ADVANCED 50 Ω PULSED AND NONLINEAR DEVICE CHARACTERIZATION UP TO 1.1 THz

Maury Microwave
Your Calibration, Measurement & Modeling Solutions Partner!

Product Flyer
Version 01.00

ROHDE&SCHWARZ
Make ideas real

VNA BASED LOAD PULL MEASUREMENTS

Applications
- ► Amplifier design
- ► Model validation and extraction
- ► Reliability test (VSWR test)

Key features
- ► High measurement frequencies
- ► Fast measurement speeds
- ► High measurement accuracy

Load pull presents a set of controlled load impedances to a device under test (DUT) while measuring several parameters for each impedance state. By systematically varying the impedance, it is possible to characterize device performance and design the ideal matching network for realistic large-signal operating conditions.

Vector receiver load pull and vector network analyzer (VNA) based load pull are modern and efficient load pull measurement methods. Low-loss couplers between the tuners and the DUT are connected to the receivers of a VNA, such as the R&S®ZNA vector network analyzer. The a and b waves can be measured at the DUT reference plane in real time, revealing vector information normally unavailable with traditional power meter load pull techniques. Vector receiver load pull allows the direct measurement of actual impedances presented to the DUT without any assumptions of precharacterized tuner positioning or losses. The delivered input power is derived from the a and b waves with high accuracy, which results in defined power added efficiency.

Output power for each frequency along with fundamental and multiple harmonics are listed, as are multitone carrier and intermodulation powers.

Measurement parameters include Z_{in}, $P_{in, avail}$, $P_{in, del}$, P_{out}, G_p, G_t, PAE, efficiency (Eff), AM/PM, intermodulation distortion (IMD), $P_{out, nF}$.

The R&S®ZNA vector network analyzer provides industry-leading dynamic range and sweep speeds, resulting in fast and accurate load pull measurements.

ACTIVE AND HYBRID-ACTIVE LOAD PULL

Load pull measures the device response as a function of load impedance. With a two-port device, the impedance presented to the DUT (Γ_L), is a_2/b_2 or the ratio between the reflected and forward traveling waves.

Instead of reflecting the original signal using a passive mechanical tuner, active load pull uses signal sources to inject a signal into the DUT output, thereby creating a_2.

Because a_2 is no longer limited to a fraction of the original signal, as is the case with traditional passive mechanical tuners, external amplifiers can be used to increase a_2 so that Γ_L touches the outer edges of the Smith chart. In addition to gamma, other active load pull advantages include speed, the ability to add active tuning loops for harmonic load pull and easy integration for on-wafer measurements.

Hybrid-active load pull combines active and passive tuning in the same system. Traditional passive mechanical tuners reflect high power at the fundamental frequency (prematching), which allows a much smaller active injection signal and the use of smaller amplifiers to overcome losses and achieve $\Gamma_L = 1$.

Applications
- ► On-wafer characterization
- ► Amplifier design (efficiency optimization including harmonics)

Key features
- ► High tuning range at DUT output
- ► Easy addition of harmonic tuning

Additionally, since the power at harmonic frequencies is often well below that of fundamental signals, more affordable wideband amplifiers can be used with active tuning for active harmonic load pull with $\Gamma_{L,nf} = 1$, which means hybrid load pulling requires less power than pure active load pulling.

In combination with external signal generators featuring magnitude and phase control and IVCAD measurements as well as modeling device characterization software from Maury Microwave, the R&S®ZNA vector network analyzer provides a turnkey solution for active and hybrid-active load pull measurements.

NONLINEAR LSA AND BEHAVIORAL MODEL EXTRACTION

Applications
- Model validation
- Behavioral model extraction
- Amplifier design (higher-order operating classes)
- System design

Key features
- Fast model extraction speed
- High-accuracy interpolation and extrapolation

Nonlinear large signal analysis (LSA), also referred to as time domain analysis and waveform engineering, means analyzing currents and voltages at the device input and DUT output terminals in order to identify the DUT operating mode. This is useful for evaluating and designing advanced amplifier operating classes including E, F, J and K classes and their inverses, which can be visualized by displaying the voltage and current shapes over time. LSA measurements achieved by recording the phase dependency of harmonic content allow a and b waves, voltage and current waveforms and load lines to be displayed for each measurement state (impedance/power/bias), and can be deembedded to the device reference plane.

LSA measurements can be used to extract measurement based behavioral models, such as enhanced polyharmonic distortion (EPHD) models. EPHD is ideal for modeling the behavior of unmatched transistors where extrapolation of loading conditions beyond those used in the modeling extraction process may be required. These models are compatible with common circuit simulators such as ADS and MWO and can be used to efficiently design complex and multistage power amplifier circuits such as Doherty amplifiers.

In combination with passive or active harmonic load pull and IVCAD measurements as well as modeling device characterization software, the R&S®ZNA vector network analyzer provides a turnkey solution for extracting EPHD behavior models and empowering first-pass amplifier designs.

mmWAVE AND SUB-THz 50 Ω GAIN COMPRESSION AND ACTIVE LOAD PULL MEASUREMENTS

Performing millimeterwave (mmWave) and sub-THz device characterization can be challenging for several reasons. First, commercially available waveguide extenders between 110 GHz and 1.1 THz tend to have fixed output power and a limited power range, which can be set manually through an integrated or external variable attenuator. Second, passive load pull is not readily available above 110 GHz. Even though passive mechanical tuners can be built at these higher frequencies, waveguide and probe losses between the tuner and DUT limit the ability to present high reflections (gammas and mismatches) at the DUT reference plane.

These challenges are addressed with MMW-STUDIO, a software module compatible with waveguide-banded mmWave VNAs, adding accurate, repeatable and high-resolution power control. The software enables direct measurement of vector-corrected power at the DUT reference plane, as well as controlling the power delivered to the DUT.

The solution enables gain compression power sweep measurements over the available power levels and S-parameter measurements at any arbitrary power level.

Applications

- ▶ Transistor characterization
- ▶ Model extraction and validation
- ▶ Amplifier/circuit design
- ▶ Robustness/mismatch testing of circuits and systems

Key features

- ▶ S-parameter measurements at user-specified power levels
- ▶ High-resolution power control for accurate and repeatable vector-corrected gain compression power sweep measurements
- ▶ Arbitrary impedance control/active load pull

When used with a vector modulation unit (VMU), MMW-STUDIO can also control the magnitude and phase of the signals delivered to the DUT input and output. By setting arbitrary impedances, the system can perform active load pull measurements and measures P_{out}, P_{in}, $P_{in, avail}$, G_t, G_p, Eff, PAE, V_{in}, V_{out}, I_{in}, I_{out} at any controlled load impedance.

In combination with waveguide frequency extenders, Vertigo Technologies VMU and MMW-STUDIO mmWave and sub-THz characterization software, the R&S®ZNA vector network analyzer provides a turnkey solution for 50 Ω gain compression and active load pull measurements up to 1.1 THz.

MOBILE PHONE TESTING UNDER REAL-WORLD CONDITIONS

Applications
- ▶ Real-world validation of antenna mismatch

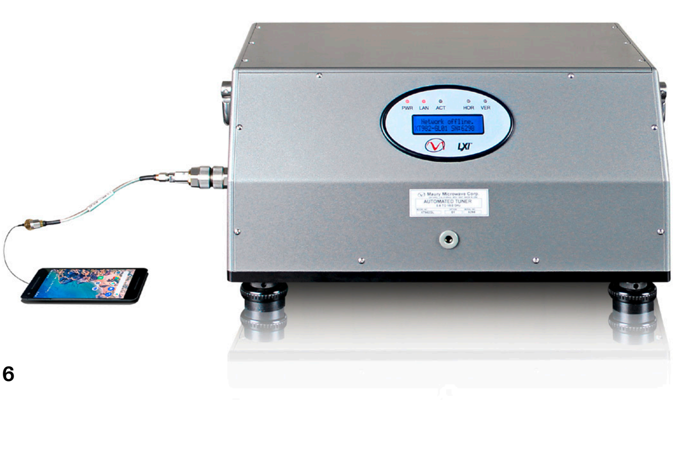
Key features
- ▶ Supports modern communications signals

Mobile phones must function properly even in non-ideal, real-world environments. This includes use when an antenna is lost or damaged, in a tunnel or locker, when held close to the body or in a pocket surrounded by coins. Each scenario is less than ideal for RF as impedance is not 50 Ω. A single tuner can vary the VSWR magnitude and phase seen by the phone's antenna port and test its performance in transmit and receive mode.

Using load pull in transmit mode makes it possible to measure the output power as a function of VSWR magnitude and phase.

Using load pull in receive mode enables phone sensitivity measurements in order to evaluate at what power level a user-specified bit error rate (BER) or frame error rate (FER) is achieved as a function of VSWR magnitude and phase.

In combination with automated impedance tuners and automated mobile phone test system (AMTS) software from Maury Microwave, the R&S®CMU universal radio communication tester and the R&S®CMW wideband radio communication tester enable efficient mobile phone testing under real-world conditions.



SYNCHRONIZED PULSED IV AND PULSED S-PARAMETER MEASUREMENTS

Synchronized pulsed IV and S-parameter measurements are the backbone for compact transistor model extraction.

S-parameter measurements help determine extrinsic parasitic device elements. Then the intrinsic linear compact model can be deembedded.

Nonlinear model extraction uses pulsed IV measurements to determine temperature-dependent performance effects in safe operating regions and to evaluate the transistor breakdown area. Pulse widths and duty cycles maintain quasi-isothermal operating conditions. Pulsed IV measurements are used to extract the diode currents, and synchronized pulsed IV and S-parameters help extract the nonlinear capacitance model.

Electrothermal circuits model transistor performance as a function of device temperature and self-heating. Transistor thermal resistance can be extracted by using the difference between continuous and short pulsed bias conditions.

Applications
- ▶ Parametric analysis
- ▶ Compact model extraction

Key features
- ▶ Turnkey solution with integrated pulsed modulators and receivers
- ▶ High dynamic range
- ▶ Fast sweep time

In combination with the AM3200 pulsed IV system and IVCAD measurement and modeling device characterization software, the R&S®ZNA vector network analyzer provides a turnkey solution for extracting compact transistor models for III-V and MOS technologies.

MEASURING S-PARAMETERS WITH MEASUREMENT UNCERTAINTY

Applications
- Production test (pass/fail)
- Research and development

Key features
- Support of most VNA models from Rohde & Schwarz
- High measurement accuracy

As new technologies emerge and are included in standards, product specifications and requirements become tougher and the competition fiercer. Engineers and designers need to squeeze out every tenth of a decibel of performance and publish ambitious specifications. This creates a potential problem: how to balance aggressive specifications but still be confident that a product will deliver the promised performance? And not just performance for the designer but also for the end user.

Scientists have been investigating uncertainty sources in microwave and RF measurements and have proposed models and techniques to quantify the individual contributions. These contributions can be systematically determined and added as part of an overall S-parameters measurement.

Maury Microwave's Insight VNA calibration and S-parameter measurement software can be used with almost any Rohde & Schwarz two-port or four-port VNA to calibrate, validate and measure S-parameters with measurement uncertainty. Individual uncertainty contributors such as the VNA, calibration kit, cable assemblies, connectors and operators are quantified and viewed in real time using S-parameter measurements. The Rohde & Schwarz VNAs offer best-in-class uncertainty, enabling more accurate S-parameter measurements. This makes it possible to report product performance with measurement uncertainties and give both designers and end users the confidence they need to ensure product performance over time.

Thanks to their low noise floor and drift, Rohde & Schwarz VNAs enable more accurate S-parameter measurements with reduced measurement uncertainties.

Maury Microwave is a global leader for non-50 Ω device characterization solutions covering 10 MHz to 1 THz, including:
- passive, active and hybrid-active fundamental and harmonic load pull
- noise parameters extraction and modeling
- pulsed IV- and S-parameters and compact transistor model extraction for III-V and MOS technologies
- behavioral model extraction of components and circuits
- automated UE test
- low, medium and high-power robustness/VSWR test
- singular software platform for measurement, model extraction, model validation, visualization and data analysis
- solutions tailored to aerospace/defense and commercial telecommunications with an emphasis on 5G and Wi-Fi

Maury Microwave develops best-in-class solutions with our partners to solve advanced customer challenges, and supports our customers with a global team of applications engineers based in the United States, France, the Netherlands, Russia and China.

Maury Microwave's characterization solutions will help characterize and model transistor technologies, design better amplifiers and circuits and validate the performance and robustness of circuits and systems.

Contact:
Maury Microwave
2900 Inland Empire Blvd Ontario, CA 91764 USA
Email: sales@maurymw.com
Phone: +1-909-987-4715
www.maurymw.com

Rohde & Schwarz GmbH & Co. KG
www.rohde-schwarz.com

Rohde & Schwarz training
www.training.rohde-schwarz.com
Rohde & Schwarz customer support
www.rohde-schwarz.com/support

PD 3609.5722.32 | Version 01.00 | March 2021 (sk)
Advanced 50 Ω pulsed and nonlinear device characterization up to 1.1 THz

3609572232
3609.5722.32 01.00 PDP/PDW 1 en