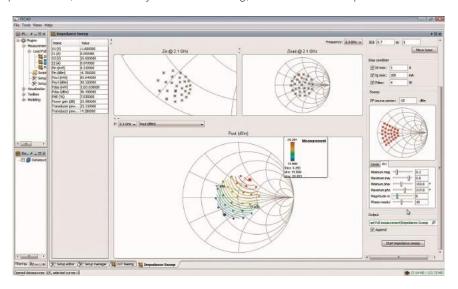
The M9485A is ideally suited for vector-receiver load pull due to its improved accuracy, fast speed, high dynamic range and extreme stability. In addition, it offers best-in-class performance for advanced multiport vector network analysis, with the possibility to expand up to 12-ports in one chassis or 24-ports in two chassis.

- Load pull measurements using modular PXI vector network analyzer
- Provides accurate measurement of vector a-waves, b-waves and S-parameters
- Measure input and output fundamental and harmonic powers, gain, efficiency, AM/PM and more
- Sweep impedance, power, bias, frequency
- Measurements de-embedded to DUT reference plane
- Automate measurements for advanced sweep plans



High-Speed Impedance Matching with Modular PXI

Starting with this solution, Keysight's modular form factor can now be considered for advanced device characterization in the same manner as benchtop instruments. Addons are available from Maury Microwave to extend the solution to include pulsed-RF, pulsed-bias, active- and hybrid-active tuning, and harmonic load pull.



System Components

Keysight Technologies

M9485A	PXIe multiport vector network analyzer
Options 3xx	Direct Receiver Access without Coupler option (2 ~ 12 port)
Options 2xx	Configurable test set option (2 ~ 12 port)
Options 4xx	Port add options
Option 009	Frequency offset mode
Option 025	Basic RF Pulse Measurements
Option 551	N-port calibrated measurement (multiport capability for > 4-port)
N99XXX	USB power sensor
N46XXX	E-cal

Maury Microwave

MT98x	Automated impedance tuner
	<u> </u>
MT930A	IVCAD base application
MT930B	IVCAD visualization
MT930C	IVCAD vector-receiver load pull

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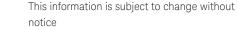
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www.marymw.com

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www.keysight.com



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X-Parameter Measurements

Keysight Technologies and Maury Microwave

Reduce design cycles by up to 50% with X-parameter measurements

X-parameters* are being used increasingly in place of S-parameters in the design of nonlinear, large signal devices and circuits such as complex power amplifiers, including multi-stage and Doherty circuits. Unlike S-parameters, X-parameters contain detailed and useful information including the magnitudes and phases of distortion products generated by the nonlinear component in response to large signal conditions.

Keysight's load impedance X-parameters option on the PNA-X nonlinear vector network analyzer (NVNA), when used with Maury Microwave's tuners and software, allows you to measure and simulate nonlinear component behavior as a function of impedance, input power, bias and frequency — at all load impedances.

This industry-first approach enables engineers to: extend X-parameter design "cascade-ability" to arbitrarily large load mismatches; automatically measure and simulate accurate, linear and nonlinear behavior over the entire Smith chart under multiple load conditions; and model devices and design multi-stage, Doherty or other complex amplifier circuits with the drag-and drop simplicity of Keysight's Advanced Design System (ADS).

The arbitrary load impedance X-parameters option of the PNA-X takes the guesswork out of the typical "trial and error" design approach and eliminates the need to "over design" to safeguard against potential errors.

As a result designers of large signal devices and circuits no longer have to compromise on their simulation models. With this new X-parameter measurement solution from Keysight and Maury you can improve your simulation accuracy, minimize the number of design iterations and reduce your overall design time by up to 50%.

- Use X- instead of S-parameters for large signal, nonlinear devices
- X-parameters allow characterization of large signal devices and circuits
- Keysight PNA-X with Maury tuners and software
- Model & design complex, multi-stage amplifiers
- Simulation models no longer have to be compromised
- Reduce design time by up to 50%





X-Parameter Measurements

System Components

Keysight Technologies

N524xB	PNA-X network analyzer
N524xB-41x/42x	4 port, dual source
S94510A/11A	Nonlinear component characterization
S94514A	Nonlinear X-parameters
S94520A	Arbitrary load-impedance X-parameters
U9391C, F or G	(2 each required), 26.5, 50 or 67 GHz comb generator
U20xxA or U848xA	USB power sensor (or other Keysight power meter & sensor)
Other entions are availa	blas contact your local Koyaight calco angineer for more details

Other options are available; contact your local Keysight sales engineer for more details

Reference documentation publication 5989-8575EN

Maury Microwave

Tuner – select from:	
MT98x	Automated Impedance Tuner (0.227 MHz to 65 GHz coaxial)
MT930x	IVCAD measurement and modeling device characterization software

Other options are available; contact Maury Sales for more details

*X-parameters is a trademark and registered trademark of Keysight Technologies in the US, EU, JP, and elsewhere. The X-parameters format and underlying equations are open and documented. For more information, visit http://www.Keysight.com/find/eesof-x-parameters-info.

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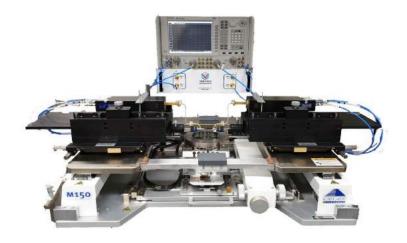


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Active Load Pull Measurements at Millimeter-Wave and Sub-THz Frequencies

Keysight Technologies and Maury Microwave



Upgrade your S-parameter test bench with accurate and repeatable gain compression and active load pull measurements at millimeter-wave and sub-THz frequencies

Performing device characterization measurements at millimeter-wave and sub-THz frequencies can be challenging for several reasons. First, it's difficult to achieve accurate and repeatable power-control at the DUT reference plane when using waveguide extenders between 110 GHz and 1.1 THz, as the extenders typically output a fixed power. However, controlling the power delivered to the input of the DUT is critical in setting the device's operating conditions and characterizing its performance over power, such as the large-signal characteristic gain compression. Second, load pull, which means changing the load impedance presented to the DUT to an arbitrary non-50 Ω value, is difficult as passive load pull impedance tuners are typically unavailable above 110 GHz, and even then, are limited in their ability to present high mismatches at the DUT reference plane.

Load pull measurements are necessary for transistor designers to properly characterize and model the high-speed behaviors of their devices. For circuit designers, load pull measurements are used to determine the ideal matching conditions and optimize performance, at powers where every fraction of a dB is important. Load pull can also be used to test systems, such as new mm-wave radars, where both contacted and over-the-air performance testing is needed.

- Measure S-parameters at user-specified power levels
- High-resolution power control for accurate and repeatable vector-corrected 50Ω gain compression power sweep measurements
- Arbitrary impedance control / active load pull
- Measure fundamental powers (Pin, Pav, Pload), gain and efficiency at 50Ω and arbitrary impedances
- Advanced measurement sequencer sweeps impedance, power, frequency and bias
- Calibrated measurements at DUT reference plane
- Supports most commercial waveguide extenders up to 1.1 THz

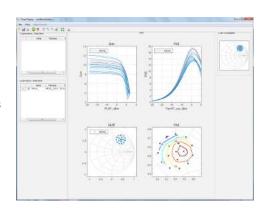


MM-STUDIO and MM-STUDIO LP Millimeter-Wave and Sub-THz Measurement Software

Maury Microwave and strategic development partner Vertigo Technologies offer an upgrade to conventional mm-wave and sub-THz S-parameter measurement systems.

MM-STUDIO is a software suite designed to work with a 4-port PNA or PNA-X using waveguide extender modules and add accurate and repeatable high-resolution power control. The software enables the direct measurement of vector corrected power at the DUT reference plane, as well as control over the power delivered to the DUT. Doing so allows engineers to perform gain compression power sweep measurements over the available level of powers, and to perform S-parameter measurements at any arbitrary power level.

MM-STUDIO LP is a software addon, which when used in conjunction with a Vector Modulation Unit (VMU), enables control over the magnitude and phase of the signals delivered to the input and output of the DUT. This enables an engineer to set arbitrary impedances, or perform active load pull measurements, where the magnitude of reflection presented to the DUT is achieved by controlling the reflected a2 wave and fulfilling Γ =a2/b2.



System Components

Keysight Technologies	
PNA	
N5222B (or higher frequency)	PNA microwave network analyzer
Option 401 (or better)	4-port with configurable test set
Tx/Rx waveguide extender mod	ules (VDI, OML, Farran)
OR	
PNA-X	
N5244B (or higher frequency)	PNA-X microwave network analyzer
Option 400 (or better)	4-port, dual source
Tx/Rx waveguide extender mod	ules (VDI, OML, Farran)

Maury Microwave	
MM-STUDIO	required for 50Ω measurements
MM-STUDIO LP	required for non-50 $\boldsymbol{\Omega}$ active load pull measurements, add-on
VMU-201802 or VMU-201901	required for non-50 $\boldsymbol{\Omega}$ active load pull measurements



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Load Pull Measurements on Mobile Phones

Keysight Technologies and Maury Microwave

Ensure your mobile phone designs operate in real-world conditions



Load pull is an ideal solution for measuring the performance of mobile phones under real-world conditions. In the real world mobile phones have to operate even with a lost or damaged antenna, in a tunnel or locker, when held close to the body or when in a pocket surrounded by coins. All of these conditions create non-ideal, non-50 ohm RF environments and designers and manufacturers have to demonstrate that their products can continue to work in these situations.

Load pull measurement techniques involve varying the load impedance seen by a device-under-test (DUT) while measuring its performance. The technique can be used to measure parameters such as power, sensitivity, throughput, bit error rate, current drain, gain, efficiency, harmonic power, inter-modulation distortion, error vector magnitude, adjacent channel power, etc. — all as a function of impedance,

Keysight Technologies and Maury Microwave provide a comprehensive, automated solution for load pull measurements of mobile phones. A complete setup for performing transmit and receive tests includes the DUT (amplifier, front end module, or mobile phone), a Maury tuner, a power supply, a Keysight 8960 or E7515A UXM wireless test set and the Maury MT910 series automated mobile test system software.

- Load pull measurements on mobile phones
- Test your mobile phone designs under real-world conditions
- Measure mobile phone parameters with varying impedance
- Uses Keysight 8960 wireless communications test set for WCDMA and GSM measurements
- Uses Keysight E7515A UXM wireless test set for LTE measurements
- Maury LXI-certified tuners and MT910 mobile phone test software
- Tests mobile phones in transmit and receive mode
- Measure multiple parameters over multiple channels/frequencies
- Fully automated for ease of use and reduced test time



Load Pull Measurements on Mobile Phones

The Keysight 8960 and E7515A UXM are one-box solutions for wireless device development, manufacturing and repair providing full RF parametric and functional data test coverage for all major cellular technologies. The Maury MT910 software is a standalone application designed specifically for the testing of mobile phones in transmit and receive modes, for output power and sensitivity respectively, as a function of VSWR magnitude and phase.

Secondary tests include stress testing and antenna VSWR specification. Keysight test sets and Maury software together provide a fully automated solution for testing a mobile phone in transmit and receive mode over a multitude of channels/frequencies, battery voltages and power levels.

With an automated load pull test solution from Keysight and Maury, you can reduce the time and effort required to ensure that your mobile phone designs will continue to operate effectively – even in the most harsh, real-world conditions.

System Components

Keysight Technologies

	E7515A UXM wireless test set, or	
E5515C 8960 series wireless		es wireless communication test set with:
	E6701x	GSM lab application
	E6702x	cdma2000 lab application
	E6703x	W-CDMA/HSPA lab application
	E6706x	1xEV-DO lab application

Maury Microwave

Tuner – select from:		
MT982GL01	LXI-certified automated impedance tuner: 0.65-18 GHz	
MT982BL01	LXI-certified automated impedance tuner: 0.8-18 GHz	
MT982EL30	LXI-certified automated impedance tuner: 0.8-8 GHz	
plus		
MT910 -series	Automated mobile test system software	

Other options are available; contact Maury Sales for more details

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Noise Parameter vs Noise Figure Measurements

Keysight Technologies and Maury Microwave

Noise Parameter Measurements in Minutes Rather than Days



The characterization of noise within a device or circuit is critical for many RF design engineers. Customers demand an accurate specification of the noise within the products they purchase and designers have to understand noise effects in order to maximise the performance of their products. The most commonly used measurement is noise figure, but this parameter is not always sufficient. Noise figure is widely used in manufacturing test, but it is not sufficient for circuit and system designers who need to know how to improve and optimize their design for best performance.

To meet these challenges you must turn to noise parameters. In the past it was not practical for circuit and systems engineers to measure noise parameters; the equipment was too specialized and the measurements took too long, often days, to complete. Now using an off-the-shelf instrument and only a noise tuner as an accessory, complete noise parameter characterization is practical, fast and just as easy as measuring S-parameters. This gives you the opportunity to optimize the performance of your products and specify them with the tighter limits demanded by your customers.

- Improves on noise figure measurements
- Makes noise parameter measurements practical
- Noise parameters measured in minutes, not days
- Characterize circuits and devices more accurately
- More accurate specification of noise in your products
- Uses Keysight PNA-X with Maury tuner and software
- Optimize the performance of your products



Noise Parameter vs Noise Figure Measurements

Noise Parameter Measurements

The traditional approach to measuring noise parameters involves a vector network analyzer (VNA), a separate noise source and noise figure analyzer and an external tuner to vary the source impedances presented to the device under test (DUT). Measurements are made at a number of points across a frequency band, with a spread of source impedances at each frequency.

Before the measurements can be made, the entire system has to be calibrated for accurate S-parameter measurement. Once this has been achieved the user then calibrates the noise receiver and measures the DUT noise parameters at every frequency point across the frequency range. Using the traditional approach, calibrating the noise receiver and measuring the noise parameters at every frequency point leads to very long test times.

When measuring S-parameters, it is common practice to sweep 400 or more points to examine the details of an amplifier's performance. Attempting to measure noise parameters across this number of frequency points can result in test and calibration times taking many days. Not only is this time consuming, it can also introduce errors due to temperature drift.

In many cases designers are forced to compromise on the number of frequency points over which they make their measurements, resulting in inaccuracy and ambiguity in their measurements.

A New Approach

A new approach to noise parameter measurements solves the problem by reducing the test and calibration times by two orders of magnitude. Measurements over 400 frequency points that would take over 160 hours using the traditional approach can now be implemented in less than 30 minutes, over 300 times faster.

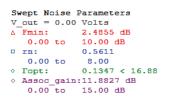
This gives immediate advantages to the designer characterizing the noise parameters of a device. There is no need to compromise on the number of frequency points, the accuracy is improved dramatically, and the ambiguity in the measurements is minimized. The new measurement approach is implemented with a Keysight Technologies PNA-X network analyzer with an integrated noise receiver, a noise source and a tuner and software supplied by Maury Microwave Corporation.

Noise Figure Measurements

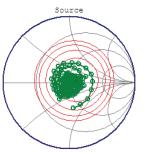
The most common measure of noise is the figure-of-merit called noise figure. Noise figure is usually measured in a 50-ohm environment and seeks to quantify the signal-to-noise degradation caused by an amplifier. Noise figure, however, varies with the source impedance presented to the amplifier so is not sufficient to fully characterize your devices.

The variations due to source impedance can be characterized and represented in terms of noise parameters. It is essential to understand the noise parameters

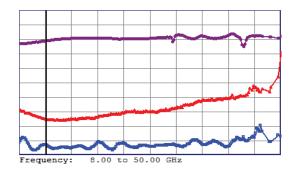
understand the noise parameters of your devices, especially when designing low-noise amplifiers using mismatched devices.



Marker: Frequency = 12.451612903 GHz







Noise Parameter vs Noise Figure Measurements

The results speak for themselves. A microwave FET was tested using both the traditional and the new approach. It was tested from 0.8 GHz to 8 GHz with a step frequency of 0.1 GHz, giving 73 test frequencies. This is much larger than is typically used with the traditional method. The measurements made using the new method exhibit much smoother results with lower scatter. This allows more accurate characterization of the parameters. In addition, the test times are slashed from over 30 hours to just over 8 minutes.

With this new approach the measurement of noise parameters now becomes a practical option for all RF designers. You don't have to compromise your noise parameter measurements or rely solely on noise figure measurements. You can now use noise parameters to optimize the performance of your products and characterize them in terms of the tight specifications required by your customers

System Components

Keysight Technologies

N524xB	PNA-X network analyzer
N524xB-029 ¹	Add low-noise receiver
S93029A	Noise figure measurements with vector correction
346x	Noise source
Other options are available; contact your local Keysight sales engineer for more details	

 N5241/42/49B, requires one of options 21x, 22x, 41x, or 42x. N5244/45/47B, requires one of options 22x or 42x. N5245B, Option 029 cannot be ordered with Option 425. N5247B, noise receiver works up to 50 GHz only.

Maury Microwave

MT98x	Automated Impedance Tuner (0.227 MHz to 65 GHz coaxial)
MT7553x	Optional NSM and NRM
MT993x	ATS Noise parameter measurement software

Other options are available; contact Maury Sales for more details

To learn how this solution
can address your specific needs
please contact
Keysight's solutions partner,
Maury Microwave
www.keysight.com/find/maurymw



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Maury Microwave has been in business for 50+ years and has become the world's leading manufacturer of laboratory devices and system components, with an emphasis on device characterization and automated tuning systems.

www.maurymw.com

For information on Keysight Technologies' products, applications and services, go to www.keysight.com



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High-Accuracy Millimeter-Wave Noise Measurements

Keysight Technologies and Maury Microwave

Accurate noise figure and noise parameter measurements on mm-wave transistors

Noise figure is the most commonly used measure of device-added noise. It is usually measured in a $50-\Omega$ environment and seeks to quantify the signal-to-noise degradation caused by an amplifier or frequency converter. Noise figure, however, varies with the source impedance presented to the amplifier, so is not sufficient to fully characterize your devices



The variations due to source impedance can be characterized and represented in terms of noise parameters. It is essential to understand the noise parameters of your devices, especially when designing low-noise amplifiers using mismatched transistors.

Noise parameters are comprised of four distinct elements: Fmin, the minimum noise figure of the transistor, G_{opt} , the optimum impedance at which Fmin occurs (in real and imaginary terms), and Rn, the equivalent series resistance of the transistor. In theory, any four controlled impedances (G_{S}) can be presented to the device and the corresponding noise figures (F) measured in order to solve four simultaneous equations for four unknowns. Practically, the impedances selected for G_{S} should be in the range of G_{opt} and proper impedance selection becomes critical if the transistor is non-50- Ω .

$$F = F_{min} + \frac{4 R_n}{Z_o} \frac{|\Gamma_s - \Gamma_{opt}|^2}{|1 + \Gamma_{opt}|^2 (1 - |\Gamma_s|^2)}$$

The Keysight N524x PNA-X Series network analyzer is the only instrument of its kind

- Millimeter-wave noise figure and noise parameter measurements
- Based on Keysight PNA-X Series network analyzer
- Maury automated impedance tuner for non-50-Ω device measurements
- Maury external noise receiver module increases sensitivity by up to 6 dB
- Maury test software for automated control of measurements
- Tests wideband noise parameters between 8 and 50 GHz
- Improves accuracy and speed of noise measurements
- High accuracy measurements on millimeter-wave transistors



High-Accuracy Millimeter-Wave Noise Measurements

that controls an electronic impedance tuner. For the N5241/42B, an external ECal is used, and for the N5244/45/47B, a built-in electronic tuner is included. The embedded tuner can be used to present the impedances required to solve the unknowns in the noise-parameter equation, but is best suited for $50-\Omega$ or near- $50-\Omega$ devices. For non- $50-\Omega$ applications, the PNA-X can be used with Maury Microwave's MT984AL01 or MT985AL01 external automated impedance tuner in order to present impedances closer to $G_{\rm opt}$.

The Keysight PNA-X is also the only instrument to combine S-parameter receivers with a dedicated and optimized low-noise receiver. The sensitivity of the noise receiver is critical in measuring noise figure by accurately measuring the noise-power contribution of the device-under-test. The accuracy of the noise measurement is directly related to the second-stage noise figure of the noise receiver, and the lower the better. The sensitivity of the PNA-X noise receiver is sufficient for many applications and, if necessary, can be increased with the use of an external noise receiver module. The addition of a Maury Microwave MT7553B03 external noise-receiver module allows the second-stage noise figure to be reduced by 5 to 6 dB.

The combination of the Keysight PNA-X network analyzer, the MT984AL01 or MT985AL01 automated impedance tuner, the MT7553B03 noise-receiver module, and Maury's MT993-series ATS software suite allows wideband noise parameters to be measured between 8 and 50 GHz with improved speed and accuracy.

Keysight's PNA-X combined with Maury's tuner, receiver, and test software allows you to achieve high-accuracy noise figure and noise parameter measurements on your millimeter-wave transistors.

System Components

Keysight Technologies

N5245/47B	PNA-X network analyzer
N5245/47B-029 ¹	Add low-noise receiver
S93029A	Noise figure measurements with vector correction
346C-K01	Noise source, 1 GHz to 50 GHz

Other options are available; contact your local Keysight sales engineer for more details

 One of options 22x or 42x is required. N5245B, Option 029 cannot be ordered with Option 425. N5247B, noise receiver works up to 50 GHz only.

Maury Microwave

MT984AL01	8 - 50 GHz automated impedance tuner*
MT985AL01	8 - 65 GHz automated impedance tune
MT7553B03	50 GHz noise receiver module for N5245A-029 ¹
MT7553N50	50 GHz noise switch module for N5245A-029
MT993B, B01, F	Noise parameter characterization software

1. Other models are available in other frequency bands



To learn how this solution
can address your specific needs
please contact
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Maury Microwave
www.keysight.com/find/maurymw



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Maury Microwave has been in business for 50+ years and has become the world's leading manufacturer of laboratory devices and system components, with an emphasis on device characterization and automated tuning systems.

www.maurymw.com

For information on Keysight Technologies' products, applications and services, go to

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Pulsed Measurement of IV Characteristics & S-Parameters

Keysight Technologies and Maury Microwave

Model devices across their linear and nonlinear regions with pulsed measurements

Current-voltage characteristics (IV characteristics) and scattering parameters (S-parameters) are critical in understanding the performance of any active device. Pulsed measurements of IV characteristics and S-parameters involve the application of a pulsed bias voltage to the device-under-test. Pulsed measurements can eliminate heating and trapping effects allowing device modeling to be undertaken under quasi-isothermal operating conditions in both their linear and non-linear operating regions.

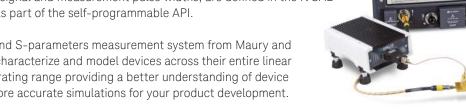
Maury Microwave provides proven technology for pulsed measurements of IV characteristics and S-parameters. For pulsed measurements of S-parameters the technology is used in conjunction with the Keysight Technologies PNA-X microwave network analyzer. A complete solution comprises a Maury pulse controller that includes DC power supplies, external gate and drain pulse heads, Maury's IVCAD software and an Keysight PNA-X for the RF measurements.

Pulse acquisition and measurement is performed via embedded hardware within the gate and drain pulse heads thereby eliminating the requirement for an external oscilloscope. The modular system offers 250V/30A pulse generation capabilities with pulse widths down to 200 ns and duty cycles between 0 and 100%. An automatic self-calibration feature makes IV calibration simple and accurate.

For pulsed measurements of IV characteristics and S-parameters, triggering and sequencing are critical. The Keysight PNA-X provides a unique gated narrowband filtering mode that performs asynchronous acquisition thereby reducing pulse desensitization and improving accuracy and dynamic range. Triggering is synchronized via the PNA-X pulse I/O adapter and the pulsed IV controller's trigger input. Sequencing for gate, drain, RF signal and measurement pulse widths, are defined in the IVCAD software suite or as part of the self-programmable API.

With a pulsed IV and S-parameters measurement system from Maury and Keysight you can characterize and model devices across their entire linear and nonlinear operating range providing a better understanding of device technology and more accurate simulations for your product development.

- Pulsed measurement of IV characteristics and S-parameters
- Pulsed measurements can eliminate heating and trapping effects
- Allows active device modeling under quasi-isothermal conditions
- Model devices across their linear and non-linear operating regions
- Uses Keysight PNA-X for pulsed measurement of S-parameters
- Pulsed measurements provide more accurate simulation of active devices

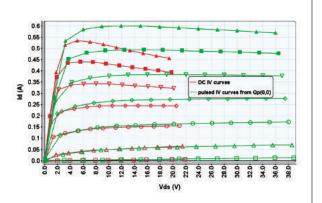




Pulsed Measurement of IV Characteristics and S-Parameters

IV Measurements

Standard DC-IV curves plot drain current as a function of drain voltage for various gate voltages, with a set of drain and gate voltages being continuously applied. A DC bias applied to a transistor may result in device self-heating; the longer the device is



on and the more power applied to the device, the more self-heating occurs.

By pulsing the bias with sufficiently short pulses and by choosing a sufficiently short duty cycle, the resulting IV curves will represent the transistor characteristics for quasi-isothermal operating conditions. Biasing a device under pulsed conditions will change the device S-parameters; therefore it is essential to properly record S-parameters under the exact application conditions.

System Components

Keysight Technologies

N522xB/4xB	PNA or PNA-X network analyzer
N522xB/4xB-021	Add pulse modulator first source
S93025A	Basic pulsed-RF measurements
N1966A	Pulse I/O adapter for PNA-X

Other options are available; contact your local Keysight sales engineer for more details

Maury Microwave

AM3203	BILT pulsed IV controller (includes DC supplies)
AM3211	BILT gate probe head
AM3221	BILT drain probe head
MT930A	IVCAD base application
MT930B	IVCAD visualization suite
MT930J	IVCAD pulsed IV curves
MT930K	IVCAD pulsed S-parameter

To learn how this solution can address your specific needs please contact Keysight's solutions partner, Maury Microwave www.keysight.com/find/maurymw

Maury Microwave

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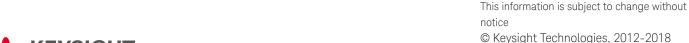
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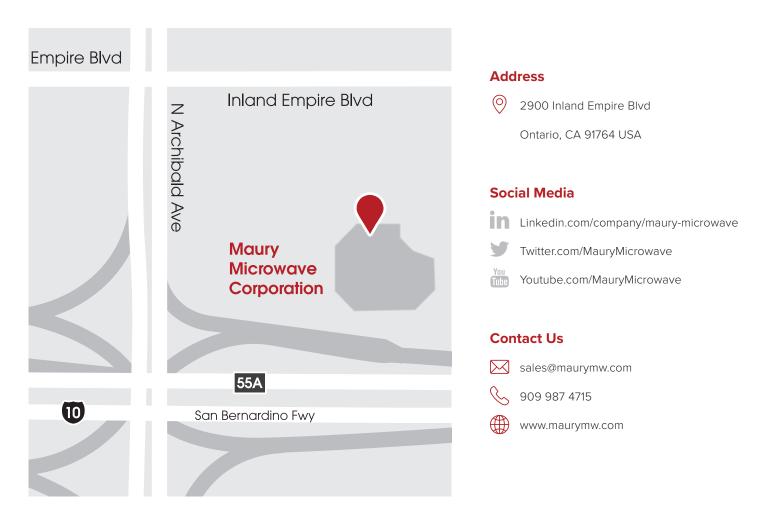


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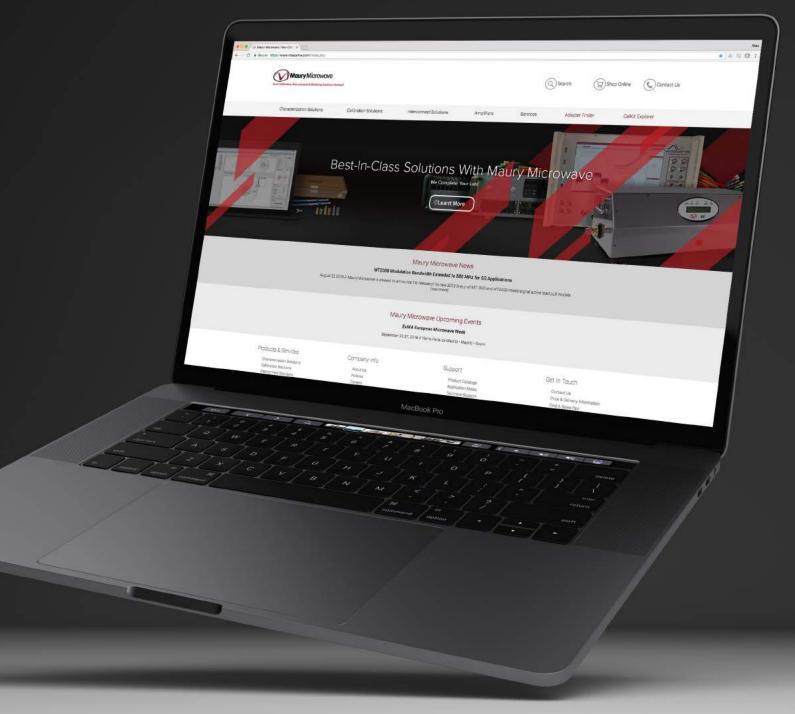
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