Measurement & Modeling Device Characterization Solutions

—MEASUREMENT & MODELING DEVICE CHARACTERIZATION SOLUTIONS

IVCAD Advanced Measurement & Modeling Software

Powered by

AMCAD Engineering
Advanced Modeling for Computer-Aided Design

MT930 Series

Maury IVCAD Software Completes the Cycle from Pulsed-IV and S-Parameters, to Harmonic Load Pull, to Compact Transistor Models!

Introduction

IVCAD advanced measurement and modeling software, offered by Maury Microwave and AMCAD Engineering supports multiple load pull techniques including traditional load pull using external instrumentation, VNA-based load pull, active load pull and hybrid load pull. It performs DC-IV and pulsed-IV measurements and incorporates device modeling tools. Its modern visualization capabilities give users a greater ability to view, plot and graph measurement data in an intuitive manner.

IVCAD Software Suite Models

MT930B1 – IVCAD Basic Visualization
MT930B2 – IVCAD Advanced Visualization Add-On
MT930C – IVCAD Vector-Receiver Load Pull
MT930C1 – IVCAD Vector-Receiver Load Pull Waveguide Add-On
MT930C2 – IVCAD Pre-RF Pulsed IV Load Pull Add-On
MT930D1 – IVCAD Traditional Load Pull
MT930D2 – IVCAD Harmonic, Spectrum and Vector Analyzer Add-On
MT930E – IVCAD DC-IV Curves
MT930F – IVCAD CW S-Parameters
MT930GA – IVCAD Time-Domain LSA Add-On
MT930GB – IVCAD Keysight NVNA Support Add-On
MT930H – IVCAD Active Load Pull
MT930H1 – IVCAD Active Load Pull Waveguide Add-On
MT930J – IVCAD Pulsed IV Curves
MT930K – IVCAD Pulsed S-Parameters
MT930L – IVCAD Scripting Language
MT930M1 – IVCAD Linear Model Extraction
MT930M2A – IVCAD Nonlinear Model Extraction, III-V
MT930M2B – IVCAD Nonlinear Model Extraction, LDMOS
MT930P – IVCAD Measurement Toolbox
MT930Q – IVCAD Stability Analysis Tool (STAN)
MT930R1 – IVCAD EPHD Behavioral Model Extraction

Advanced Measurement & Modeling

The consolidation of industry players and an overall reduction in acceptable time-to-market has led to a demand for streamlined and efficient measurement and modeling device characterization tools. Maury Microwave, along with strategic partner AMCAD Engineering, have succeeded in this challenge by releasing its IVCAD measurement and modeling device characterization software, the most complete commercial solution to cover the design flow from component to circuit to system.

Pulsed IV, Pulsed RF and Compact Transistor Modeling (III-V and LDMOS)

The design flow begins with component-level linear and nonlinear model extraction of popular transistor technologies such as GaN FET and LDMOS.

First, IVCAD, in conjunction with a BILT pulsed-IV system and pulsed-network analyzer will measure synchronized pulsed-IV and pulsed S-parameter data under varying gate and drain bias conditions. Specific pulse widths will be set in order to eliminate self-heating and operate the transistor under quasi-isothermal conditions. The quiescent gate and drain voltages will be set to isolate and model gate-lag and drain-lag trapping phenomena. Measurements can be repeated under varying chuck temperatures, varying pulse widths and quiescent bias points, to extract an electrothermal model component.

AMCAD III-V and LDMOS model extraction is performed within the IVCAD platform; the same tool used to record relevant measurements is also used to extract the complete compact model. The measured S-parameters are used to extract a linear model consisting of extrinsic (pad capacitances, port metallization inductances, port ohmic resistances) and intrinsic parameters (channel capacitances, ohmic resistances, mutual inductance, output capacitance and resistance). Synchronized pulsed IV and pulsed S-parameter are used to extract nonlinear capacitances, voltage controlled output current source, diodes, breakdown generator, thermal and trapping circuits.

Load Pull (Vector-Receiver and Traditional)

Load pull involves varying the load impedance presented to a device-under-test (DUT) at one or more frequencies and measuring its performance, including output power at the fundamental and harmonic frequencies, gain, efficiency, intermodulation distortion… Load pull can be used for amplifier design, model extraction, model validation, performance testing as function of mismatch, and to test the robustness of finished systems, among other things.

Once a nonlinear compact model has been extracted, load pull can be used for model refinement by adjusting nonlinear parameters to better match the nonlinear measurements. Load pull can also be used for model validation by overlaying simulated and measured transistor performance as a function of load impedance presented to the transistor.

IVCAD supports multiple forms of traditional (scalar, modulated) and vector-receiver (VNA-based, real-time) load pull methodologies. Traditional load pull includes CW and pulsed-CW single-tone and two-tone, as well as modulated input signals, fundamental and harmonic impedance control on the source and load, passive impedance generation techniques, under DC and pulsed bias stimulus. Vector-receiver load pull includes CW and pulsed-CW single-tone and two-tone input signals, fundamental and harmonic impedance control on the source and load, passive, active and hybrid-active impedance generation techniques, time-domain waveform NVNA load pull, under DC and pulsed bias stimulus.

Passive load pull allows engineers to use mechanical impedance tuners to vary the source and load impedance presented to the DUT. Passive load pull is available at the fundamental and harmonic frequencies.

Active load pull replaces passive tuners at one or more frequencies with "active tuners", which use a magnitude and phase controllable source to inject power into the output of the DUT, thereby creating the "reflection" signal needed to vary the impedance presented. Active load pull overcomes the mechanical and VSWR challenges presented by harmonic passive tuners, as well as tuning isolation challenges between the different frequencies related to the combined movement of the tuner's slugs.

Hybrid-active load pull combines the strengths of active and passive load pull, allowing the passive tuner to act as a prematch, to lower the power required by the "active tuner", and divide-and-conquer multiple frequencies.

Time-domain NVNA load pull allows for the recording of voltage and current waveforms and load lines in addition to the typical measurement parameters. This additional information can be useful in studying the sensitivity of a transistor as well as class of operation.

Synchronized pulsed-RF pulsed-bias load pull uses the BILT PIV system to bias the DUT for a true pulsed measurement. Pulsing the bias can set the thermal state of the transistor and avoid self-heating. It is also useful to MMIC applications in which the bias will be pulsed.

Behavioral Modeling

Behavioral modeling is a "black-box" modeling technique which models the DUT's response to a specific set of stimuli (input power, bias, impedance…). Compared with compact models which completely define the characteristics of the transistor, behavioral models define only the "behavior" and static models are valid under the conditions in which they were extracted. Behavioral models are useful in several applications: to hide the details of the transistor specifics while concentrating on its performance and response (ideal for public distribution), to improve the speed of simulation (behavioral models will generally simulate faster than a compact model containing the same data), to model a packaged component, or even a complete circuit or system (incompatible with compact modeling).

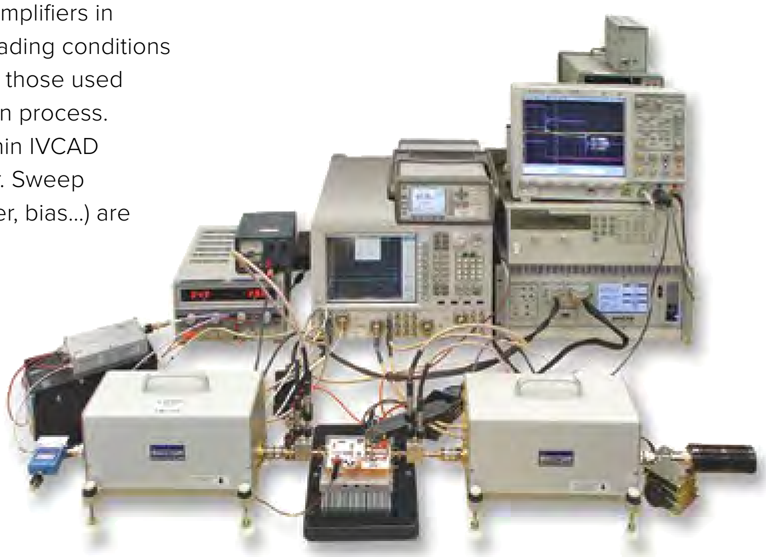
IVCAD supports three behavioral modeling methodologies: Keysight's X-Parameters and AMCAD's Multi-Harmonic Volterra (MHV) and Enhanced PHD. X-Parameters are the result of poly-harmonic distortion methodology (harmonic superposition) which uses harmonic extraction tones to quantify the harmonic nonlinearities of a DUT. The MHV modeling technique is based on harmonic superposition combined with dynamic Volterra theory resulting in a model that can handle both low frequency and high frequency memory effects. The strength of MHV modeling is that it enables accurate and reliable simulations in commercial RF circuit or system simulators, even when using complex modulated wideband signals. Thanks to this accuracy, the most important figures of merit of RF systems can be analyzed safely (e.g., EVM, ACPR, IM3, etc.).

Enhanced PHD (EPHD) is ideal for behavioral modeling of amplifiers in which extrapolation of loading conditions may be required beyond those used in the modeling extraction process. Behavioral modeling within IVCAD is transparent to the user. Sweep plans (impedances, power, bias…) are defined and the measurement is run as normal, however the software will communicate with the relevant model extraction application and present a completed model upon completion of the measurement routine.

Stability Analysis of Circuits

Once an amplifier or integrated circuit has been designed on a circuit simulator, it is critical to test the design for low- and high-frequency oscillations. IVCAD offers a Stability Analysis module (STAN) which is compatible with commercial circuit simulation tools. Single-node and multi-node analysis identifies the cause and localization of oscillations. Parametric analysis determines oscillations as a function of varying input power, bias, load impedance and stabilization network parameters (resistance values). Monte Carlo analysis discovers oscillations as a function of manufacturing dispersions and tolerances.

Whether being used for a single purpose or across multiple modeling, design and production groups, IVCAD measurement and modeling device characterization software suite offers an intuitive, methodical and efficient solution for first-pass design success and quickest time to market.



MT930B1 IVCAD Basic Visualization

IVCAD offers a modern and intuitive basic visualization package for IV, S-Parameters and Load Pull data.

> Basic I(V) Viewer plots IV curves of Vd, Vg, Id and Ig

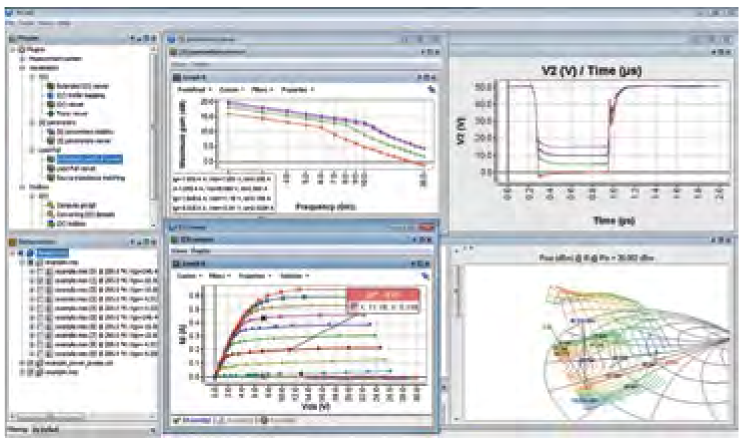
> IV Trace Viewer

> Basic S Parameter Viewer plots S-parameters in standard and custom formats including log magnitude, linear magnitude, phase, polar, and Smith Chart

> Basic Load Pull Viewer plots impedance sweeps and power sweeps with advanced filtering capabilities

Dockable windows allow users to create and save custom IVCAD environments. Templates allow users to save their preferred visualization graphs and recall or share with colleagues. Data Editor allows users to create new parameters based on equations and visualize alongside measurement data. Export allows users to save graphs and plots as JPG or PDF files for reporting. Visualization is compatible with Maury Microwave and common commercial data formats.

Visualization of S-Parameters, IV Curves, Pulse Shape and 3D Load Pull Contour



MT930B2 IVCAD Advanced Visualization Add-On

MT930B2 is an add-on module for MT930B1 which enables advanced visualization capabilities including:

> Extended IV Viewer

> I(V) Wafer Mapping

> S parameter stability analysis

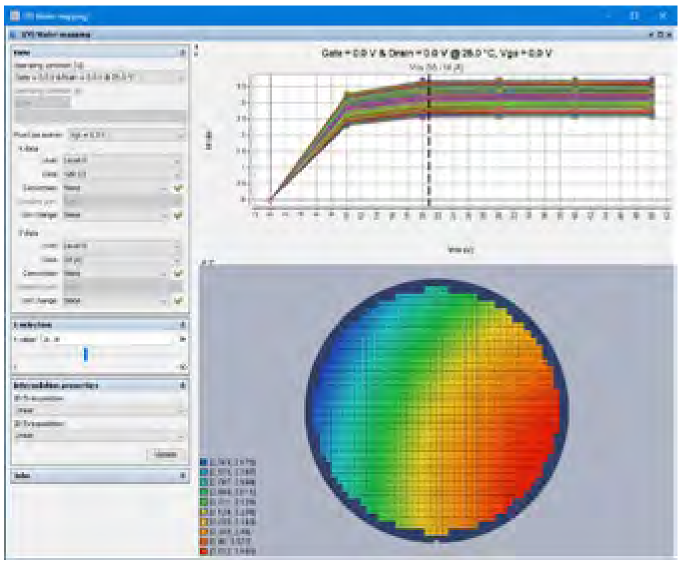
> Extended Load Pull Viewer

> Load Pull time domain visualization

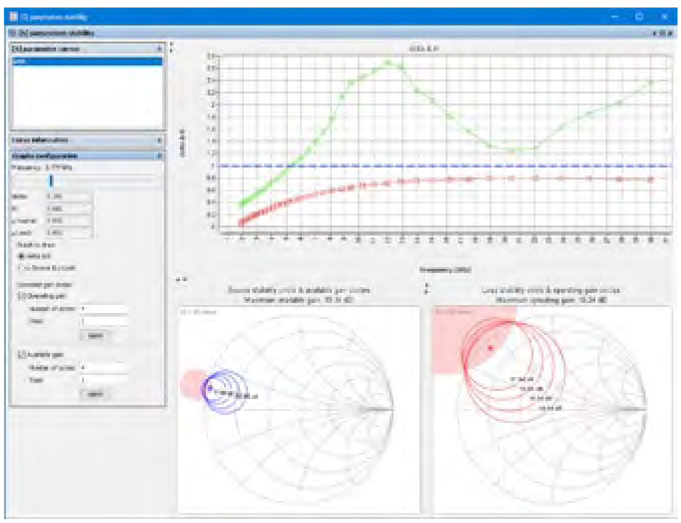
> Magic Source Pull

Extended IV Viewer – enables users to visualize a transistor's pulsed IV characteristics versus time. This is useful in observing dynamic self-heating in the saturated region while moving different time markers. A second use is to determine the ideal measurement windows, i.e. the steady-state measurement area, so that the measurement data is not recorded in an area of overshoot or ringing. This is critical in defining the minimum pulse width for any given measurement, since the ideal value is tied to transistor size, bias tees, cables, etc, and can only be determined by visualizing the shape of the pulse over time.

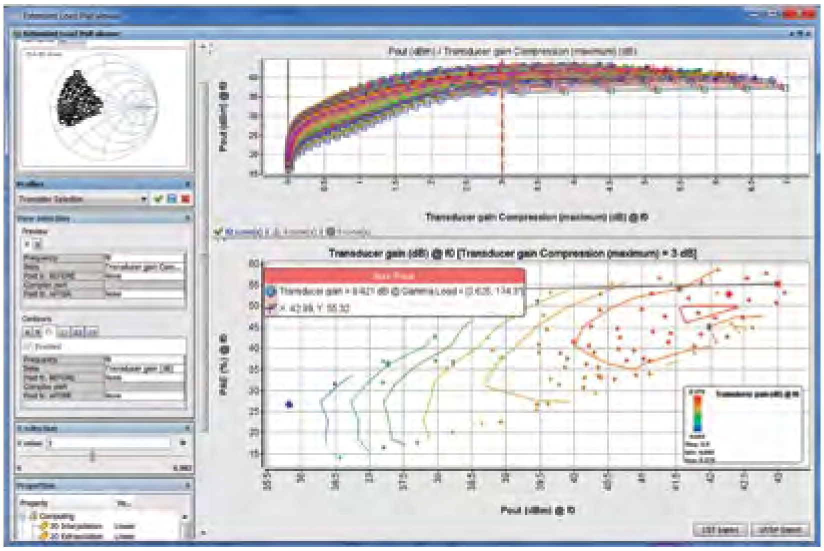
I(V) Wafer Mapping – makes use of IVCAD's automated probe station control for step-and-repeat IV measurements and plots critical IV characteristics as a function of transistor over the wafer. DC Gm and Gd characteristics can be dynamically observed, as well as Gate Lag and Drain Lag over the wafer.



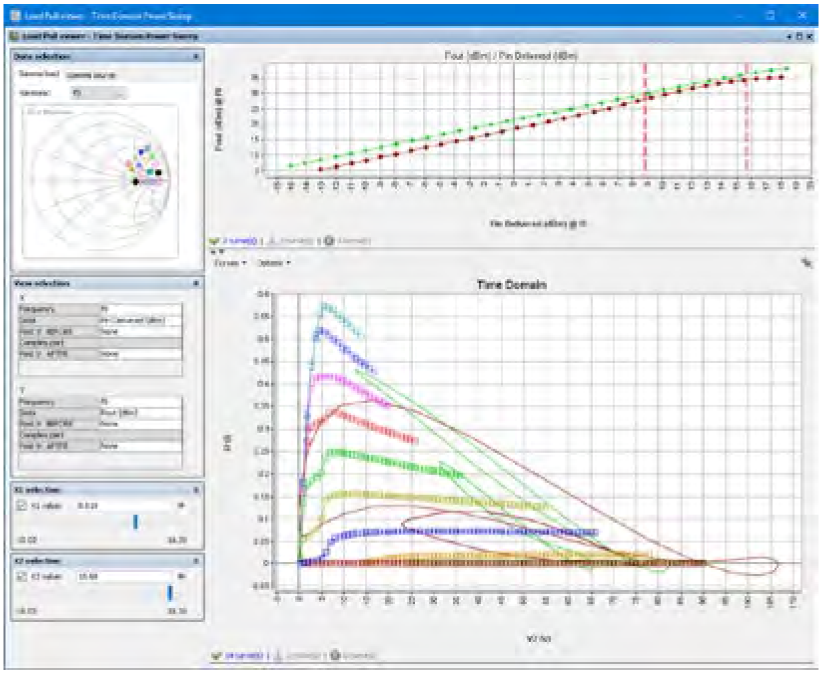
S-parameter stability analysis – allows users to visualize source and load stability circles extracted from linear S parameter measurements. Constant available gain and operating gain circles are also plotted and updated in real-time as a function of frequency.



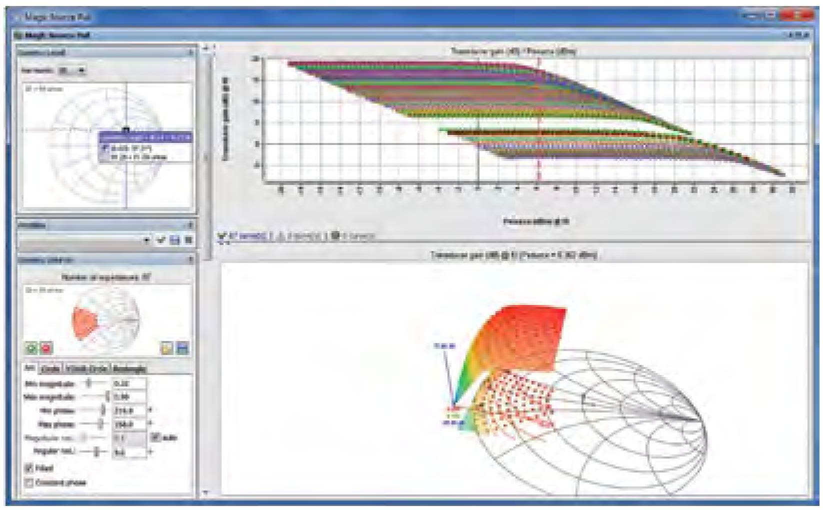
Extended Load Pull viewer – enables users to dynamically plot XY graphs and Smith Chart contours based on a dependency variable, such as input power, output power, gain compression, efficiency or EVM. The viewer links two independent plots, such that the first plot is used to determine the dependency value, while the second plot is automatically updated as a function of the dependency value, and can be customized on the fly. Extended Load Pull viewer is invaluable when sorting through large sets of measurement data, such as nested measurements (i.e. load pull over a region of the Smith Chart, while sweeping power at each load).



Load Pull Time Domain visualization – enables the plotting of voltage and current waveforms and load lines measured using the MT930G IVCAD Time-Domain Waveforms add-on module for MT930C IVCAD Vector-Receiver Load Pull. In addition, linear models extracted using MT930M1 IVCAD Linear Model Extraction can be used to de-embed the time-domain waveforms to the intrinsic transistor reference plane, and intrinsic RF load lines can be superimposed with Pulsed IV plots to give valued information regarding high efficiency operating classes (i.e. Class F, Inverse Class F…). Markers can be placed at different powers to visualize the effects of gain compressions on load line saturation.



Magic Source Pull (Source Pull Converter) – Large signal input impedance can be found by measuring DUT a- and b-waves at the DUT reference plane. A patented technique simulates source matching, without varying the source impedance. Even under extremely mismatched conditions this “virtual source matching” is highly reliable, provided the DUT is sufficiently unilateral (S21~ >S12+50dB). Simulated source contours are drawn, and trade-offs between maximum gain, efficiency and other parameters can be viewed in real-time without multiple source-load measurement iterations. Direct computation of the input VSWR versus source power and source impedance is also enabled.



MT930C IVCAD Vector-Receiver Load Pull

IVCAD offers a modern, efficient methodology for load pull measurements, with low-loss couplers between the tuners and DUT. Connecting the couplers to a VNA allows real-time measurement of a- and b-waves at the DUT reference plane, presenting vector information not normally made available. IVCAD measures the actual impedances presented to the DUT without assumptions of pre-characterized tuner positioning or losses. Extremely accurate transistor's input impedance derived from the a- and b-waves results in properly-defined delivered input power, true power added efficiency and true power gain measurements. Output powers at each frequency, fundamental and multiple harmonics, are made available as are multi-tone carrier and intermodulation powers.

Key Features:

> Supports single-tone and two-tone CW and pulsed-CW drive signals

> Fundamental and harmonic impedance control on source and load

> Automatically measures and calculates available parameters based on instrumentation

> DC and pulsed bias with interactive bias control

> Measure Zin in real-time to determine Pin,delivered

> Automatically tune the source tuner to the complex conjugate match of Zin for maximum power delivered to the DUT

> Measure actual Zl load impedances presented to DUT

> Two-tone IMD load pull using PNA-X

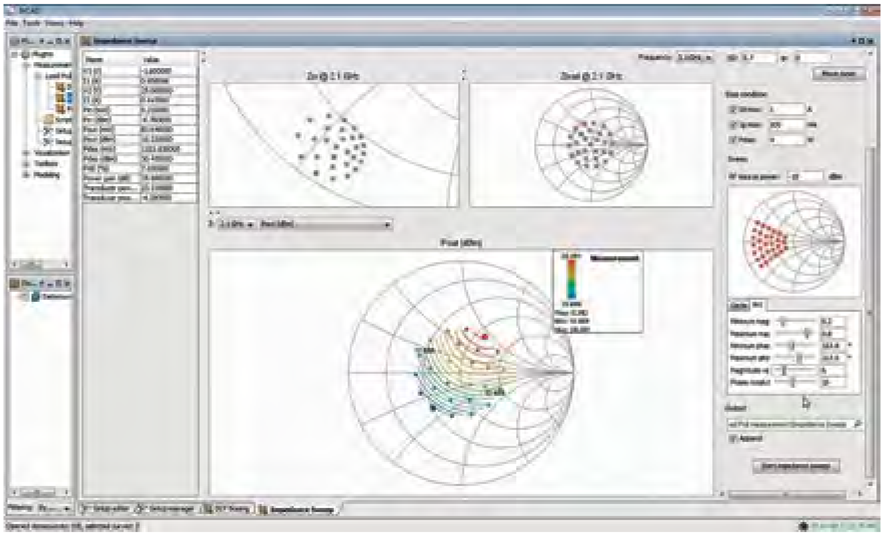
> Automatically de-embed and correct S-parameters of components between tuner and DUT

> Advanced peak search algorithm determines the region of maximum performance

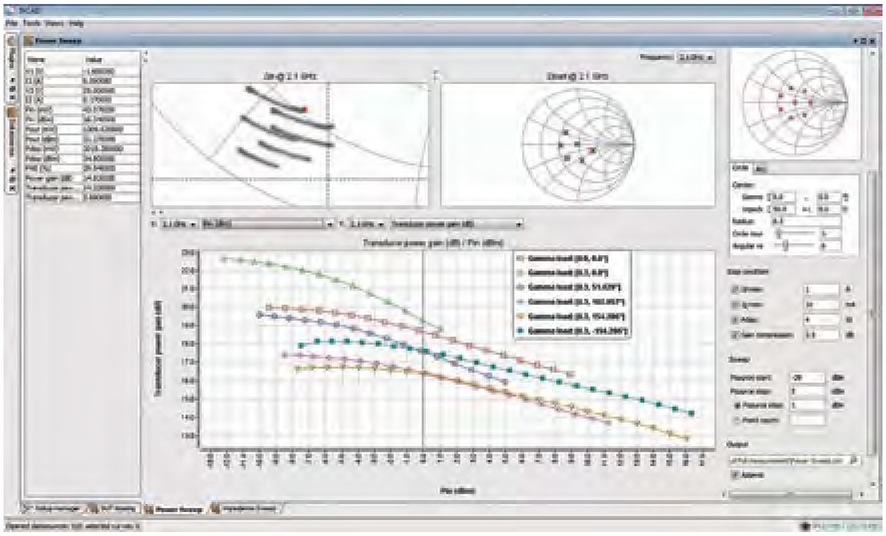
> Real-time visualization of load contours and power sweeps

> Integrate VRLP and TLP in one setup

> Export data to CSV or MDF



Impedance Sweep at Fixed Power



Power Sweep at Multiple Impedances

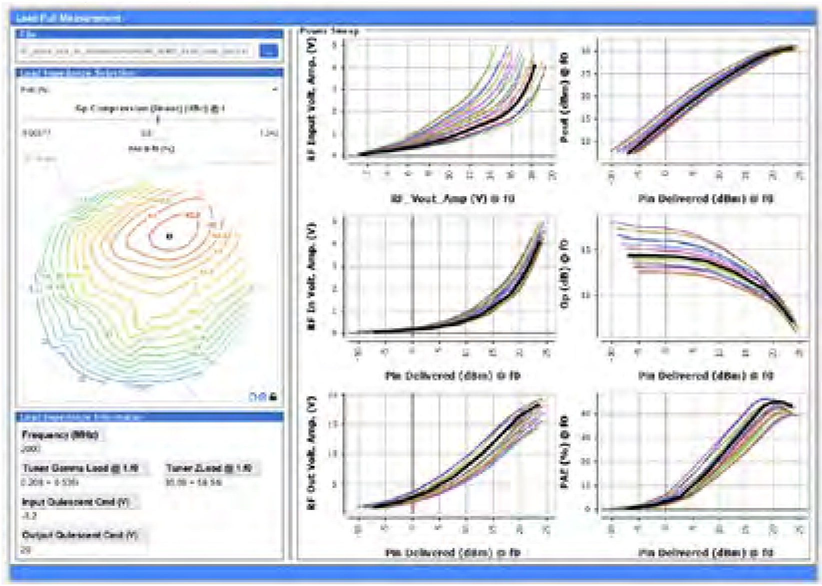
MT930C2 Pre-RF Pulsed IV Load Pull Add-On

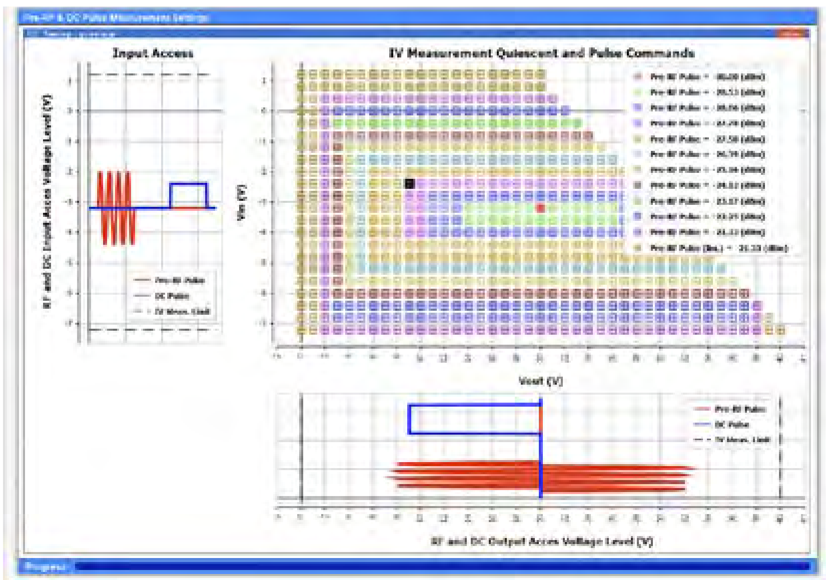
MT930C2 is an add-on software module for MT930C Vector-Receiver Load Pull and MT930J Pulsed IV Curves which measures the I-V characteristic of GaN HEMT transistors in pulse mode by considering the "real" state of charge of the traps, i.e., the one imposed by the component's environment in its final application. The measurement involves applying a RF pre-pulse before each IV measurement point which conditions the charge of the traps at a level determined by the I-V area and is varied throughout the measurement to represent the signal envelope's evolution. The solution uses vector-receiver load pull measurements to set the impedance states to match the final application and set the load lines appropriately.

MT930C2 has been developed to create a more accurate compact transistor model and to speed-up the model extraction and validation process. MT930C2 simplifies the trap models development and embeds non-50ohm measurements into the model extraction process.

Key Features

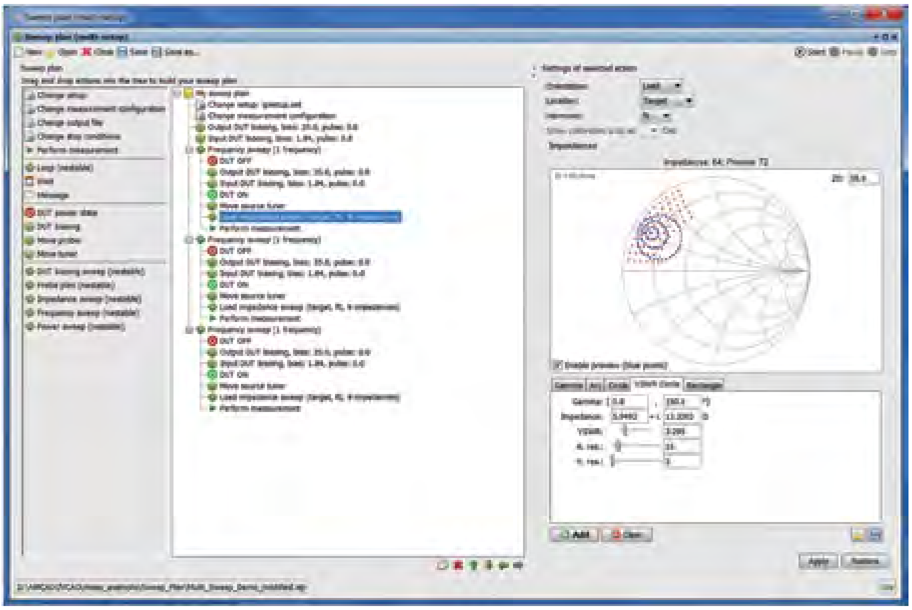
- I-V measurements are taken in non-50 Ω environment with dynamic trapping effects
- Automatic power configuration of the RF pre-pulse
- Real-time visualization of the I-V network under varying pre-pulse power levels





MT930C1 — is an add-on module for MT930C which enables vector-receiver load pull measurements using waveguide tuners and waveguide frequency extender modules.

Advanced Sweep Plan – available with both MT930C and MT930D1; by performing sweeps at multiple impedances, sufficient data is gathered that target parameters can be changed post-measurement without the need for additional measurement iterations. The same data set can be used to plot selected parameters at a constant input power, parameters at a constant output power, and parameters at constant compression level. This process greatly reduces total measurement time by gathering sufficient data first-pass, and shifting capabilities towards data visualization and analysis. Sweep parameters include DUT biasing, probe map, impedance sweep, frequency sweep, and power Sweep. Advanced capabilities include changing setup File, measurement configuration, output File During Sweep and stop conditions throughout the plan, as well as adding nestable loops, wait times and messages.



Advanced Sweep Plan Varying Bias, Impedance and Power

MT930D1 Traditional Load Pull and MT930D2 Harmonic, Spectrum and Vector Analyzer Add-On

IVCAD offers a flexible solution for traditional load pull based on power meters and optional spectrum or vector signal analyzers. In its simplest configuration, IVCAD can use a single signal source and power meter to measure power, gain, and efficiency. Adding an optional second power meter will enable input signal monitoring or reflection power measurements, or powers at harmonically separated frequencies when combined with a multiplexer. Adding an optional spectrum analyzer will enable the measurement of power at fundamental and harmonic frequencies. Adding an optional second source and spectrum analyzer will enable the measurement of two-tone IMD products. Adding an optional vector signal source and vector spectrum analyzer will enable the measurement of ACPR and EVM for modulated signals. IVCAD uniquely enables multiple calibration techniques including S-parameter calibration and power calibration with and without input power meters.

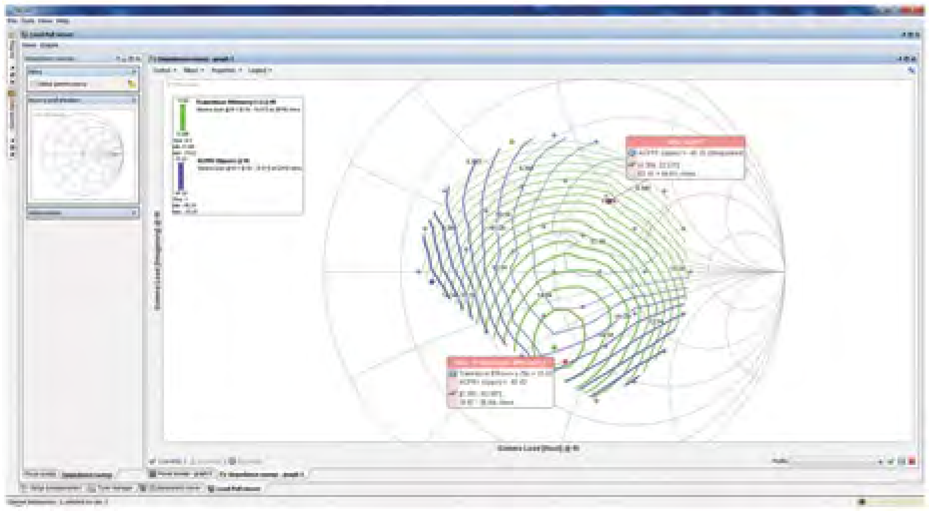
MT930D1 – includes CW and pulsed-CW single tone load pull using a power meter to measure output power

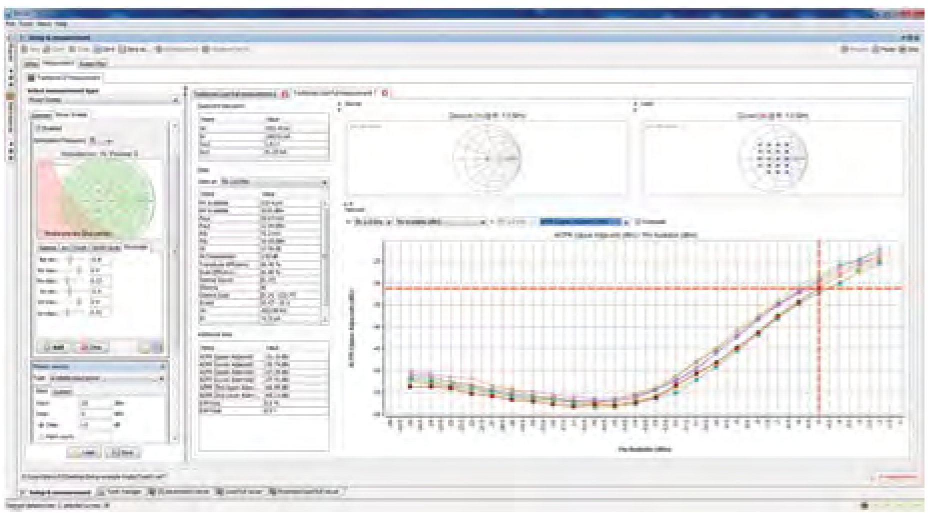
MT930D2 – is an add-on module for MT930D1 and enables the addition of a multiplexer with multiple power meters for harmonic power measurements, a spectrum analyzer for harmonic power measurements and two-tone IMD measurements (when paired with a second or two-tone signal source), a vector analyzer for modulated signal measurements of ACPR and EVM (when paired with a vector signal generator), and harmonic load pull (when paired with compatible impedance tuners.)

Advanced Sweep Plan – See Advanced Sweep Plan description in MT930C.

Key Features

- Supports single-tone and two-tone CW and pulsed-CW and modulated drive signals
- Fundamental and harmonic impedance control on source and load
- Automatically measures and calculates available parameters based on instrumentation
- DC and pulsed bias with interactive bias control
- S-parameter and power calibration methodologies
- Harmonic load pull using power meters or spectrum analyzers
- Two-tone IMD load pull using spectrum analyzers
- Modulated load pull using vector analyzers
- Real-time visualization of load contours and power sweeps
- Integrate VRLP and TLP in one setup
- Export data to CSV or MDF



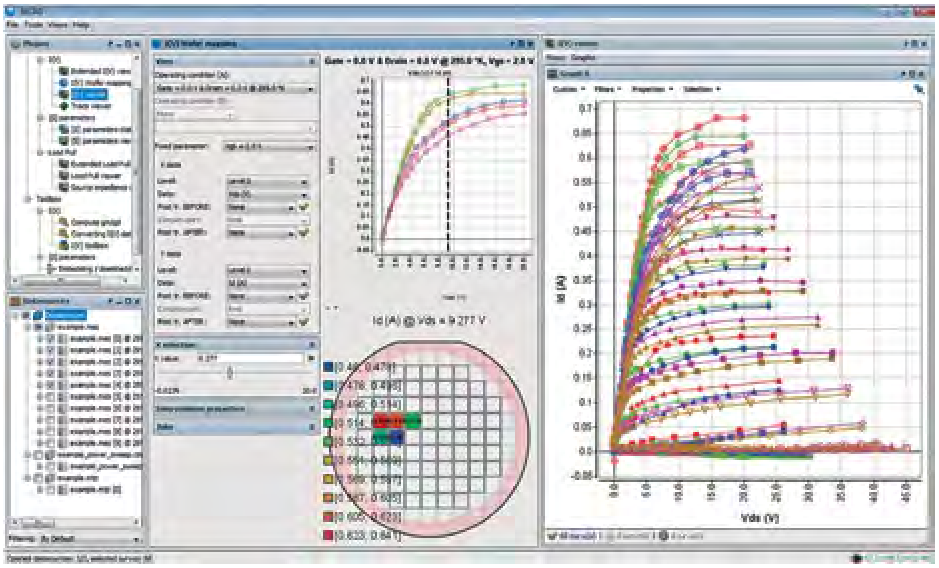


MT930E IVCAD IV Curves

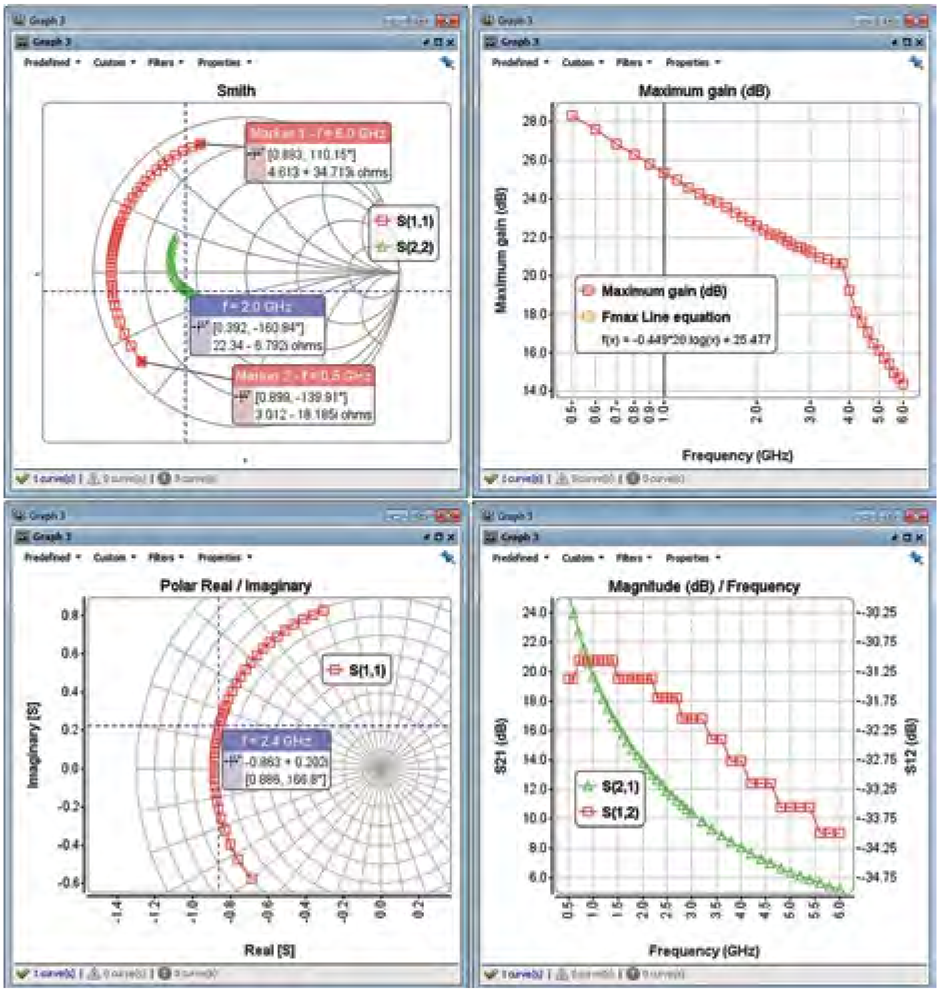
MT930E is a standalone module which enables DC-IV curves to be generated for a list of drain and gate voltages.

MT930F IVCAD CW S-Parameters

MT930F is an add-on module for MT930E which enables CW S-parameters to be measured at each DC IV bias point.



IV Curves at Various Wafer Positions



S-Parameters Plotted on Smith Chart, Maximum Gain, Polar, and Magnitude

MT930GA IVCAD Time-Domain LSA Add-On

MT930GA is an add-on module for MT930C Vector-Receiver Load Pull which enables time-domain large signal analysis and waveform reconstruction when used with supported VNAs and comb generators (harmonic phase references), and does not require third-party nonlinear VNA software. The LSA add-on records the phase dependency of harmonic content and allows a- and b-waves, voltage and current waveforms, and load lines to be displayed for each measurement state (impedance/power/bias) and can be de-embedded to the device reference plane.

Time-domain analysis, or Waveform Engineering, allows the analysis of currents and voltages at the device input and output terminals in order to identify the DUT's mode of operation. This tool is useful in the study and design of advanced amplifier classes of operation including E, F, J and K and their inverses.

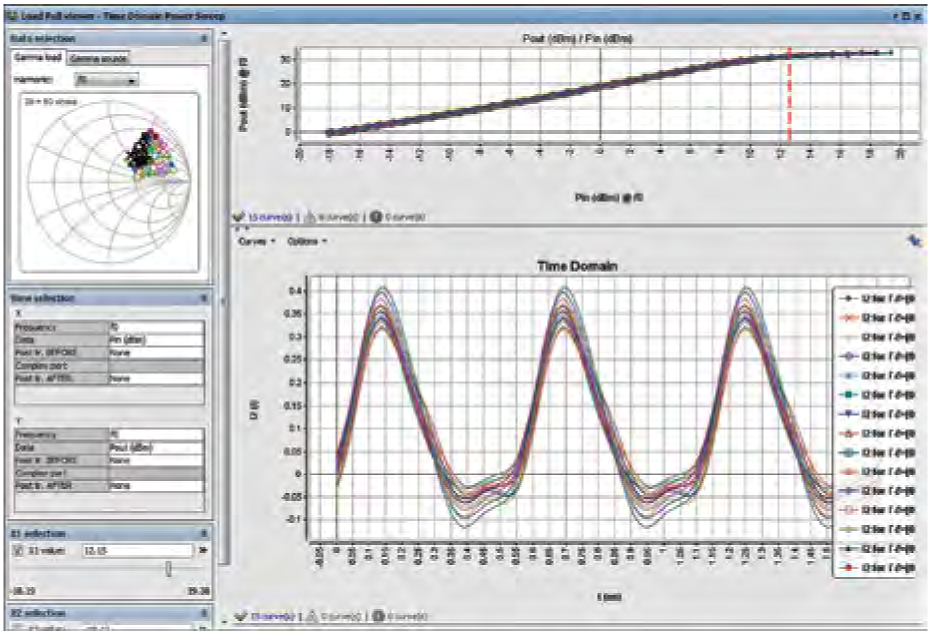
When used in combination with MT930R1 IVCAD EPHD Behavioral Model Extraction, an enhanced Poly- Harmonic Distortion behavioral model can be extracted for each measurement state with no significant addition of time.

MT930GB IVCAD Keysight NVNA Support Add-On

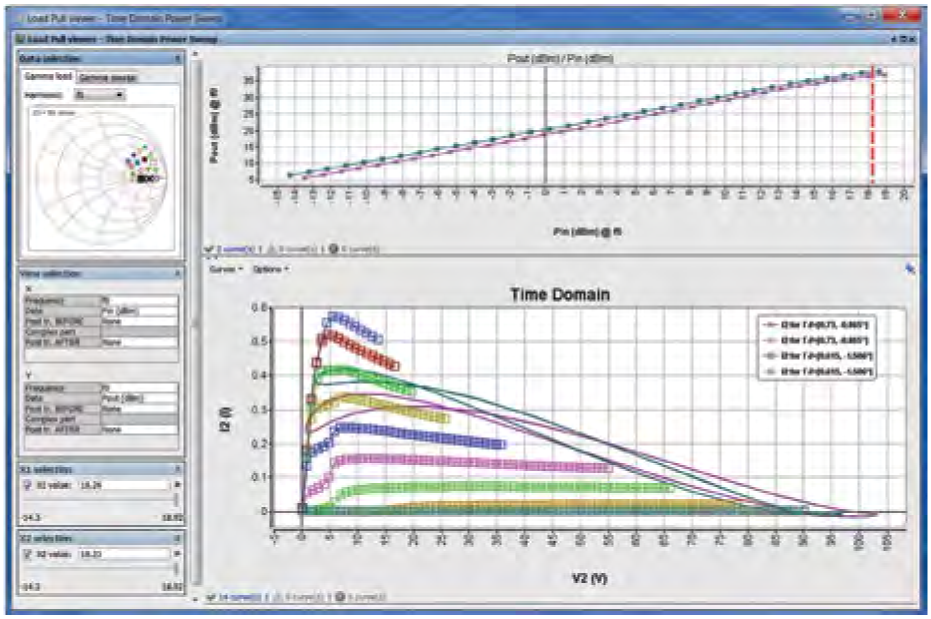
MT930GB is an add-on module for MT930C Vector-Receiver Load Pull which enables time-domain large signal analysis and waveform reconstruction in conjunction with Keysight PNA-X network analyzer with NVNA software option enabled.

MT930GB relies on the NVNA application to measure the phase dependency of harmonic content and allows a- and b-waves, voltage and current waveforms, and load lines to be displayed for each measurement state (impedance/power/bias) and can be de-embedded to the device reference plane.

With the appropriate PNA-X options, MT930GB also enables the extraction of X-parameters behavioral models.



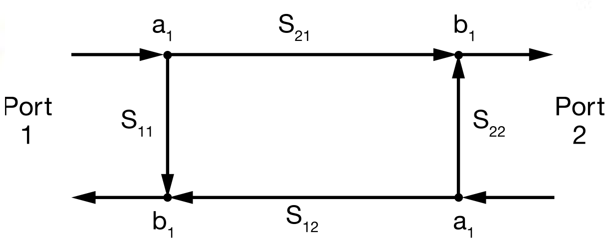
Output Current Waveforms at Constant Input Power Under Varying Load Impedances



DC and RF Load Lines at Constant Input Power Under Varying Load Impedances

MT930H IVCAD Active Load Pull and MT930H1 IVCAD Active Load Pull Waveguide Add-On

MT930H is an add-on module for MT930C Vector -Receiver Load Pull which enables active load pull in conjunction with internal and external sources for fundamental and harmonic load pull measurements. Considering our DUT as a two-port device shown below, Γ_L is nothing more than a_2/b_2, or the ratio between the reflected- and forward-traveling waves. A generalized form of the formula can be written as $\Gamma_{x,n}(f_n)=\frac{a_{x,n}(f_n)}{b_{x,n}(f_n)}$



Two-port Scattering Parameter Model.

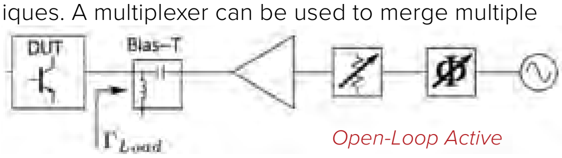
Key Features

- > Enhanced active load pull algorithm for faster and safer convergence

A closer examination of the formula $\Gamma_L=a_2/b_2$ reveals that there is no limitation on separating the sources of a_2 and b_2. It is obvious that b_2 is the wave coming from the device, of which we have no direct control; however a_2 need not be a reflected version of b_2 but can be a new signal entirely!

Active Load Pull – Active injection load pull, more commonly referred to as active load pull, relies on external sources to inject a signal into the output of the DUT, thereby creating a_2. Because a_2 is no longer limited to a fraction of the original reflected signal, as is the case with the traditional passive mechanical tuner, external amplifiers may be used to increase a_2 nearly indefinitely so that Γ_L can achieve unity. The simple active tuning chain consists of a signal source, a variable phase shifter and a variable gain stage, shown in the diagram below. Common signal generators that have built-in amplitude and phase control of the injected signal are ideal for active load pull.

Harmonic load pull, or tuning impedances at multiple frequencies simultaneously, becomes simple when using active load pull techniques. A multiplexer can be used to merge multiple active tuning paths, one per frequency,



Open-Loop Active Tuning Block Diagram.

so that $\Gamma_{x,n}(f_n)=\frac{a_{x,n}(f_n)}{b_{x,n}(f_n)}$ is satisfied.

Any loses inherent to multiplexers are easily overcome by the amplifiers used in each active tuning chain.

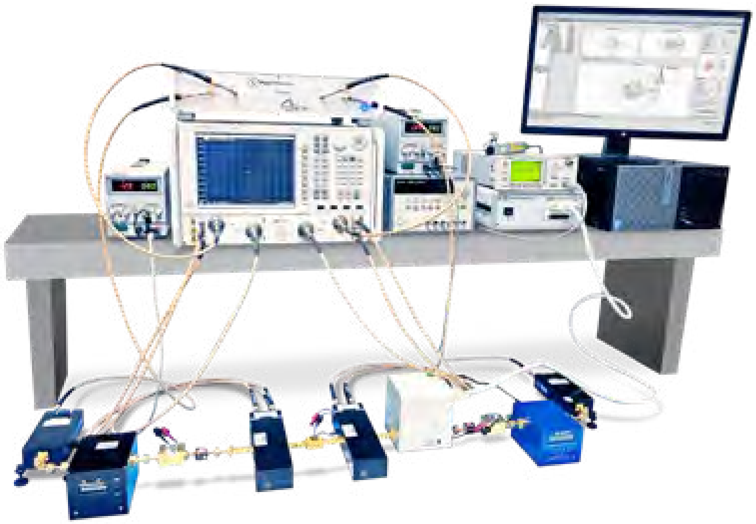
Hybrid-Active Load Pull – Both traditional passive mechanical tuner systems and active injection load pull systems have their advantages and disadvantages. While mechanical tuners are simple, less expensive and can handle high power, there is no physical way to overcome the losses involved with the system that limit achievable Γ_L. While active load pull systems are extremely quick, capable of Γ_L=1 and easily integrated for harmonic measurements on-wafer, high-power setups require more-expensive band-limited amplifiers.

It is possible to obtain the advantages of both systems while minimizing the disadvantages, using a technique referred to as hybrid load pull. Hybrid load pull refers to a combination of active and passive tuning in the same system. Traditional passive mechanical tuners can be used to reflect high power at the fundamental frequency allowing a much smaller active injection signal, using much smaller amplifiers, to overcome losses and achieve Γ_L=1. Additionally, since the powers at harmonic frequencies are often well below the power of the fundamental signal, less-expensive wideband amplifiers may be used with active tuning to accomplish active harmonic load pull with $\Gamma_{L,nf}$=1. In both cases, only a low power is required for active tuning.

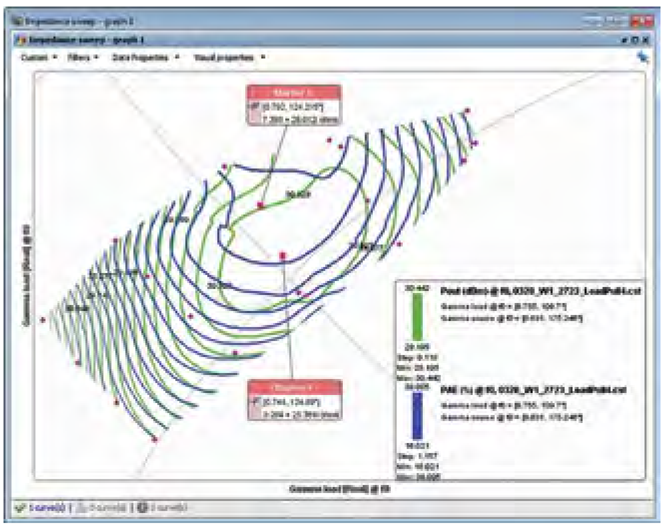
MT930H IVCAD Active Load Pull (continued)

MT930H1 — is an add-on module for MT930H which enables active and hybrid-active load pull measurements using waveguide tuners and waveguide frequency extender modules

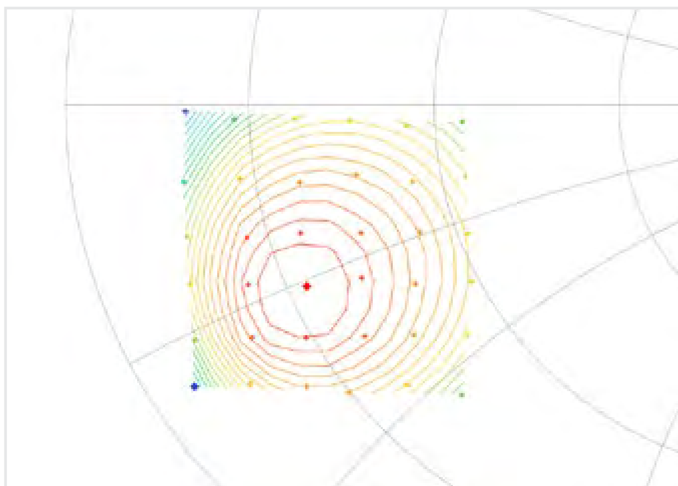
Hybrid-Active Load Pull at 30–50 GHz



Hybrid-active load pull system with WR12 automated impedance tuner, low-loss couplers and waveguide extenders covering 60-90 GHz



Output Power and PAE Contours at High-Gamma Enabled by Hybrid-Active Load Pull



Characterization of HBT transistor at 80 GHz with Pout=15dBm, optimum efficiency at Γ =0.68 and closed contours at Γ =0.92

MT930J IVCAD Pulsed IV Curves

MT930J is a stand-alone module for advanced Pulsed IV measurements using dedicated pulsing hardware (e.g., AMCAD's BILT Pulsed IV system).

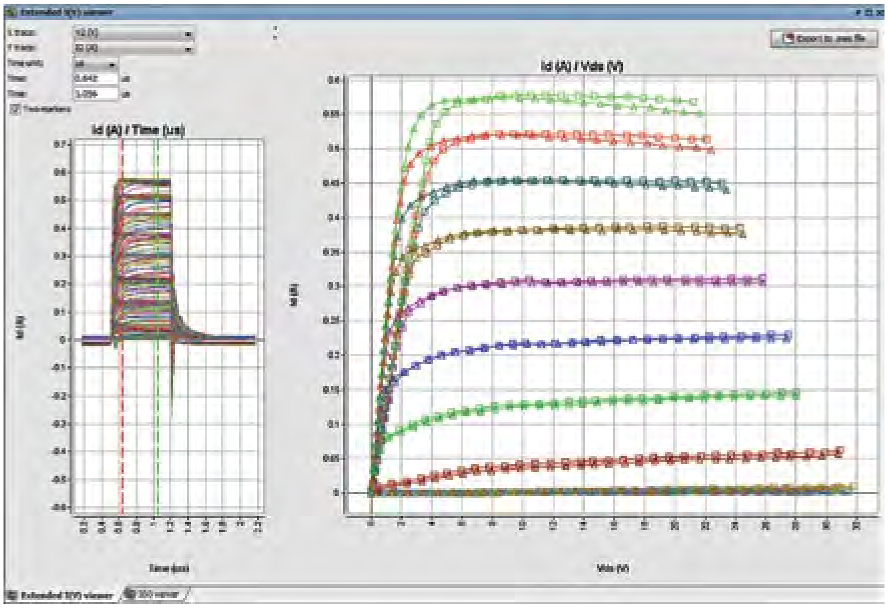
Current-voltage (IV) measurements are used to describe the relationship between the input and output currents and voltages of a device. Standard GaN Field Effect Transistors (FETs) are characterized by measuring the output current as a function of output voltage for swept input voltages. Because GaN devices tend to self-heat and are susceptible to trapping effects, it is important to pulse voltages between a quiescent and hot value and define appropriate pulse-widths. By pulsing the voltage, a lower average power will be delivered to the device thereby reducing self-heating. Such a measurement allows for near-isothermal performance.

IVCAD enables the visualization of trapping phenomena, gate lag and drain lag, on GaN transistors. It is a simple task to view trapping effects as a function of varying quiescent bias.

IVCAD has implemented full wafer control by interfacing with Cascade Nucleus software.

Key Features:

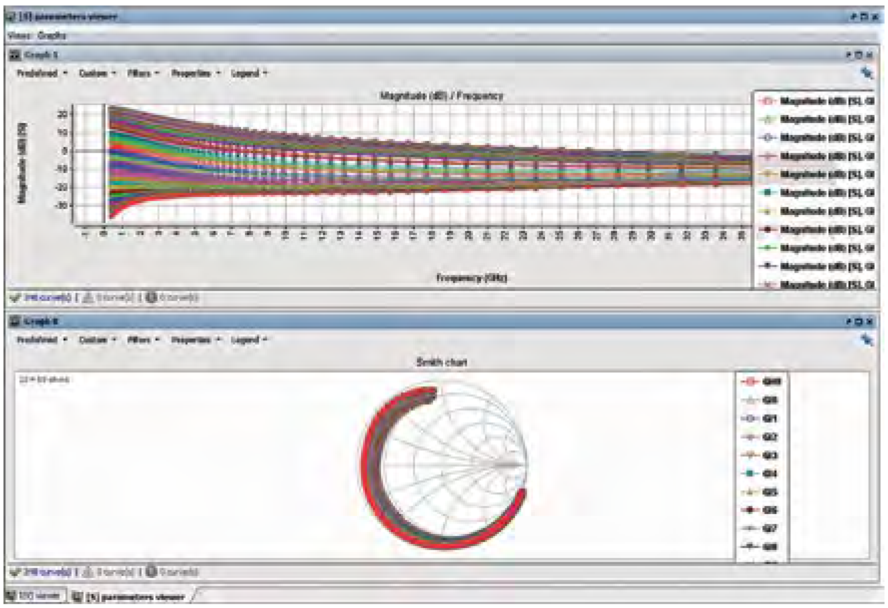
- Pulsed configuration and calibration of all instruments (including PIV system and VNA) controlled by IVCAD
- Graphical pulsed chronogram easily defines gate, drain, RF source and measurement windows
- Sweep input or output voltages in linear, adaptive and custom voltage steps
- IV trace screenshot visualizes IV waveform without the need for an oscilloscope
- VNA operated in NBW for enhanced accuracy S-parameters
- Multiple stop conditions for voltages, currents, powers and temperatures
- Automated probe station control
- Export data to ICCAP, ADS and Microwave Office



Pulsed IV Curves Plotted at Different Times with Pulse

MT930K IVCAD Pulsed S-Parameters

MT930K is an add-on module to MT930J which enables synchronized Pulsed S-Parameter measurement in conjunction with Pulsed IV.



Pulsed S-Parameters Under Varying Bias Conditions

MT930L IVCAD Scripting Language

MT930L is an add-on module to MT930C/D/J/K which enables complex test sequencing through a dedicated scripting language.

Scripting is available both internally to IVCAD and as an external script server. The script server allows users to run IVCAD as slave software, controlled by an external application, through TCP/IP sockets.

TCP/IP sockets allow programs to talk through a network, but a communication between two programs on the same computer can also be established.

Internal scripting is managed by the script editor, which includes functions divided into several categories:

Concurrency – functions related to threading

User interfaces – functions related to creating windows, docking windows, fonts, labels, 2D and 3D graphs, wafer maps

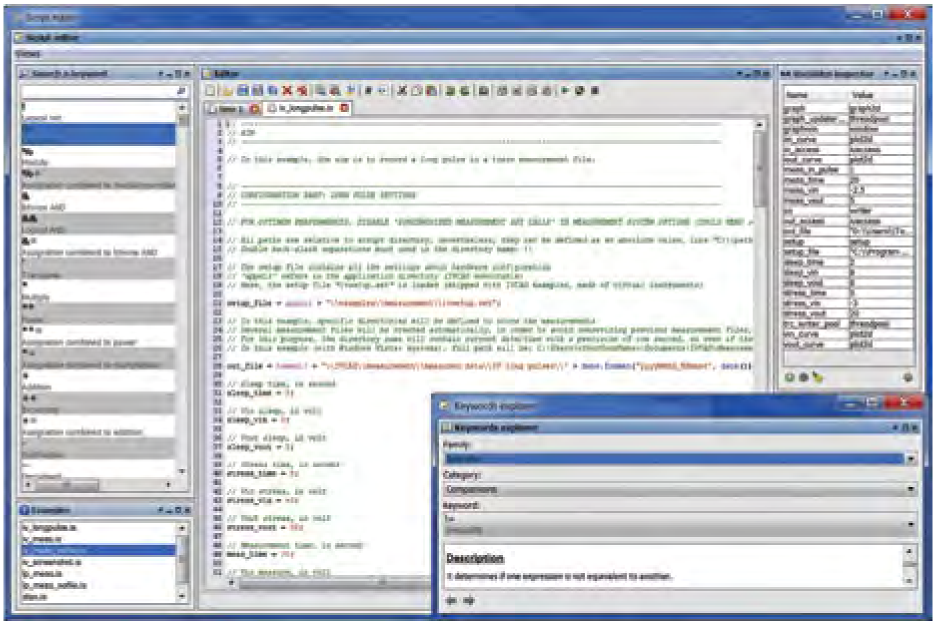
I/O – functions related to logging events, printing messages, reading and writing characters, managing files and directories

Math – functions related to math, values, vectors, arrays, rows, factorial operations, complex numbers, conversions, exponents, interpolation, trigonometry

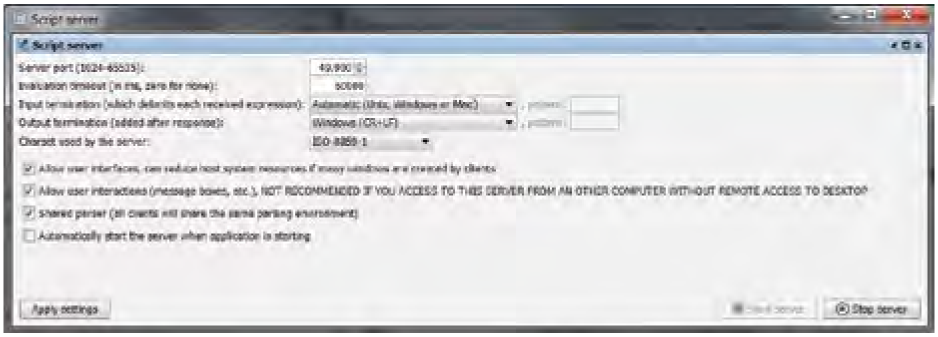
Measurements – functions related to impedance control, IV control, probe station control, tuner control, setup management

Scripting – functions related to loops, conditions, if/else

SQL – functions related to database management



Script File Tuning Source and Load Within IVCAD



Script Server

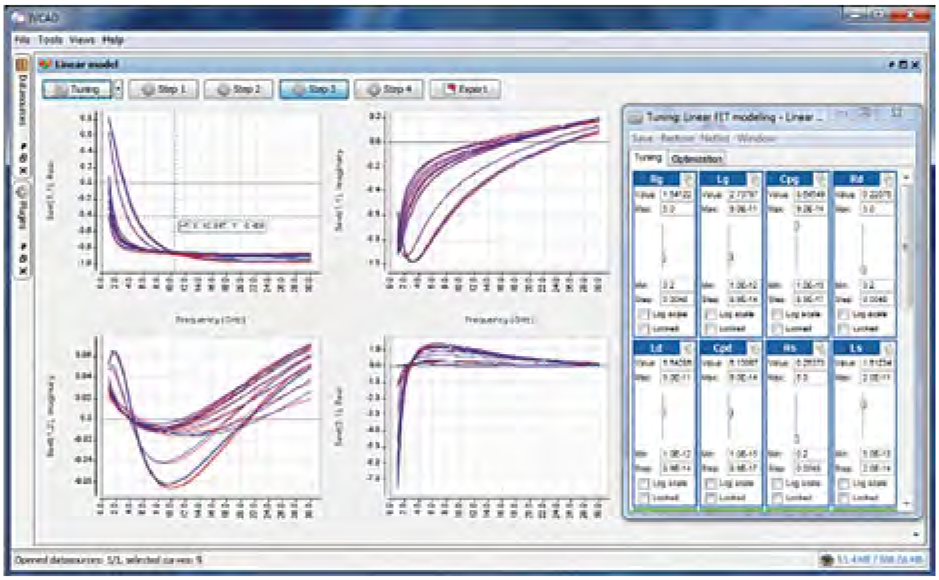
MT930M1 IVCAD Linear Model Extraction

MT930M1 is an add-on module to MT930J and MT930K for Linear Model Extraction.

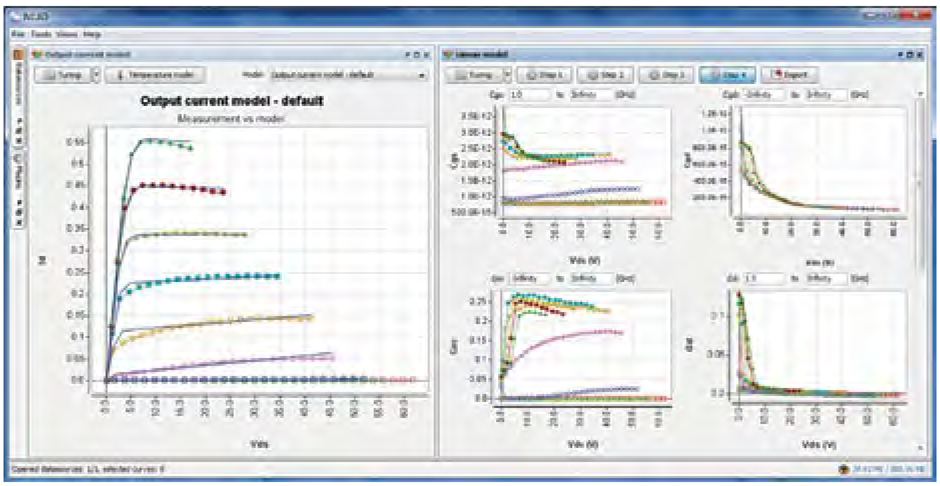
Linear Model Extraction is used to determine the extrinsic parameters (parasitic elements) and intrinsic parameters of III-V and LDMOS transistors. Linear modeling fits measured data to linear model equations, and can be automatically optimized or manually tuned to solve for values of the extrinsic (Rg, Lg, Cpg, Rd, Ld, Cpd, Rs, Ls) and intrinsic parameters.

Linear model extraction is a critical first step in the transistor modeling process, and any errors resulting from linear model inaccuracies will prevent the extraction of nonlinear models. A wizard guides users through a step-by- step process in order to eliminate user errors and ensure first-pass linear model extraction success. Validation is provided by comparing intrinsic elements through a multi-bias extraction. Netlist export is available at each level of the linear model extraction process.

The resulting linear model can be used with MT930M2A and MT930M2B to generate nonlinear models, or exported to commercial circuit simulators. The linear model can also be used to de-embed time-domain load pull data to the intrinsic device reference plane, and visualize intrinsic load lines for advanced amplifier classes.



Linear Model Comparing Measured And Optimized Data



Multi-Bias Capacitances and Transconductance Model Extraction

MT930M2A IVCAD Nonlinear Model Extraction, III-V

MT930M2A is an add-on module to MT930M1 for Nonlinear Model Extraction of III-V device technologies. The extrinsic parameters measured through linear modeling (MT930M1) are used to extract intrinsic parameters.

In quasi-isothermal conditions, MT930M2 uses synchronized pulsed IV/RF measurements to extract the parameters of the AMCAD nonlinear equations that describe the nonlinear capacitances, diodes, and current sources of the transistor. Pulse widths are kept sufficiently short in order to avoid a strong temperature variation during the pulse duration and the duty cycle is kept sufficiently low in order to avoid a mean variation of the temperature, so that the transistor's pulsed IV measurements are obtained under quasi-isothermal operating conditions. S-parameters are measured in the steady-state region of the signal.

Nonlinear Capacitance Model Extraction – For III-V or LDMOS transistors, thanks to a selection of the IV plots close to the expected RF load line, the capacitance values will be extracted according to the instantaneous Vgs and Vds values. In order to extract an accurate and robust model regarding the convergence of the simulation, the nonlinear models will be provided under the form of a "one dimension" formulation. Thus Cgd will be a function of intrinsic Vgd while Cgs will be a function of the intrinsic Vgs voltage. The comprehensive parameters of these equations can be tuned manually or optimized automatically. For III-V transistors Cds is provided as a linear model; for LDMOS transistors Cds is provided as a nonlinear capacitance model.

Diode Parameter Extraction – For III-V transistors, the gate current will be accurately modeled by two diodes (Dgs and Dgd), biased in forward mode.

The manual or automatic tuning of the diode's parameters provides an accurate fit of the positive gate current at low Vds and high Vgs voltages. The negative gate current for high Vds voltages in pinch-off conditions is provided by a breakdown generator.

Output Current Extraction – A specific algorithm is used to extract the output current source model, which provides a reliable description of the Ids current for different Vds and Vgs voltages.

The formulation used enables an accurate description of the output current sources and its derivatives (gm, gd). The comprehensive parameters of these equations can be tuned manually or optimized automatically.

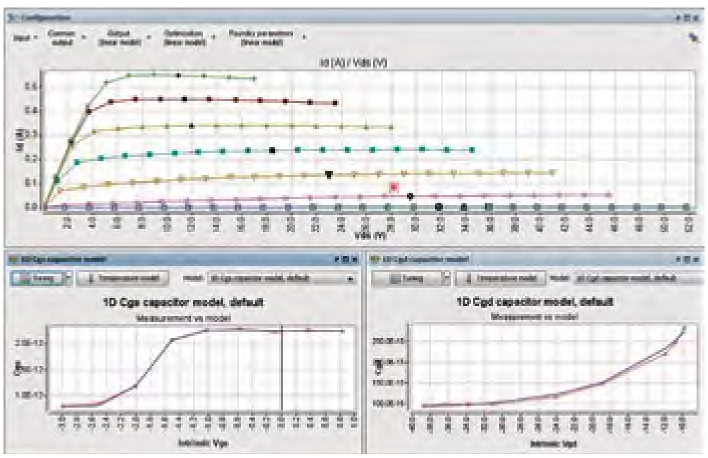
MT930M2A uses a modified Tajima current source model for III-V transistors.

IVCAD employs a comprehensive library and flexible formula editor which allows users to create custom model parameters and parameter extraction equations. Users can implement proprietary equations based on their own experiences and expertise, and benefit from IVCAD's optimization algorithms and GUIs.

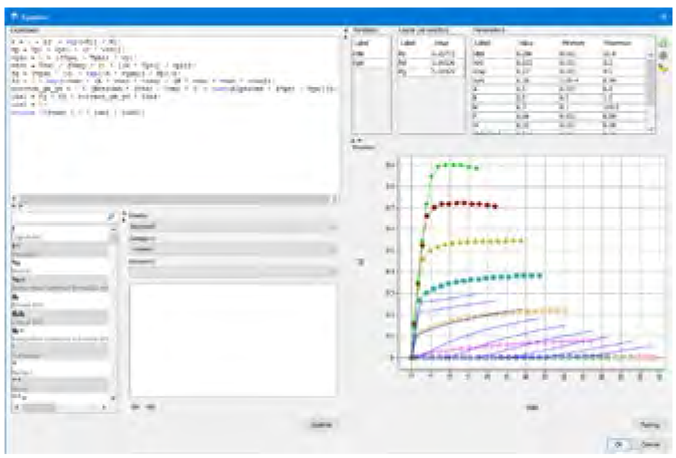
MT930M2B IVCAD Nonlinear Model Extraction, LDMOS

MT930M2B is an add-on module to MT930M1 for Nonlinear Model Extraction of LDMOS transistors. The extrinsic parameters measured through linear modeling (MT930M1) are used to extract intrinsic parameters.

MT930M2B uses a proprietary AMCAD current source model for LDMOS transistors.

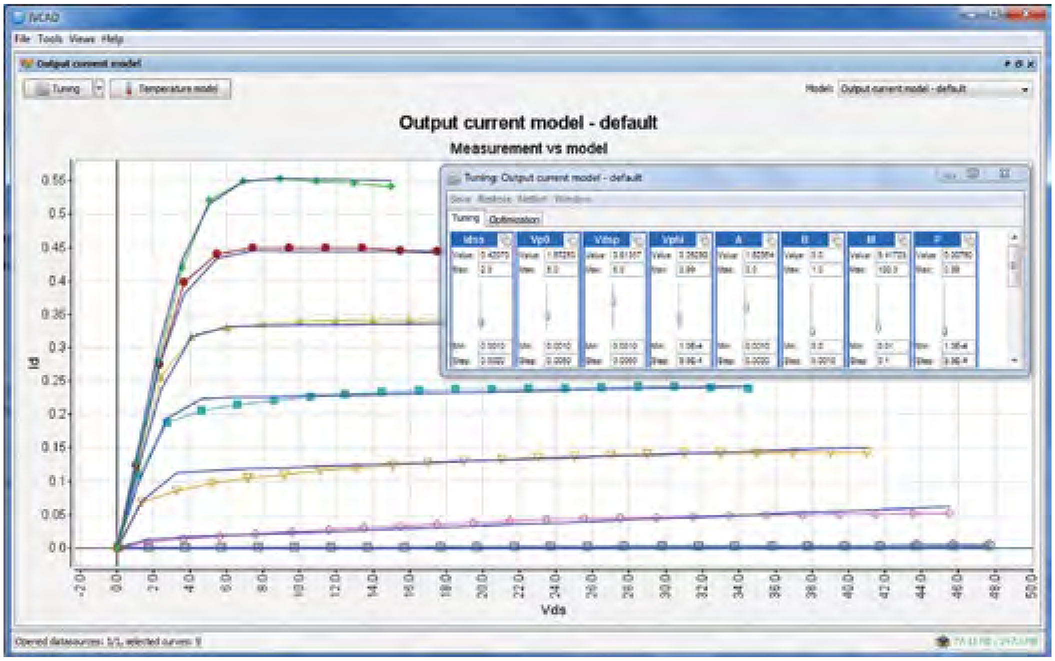


Capacitance Model Extraction Showing Excellent Match Between Measurement and Modeled Data

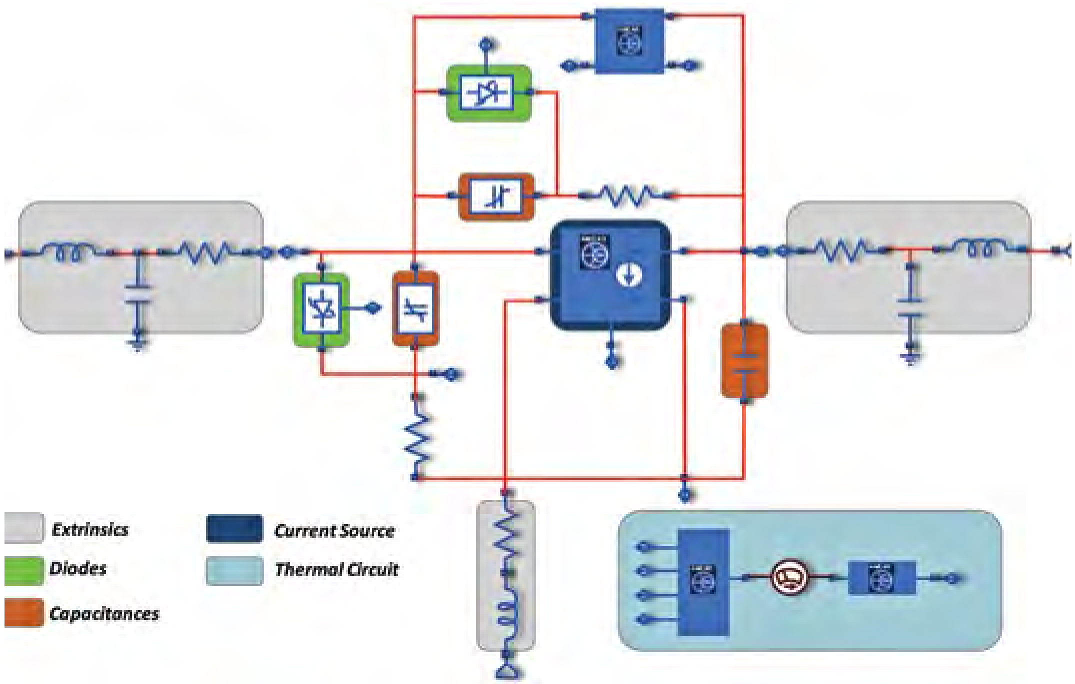


Equation Editor for Nonlinear Model Extraction

Current Source Extraction Showing Excellent Match Between Measured And Modeled Data



AMCAD III-V Model Template



MT930P Toolbox

MT930P is a stand-alone module which enables useful mathematical tools post-measurement.

> IV Tools – compute gm/gd, convert IV data sets, interpolate/extrapolate IV points.

> S-parameters – TRL fixture extraction, interpolate/extrapolate S-parameters.

> De-embedding – de-embedding S-parameters, intrinsic de-embedding of S-parameters based on linear model.

> Converter – mathematical calculator for converting phase, power, VSWR, impedance.

MT930Q IVCAD Stability Analysis Tool

Stability Analysis Tool (STAN) is a revolutionary stability analysis technique for microwave circuits, which is valid for both small-signal and large-signal regimes. This tool is able to detect and determine the nature of oscillations, such as parametric oscillations in power amplifiers, that may be functions of the input drive signal. Knowledge of the type of oscillation mode facilitates the insertion of stabilization networks, with a better balance between the required oscillation avoidance and maintaining the original circuit performances.

The STAN approach calculates a single-input, single-output (SISO) transfer function for a circuit of interest linearized around a given steady state. A simulated frequency response of the linearized circuit is fitted to a rational polynomial transfer function by means of frequency-domain identification algorithm. If no poles on the right-half plane (RHP) are found, it is considered stable.

Key Features:

> Single-node analysis

> Multi-node analysis

> Parametric analysis under varying load impedances

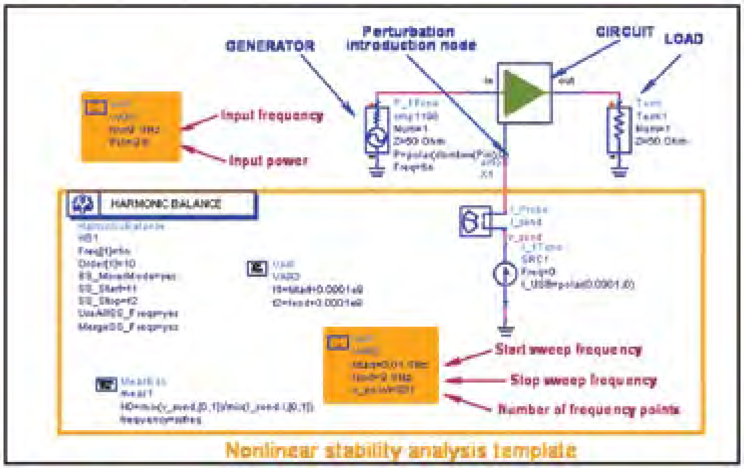
> Parametric analysis under varying input signal power

> Monte Carlo analysis

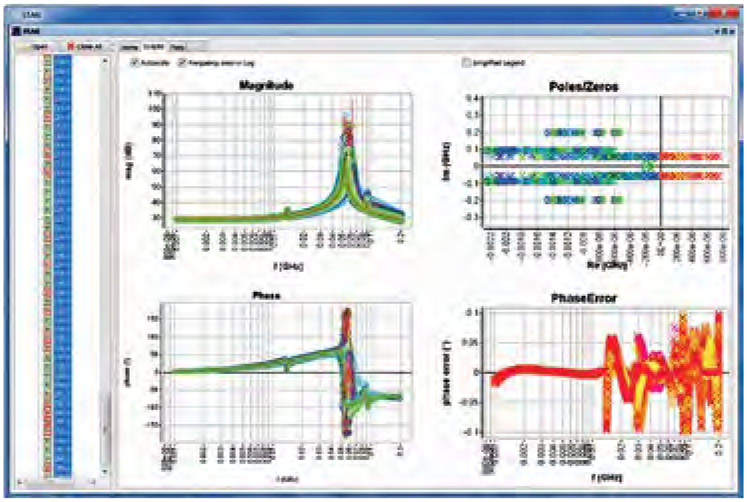
> Compatible with IC, MMIC and hybrid-amplifier designs

> Templates supplied

STAN is compatible with major commercial circuit simulator tools.



Nonlinear Stability Analysis Template



STAN Tool Graphical User Interface

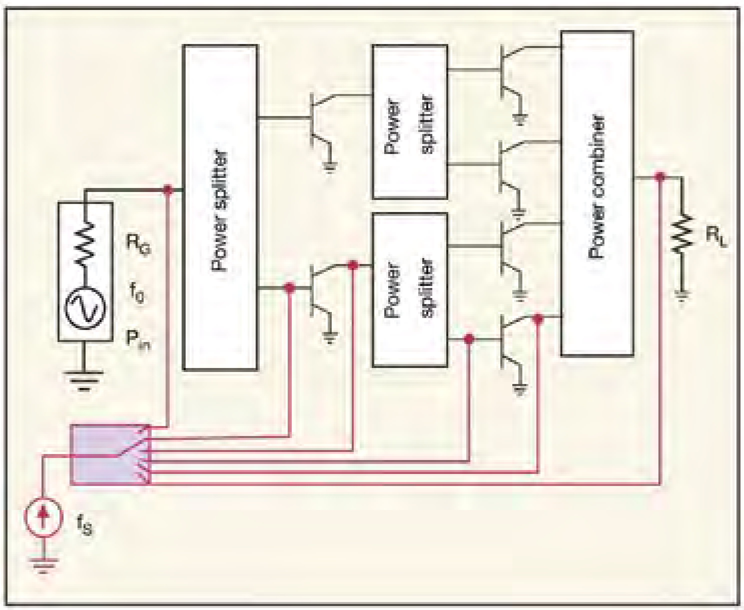


Diagram Showing a Multinode Stability Analysis of an RF/microwave Amplifier

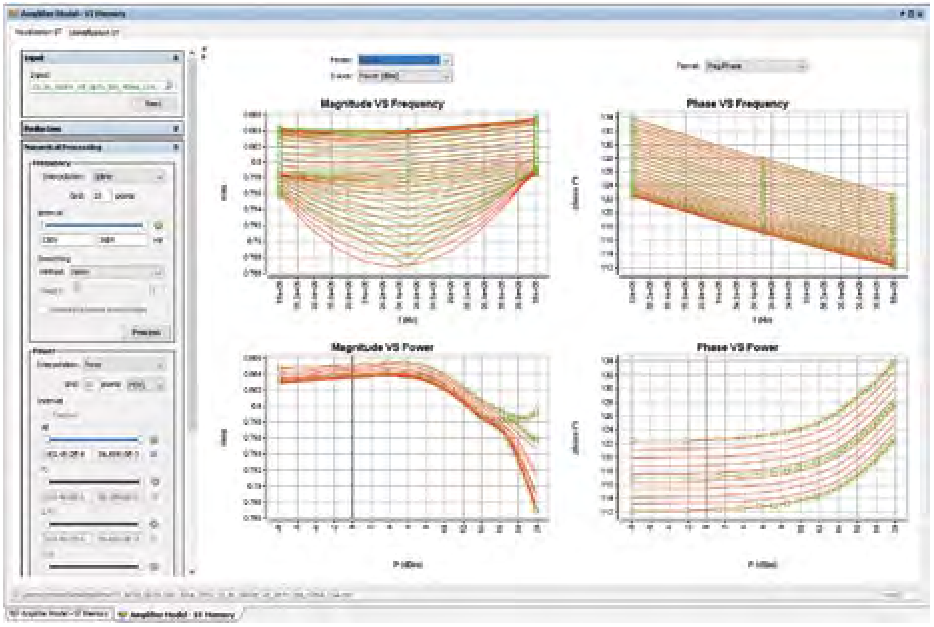
MT930R1 IVCAD EPHD Behavioral Model Extraction

MT930R1 is a stand-alone module for Enhanced PHD (EPHD) behavioral model extraction directly from Vector-Receiver Load Pull measurement data.

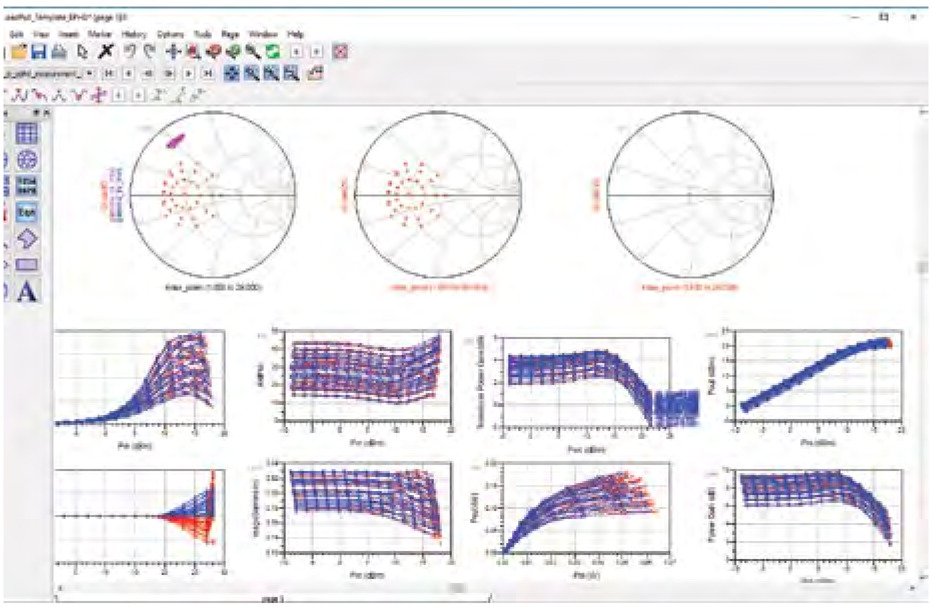
The EPHD Model is based on Poly-Harmonic Distortion theory with a dynamic power expansion order. The methodology has been designed for simulation requirements where loading conditions are significantly different than those used during the measurement, and accurate interpolation and/or extrapolation is required.

Based on successful industry implementation, the EPHD behavioral model has been proven to show excellent robustness and convergence even when a DUT sees a dynamic load impedance modulation, which is typical in the case of highly nonlinear classes of operation (i.e. Class C).

MT930R1 is especially useful for the behavioral model extraction of packaged transistors to be used in the design of power amplifier circuits.



Visualization of Behavioral Model Terms



ADS Comparison of Measured and Modeled Performance Parameters

Recommended Reading

The following literature is recommended for those who wish to learn more about the IVCAD Advanced Measurement & Modeling Software Suite and the test and measurement applications it supports.

5A-069 VNA Based Load Pull Harmonic Measurement De-embedding Dedicated to Waveform Engineering

Abstract – This paper presents a simple methodology to observe the RF waveforms at the drain source current reference plane of the transistor, without using a complete nonlinear model. The aim is to allow Power Amplifier designers starting their work using VNA based harmonic and time domain load pull measurements, and S parameter measurements. The later measurements will be used to extract a linear model first. Then the parameters of the linear model will be used to deembed the load pull measurements directly at the voltage controlled current source plane, in order to enable waveform engineering. Because of the well know theoretic conditions that enable optimum efficiency, this methodology can also be used to avoid time consuming multi-harmonic load pull measurements. Harmonic impedances can be defined accordingly to the knowledge of the operating class addressed, while load pull optimization can be addressed to refine the fundamental matching only.

5A-067 A multi-harmonic model taking into account coupling effects of long- and short-term memory in SSPAs

Abstract – This paper presents a new macro modeling methodology for solid-state power amplifiers (SSPAs) and packaged transistors used in communication systems. The model topology is based on the principle of harmonic superposition recently introduced by Keysight Technologies' X-parameters™ combined with dynamic Volterra theory. The resulting multi-harmonic bilateral model takes into account the coupling effects of both short- and long-term memory in SSPAs. In this work, the behavioral model was developed from time-domain load pull and used to simulate the amplifier's response to a 16-QAM signal with specific regards to ACPR and IM3.

5A-066 Behavioral Power Amplifier Model considering Memory Effects dedicated to radar system simulation

Abstract – In radar systems, where pulsed RF signals are used, one of the main concern is the spurious emission. Such spurious are emissions of frequencies outside the bandwidth of interest. The spurious level must be kept under a Aaaaa level to be compliant with the specifications. In order to check all these specifications, system level simulation can be used, but accuracy and reliability of the simulation results will depend on the circuit model reliability, especially for the Power Amplifier (PA) which is a critical element. Such model must take into account the different memory effects. This paper proposes a complete and practical methodology to extract a Behavioral PA model dedicated to radar applications. A specific attention is paid on the coupling effects between short and long term memory dynamics.

5A-065 High Efficiency Doherty Power Amplifier Design using Enhanced Poly-Harmonic Distortion Model

Abstract – This application note presents new identification methodologies dedicated to packaged transistor behavioral modeling. Using the background of the Poly-Harmonic Distortion (PHD) model formalism, the extension of the model kernels description up to the third order makes the behavioral model more robust and accurate for a wide range of impedance loading conditions, which is a primordial when designing a High Power Added Efficiency Doherty Amplifier, where a load impedance variation can be observed as a function of the power level. In this paper, a model of a 15 W GaN Packaged Transistor has been extracted from Load Pull measurements for Class AB and Class C conditions. This new Enhanced PHD model (EPHD) and the original PHD model are benchmarked against Load Pull measurements in order to check the new formulation. An advanced validation at the circuit level was done in order to verify the ability of the EPHD model to predict the overall Doherty Amplifier performances.

5A-063 Selecting the Node: Understanding and overcoming pole-zero quasi-cancellations

Abstract – This application note provides the fundamentals to understand the origin of pole-zero quasi-cancellations and the tips to get a reliable analysis that unambiguously decides on the stability/instability of the circuit in the presence of quasi-cancellations.

5A-061 Multiharmonic Volterra (MHV) Model Dedicated to the Design of Wideband and Highly Efficient GaN Power Amplifiers

Abstract – This paper presents a complete validation of the new behavioral model called the multiharmonic Volterra (MHV)model for designing wideband and highly efficient power amplifiers with packaged transistors in computer-aided design (CAD) software. The proposed model topology is based on the principle of the harmonic superposition introduced by the Keysight X-parameters, which is combined with the dynamic Volterra theory to give an MHV model that can handle short-term memory effects. The MHV models of 10- and 100-W packaged GaN transistors have been extracted from time-domain load–pull measurements under continuous wave and pulsed modes, respectively. Both MHV models have been implemented into CAD software to design 10- and 85-W power amplifiers in - and -bands. Finally, the first power amplifier exhibited mean measured values of 10-W output power and 65% power-added efficiency over 36% bandwidth centered at 2.2 GHz, while the second one exhibited 85-W output power and 65% drain efficiency over 50% bandwidth centered at 1.6 GHz.

5A-057 Assets of Source Pull for NVNA Based Load Pull Measurements

Abstract – This study deals with Vector Network Analyzer based source/load-pull measurements. While a lot of papers demonstrated the influence of harmonic load impedances on PAE performances and time domain RF waveforms shaping, the harmonic source-pull topic has been a little bit less addressed. When using a traditional power meter based source/load-pull bench, source pull measurements are mandatory. Indeed, for a fixed power level and a given set of load impedances, the source pull optimization highlights the conditions to match the transistor's input access. Nowadays, modern Vector Network Analyzer based source-load pull systems provide the direct measurements of the transistor input impedance. Thus, from the theoretical definition of any arbitrary source impedance, the mismatch calculus between input and source impedances is possible. It gives rise to a new kind of virtual source pull measurements. Some of us have called this method "magic source pull". This traditional source pull and Vector Network Analyzer based "magic source pull" will be provided.

5A-054 Software Simplifies Stability Analysis

Abstract – Stability analysis software helps to reveal any unwanted oscillations in an amplifier or other high-frequency design before committing the design to an expensive foundry run. Stability can be difficult to achieve in microwave circuits with gain (nonlinear behavior), such as amplifiers and oscillators. Amplifier designers, for example, have long dreaded the appearance of oscillations in a carefully considered circuit. When that circuit is in monolithic-microwave-integrated-circuit (MMIC) form, a "fix" requires another foundry run. But help in achieving microwave circuit stability has arrived, by way of the stability analysis (STAN) software developed by AMCAD Engineering and sold by Maury Microwave Corporation.

5A-052 Compact Transistor Models: The Road Map to First-Pass Amplifier Design Success

Abstract – Amplifier designers have been making use of modern transistor models since their first appearance in the mid-1970s. Models have allowed engineers to create advanced designs with first-pass success, without the need for multiple prototypes and design iterations. But with so many different modeling techniques, how does one select which one to use? The three most common types of models used in industry today are: physical models, compact models and behavioral models.

5A-051 Vector-Receiver Load Pull Measurement

Abstract – The following special report considers the improvements in large-signal device characterization brought on by a new class of vector receiver load pull systems compared to older scalar techniques using calibrated automated load pull tuners. Recent improvements to nonlinear device measurement systems have greatly enhanced load pull characterization, which in turn impacts RF board level circuit design, particularly power amplifiers using discrete transistors.

5A-050 Tracing The Evolution of Load-Pull Methods

Abstract – The evolution of load-pull tuning has led to hybrid and mixed-signal approaches that use the best features of mechanical and active tuners to speed measurements on nonlinear devices.

5A-043 Pulse-Bias Pulsed-RF Harmonic Load Pull for Gallium Nitride (GaN) and Wide Band-Gap (WBG) Devices

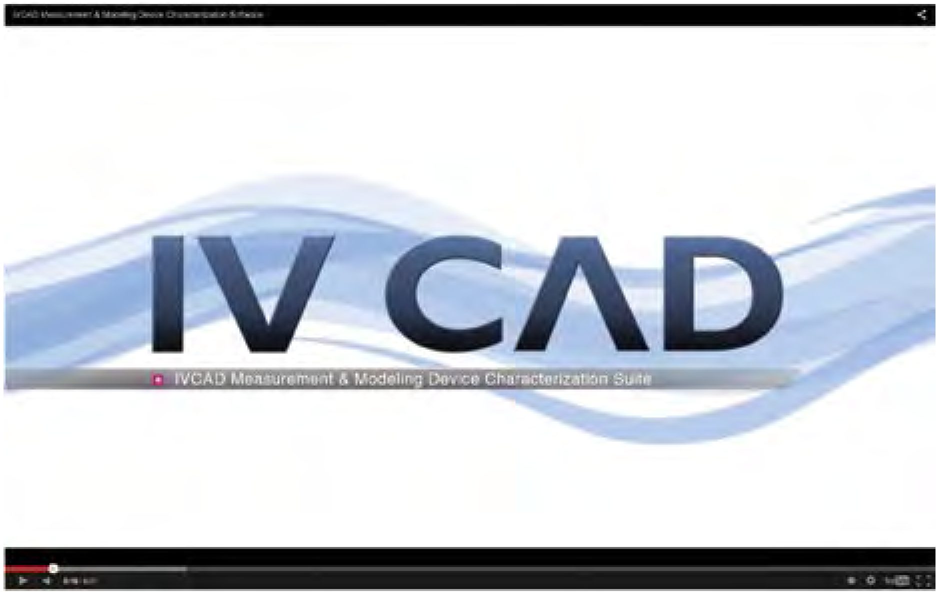
Abstract – For the first time ever, a commercially available pulse -bias pulsed-RF harmonic load pull system is being offered for high power and wide band-gap devices. Pulsing DC bias in conjunction with pulsing RF reduces slow (long-term) memory effects by minimizing self-heating and trapping, giving a more realistic observance of transistor operating conditions. IV, S-Parameter and Load Pull measurements taken under pulsed-bias pulsed-RF conditions give more accurate and meaningful results for high-power pulsed applications.

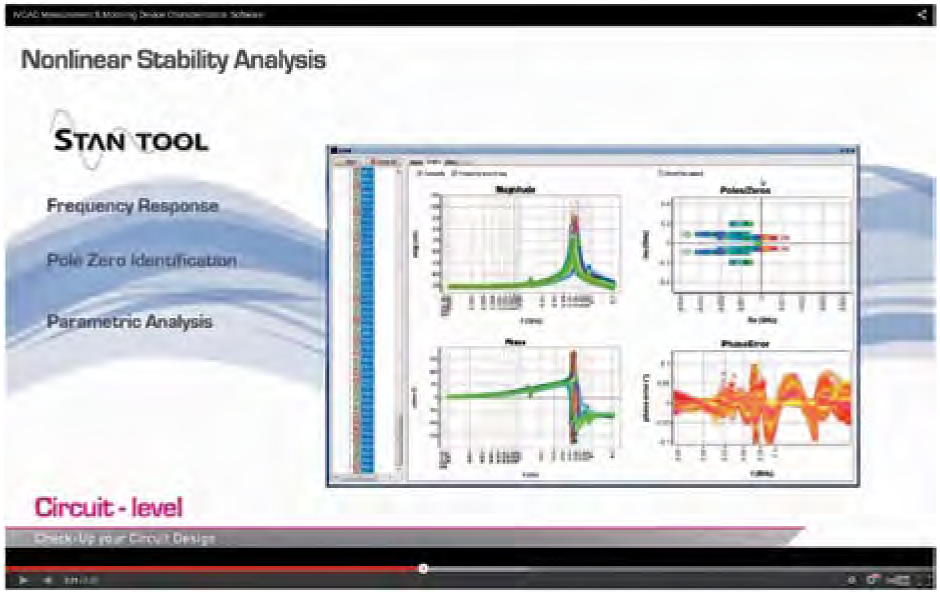
SEE THE IVCAD MEASUREMENT & MODELING DEVICE CHARACTERIZATION SOFTWARE SUITE IN ACTION!

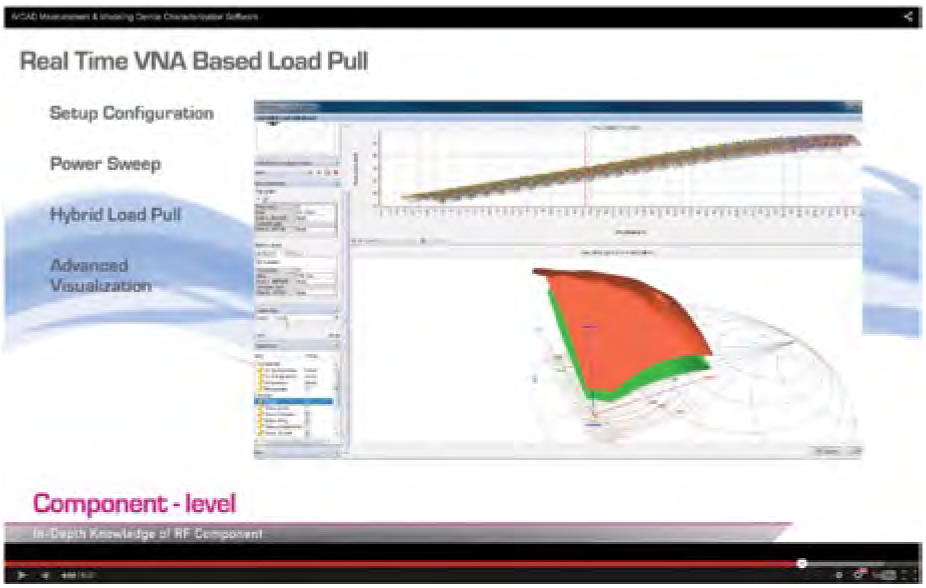
View the Video Online

Go To

youtube.com/MauryMicrowave







Vertigo MT920-Series MMW-STUDIO

MILLIMETER-WAVE AND SUB-THZ CHARACTERIZATION SOFTWARE

Introduction

MT920A MMW-STUDIO is a software suite designed to work with waveguide-banded millimeter-wave VNA systems 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 levels of power, and to perform S-parameter measurements at any arbitrary power level.

MMW-STUDIO enables:

- S-parameters measurements at user-specified power levels
- Fundamental powers (P_{in}, P_{av}, P_{load}), gain and efficiency measurements at 50Ω
- High-resolution power control for accurate and repeatable vector-corrected 50Ω gain compression power sweep measurements
- Calibrated measurements at DUT reference plane
- Support for most commercial waveguide extenders up to 1.1 THz
- Power, frequency and bias sweep

MT920B MMW-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 a_2 wave and fulfilling $\Gamma = a_2/b_2$.

MMW-STUDIO LP adds:

- Arbitrary impedance control / active load pull
- Measurements of fundamental powers (P_{in}, P_{av}, P_{load}) at arbitrary impedance

The system takes advantage of the frequency multiplication provided by millimeter wave extenders to extend active impedance tuning up to 1.1 THz.

MMW-STUDIO and MMW-STUDIO LP empower conventional waveguide banded millimeter-wave VNA systems to perform power measurements, large signal testing and active load-pull without using power meters[1], passive impedance tuners or additional test-sets, thereby taking advantage of the large dynamic range and high speeds of the VNA's receivers while maintaining a seamless setup configuration and user experience. These capabilities are critical for:

- Small/large signal model extraction of high frequency transistors up to f_T/f_{max}
- Small/large signal model validation of high frequency transistors up to f_T/f_{max}
- Prototype testing and optimization of (sub)THz active circuits
- Research and development, design validation test, and on-wafer production test

[1] A waveguide-flanged power meter is needed during calibration but is not employed for direct power measurement of the DUT.

Power control at millimeter-wave and sub-THz frequencies

Typical millimeter-wave S-parameter measurement systems use banded waveguide extenders to measure at the frequencies of interest, each having a fixed output power determined by the response of the up-conversion chain. Because of the nonlinearity of this response across frequency, the power at the output of the extender will vary as a function of frequency, with a flatness as high as 10 dB over the entire band. Some vendors will offer optional manual attenuators, but these are cumbersome to use and do not offer the high dynamic range required to fully characterize a DUT. In addition, the conventional power-control loop of the VNA is excluded from the measurement path which makes controlling the power complicated.

MMW-STUDIO employs a proprietary calibration procedure and algorithm to control the power delivered to the DUT at every frequency supported by the banded waveguide extender. The system block diagram, typical power flatness of a banded waveguide extender, and power control using MMW-STUDIO are shown in Figure 1.

The procedure is comprised of four steps, and is outlined in Figure 2:

1. S-parameter calibration at waveguide test-port. VNA S-parameter calibration using TRL or LRM methods
2. Power calibration

Using a waveguide-flanged power meter connected to one of the mm-wave extenders, the absolute power is measured across frequency and associated with the measurement of waves using the VNA's receivers. This procedure empowers the system to directly measure power using the VNA instead of a power meter.

3. Power levelling

The nonlinear power responses of the millimeter-wave extenders are characterized by sweeping the frequency at different input power levels (the control dynamic range) in order to cover the entire extender dynamic range (the detection dynamic range). This results in the creation of a look-up-table (LUT) which associates the power set by the VNA to the power available at the waveguide test-port at each frequency. This LUT is used to set any arbitrary power at the test-port, within the extender module's dynamic range.

4. Probe-tips/on-wafer calibration

The effect of wafer probes can be characterized using MMW-STUDIO's calibration GUI, or by using external software (such as WinCal XE). The measurement reference plane is then transferred from the waveguide extender to the probe-tip.

After the system is calibrated, MMW-STUDIO allows, in the entire frequency range of the employed waveguide-banded mm-wave extenders:

> S-parameters measurements with arbitrary power control at each frequency, defined at the DUT reference plane.

> Gain compression power sweep measurements over large dynamic ranges at the DUT reference plane.

> Measurements of fundamental powers (P_{in}, P_{av}, P_{load}), gain and efficiency at 50Ω

Figure 1:

a) Simplified schematic of a conventional mm-wave VNA setup based on waveguide banded module. When coupled with an external controlling computer and a power meter, MMW-STUDIO can be used to allow power control

b) Power available at the waveguide port of a commercially available WR5 VNA extender, without power control (asterisks) and with fixed -30 dBm power control using MMW-STUDIO (filled square)

a)

b)

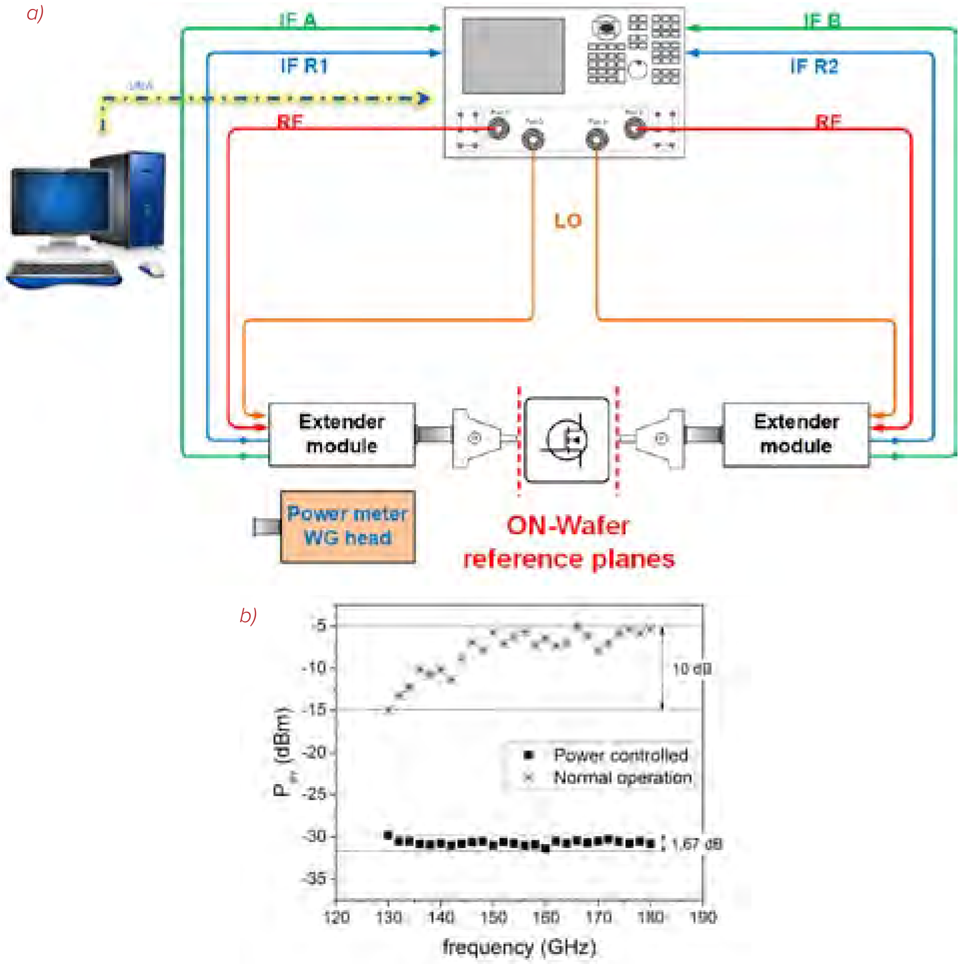
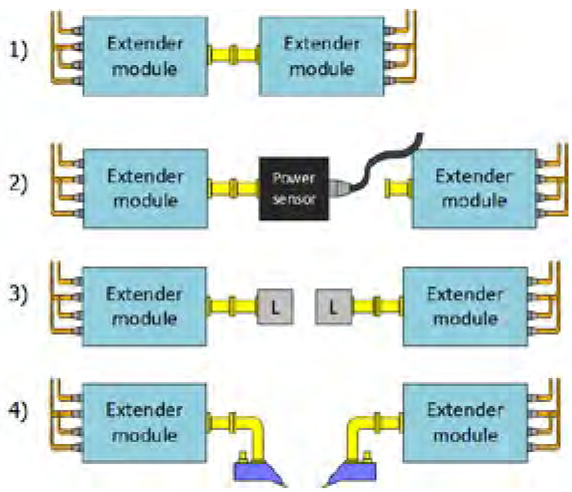


Figure 2:

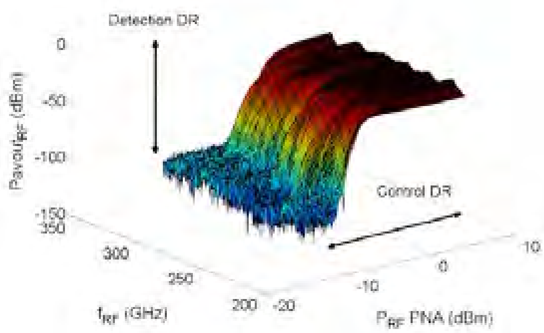
a) Calibration steps for MMW-STUDIO

b) LUT resulting of a power levelling using commercially available WR3 extender modules

a)



b)



Load pull at millimeter-wave and sub-THz frequencies

An introduction to load pull

Load Pull is the act of presenting a set of controlled impedances to a device under test (DUT) and measuring a set of parameters at each point. By varying the impedance, it is possible to fully characterize the performance of a DUT and use the data to:

- Verify simulation results of a transistor model (model validation).
- Gather characterization data for model extraction (behavioral model extraction).
- Design amplifier matching networks for optimum performance (amplifier design).
- Ensure a microwave circuit's ability to perform after being exposed to high mismatch conditions (ruggedness test).
- Confirm the stability or performance of a microwave circuit or consumer product under non-ideal VSWR conditions (stability/performance/ conformance/antenna test).

Figure 3a—Example of load pull measurements with Output Power (Pout) contours plotted on a Smith Chart.

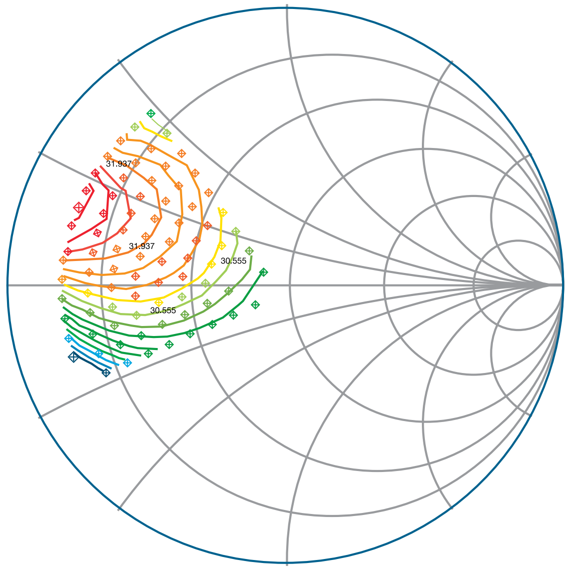


Figure 3b—Iso Pout Contours Measured @ 1.85 GHz

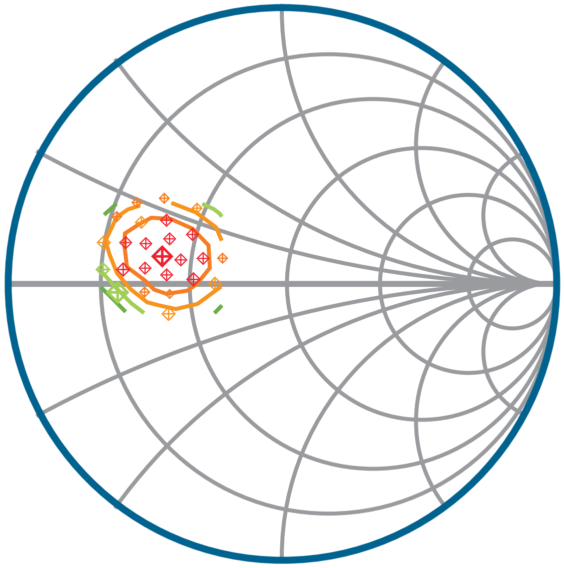
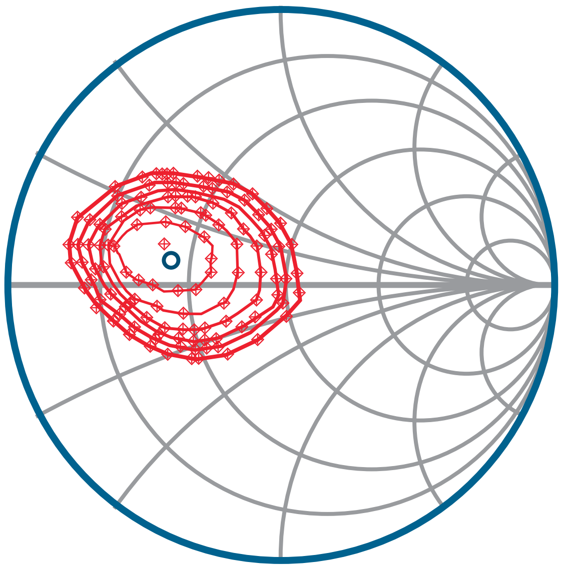


Figure 3c—Iso Pout Contours Simulated @ 1.85 GHz



Active load pull

In order to understand how the impedance presented to a DUT is varied, we must first consider the DUT as a two-port network shown in Figure 4.

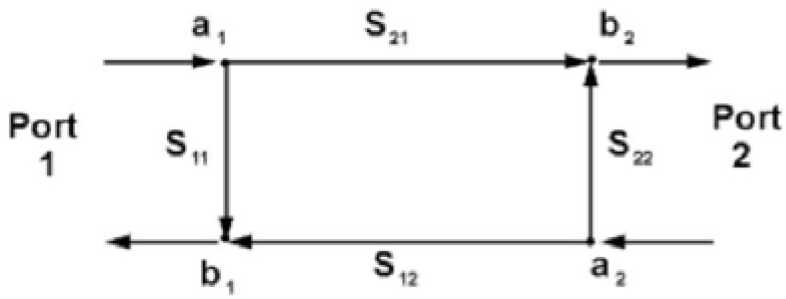


Figure 4: Two-port representation of a DUT

The two-port network consists of four waves, a_1, b_1, b_2 and a_2.

- a_1 is the input signal which is injected into port 1 of the DUT
- b_1 is the input signal which is reflected from the input of the DUT due to the mismatch between the DUT's input impedance and the load impedance of the input network
- b_2 is the signal which emerges from port 2 of the DUT
- a_2 is the output signal which is reflected from the output of the DUT due to the mismatch between the DUT's output impedance and the load impedance of the output network

The magnitude of reflection presented to the DUT is calculated as $\Gamma_L = \frac{a_2}{b_2}$. The magnitude and phase of the reflection presented to the load of the DUT can be varied by changing the magnitude and phase of the signal a_2. In other words, any load impedance $Z_L = \frac{Z_0(1-\Gamma_L)}{1+\Gamma_L}$ can be presented to the DUT as long as the signal a_2 can be achieved.

With regards to active load pull, the signal a_2 is a vector combination of the reflected portion of b_2 due to the mismatch between the DUT's output impedance and the load impedance of the output network, and a new signal created by a signal generator with magnitude and phase variability (referred to as an active tuning loop). An example block diagram of an active tuning loop is shown in Figure 5.

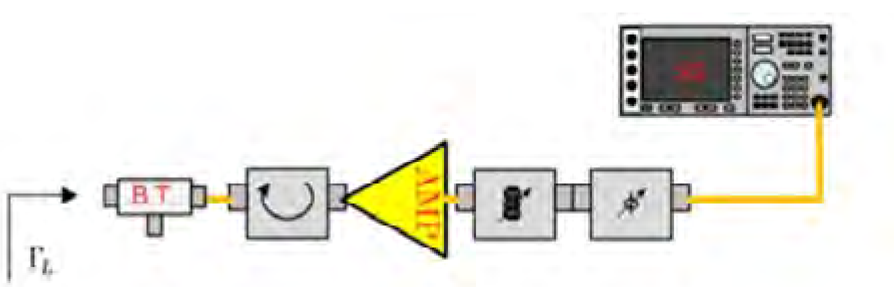


Figure 5: Output network of a simple active load-pull setup

In order to perform active load pull, it is necessary to have a vector-receiver capable of accurately measuring the a- and b-waves, as well as signal generator(s) capable of generating output tuning signals.

Millimeter-wave and sub-THz active load pull

The challenge with active load pull at millimeter-wave and sub-THz frequencies using waveguide extenders is solving how to adjust the magnitude and phase of the a_2 signal in order to obtain the desired Γ_L. MMW-STUDIO LP's methodology is to manipulate the magnitude and phase of the low-frequency signal going into the waveguide extender before the frequency multiplication occurs. This results in a change of the high-frequency signal's magnitude and phase, and when fully characterized, can be used to set an arbitrary a_2 wave and hence perform active load pull. The low-frequency signal is generated using the internal, low-phase-noise, synthesizer of the VNA. The magnitude and phase of the signal is manipulated using a vector modulator unit (VMU), which allows an arbitrary impedance to be set. Like lower frequency active load pull, the high dynamic-range receivers of the VNA are used to measure the a_1, b_1, a_2 and b_2 waves.

A simplified system block diagram of a millimeter-wave and sub-THz load pull system is shown in Figure 6. Compared with the typical 50Ω system shown in Figure 1, the main differences are as follows:

1. The RF signal for both P1 and P2 is obtained from a single shared VNA source
2. VMUs are placed between the VNA and the millimeter-wave extender modules
3. Control signals (CS1 and CS2) are used to tune the output signal of the VMU and are generated using an external digital-to-analog converter (DAC)

During active load pull, a single-tone signal is generated by the internal synthesizer of the VNA, at a frequency $f_{vna} = \frac{f_{meas}}{N}$,

where f_{meas} is the intended millimeter-wave measurement frequency, and N is the multiplication factor of the millimeter-wave extender module. Using CS1 (and the VMU) the power available at P1 is controlled and provided to the DUT. The response, b_2, of the DUT is measured at frequency fmeas using the receiver path of the extender module at P2 and the VNA receivers. The a_2 wave needed to synthesize a desired Γ_L is computed, and achieved using CS2, the VMU and iterative measurements. Finally, the a- and b-waves are measured at the DUT reference plane and used to compute all the quantities of interest (reflection coefficients, fundamental powers, gain and efficiency).

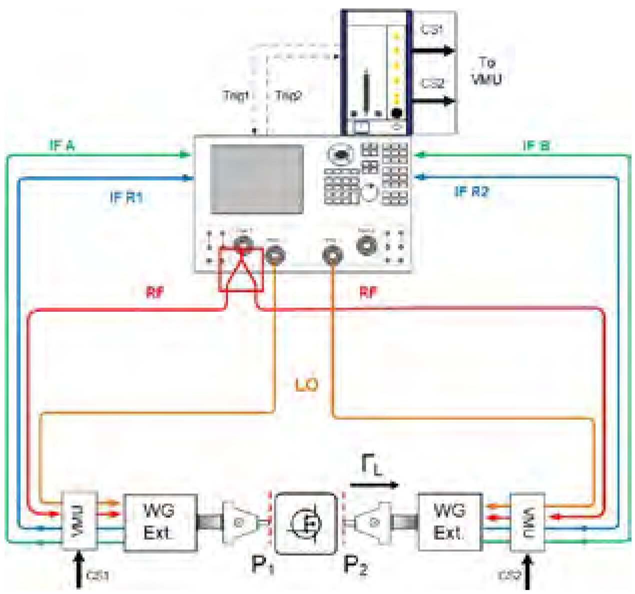


Figure 6: Simplified schematic of a load-pull architecture controllable with MMW-STUDIO LP

MT920A MMW-STUDIO – High resolution power control for S-parameters and gain compression power sweep measurements

MMW-STUDIO is the base module required for high resolution power control for S-parameters and gain compression power sweep measurements. It consists of the following capabilities:

> Instrument control[2] (VNA, power meter, bias control)

> Millimeter-wave VNA configuration (compatible with most commercial mm-wave extenders up to 1.1 THz)

> Full calibration routine

> Frequency, power and bias (up to two bias sources) sweeps

> Small-signal measurements (standard/power-controlled S-parameters)

> Large-signal measurements (P_{out}, P_{in}, P_{avs}, G_t, G_p, E_{ff}, PAE, V_{in}, V_{out}, I_{in}, I_{out}) at 50Ω

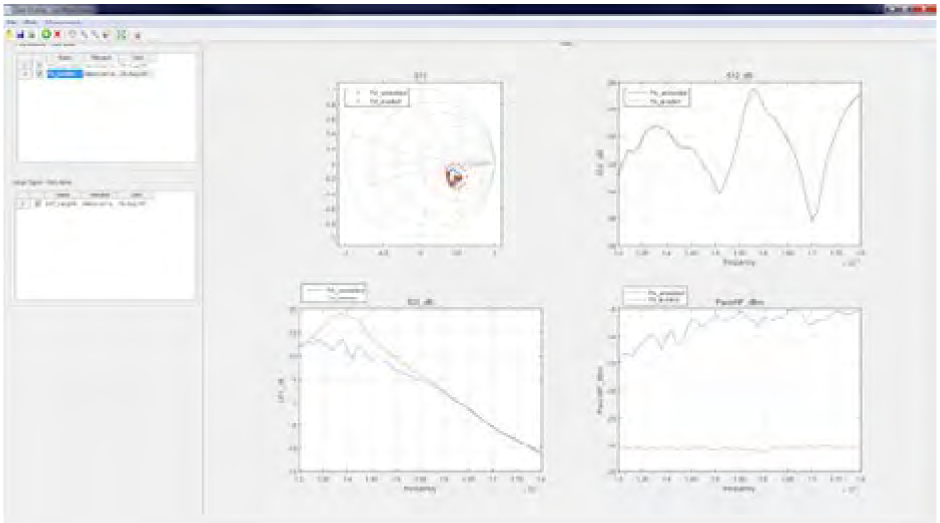


Figure 7: Measurements of S-parameters of a two-stage power amplifier in the frequency range between 130 GHz and 180 GHz, without power levelling (blue) and with power levelling (red).

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[2] Please see list of compatible devices

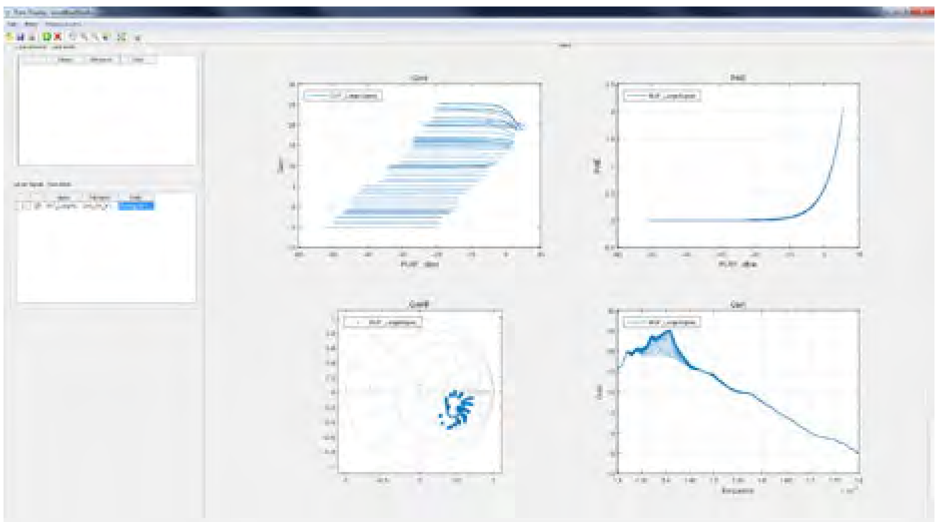

Figure 8: Large signal (power sweep) measurement of a two-stage power amplifier, at multiple frequencies (51 in the range 130 GHz to 180 GHz) for an input power range between -45 and -13 dBm

MT920B MMW-STUDIO LP – Active load pull at millimeter-wave and sub-THz frequencies add-on

MT920B MMW-STUDIO LP is an add-on option to MT920A MMW-STUDIO which enables active load-pull measurements. In addition to the capabilities of the base module MMW-STUDIO, MMW-STUDIO LP provides:

- Additional instrument control (VMU, DACs)
- Fundamental load impedance control
- Large-signal measurements (P_{out}, P_{in}, P_{avs}, G_t, G_p, E_{ff}, PAE, V_{in}, V_{out}, I_{in}, I_{out}) at any controlled load impedance

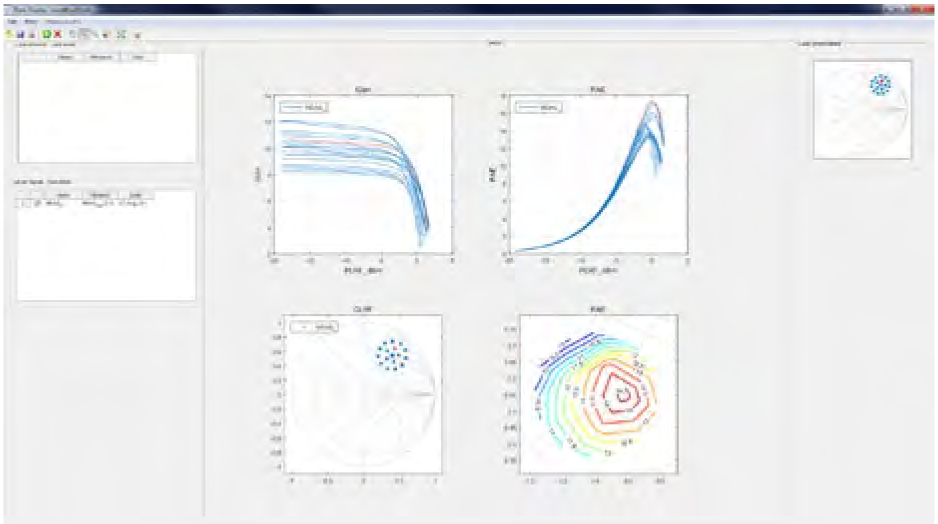

Figure 9: Data Display, showing results an active load-pull measurement of a SiGe 130nm HBT over 15 loading condition, at 75 GHz, for a set input power sweep from -30 to -2 dBm. In the plots: Power gain vs. power delivered to the load, PAE vs available power at the input, measured load impedances, PAE contour at P1dB.

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Note: a VMU is required to perform active load pull using MMW-STUDIO LP

MT920C MMW-STUDIO DD –Data display

MT920C MMW-STUDIO DD is the standalone version of the data display GUI and allows visualization and data analysis of measurements performed with MMW-STUDIO and MMW-STUDIO LP.

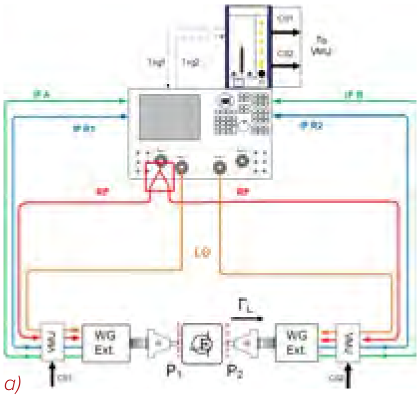
Hardware (VMU) models

A Vector Modulator Unit (VMU) is a required accessory for MMW-STUDIO LP in order to perform millimeter-wave and sub-THz active load pull.

VMU201802

VMU201802 are vector modulator units that are mounted on top of the waveguide extender modules. A single VMU201802 connects to a one waveguide extended module, and hence two VMUs are required per system.

	Min.	Typ.	Max.	Ext.
Pin	4 dBm	8 dBm	13 dBm	-
Pout	-	-	13 dBm	-
Frequency range	-	8 - 18 GHz	-	5 – 20 GHz
Vdc I,Q (abs)	0 V	-	1 V	-



a)

b)

Figure 10:

a) Basic schematic architecture of the MMW-STUDIO LP employing VMU201802.

b) Example of system implementation for load-pull measurements using MMW-STUDIO; 2x VMU201802 are mounted directly on WR10 OMLN5260-60003 extender.

a)

b)

Figure 11:

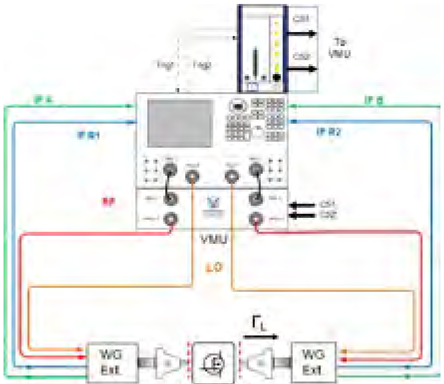
a) Example of VMU201802 casing (please notice, color and dimension may slightly change).

b) Mounting detail of a VMU201802 on an OML N5260-60003 extender.

VMU201901

VMU201901 are vector modulator units that are mounted in a standard 19” rack. A single VMU201901 connects to two waveguide extender modules, and hence only one VMU is required per system.

	Min.	Typ.	Max.	Ext.
Pin	9 dBm	13 dBm	17 dBm	-
Pout	-	-	10 dBm	-
Frequency range	-	8 - 18 GHz	-	5 – 20 GHz
Vdc I,Q (abs)	0 V	-	1 V	-



a)

b)

Figure 12:

a) Basic schematic architecture of the MMW-STUDIO LP employing VMU201901.

b) Example of system implementation for load-pull measurements using MMW-STUDIO LP and VMU201901. The VMU is now a single rack-mount box, fixed under the VNA. In this setup, VDI VNAX WR6.5 extenders are used.

Typical system performance

The performance of an millimeter-wave active load pull system (i.e. absolute power control, power handling, dynamic range, stability of power and impedance, etc.) is highly dependent on the specific millimeter-wave VNA system used and is influenced by both the VNA and the waveguide extender modules, and can vary from system to system.

The following table shows typical performance measured on commercially available VNAs and extender modules.

Frequency (GHz)	Stability of Amplitude σ(|Γ|)	Stability of Phase σ(∠(Γ)) (deg)
96	0.002	0.05
140	0.0035	0.33
180	0.0016	0.17
288	0.001	0.29
500	0.0046	0.57

Reported performances:

- Stability of $|\Gamma_L|$: reports the capability to reproduce a certain loading condition, and the variation on the absolute value, at a specific frequency, over 100 measurements, averaged over four different points on the Smith Chart. This value is reported as an absolute standard deviation (std).
- Stability of $\angle\Gamma_L$: reports the capability of reproduce a certain loading condition, and the variation on the phase (in degrees), at a specific frequency, over 100 measurements, averaged over four different points on the Smith Chart. This value is reported as an absolute standard deviation (std).

Supported instrumentation

VNA

- Keysight N5222A or N5222B (or higher frequency) PNA with options 401 and 080/S93080A/S93080B
- Keysight N5242A or N5244B (or higher frequency) PNA-X with options 400 and 080/S93080A/S93080B
- Rohde & Schwarz ZNA26 (or higher frequency) with 4-ports and options B16, K4 and K8

Power meters

- Keysight/Agilent/HP E4418/19A/B EPM Series Power meter
- Keysight N1913/14A EPM Series Power meter
- Erickson/VDI PM4 and PM5

DC sources/Parameter Analyzers

- Keysight/Agilent E5270B
- Keysight/Agilent HP4142B
- Keysight/Agilent 66xxA
- Keysight/Agilent 662xA
- Keysight/Agilent E364xA
- Keysight/Agilent E3631A
- Keysight/Agilent E5260
- Keysight/Agilent N57xx
- Keysight/Agilent B2900
- Keysight/Agilent/HP 4156C
- Keithley 2400 series

DACs

- NI PXIe-4463
- NI PXI-6733
- NI PXI-5422

Note: supported instrumentation is being continuously updated. Please contact us for a list of the latest instruments, or to request support for an unsupported instrument.

ATSv5 Automated Tuner System Software

MT993 SERIES

MT993B

Noise Characterization Application Software

General

The MT993B noise characterization application software is designed to operate with ATS tuners and determine the noise parameters of a linear device, module or sub-assembly. The program is provided as part of an ATS system specified for noise characterization separately as model MT993B.

Noise Parameters

Good noise performance is a critical element of most receiving systems. Knowledge of the noise parameters which define the noise performance of a device can be an invaluable aid to the receiver/ amplifier designer by saving hours of design time and reducing, or even eliminating, "cut-and-try" iterations.

An ATS system, operating with the Maury noise application software, can provide fast, accurate measurements of minimum noise figure, optimum source reflection coefficient, and equivalent noise resistance. The program will also provide the gain parameters of the device and has a built-in general purpose S-parameter measurement program. All measurements can be de-embedded to the device input and output planes. The software provides for both data and graphical hard copy outputs.

Interactive Measurement Mode

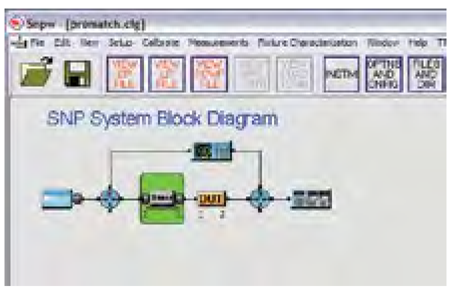
This is a single frequency display that permits the user to: a) measure the device noise parameters; b) measure noise figure and gain at any available source impedance; c) select the noise parameter measurement method; and d) select the impedances used in the noise parameter determination or let the software determine these automatically. Constant noise figure and gain circles can also be plotted on the source impedance Smith Chart. An advanced sweep plan is available to define fully-automated, multi-frequency, multi-bias noise characterization projects.

Swept Noise Display

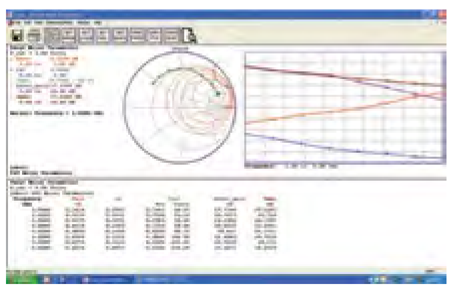
The measured parameters can be simultaneously displayed versus frequency and bias. A mouse or cursor key controlled marker provides for readouts at measured or interpolated points. Data smoothing (1st or 2nd order) is available, and graphics scales are user-controlled. Noise parameters as well as maximum gain, associated gain and stability factor (k) are tabulated and available for printout below the plots.

Noise Statistics Display

This is a statistics window screen which shows agreement between the noise parameter solution and individual points. The noise parameter solution is also displayed so the effect of changing options can be immediately seen. This display may be toggled between calibration and DUT measurement data so the effect of calibration options can be seen on the measured DUT data.



Typical setup for performing noise characterization measurements.



Typical swept noise display.

MT993B01

High-Speed Noise Parameter Measurement Option

General

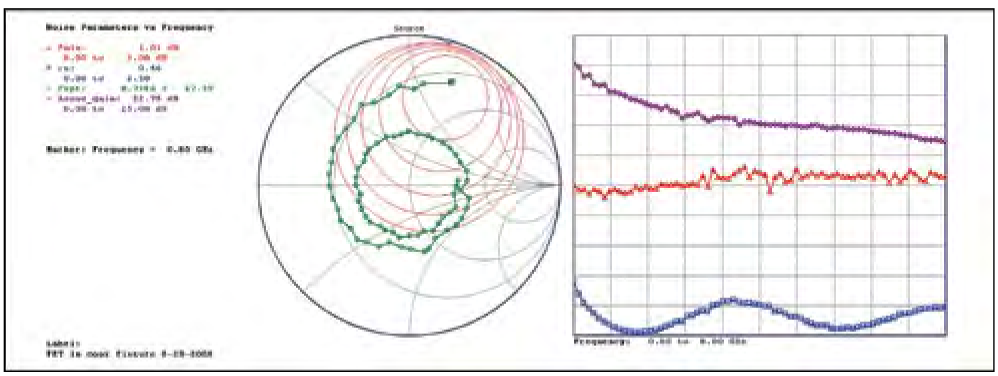
The MT993B01 high-speed noise parameter measurement option (patent pending) operates with the MT993B noise characterization application software and Keysight's PNA-X to take advantage of the built-in noise receiver and fast sweep capability of the analyzer. This typically speeds up the calibration and measurement time by 200X – 400X; making it practical to sweep a much larger frequency set. Typical test bench setups are simplified (as shown in the photograph below), which reduces the number of cables and connections, thus helping to stabilize the setup. This setup produces data that is smoother and has less scatter than traditional methods of noise measurement. The fast measurement speed eliminates temperature drift, and using a VNA with an internal noise receiver simplifies the setup and makes it much more stable and consistent.

Benefits and Features

The MT993B01 option includes two key features that contribute to the breakthrough speed improvement: 1) The ATS tuner is characterized with one set of states (physical tuner positions) that are selected to give a reasonable impedance spread over the frequency band of interest; and 2) the noise power measurement is swept over the frequency range at each state, so that the tuner only moves to each position once; thereby minimizing tuner movement.

The much higher speed makes it practical to always do a full in-situ calibration to minimize errors, and to measure more frequencies to get a better view of scatter and cyclical errors, and to be able to use smoothing with more confidence. The higher frequency density also enhances accuracy by reducing shifts due to aliasing.

Typical setup for performing high-speed noise parameter measurements.



Measured noise parameter data using MT993B01 (no smoothing).

Optional Software Features

Programmers Addition (MT993E)

MT993E is an option which allows external control of ATS software through a programming interface called SNP DLL. MT993E is useful for users that want to control ATS from a third party application such as C++, C#, LabVIEW or MATLAB.

System Control Option (MT993F)

MT993F is an option that extends the capability of MT993B to provide automated switching between S-parameters and Noise Parameters from a single setup.

MT993F is required when using switches for Noise Parameter measurements. Switches can be external, integrated into NSM/NRM, or integrated inside the measurement instrument (i.e. Keysight Technologies PNA-X).

DC I-V Curve Option (MT993G)

MT993G is an option that extends the capability of MT993B to provide for automatic measurement and display of device DC current-voltage curves. For FET devices, the measurement display is a family of output current versus output voltage curves with input voltage as the parameter. For bipolar devices, the measured display is a family of output current versus output voltage curves with input current as the parameter. A maximum dissipation value can be entered which will cause each sweep to terminate when that condition is reached.

Fixture Characterization Option (MT993J)

MT993J is a standalone option that enables the S-Parameters of a test fixture or probe setup to be determined from two network analyzer calibrations. First, a 2-port calibration at the coaxial cable reference plane (or similar) is performed; second, a 2-port calibration at the DUT reference plane is performed. The resulting calibrations are mathematically compared and two separate S-Parameter files, each one representing a fixture half, are generated.

Automated Tuners

GENERAL INFORMATION

What is load pull?

Load Pull is the act of presenting a set of controlled impedances to a device under test (DUT) and measuring a set of parameters at each point. By varying the impedance, it is possible to fully characterize the performance of a DUT and use the data to:

> Verify simulation results of a transistor model (model validation)

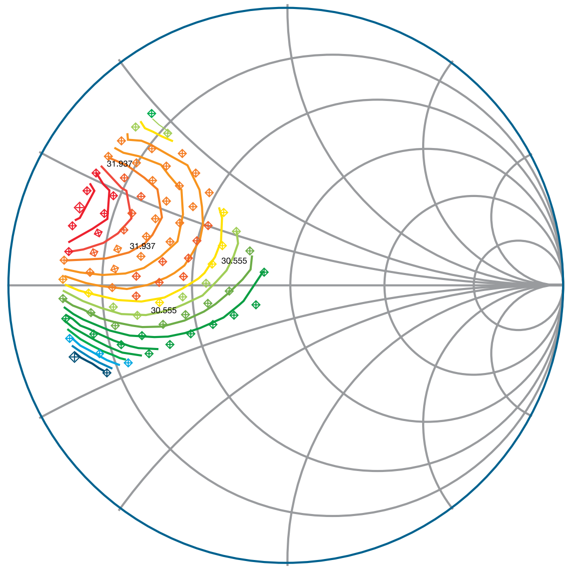
> Gather characterization data for model extraction (behavioral model extraction)

> Design amplifier matching networks for optimum performance (amplifier design)

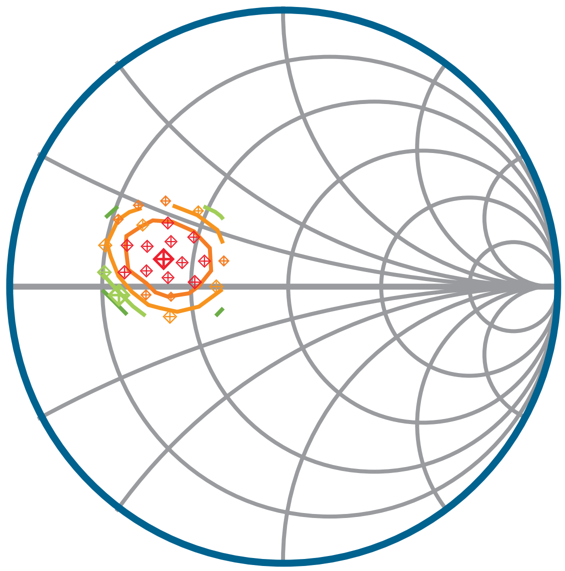
> Ensure a microwave circuit's ability to perform after being exposed to high mismatch conditions (ruggedness test)

> Confirm the stability or performance of a microwave circuit or consumer product under non-ideal VSWR conditions (stability/performance/conformance/antenna test)

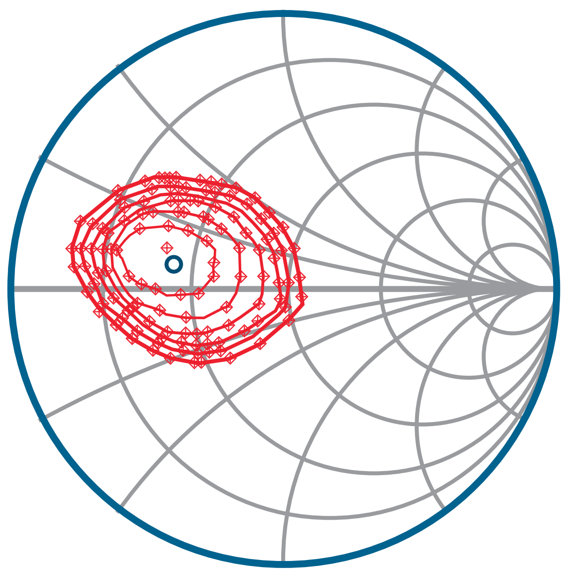
Example of load pull measurements with Output Power (Pout) contours plotted on a Smith Chart.



Iso Pout Contours Measured @ 1.85 GHz

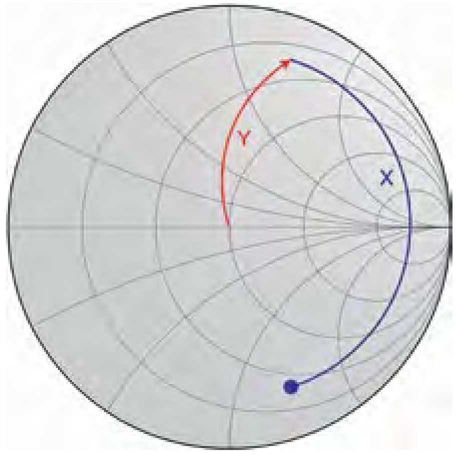


Iso Pout Contours Simulated @ 1.85 GHz

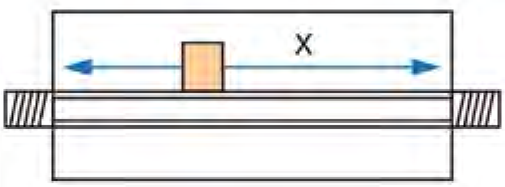


Slide-Screw Impedance Tuner

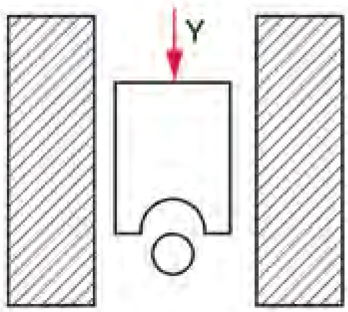
One tool available to vary the impedances presented to a DUT is the slide-screw impedance tuner. The slide-screw tuner is based on a 50Ω slabline and a reflective probe, sometimes referred to as a slug. Ideally, when the probe is fully retracted, the tuner presents a near-50Ω impedance represented by the center of a normalized Smith Chart. As the probe is lowered into the slabline (Y-direction) it interrupts the electric field that exists between the center conductor and walls of the slabline, reflects some of the energy back towards the DUT, creates a capacitance and increases the magnitude of reflection (represented by the red curve on the Smith Chart at right). As the probe travels along the slabline (X-direction), the distance between the probe and the DUT is altered, thereby rotating the phase of the reflection (represented by the blue curve on the Smith Chart). It is therefore possible to recreate nearly any arbitrary impedance without the need of discrete components (lumped elements or transmission lines).



Simplified representation of a slide-screw tuner.

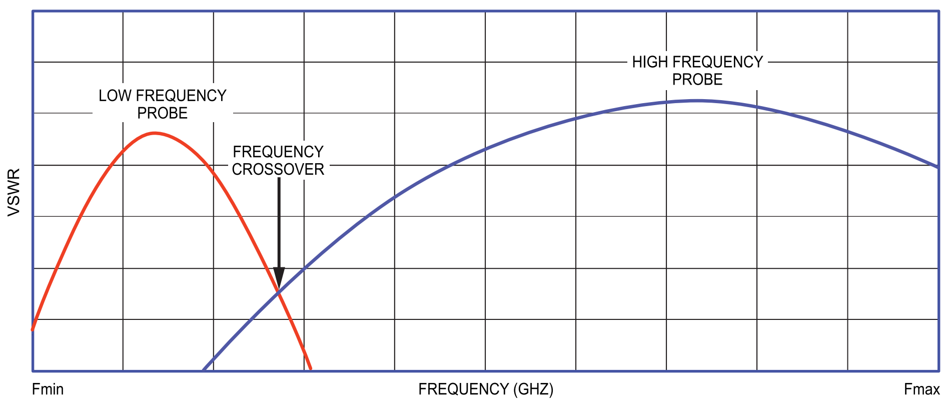


(Side View)



(End View)

The probes used in slide-screw tuners are wideband in nature, and have similar reflective properties over a wide range of frequencies. In order to increase the overall useful bandwidth of the tuner, two probes of varying dimensions are independently used within a tuner; one for low frequencies and one for high frequencies. In this manner, it is common for slide-screw tuners to achieve an overall frequency range of several octaves to over a decade.



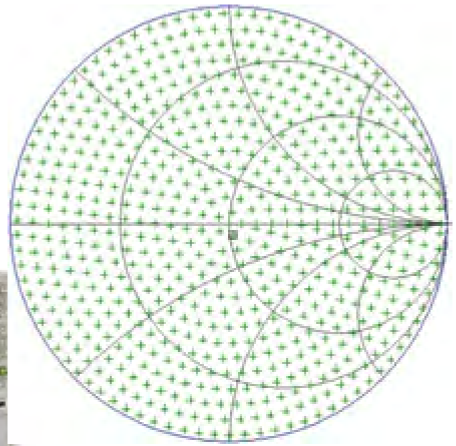
VSWR versus Frequency of a two-probe slide-screw tuner.

Pre-Calibration (Pre-Characterization)

Slide-screw tuners are available in both manual and automated varieties. While they both work on the same slabline and capacitive probe technique, automated tuners have the ability to be pre-calibrated. Pre-calibration involves recording the s-parameters of each probe at varying X and Y positions for the frequencies of interest using a calibrated vector network analyzer. In general, X and Y positions are selected such that an even distribution of impedances are recorded over the Smith Chart. Once the calibration data is stored in a lookup table, the VNA is no longer required to use the tuner; the tuner 'knows' how to present impedances accurately without VNA verification.

Tuner Repeatability

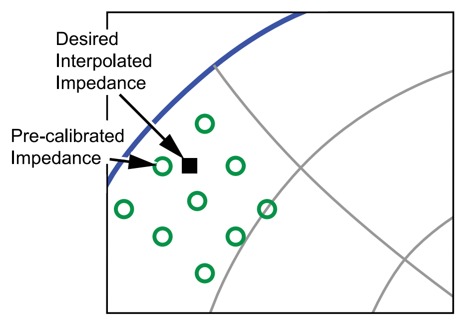
Tuner repeatability is defined as the vector difference between the pre-calibrated s-parameter data and subsequent s-parameter measurements after movement, when returning the probe to a given X and Y position. Since the impedances presented to the DUT are reliant on the tuner's ability to accurately return to pre-calibrated states, repeatability is a critical tuner characteristic that affects the reliability of measurement data. In order to guarantee a high level of repeatability, precision mechanics and motors within the tuner are used to return the probe to its pre-calibrated positions with s-parameter vector differences of –40 to –50dB or better (see specific tuner model pages 236-242 for typical repeatability graphs).



Tuning Accuracy and Interpolation

During pre-calibration, the tuner's s-parameters are recorded at a user-definable number (normally between 300-3000) of X and Y positions giving an even distribution over the Smith Chart. However, an arbitrary load impedance that falls between pre-calibrated states might be required. To achieve a high level of accuracy, a two-dimensional algorithm is used to interpolate between the closest pre-calibrated impedances in order to determine the new physical X and Y positions of the desired interpolated impedance. Interpolation increases the number of tunable impedances well beyond the initial pre-calibration range.

Given a sufficiently dense pre-calibration look-up table, a tuner's repeatability (ability to return to pre-calibrated states) and accuracy (ability to interpolate between pre-calibrated states) offer similar performances.



Patented Embedded Tuner Controller

(U.S. Patent No. 8,823,392)

All Maury slide-screw automated impedance tuners are equipped with a patented embedded controller (U.S. Patent No. 8,823,392) with onboard microprocessor and memory. After pre-calibration, the lookup table is copied onto the tuner's embedded flash memory storage, as are any s-parameter files of passive components that will be used with the tuner (adapters, cables, fixtures, probes, attenuators...). The tuner's onboard microprocessor will use the lookup table and component s-parameter blocks to calculate the probe positions required to present an arbitrary load impedance taking into account (de-embedding) all adapter/fixture losses between the tuner and DUT, and all back-side losses between the tuner and the measurement instrument, as well as possible non-50Ω terminations.

An integrated web interface allows for easy point-and-click tuning. tuner control settings including IP address and firmware upgrade.

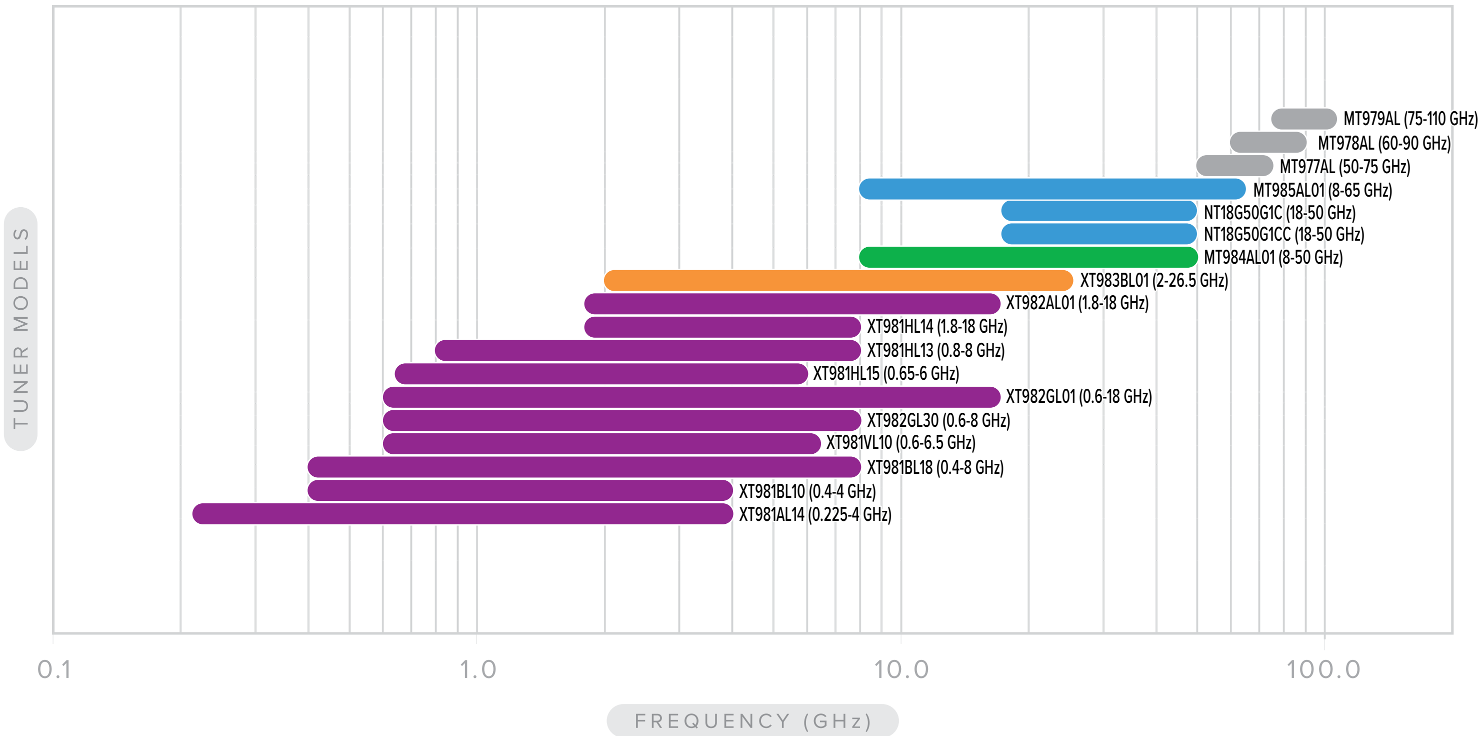
Direct ASCII commands can be sent through raw TCP/IP interface over Ethernet or USB and used with any socket programming language or through any Telnet client program in any operating system. Commands include direct impedance tuning, reference-plane shifting, VSWR testing and more.

Parameter	Value
Manufacturer	Maury Microwave Corporation
Instrument Model	MT982-EL30
Serial Number	5270
Firmware Revision	3.4-1.24
Description	Maury MT982-EL30 - 5270
LXI Extended Features	LXI Core Functions
LXI Version	1.4
mDNS-Hostname	169.254.6.77, MT982-EL30-5270.local
IP Address	169.254.6.77
MAC Address	fc:6c:31:00:00:e6
Device Address	TCPIP0::169.254.6.77::5025::SOCKET
Telnet Address	telnet://169.254.6.77:5024

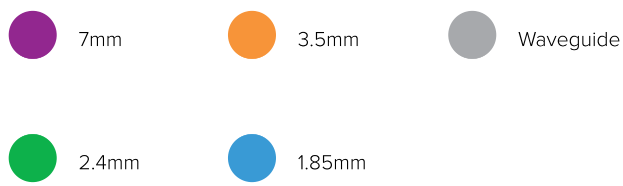
Parameter	Currently in use
VXI-11 Discovery	On
mDNS Discovery	On
DHCP	On
Auto-IP	On
Network-Hostname	MT982-EL30-5270.local
IP Address	169.254.6.77
Netmask	255.0.0.0
Gateway	0.0.0.0
Dynamic DNS Updates	On
Manual DNS	Off
Domain	Belkin
Primary DNS	10.10.1.17
Secondary DNS	10.10.1.19
Description	Maury MT982-EL30 - 5270
Web Password	hidden

Edit Configuration

Tuners Frequency Graph



Proposed IEEE P287
High Frequency
Connector Color Code



High-Gamma™ & High-Power Automated Tuners

225 MHZ TO 8 GHZ

Products covered by one or more of the following patents 9,209,786 / 8,823,392 / 7,589,601 B2

Specifications

Frequency Range -- See Available Models Table
VSWR Matching Range -- See Available Models Table
Step Size (Probes) -- 7.8 microinches[1]
Step Size (Carriage) -- 234.4 microinches[1]
Connectors: -- Precision 7mm[2]

Accessories Provided

Each XT981( )L series tuner is provided with one (1) MT1020F power supply, one (1) USB cable, one (1) Ethernet cable, one (1) USB to Ethernet adapter, and one (1) operating manual.

Recommended Accessories

2698C2 Torque Wrench

A028D 7mm Connector Gage Kit

8022S1/8022T1 Precision 7mm/3.5mm (Female & Male) Adapters

Available Models

Model	Frequency Range (GHz)	Matching Range		Power Capability [4]	Vector Repeatability (Minimum)	Insertion Loss (Probes Fully Retracted)	Mating Surface Dimensions
		Minimum	Typical [3]				
XT981HL13	0.80 – 6.5	100:1	200:1	250 W CW 2.5 kW PEP	–40 dB	0.3 dB	18.51" [47.02 cm]
	6.5 – 8.0	60:1	100:1				
XT981HL14	1.8 – 8.0	100:1	200:1				12.5" [31.75 cm]
XT981HL15	0.65 – 6.0						24.51" [62.26 cm]
XT981AL14	0.225 – 4.0	15:1	25:1		–50 dB		37.01" [94.01 cm]
XT981BL10	0.40 – 4.0						24.51" [62.26 cm]
XT981BL18	0.40 – 8.0	10:1			–40 dB		
XT981VL10	0.60 – 5.5	40:1	50:1		–50 dB		18.51" [47.02 cm]
	5.5 – 6.5	25:1					

[1] Based on microstepping (1/16) the drive motors.
[2] Precision 7mm per Maury data sheet 5E-060.
[3] Defined as the minimum VSWR over 70% of the frequency range.
[4] Power rated at maximum VSWR.

7mm Automated Tuners

0.6 TO 18 GHZ

Products covered by one or more of the following patents 9,209,786 / 8,823,392 / 7,589,601 B2

Specifications

Frequency Range -- See Available Models Table
VSWR Matching Range -- See Available Models Table
Step Size (Probes) -- 7.8 microinches[1]
Step Size (Carriage) -- 62.5 microinches[1]
Connectors -- Precision 7mm[2]

Accessories Provided

Each tuner is provided with one (1) MT1020F power supply, one (1) USB cable, one (1) Ethernet cable, one (1) USB to Ethernet adapter, and one (1) operating manual.

Recommended Accessories

2698C2 Torque Wrench

A028D 7mm Connector Gage Kit

8022S1/8022T1 Precision 7mm/3.5mm (Female & Male) Adapters

Available Models

<table>
<tr><th rowspan="2">Model</th><th rowspan="2">Frequency Range (GHz)</th><th colspan="2">Matching Range</th><th rowspan="2">Power Capability [4]</th><th rowspan="2">Vector Repeatability (Minimum)</th><th rowspan="2">Insertion Loss (Probes Fully Retracted)</th><th rowspan="2">Mating Surface Dimensions</th></tr>
<tr><th>Minimum</th><th>Typical [3]</th></tr>
<tr><td>XT982GL01</td><td>0.6 – 18.0</td><td>10:1</td><td>18:1</td><td rowspan="4">50 W CW
0.5 kW PEP</td><td rowspan="4">–40 dB</td><td rowspan="3">0.5 dB</td><td rowspan="3">17.92"
[45.52 cm]</td></tr>
<tr><td rowspan="2">XT982GL30</td><td>0.6 – 2.0</td><td>30:1</td><td>40:1</td></tr>
<tr><td>2.0 – 8.0</td><td>15:1</td><td>20:1</td></tr>
<tr><td>XT982AL02</td><td>1.8 –18.0</td><td>15:1</td><td>20:1</td><td>0.4 dB</td><td>10.92"
[27.74 cm]</td></tr>
</table>

[1] Based on microstepping (1/16) the drive motors.
[2] Precision 7mm per Maury data sheet 5E-060.

[3] Defined as the minimum VSWR within 70% of the frequency range.

[4] Power rated at maximum VSWR.

3.5mm Automated Tuners

2 TO 26.5 GHZ

Products covered by one or more of the following patents 9,209,786 / 8,823,392 / 7,589,601 B2

Specifications

Frequency Range -- 2-26.5 GHz
VSWR Matching Range -- 10:1
Step Size (Probes) -- 7.8 microinches[1]
Step Size (Carriage) -- 62.5 microinches[1]
Connectors -- Precision 3.5mm, male/female[2]

Accessories Provided

Each tuner is provided with one (1) MT1020F power supply, one (1) USB cable, one (1) Ethernet cable, one (1) USB to Ethernet adapter, and one (1) operating manual.

Recommended Accessories

8799A1 Torque Wrench

A050A 2.92mm/3.5mm Digital Connector Gage Kit

Available Models

Model	Frequency Range (GHz)	Matching Range		Power Capability [4]	Vector Repeatability (Minimum)	Insertion Loss (Probes Fully Retracted)	Connector Type	Mating Surface Dimensions
		Minimum	Typical [3]					
XT983BL01	2.0 – 26.5	10:1	15:1	25 W CW 250 W PEP	–40 dB	0.6 dB	3.5mm (male/female)	10.13" [25.73 cm]

[1] Based on microstepping (1/16) the drive motors.
[2] Precision 3.5mm per Maury data sheet 5E-062.
[3] Defined as the minimum VSWR over 70% of the frequency range.
[4] Power rated at maximum VSWR.

Nano Automated Tuners

18 TO 50 GHZ

Products covered by one or more of the following patents 9,209,786 / 8,823,392 / 7,589,601 B2

Specifications

Frequency Range -- 18.0 to 50.0 GHz
VSWR Matching Range
  Minimum -- 10:1
  Typical -- 40:1 @ 28 GHz, 39 GHz
Step Size (Probes) -- 3.94 microinches
Step Size (Carriage) -- 3.94 microinches
Connectors -- Precision 1.85mm, M/F [1]

Accessories Provided

Each tuner is provided with one (1) MT1020F power supply, one (1) USB cable, one (1) Ethernet cable, one (1) USB to Ethernet adapter, and one (1) operating manual.

Available Models

Model	Frequency Range (GHZ)		Integrated coupler[1]	Matching Range		Power capability (W)	Vector repeatability (dB)	IL (dB)	Connector type	Weight (lbs)	Length (in)
	Tuner	Impedance control		Minimum	Typical						
NT-18G-50G-1C	DC - 65	18-50	no	10:1	40:1 @ 28, 39 GHz	10 CW, 100W PEP	-40	0.5	1.85mm	0.7	2.35"
NT-18G-50G-1C-C			yes								3.35"

[1] 40 dB coupling factor

2.4mm & 1.85mm Automated Tuners

8 TO 65 GHZ

Products covered by one or more of the following patents 9,209,786 / 8,823,392 / 7,589,601 B2

Specifications

Frequency Range -- See Available Models Table
VSWR Matching Range -- 10:1
Step Size (Probes) -- 31 microinches[1]
Step Size (Carriage) -- 50 microinches[1]
Connectors -- See Available Models Table

Accessories Provided

Each tuner is provided with one (1) MT1020F power supply, one (1) USB cable, one (1) Ethernet cable, one (1) USB to Ethernet adapter, and one (1) operating manual.

Recommended Accessories

8799A1 Torque Wrench

A048A 2.4mm/1.85mm Digital Connector Gage Kit

Available Models

Model	Frequency Range (GHz)	Matching Range		Power Capability [3]	Vector Repeatability (Minimum)	Insertion Loss (Probes Fully Retracted)	Connector Type	Mating Surface Dimensions
		Minimum	Typical [2]					
MT984AL01	8.0 – 50.0	10:1	20:1	10 W CW 100 W PEP	–40 dB	0.60 dB	2.4mm (male/female)	5.47" [13.88 cm]
MT985AL01	8.0 – 65.0					1.15 dB	1.85mm (male/female)	

[1] Based on 1/2 stepping the drive motors.

[2] Defined as the minimum VSWR within 70% of the frequency range.

[3] Power rated at maximum VSWR.

Millimeter-Wave Automated Tuners

50 TO 110 GHZ

MT977AL
Automated Tuner
U.S. Patent No. 5,910,754
International Patents Pending

Specifications

Frequency Range -- See Available Models Table
VSWR Matching Range -- See Available Models Table
Step Size (Probes) -- 0.5 microinches[1]
Step Size (Carriage) -- 0.5 microinches[1]
Flanges -- MPF15 (WR15), MPF12 (WR12) and MPF10 (WR10)[2]

Accessories Provided

Each tuner is provided with one (1) MT1020F power supply, one (1) USB cable, one (1) Ethernet cable, one (1) USB to Ethernet adapter, one (1) MT979C12 tuner control cable, and one (1) operating manual.

Available Models

Model	Frequency Range (GHz)	Matching Range		Power Capability[4]	Vector Repeatability (Minimum)	Insertion Loss[5] (Maximum)	Dissipative Loss[6] (Maximum)
		Minimum	Typical[3]				
MT977AL	50.0 — 75.0					0.35 dB	
MT978AL	60.0 — 90.0	20:1	30:1	20 W CW 200 W PEP	-40.0 dB	0.5 dB	7.0 dB
MT979AL	75.0 — 110.0					0.6 dB	

[1] Based on 1/2 stepping the drive motors.
[2] Maury Precision Flanges (MPF) equivalent to IEEE WR sizes.
[3] Defined as the maximum VSWR within 20% of the peak VSWR.
[4] Power rated at maximum VSWR.
[5] With probes fully retracted.
[6] At maximum VSWR.

3.5mm & 7mm Multi-Harmonic Automated Tuners

0.6 TO 26.5 GHZ

XT982ML01
Automated Tuner
U.S. Patent No. 8,823,392
International Patents Pending

Specifications

Frequency Range -- See Available Models Table
VSWR Matching Range -- See Available Models Table
Step Size (Probes) -- See footnote[1]
Step Size (Carriage) -- See footnote[2]
Connectors: -- See Available Models Table

Accessories Provided

Each tuner is provided with one (1) MT1020F power supply, one (1) USB cable, one (1) Ethernet cable, one (1) USB to Ethernet adapter, and one (1) operating manual.

Recommended Accessories

8799A1 or 2698C2 Torque Wrench

A028D 7mm Connector Gage Kit

A050A 2.92mm/3.5mm Digital Connector Gage Kit

Available Models

<table>
<tr><th rowspan="3">Model</th><th rowspan="3">Frequency Range (GHz) [3]</th><th colspan="6">Matching Range</th><th rowspan="3">Power Capability [4]</th><th rowspan="3">Vector Repeatability (Min)</th><th rowspan="3">Insertion Loss [5] (Max)</th><th rowspan="3">Connectors [6]</th></tr>
<tr><th colspan="2">Single Frequency Tuning (Minimum)</th><th colspan="2">Two Frequency Tuning</th><th colspan="2">Three Frequency Tuning</th></tr>
<tr><th>Fmin</th><th>Fmax</th><th>Fmin</th><th>Fmax</th><th>Fmin</th><th>Fmax</th></tr>
<tr><td>XT981ML01</td><td>0.65 – 8.0</td><td rowspan="4">100:1</td><td rowspan="4">40:1</td><td rowspan="4">10:1–100:1</td><td rowspan="4">10:1–100:1</td><td colspan="2" rowspan="2">N/A</td><td>250 W CW
2.5 kW PEP</td><td>–50 dB</td><td>0.3 dB</td><td rowspan="3">7mm</td></tr>
<tr><td>XT982ML01</td><td>0.6 – 18.0</td><td rowspan="2">50 W CW
0.5 kW PEP</td><td rowspan="3">–40 dB</td><td>0.6 dB</td></tr>
<tr><td>XT982ML03</td><td>0.8 – 18.0</td><td>10:1–100:1</td><td>10:1–100:1</td><td>1.0 dB</td></tr>
<tr><td>XT983ML01</td><td>2.0 – 26.5</td><td colspan="2">N/A</td><td>25 W CW
250 W PEP</td><td>0.8 dB</td><td>3.5mm
(male/female)</td></tr>
</table>

[1] Based on microstepping (1/16) the drive motors
XT981ML01 -- 7.8 microinches
XT982ML01 -- 7.8 microinches
XT983ML01 -- 7.8 microinches

[2] Based on microstepping (1/16) the drive motors
XT981ML01 -- 234.4 microinches
XT982ML01 -- 62.5 microinches
XT983ML01 -- 62.5 microinches

[3] Including fundamental and harmonic frequencies.
[4] Power rated at maximum VSWR.
[5] With probes fully retracted.
[6] Precision 7mm per Maury data sheet 5E-060; Precision 3.5mm per Maury data sheet 5E-062.

Wide Matching Range Slide Screw Tuners

SERIES MST981, MST982, MST983 & MST984

MST982E35

Features

- Slab-line Transmission Structure
- Dual Probes for Improved Matching Characteristics
- LCD Readout for Carriage Position

General Information

Maury manual tuners are based on precision slide screw technology that utilizes broadband slab line transmission structure and passive probes to create impedances for devices. The probes are designed to be very close to one-quarter wavelength in the linear dimension at the mid-band of each range. Since each tuner has two probes, this results in improved matching characteristics for each unit. Another key feature of this series of tuners is the inclusion of a LCD position readout of the carriage position on those units operating below 18 GHz. Higher frequency tuners utilize a micrometer carriage drive.

The positional repeatability and high matching range of these tuners make them ideally suited for use as a variable impedance source in applications like device characterization. Such measurements depend upon the ability of the tuner to establish impedances out near the edge of the Smith Chart and to reproduce the electrical characteristics as a function of mechanical position. The tuners in this series are also easy to use due to the nearly independent electrical results of the mechanical motions. The depth of penetration of the probe into the transmission line determines the magnitude of the reflection, while the position of the probe along the line determines the phase. While there is some interaction, the effects are almost independent of each other.

Functional Description

The dual probe structure in Maury coaxial slide screw tuners is designed so that one probe (low frequency) covers the range from the lowest frequency to the crossover frequency listed in the Available Models table. The second probe (high frequency) covers the range from the crossover frequency to the tuner's maximum rated frequency. The optimum crossover frequency varies from tuner to tuner.

As each micrometer-driven probe is introduced into the slab-line transmission structure it induces a mismatch in its frequency range. The magnitude of this impedance mismatch is determined by the probe position (depth); the closer the probe approaches the center conductor, the greater the magnitude. The phase of the impedance mismatch is determined by the carriage position along the slab-line. The probes operate independently of each other with little or no interaction. Each probe will meet its specifications over its rated frequency range, and typically has considerably higher matching capability in the middle of its band. Figure 1 shows responses that are typical of those seen in a low frequency/ high frequency pair of probes.

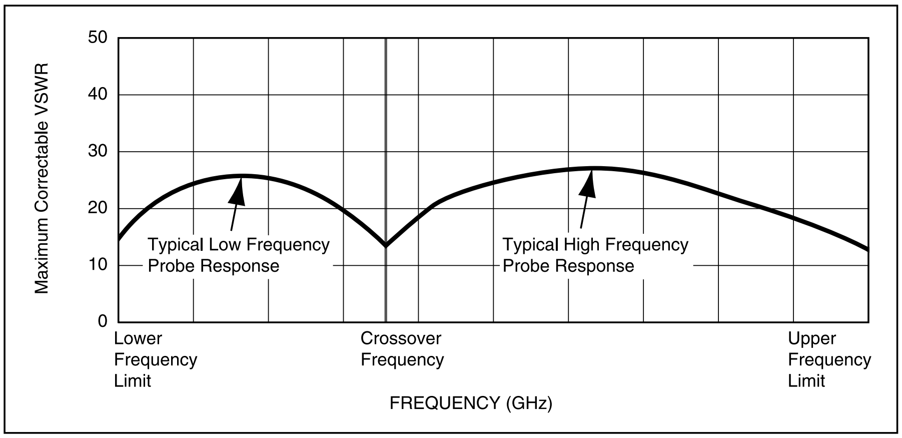
Available Models

Model	Frequency Range (GHz)	Connector Type	VSWR Matching Range	Maximum Loss (Probes Retracted)	Probe Crossover Frequency	Power Handling [1] (Ave/Peak Watts)	Dimension "A"	
							Inches	(CM)
MST981BN MST981B35	0.4 – 4.0	Type N [4] 3.5mm [3]	25:1	0.2 dB	1.4 GHz	250/2500 125/1250	14.75	(37.47)
MST981EN MST981E35	0.8 – 8.0	Type N [4] 3.5mm [3]	35:1	0.2 dB	2.8 GHz	250/2500 125/1250	7.37	(18.72)
MST982VN MST982V35	0.6 – 8.0	Type N [4] 3.5mm [3]	20:1	0.5 dB	2.8 GHz	50/500 25/250	9.83	(24.97)
MST982GN MST982G35	0.6 – 18.0	Type N [4] 3.5mm [3]	10:1	0.6 dB	4.2 GHz	50/500 25/250	9.83	(24.97)
MST982AN MST982A35	1.8 – 18.0	Type N [4] 3.5mm [3]	12:1	0.4 dB	5.5 GHz	50/500 25/250	3.28	(8.33)
MST983B35	12.0 – 34.0	3.5mm [3, 5]	10:1	0.7 dB	16.0 GHz	15/150	0.49	(1.24)
MST984A24	12.0 – 50.0	2.4mm [2, 5]	10:1	1.0 dB	21.5 GHz	15/150	0.49	(1.24)

[1] Within rated matching range.
[2] Precision 2.4mm per Maury data sheet 5E-064.
[3] Precision 3.5mm per Maury data sheet 5E-062.
[4] Precision type N per Maury data sheet 5E-049.
[5] Non LCD readout model, micrometer-driven carriage.

Typical Responses

Figure 1. Typical responses seen in low frequency and high frequency probes as they are used in Maury coaxial slide screw tuners.



Low-Loss Probe Mounts

SERIES MT902

Features

- On-Wafer Broadband Pre-Matching
- Low Loss Wafer Probe Mount
- 2.0 to 65.0 GHz
- Ultra-High Stability Design

MT902A2 Pre-Matching Probe Mount on a 50 GHz model MT984AL01, 2.4mm Automated Tuner. This launch configuration is also used on MT902A1 and MT902A3.

General

The MT902 series of pre-matching tuners are highly stable, low loss wafer probe mounts used in on-wafer device characterization applications. By extending a wafer probe away from the tuner body, these mounts create additional clearance for proper probe alignment. The ultra-high stability, inherent in their design, eliminates the possibility of undesired movement during operation.

MT902A5 Basic Probe Mount on a MT984AL01, 50 GHz Automated Tuner. This launch configuration is also used on MT902A6, MT902A7, and MT902D5.

Specifications

Frequency Ranges -- 2.0 to 26.5 GHz & 8.0 to 65.0 GHz
VSWR Range -- 10:1 minimum
Insertion Loss -- 0.30 dB[1]/0.30 dB[2]/0.36 dB[3]/0.45 dB[4]/0.6 dB[5]
Repeatability -- 40 dB minimum
Power Handling -- 10W CW, 0.5 kW peak
Connectors -- 3.5mm[6]/2.4mm[7]/1.85mm[8]

MT902D5 Basic Probe Mount

[1] MT902C1/2 at 26.5 GHz with probe retracted.
[2] MT902C5/6 at 26.5 GHz with probe retracted.
[3] MT902A1/2/3 at 50 GHz with probe retracted.
[4] MT902A5/6/7 at 50 GHz with probe retracted.
[5] MT902D5 at 65.0 GHz.
[6] Precision 3.5mm per Maury data sheet 5E-062.
[7] Precision 2.4mm per Maury data sheet 5E-064.
[8] Precision 1.85mm per Maury data sheet 2K-001.

Available Models

Model	Description	Frequency Range (GHz)	Matching Range	Recommended For Use With Probe Stations
MT902A1	Basic Probe Mount	DC – 50.0	N/A	Cascade M150 MPI TS150-AIT MPI TS200-THZ MPI TS300-AIT
MT902A2	High frequency pre-matching probe mount	21.5 – 50.0	10:1	
MT902A3	Low frequency pre-matching probe mount	8.0 – 21.5	10:1	
MT902A5	Basic probe mount	DC – 50.0	N/A	Cascade 11K Cascade 12K Cascade S300 MPI TS150-AIT MPI TS200-THZ MPI TS300-AIT
MT902A6	High frequency pre-matching probe mount	21.5 – 50.0	10:1	
MT902A7	Low frequency pre-matching probe mount	8.0 – 21.5	10:1	
MT902C1	Basic probe mount	DC – 26.5	N/A	Cascade M150 MPI TS150-AIT MPI TS200-THZ MPI TS300-AIT
MT902C2	High frequency pre-matching probe mount	7.3 – 26.5	10:1	
MT902C5	Basic probe mount	DC – 26.5	N/A	Cascade 11K Cascade 12K Cascade S300 MPI TS150-AIT MPI TS200-THZ MPI TS300-AIT
MT902C6	High frequency pre-matching probe mount	7.3 – 26.5	10:1	
MT902D5	Basic probe mount	DC – 65.0	N/A	Cascade 11/12K Cascade S300 MPI TS150-AIT MPI TS200-THZ MPI TS300-AIT

Noise Receiver and Noise Switch Modules

SERIES MT7553

Features

- Instantaneous Ultra-Wideband Measurements from 100 MHz – 65 GHz
- Banded Measurements from 50–75 GHz, 60–90 GHz, and 75–100 GHz
- Automates Noise Parameter Measurement Systems
- Replaces External Banded Components
- Integrated Downconverter, Bias Tees, Low-Noise Amplifier, and Switches
- Low Noise Figure for Improved System Calibration Accuracy and Repeatability

MT7553B03

MT7553C01

Noise Parameters System

Introduction

Noise Parameters are the non-50Ω extensions of Noise Figure, and are an important modeling and model validation tool to understand how a device-under-test's performance changes as a function of source impedance. Noise Parameter measurements are typically performed using a Vector Network Analyzer (VNA) to measure the S-Parameters of the DUT, and a Noise Analyzer (either Noise Figure Analyzer NFA or Spectrum Analyzer SA) to measure the noise power of the DUT, with typical system block diagrams shown in Figures 1 and 2. Noise parameters are calculated from a combination of known source impedances, S-parameters and noise powers.

Figure 1. Block diagram of typical Noise Parameters setup with separate VNA and NFA

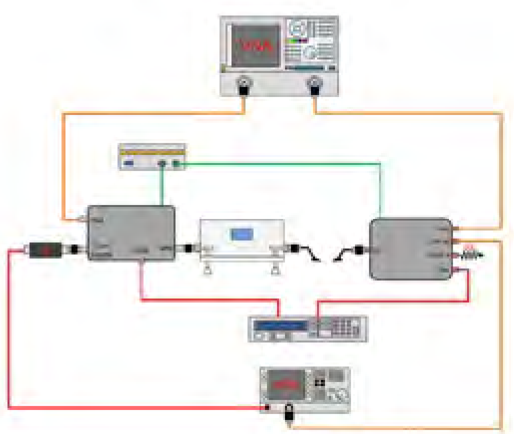
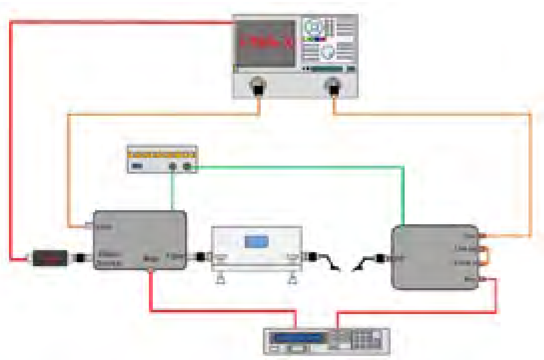


Figure 2. Block diagram of typical Noise Parameters setup with combined VNA and NFA



Noise Receivers and Noise Receiver Calibration

The Noise Receiver consists of the component chain from the DUT output to, and including, the Noise Analyzer. The minimum Noise Figure (Fmin) of the Noise Receiver will affect the minimum accurately measurable Noise Figure of the DUT by increasing the sensitivity of the receiver. Therefore, it is critical to provide a Noise Receiver with the lowest Fmin possible. In addition, Noise Analyzers may not be available at the frequencies of interest and in these cases it is common to use a downconverter chain to lower the frequency of the signal to one that can be measured by the Noise Analyzer. Maury's family of MT7553-series Noise Receiver Modules assist in doing exactly these things. Typical noise receiver calibrations using MT7553-series NRMs are shown in Figures 3-5.

MT7553-series Coaxial Noise Receiver Modules

MT7553-series coaxial Noise Receiver Modules integrate the entire output network of a typical Noise Parameter measurement system into a turnkey solution. These NRMs consist of:

- Wideband low-noise amplifiers to improve the sensitivity of the Noise Receiver.
- RF switches to switch between VNA and NFA paths.
- Wideband bias tees to provide bias to the device under test.

The MT7553A03 NRM covers 0.1-26.5 GHz and is designed to operate with either standalone Noise Analyzer or combined VNA/NFA up to 26.5 GHz.

The MT7553B03 NRM covers 0.1-50 GHz and is designed to operate with either standalone Noise Analyzer or combined VNA/NFA up to 50 GHz.

In cases where the NFA does not match the Noise Parameters frequency of interest, an NRM with integrated downconverter module may be used to accept an input signal (commonly referred to as RF signal) at F1 and mix it with local oscillator signal F2, resulting in an intermediate frequency (IF) of F1-F2, a frequency able to be directly measured by a lower frequency NFA.

The MT7553B01 NRM covers 0.1-50 GHz and is designed to operate with either standalone Noise Analyzer or combined VNA/NFA where the VNA operates to at least 50 GHz, but the NFA operates to 26.5 GHz.

The MT7553C01 NRM covers 0.1-65 GHz and is designed to operate with either standalone Noise Analyzer or combined VNA/NFA where the VNA operates to at least 65 GHz, but the NFA operates to 50 GHz.

MT7553M-series Millimeter Wave Noise Receiver Modules

MT7553M-series waveguide Noise Receiver Modules are designed for full millimeter-wave noise parameter measurements within the TE10 waveguide band of operation and downconverts noise power densities from the frequency of interest to the NFA bandwidth using a double sideband swept LO technique. Models are available between 50-75 GHz (WR15), 60-90 GHz (WR12) and 75-100 GHz (WR10). Biasing and switching functions are external to the MT7553M-series NRMs.

MT7553N-series Noise Switching Modules

MT7553N-series Noise Switching Modules integrates the entire input network of a typical Noise Parameter measurement system into a turnkey solution. These NSMs consist of

- RF switches to switch between the VNA and noise source paths
- Wideband bias tees to provide bias to the device under test

The MT7553N26, MT7553N50 and MT7553N65 cover 0.1-26.5 GHz, 0.1-50.0 and 0.1-65.0 GHz respectively.

Available Noise Receiver Modules

<table>
<tr><th rowspan="2">Model</th><th rowspan="2">System Input Frequency (GHz)</th><th rowspan="2">NFA Output Frequency (GHz)</th><th rowspan="2">LO</th><th rowspan="2">Mixer</th><th rowspan="2">LNA</th><th rowspan="2">Bias Tee</th><th rowspan="2">RF Switch</th><th rowspan="2">VNA/NFA Ports</th><th colspan="2">Noise Figure</th><th rowspan="2">Connector</th></tr>
<tr><th>Typ</th><th>Max</th></tr>
<tr><td>MT7553A03</td><td>0.1 – 26.5</td><td rowspan="2">0.1 – 26.5</td><td colspan="2">N/A</td><td rowspan="7">Internal</td><td colspan="2" rowspan="4">Internal</td><td rowspan="4">Separate/ Combined</td><td>6</td><td>8</td><td>3.5mm female</td></tr>
<tr><td>MT7553B01</td><td rowspan="2">0.1 – 50.0</td><td colspan="2">Internal</td><td>15</td><td>20</td><td rowspan="2">2.4mm female</td></tr>
<tr><td>MT7553B03</td><td rowspan="2">0.1 – 50.0</td><td colspan="2">N/A</td><td rowspan="2">10</td><td>16</td></tr>
<tr><td>MT7553C01</td><td>0.1 – 65.0</td><td rowspan="4">External</td><td rowspan="4">Internal</td><td>18</td><td>1.85mm female</td></tr>
<tr><td>MT7553M15</td><td>50.0 – 75.0</td><td rowspan="3">0.1 – 26.5</td><td colspan="2" rowspan="3">External</td><td rowspan="3">Separate</td><td colspan="2" rowspan="3">12</td><td>WR15</td></tr>
<tr><td>MT7553M12</td><td>60.0 – 90.0</td><td>WR12</td></tr>
<tr><td>MT7553M10</td><td>75.0 – 110.0</td><td>WR10</td></tr>
</table>

Available Noise Switching Modules

<table>
<tr><th>Model</th><th>Frequency (GHz)</th><th>Bias Tee</th><th>RF Switch</th><th>Connector</th></tr>
<tr><td>MT7553N26</td><td>0.1 – 26.5</td><td colspan="2" rowspan="3">Internal</td><td>3.5mm female</td></tr>
<tr><td>MT7553N50</td><td>0.1 – 50.0</td><td>2.4mm female</td></tr>
<tr><td>MT7553N65</td><td>0.1 – 65.0</td><td>1.85mm female</td></tr>
</table>

Maury Microwave MT981BL18 and MT983AL01 automated impedance tuners were used to cover the frequency range.

Maury Microwave MT7553A03 (direct frequency to 26.5 GHz) and MT7553N26 NRM and NSM modules were used as the input and output noise modules.

Keysight N5247A PNA-X with option 029 was used as the VNA and NFA. Noisewave NW346V was used as the noise source.

Maury Microwave ATS software was used to perform measurements with the following settings: fast noise with 22 source impedance points, noise averaging of 16, noise receiver gain set to high gain, noise calculation using cold only formulation.

Fmin reported at the NRM connector reference plane.

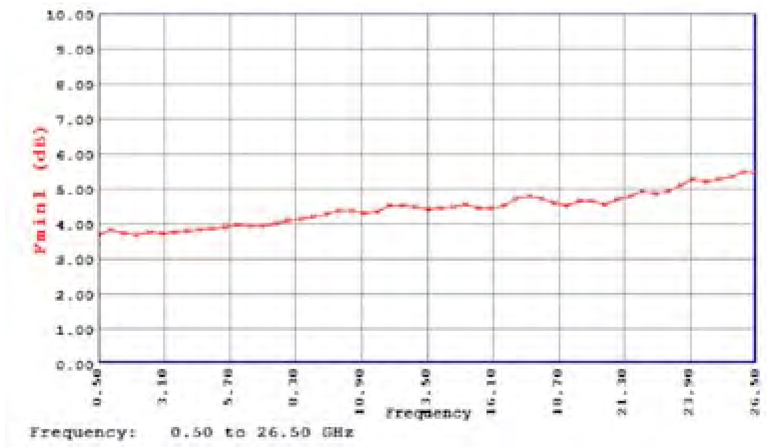


Figure 3. Typical Noise Receiver Calibration Using MT7553A03

Maury Microwave MT981BL18 and MT985AL01 automated impedance tuners were used to cover the frequency range.

Maury Microwave MT7553B03 (direct frequency to 50 GHz) and MT7553N50 NRM and NSM modules were used as the input and output noise modules.

Keysight N5247A PNA-X with option 029 was used as the VNA and NFA. Noisewave NW346V was used as the noise source.

Maury Microwave ATS software was used to perform measurements with the following settings: fast noise with 22 source impedance points, noise averaging of 16, noise receiver gain set to high gain, noise calculation using cold only formulation.

Fmin reported at the NRM connector reference plane.

Figure 4. Typical Noise Receiver Calibration Using MT7553B03

Maury Microwave MT981BL18 and MT983AL01 automated impedance tuners were used to cover the frequency range.

Maury Microwave MT7553C01 (direct frequency to 50 GHz, downconverted frequencies between 50-65 GHz) and MT7553N65 NRM and NSM modules were used as the input and output noise modules.

Keysight N5247A PNA-X with option 029 was used as the VNA and NFA. Noisewave NW346V was used as the noise source.

Maury Microwave ATS software was used to perform measurements with the following settings: fast noise with 22 source impedance points, noise averaging of 16, noise receiver gain set to high gain, noise calculation using cold only formulation.

Fmin reported at the NRM connector reference plane.

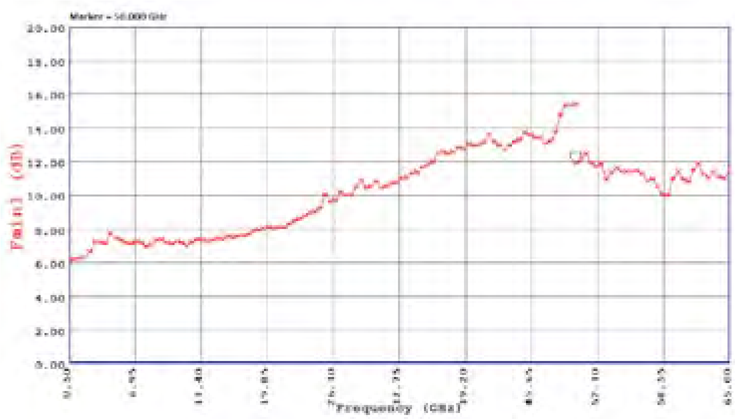


Figure 5. Typical Noise Receiver Calibration Using MT7553C01

Low-Loss Couplers

LOW-LOSS, HIGH DIRECTIVITY, HIGH POWER COUPLERS FOR
LOAD PULL AND OTHER POWER APPLICATIONS

Features

> High Power Handling
> High Directivity
> Low Insertion Loss
> Broadband Performance
> Excellent VSWR

Applications

> Amplifier Power Monitoring
> High-Power Base Station Integration
> Test and Measurement (Load Pull, Antenna Test, General Lab...)

LLC18-7 Low-Loss Coupler

LLC18-N-MF Low-Loss Coupler

LLC34-35-MF Low-Loss Coupler

LLC40-292-MM Low-Loss Coupler

LLC67-185-MM Low-Loss Coupler

Description

The LLC-series of bidirectional airline couplers represents a breakthrough in high-power coupler technology. Combining precision machining with stellar electrical characteristics, LLC-series couplers offer unmatched performance. The differentiating features of the LLC-series bidirectional coupler include high power handling, high directivity, low insertion loss and broadband performance. High power handling enables integration in high-power applications including amplifiers and base stations, and for high-power test and measurement applications including PA testing and load pull. Unlike inferior models which are rated at breakdown, Maury defines power handling capability as the power at which there is no discernible change in the performance of the coupler.

High directivity, the difference between coupling and isolation, enables highly-accurate measurements by isolating the direct and coupled measurement pathways. This is especially important in a calibrated system where changing coupler characteristics due to poor directivity can invalidate the calibration and result in erroneous measurements. Low insertion loss is critical for high-power applications in order to avoid power loss and eliminate drift due to heating. Compared with microstrip couplers that suffer losses and self-heating due to metal resistivity and dielectric permittivity, LLC-series airline couplers have no added dielectric. When used as part of a vector-receiver load pull setup, low insertion loss directly maximizes tuning range when combined with an impedance tuner. The broadband nature of the coupler allows it to be used for wideband applications.

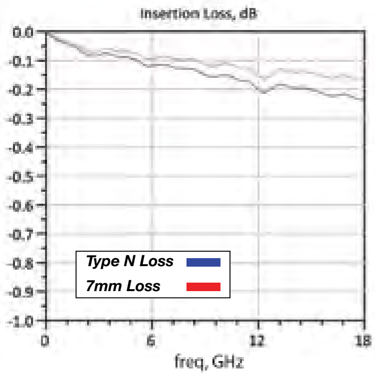
Specifications

Available Models	Connector		Coupling Ports	Frequency Range[1] (GHz)	Max Insertion Loss at Fmax	Directivity Typ.	Coupling Typ.	Power Handling
	Input Port	Output Port						
LLC18-7	7mm	7mm	3.5mm Female	0.6 – 8.0 8.0–18.0	0.15 dB 0.25 dB	15 dB 10 dB	30 dB[2] ±3 dB	500 W CW / 2 KW Peak
LLC18-N-FF	Type N Female	Type N Female			0.25 dB 0.35 dB			
LLC18-N-MF	Type N Male	Type N Female						
LLC18-N-MM	Type N Male	Type N Male						
LLC34-35-FF	3.5mm Female	3.5mm Female	2.92mm Female	2.0 – 26.5 26.5–34.0	0.35 dB	14 dB 10 dB		150 W CW / 500 W Peak
LLC34-35-MF	3.5mm Male	3.5mm Female						
LLC34-35-MM	3.5mm Male	3.5mm Male						
LLC40-292-FF	2.92mm Female	2.92mm Female	2.92mm Female	3.0-10.0 10.0-40.0	0.1 dB 0.2 dB	18 dB 12 dB	45 ±5 dB[3] 35 dB ±5 dB	10 W CW / 100W Peak
LLC40-292-MF	2.92mm Male	2.92mm Female						
LLC40-292-MM	2.92mm Male	2.92mm Male						
LLC67-185-FF	1.85mm Female	1.85mm Female	1.85mm Female	3.0-20.0 20.0-67.0	0.2 dB 0.4 dB	18 dB 12 dB	45 ±5 dB[3] 35 dB ±5 dB	10 W CW / 100W Peak
LLC67-185-MF	1.85mm Male	1.85mm Female						
LLC67-185-MM	1.85mm Male	1.85mm Male						

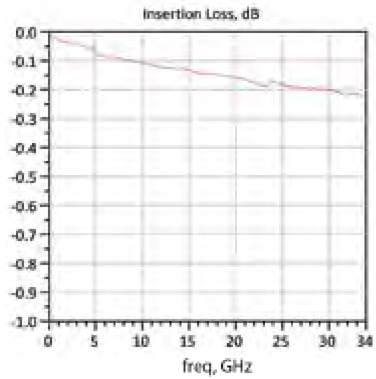
[1] Usable from 0.1 GHz with increased coupling.
[2] ±6dB 0.6 – 0.8 GHz for LLC18 and 2.0 – 3.0 GHz for LLC34.
[3] ±10 dB 3.0 – 6.0 GHz.

Mainline Insertion Loss

LLC18

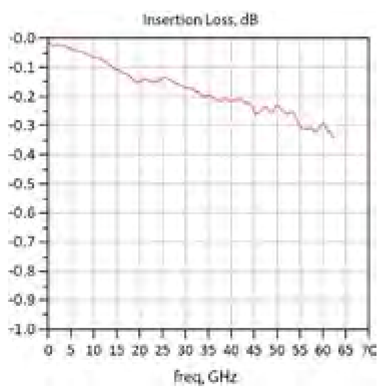


LLC34



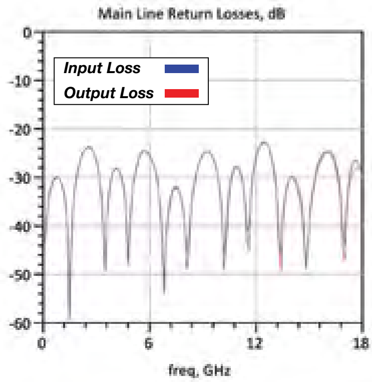
LLC40

LLC67

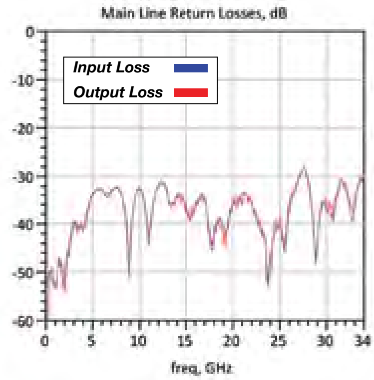


Mainline Return Loss

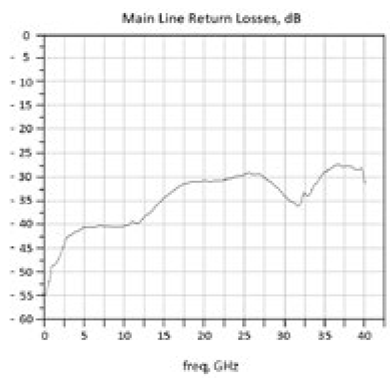
LLC18



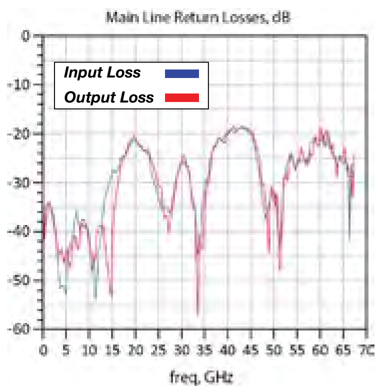
LLC34



LLC40

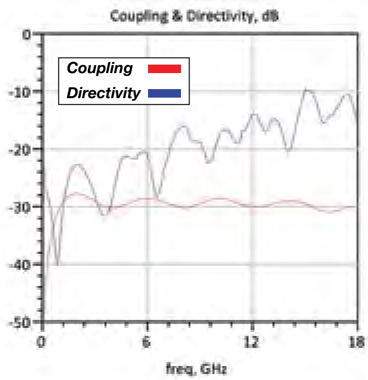


LLC67

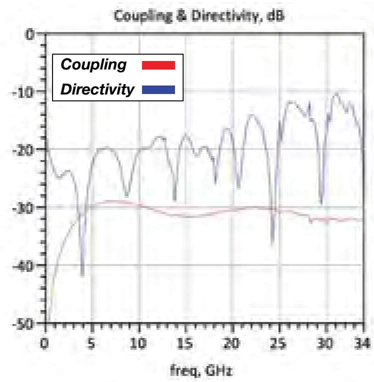


Coupling and Directivity

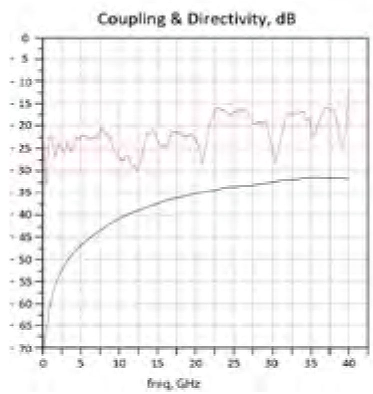
LLC18



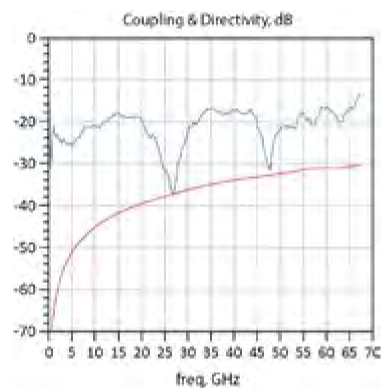
LLC34



LLC40



LLC67



Low-Loss Couplers with Integrated Downconverters

LOW-LOSS, HIGH DIRECTIVITY, HIGH POWER COUPLERS FOR LOAD PULL AND OTHER POWER APPLICATIONS

Features

- High Power Handling
- High Directivity
- Low Insertion Loss
- Full Waveguide Band
- Excellent VSWR
- Integrated Downconverter

Description

The LLC-series of bidirectional waveguide couplers with integrated downconverters are ideal for waveguide banded mmW load pull applications. The coupler's low insertion-loss and high-directivity ensures a minimal impact on the tuning range at the DUT reference plane, while enabling the benefits of vector-receiver load pull measurements. The integrated downcoverters allow a direct connection to a sub-26.5 GHz VNA's receiver ports without worrying about mechanical incompatibilities of standard waveguide frequency extender modules.

Specifications

Available Models	Connector		Coupling Ports	Frequency Range[1] (GHz)	Typ. Insertion Loss at Fmax	Directivity Typ.	Coupling Typ.	Power Handling
	Input Port	Output Port						
LLC75WR15	WR15	WR15	3.5mm[4]	50-75	0.8dB	30dB	36[5]	5W
LLC90WR12	WR12	WR12	3.5mm[4]	60-90	0.8dB	30dB	43[5]	5W
LLC110WR10	WR10	WR10	3.5mm[4]	75-110	0.8dB	30dB	42[5]	2W

[4] *X6 down conversion included, it requires external LO (max 2dBm).*

[5] *A micrometer is included to reduce the coupling factor of 30dB.*

High-Power Low-Loss Pulsed Bias Tees

Features

- > High RF Power Handling
- > High Breakdown Voltage
- > High Current Handling
- > Low Insertion Loss
- > Excellent Return Loss
- > Pulsing Capable

Applications

- > High-Power System Biasing
- > High-Power Base Station Integration
- > Test and Measurement (Load Pull, Pulsed Measurements, General Lab...)

Model:
MBT18-7-1000
U.S. Patent No. 9,614,267

Description

Bias tees are passive RF circuits which provide DC bias to an active device under test. Normally consisting of a capacitor and inductor, bias tees act as diplexers by combining low-frequency (DC) and high frequency (RF) signals onto a common port (RF+DC). In a classic capacitor/inductor design, the capacitor acts as a DC block and prevents DC bias from entering the RF path, while the inductor acts as an RF choke preventing RF energy from entering the DC instrumentation.

Typical applications include providing bias to amplifiers inside of complex systems including base stations and radios; and biasing discrete transistors or packaged devices in test and measurement applications such as DC/pulsed-bias S-parameters, DC/pulsed-IV, DC/pulsed-bias load pull, stability-, robustness-, burn-in-, pre-production- and production-test.

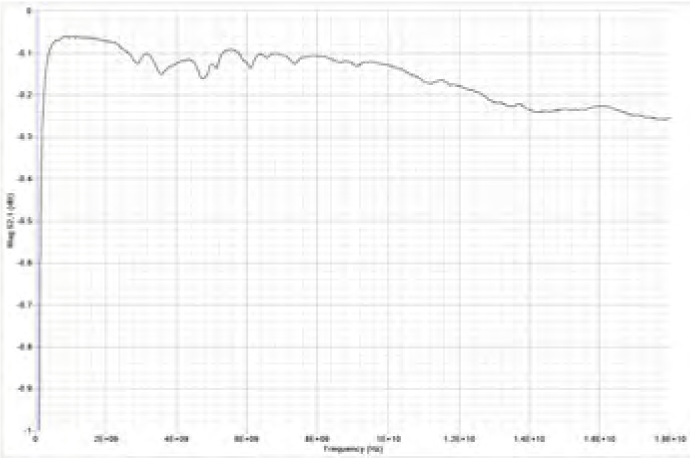
Important characteristics of a bias tee include the frequency range over which the bias tee will function with minimal to no performance degradation, the insertion loss and VSWR (or return loss) over the usable frequency range of the bias tee. Voltages, currents and RF powers are critical both in average/DC/CW and pulsed/peak operations. It is also essential to have bias tees with minimal overshoot of the signals under pulsed bias/pulsed RF conditions.

Specifications

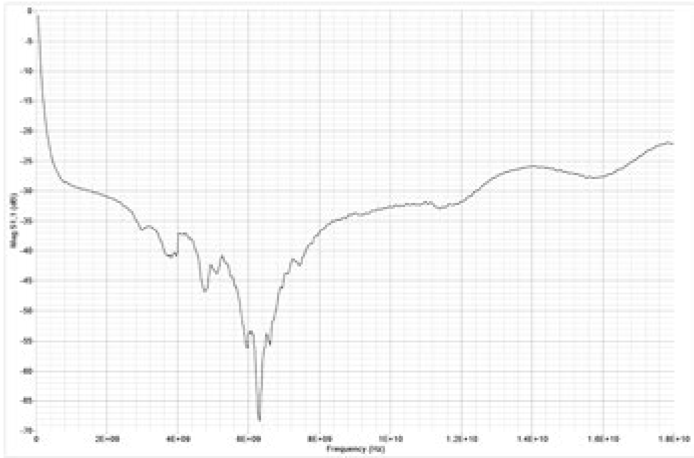
Model	Connector			Frequency Range (GHz)	Insertion Loss (dB)		Return Loss (dB) Typical	Max Voltage (V)	Max DC Current (A)	RF Rating				Isolation (dB) Typical	DC Resistance (ohm) Typical	DC BW (MHz) Typical
	RF Port	RF+DC Port	DC Port		Typ	Max				CW Current (A)	CW Power (W)	Peak Current (A) [1]	Peak Power (W) [1]			
MBT18-7-1000	7mm		SMA Female	0.35 - 18	0.28	0.6	22	100	1	1	10	2	40	34	0.4	10
MBT18-7-5000	7mm		SMA Female	6 - 18	1.1	1.5	15	100	5	5	50	15	250	30	0.4	10
MBT18-NMF-5000	Type N (male)	Type N (female)	SMA Female	6 - 18	1.1	1.5	15	100	5	5	50	15	250	30	0.4	10
MBT18-NFM-5000	Type N (female)	Type N (male)	SMA Female	6 - 18	1.1	1.5	15	100	5	5	50	15	250	30	0.4	10

[1] Power and current rating valid under the following condition: Ton = 100us, Duty Cycle = 10%, Iq ≤ 500mA. Different pulse conditions will affect the peak power and current handling.

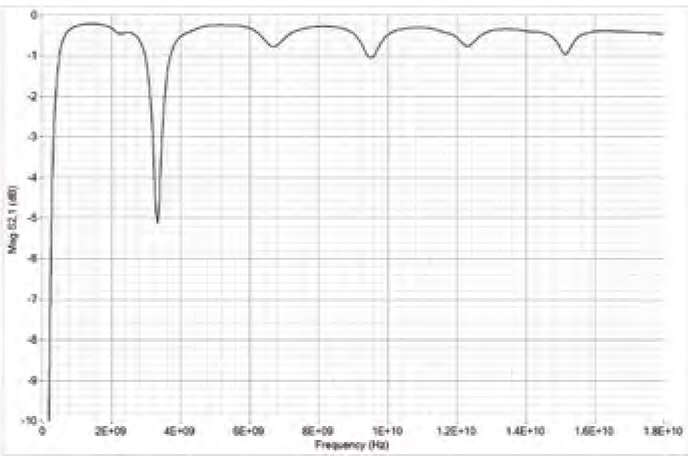
MBT18-7-1000
Typical Insertion
Loss - dB



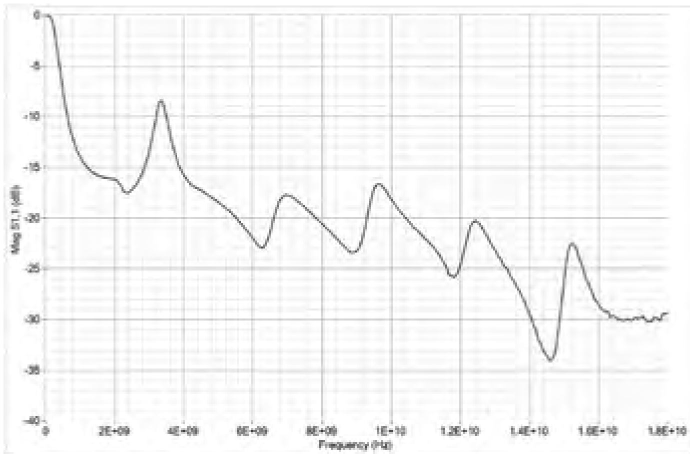
MBT18-7-1000
Typical Return
Loss - dB



MBT18-7-5000
Typical Insertion
Loss - dB

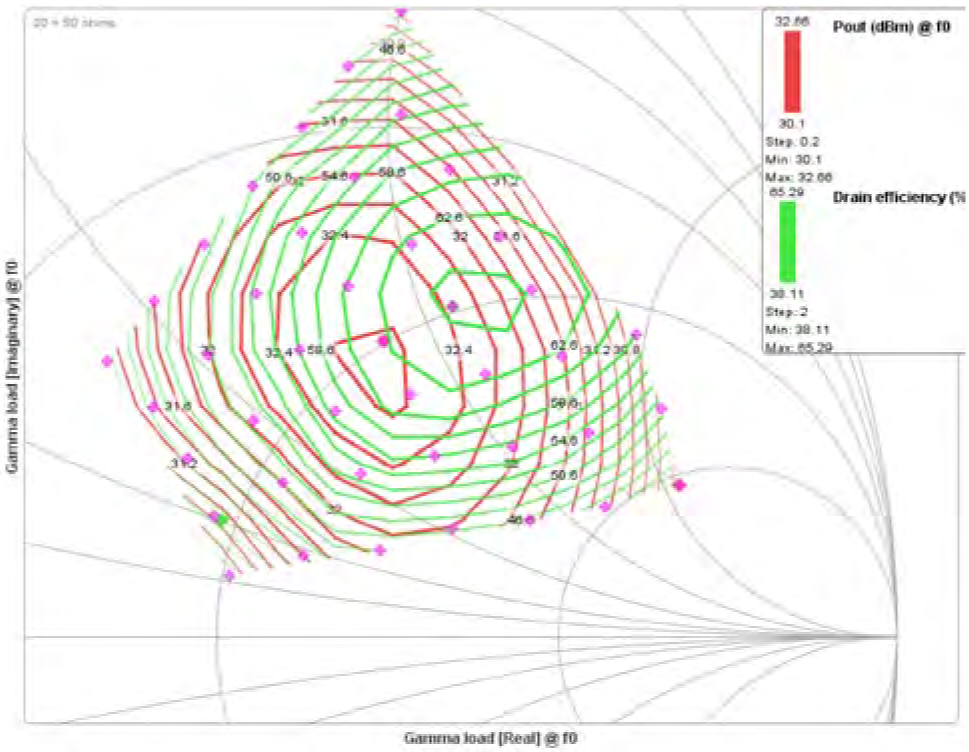


MBT18-7-5000
Typical Return
Loss - dB

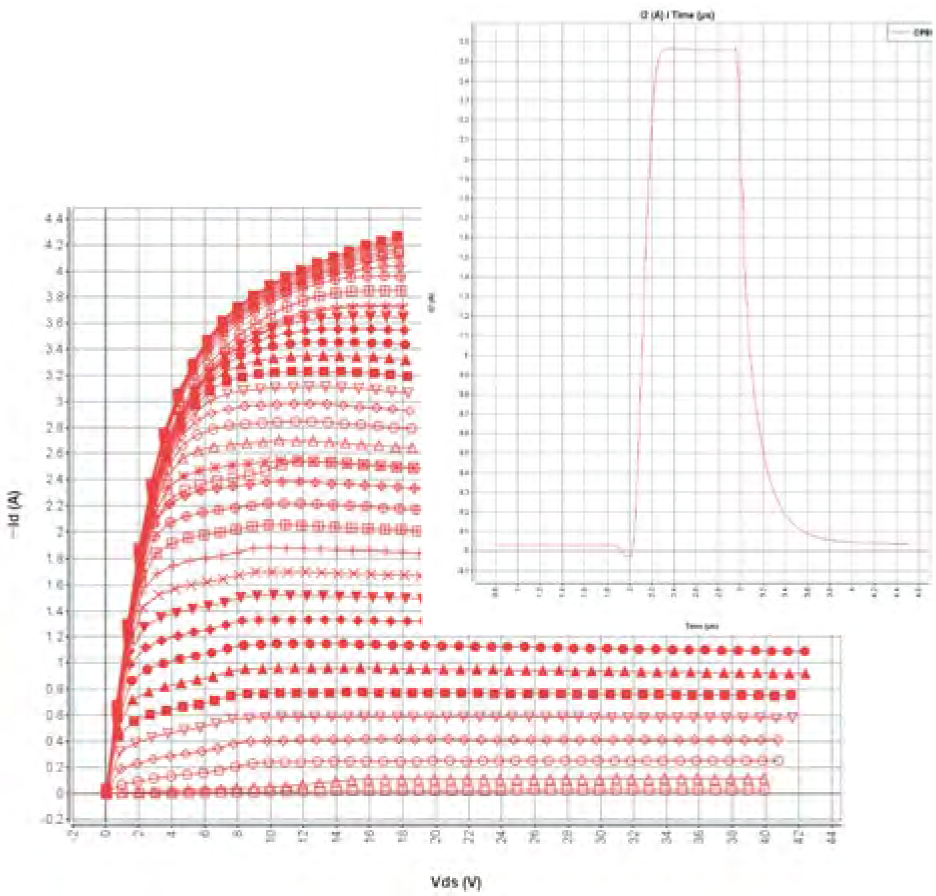


Typical Applications

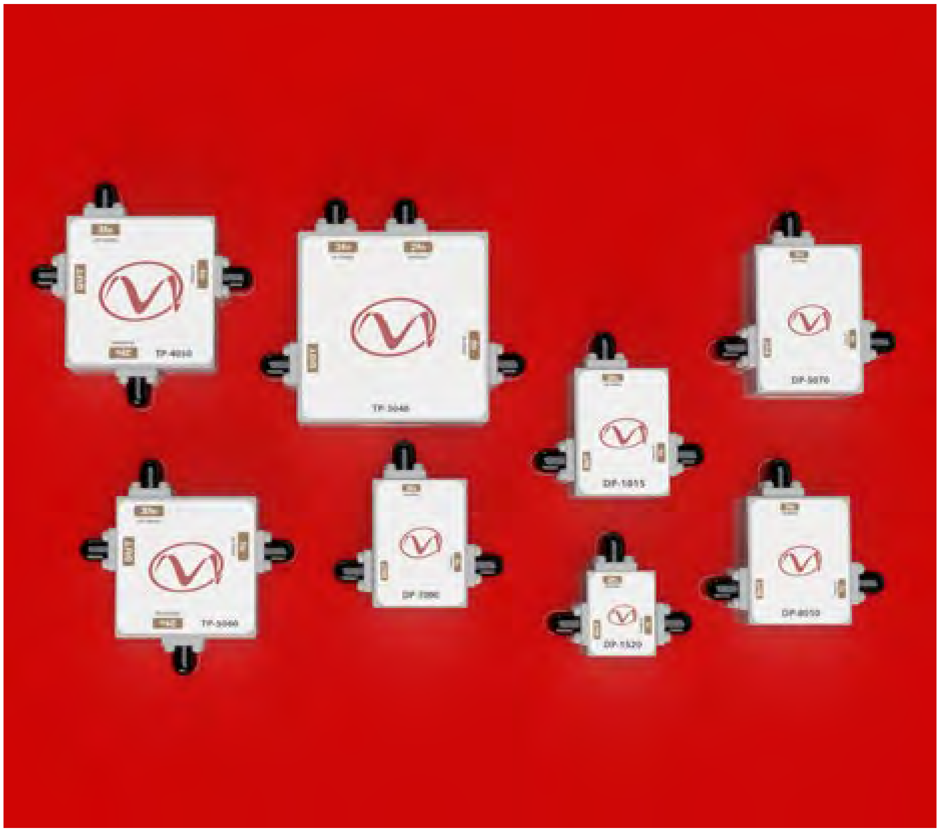
Load pull



Pulsed IV down to 1us



Low-Loss Coaxial Multiplexers



What Are Multiplexers?

With regards to microwave and RF networks, multiplexers are multi-port frequency-selective combiners/splitters built from a series of filters to combine/split carrier signals at multiple frequencies while providing a high degree of isolation between ports.

Multiplexers are an effective solution for combining signals at different frequencies onto a common transmission line without the resistive losses found in traditional wideband combiners/splitters. Multiplexers can be created from a number of different filters, including low-pass, bandpass and high-pass, depending on the nature of the multiplexer.

Diplexers are typically created from low-pass and high-pass filters, whereas triplexers often have low-pass, bandpass and high-pass networks. Some multiplexers allow the passing of DC bias between the low-band and common ports, while others using only bandpass filters may block bias. Insertion loss between the frequency-selective and common ports may vary depending on the technology used to build multiplexers, as does power handling capability.

DP-Series and TP-Series Overview

Maury's line of diplexers (DP-series) and triplexers (TP-series) are designed for applications which require combining/splitting signals at or around harmonic frequencies (nFo) and are connectorized for design-in and test and measurement applications.

DP-series diplexers are designed using low-pass and high-pass filters and pass bias between the low-frequency (or Fo) port and the common (or DUT) port. TP-series triplexers are designed using low-pass, bandpass and high-pass filters and pass bias between the low-frequency (or Fo) port and the common (or DUT) port.

Typical S-parameter data can be downloaded at maurymw.com.

Available Models (DP Series Diplexers)

Model	Frequency Range (GHz)		Typical Insertion Loss @ Fmin (dB)		Typical Insertion Loss @ Fmax (dB)		Power Rating In Fundamental Band	Connectors		
	Fo	2Fo	Fo	2Fo	Fo	2Fo		Fo Input	Fo Output	2Fo Output
DP-06810	0.68 - 1.0	1.36 - 2.0	0.5	1.1	0.6	0.6	100 W CW	SMA female		
DP-1220	1.20 - 2.0	2.40 - 4.0	0.4	1.5	0.7	0.9	100 W CW	SMA female		
DP-1823	1.80 - 2.30	3.60 - 4.60	0.4	1.3	0.6	1.1	100 W CW	SMA female		
DP-2232	2.20 - 3.20	4.40 - 6.40	0.4	1.4	0.8	0.7	100 W CW	SMA female		
DP-2942	2.90 - 4.20	5.80 - 8.40	0.8	1.4	0.9	1.5	100 W CW	SMA female		
DP-3957	3.90 - 5.70	7.80 - 11.40	0.4	1.4	0.7	1.3	100 W CW	SMA female		
DP-5070	5.0 -7.0	10.0 - 14.0	0.5	1.0	0.5	1.3	50 W CW	2.92mm female		
DP-7090	7.0 - 9.0	14.0 - 18.0	0.5	1.0	0.5	1.3	50 W CW	2.92mm female		
DP-8010	8.0 - 10.0	16.0 - 20.0	0.6	1.0	0.6	1.3	40 W CW	2.92mm female		

Available Models (TP Series Triplexers)

Model	Frequency Range (GHz)			Typical Insertion Loss @ Fmin (dB)			Typical Insertion Loss @ Fmax (dB)			Power Rating In Fundamental Band	Connectors			
	Fo	2Fo	3Fo	Fo	2Fo	3Fo	Fo	2Fo	3Fo		Fo Input	Fo Output	2Fo Output	3Fo Output
TP-08710	0.87 - 1.0	1.74 - 2.0	2.61 - 3.00	0.8	1.1	1.4	0.8	0.8	1.2	100 W CW	SMA female			
TP-1822	1.80 - 2.20	3.60 - 4.40	5.40 - 6.60	0.4	1.4	1.5	0.5	1.8	1.3	100 W CW	SMA female			
TP-2226	2.20 - 2.65	4.40 - 5.30	6.60 - 7.95	0.3	1.7	1.8	0.4	1.7	1.4	100 W CW	SMA female			
TP-2631	2.60 - 3.10	5.20 - 6.20	7.80 - 9.30	0.8	1.3	1.9	0.9	1.8	1.9	100 W CW	SMA female			
TP-3040	3.0 - 4.0	6.0 - 8.0	9.0 - 12.0	0.5	1.0	1.0	0.6	1.3	1.3	50 W CW	2.92mm female			
TP-4050	4.0 - 5.0	8.0 - 10.0	12.0 - 15.0	0.5	1.0	1.0	0.6	1.3	1.3	50 W CW	2.92mm female			
TP-5060	5.0 - 6.0	10.0 - 12.0	15.0 - 18.0	0.5	1.0	1.0	0.8	1.3	1.3	20 W CW	2.92mm female			

MT964 Load Pull Test Fixtures

LOW-LOSS TEST FIXTURES FOR LOAD PULL AND OTHER POWER APPLICATIONS

Features

- Low Insertion Loss for High VSWR Tuning
- Multiple Connector Configurations
- 50Ω and Transformers Available
- Heatsinks and Fans Available
- Water Cooling Available
- Integrated Biasing Available

Accessories Provided

- TRL Calibration Kit [1]

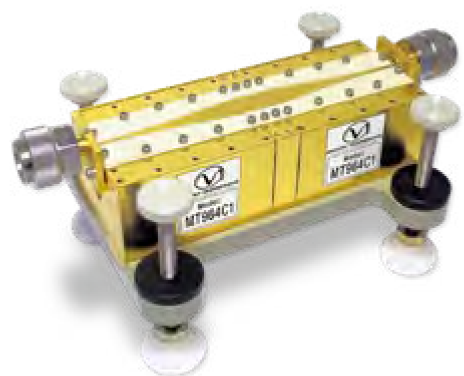
Optional Accessories

- Water Cooling
- Device Inserts

MT964A1-50
7mm Load Pull
Test Fixture

Available Models

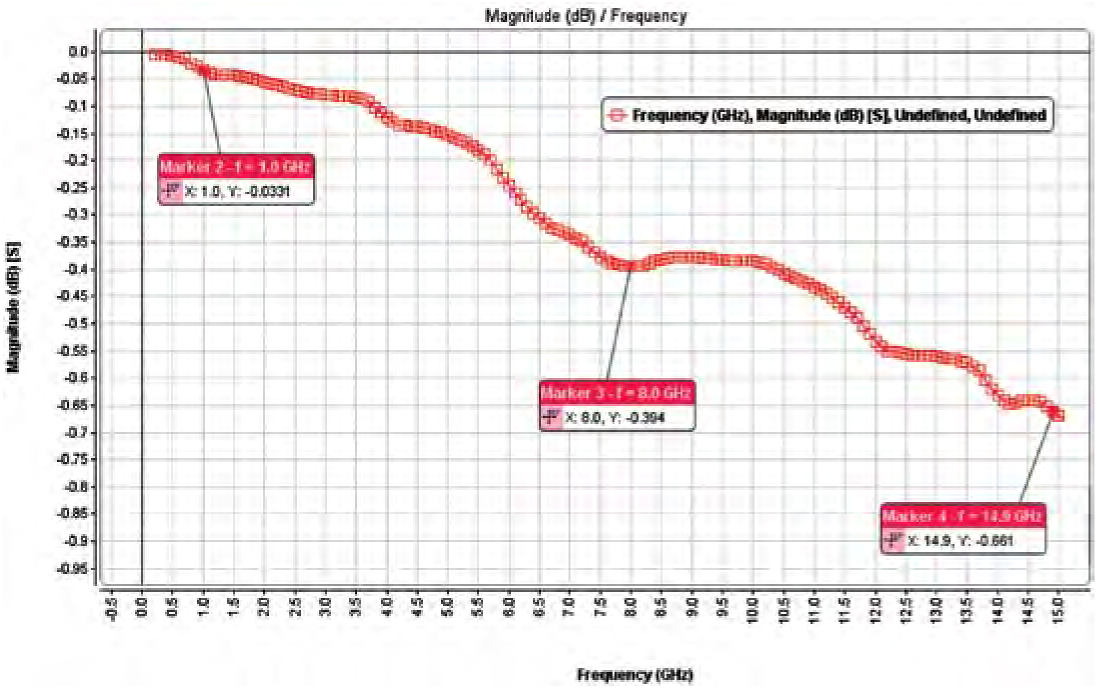
<table>
<tr><th>Available Models</th><th>Frequency Range (GHz)</th><th>Impedance</th><th>Connector</th><th>Fixture Size</th><th>Bias</th><th>Power Handling[2]</th></tr>
<tr><td>MT964A1-50</td><td rowspan="3">0.1 – 15.0</td><td rowspan="3">50 Ω</td><td>7mm</td><td rowspan="3">950 mil</td><td rowspan="3">No</td><td>250 W CW</td></tr>
<tr><td>MT964A2-50</td><td>3.5mm</td><td rowspan="2">25 W CW</td></tr>
<tr><td>MT964A3-50</td><td>2.4mm</td></tr>
<tr><td>MT964C1-50</td><td rowspan="6">0.8 – 15.0</td><td rowspan="3">50 Ω</td><td>7mm</td><td rowspan="6">2500 mil</td><td rowspan="6">Optional[3]</td><td>250 W CW</td></tr>
<tr><td>MT964C2-50</td><td>3.5mm</td><td rowspan="2">25 W CW</td></tr>
<tr><td>MT964C3-50</td><td>2.4mm</td></tr>
<tr><td>MT964C1-10</td><td rowspan="3">10 Ω</td><td>7mm</td><td>250 W CW</td></tr>
<tr><td>MT964C2-10</td><td>3.5mm</td><td rowspan="2">25 W CW</td></tr>
<tr><td>MT964C3-10</td><td>2.4mm</td></tr>
</table>



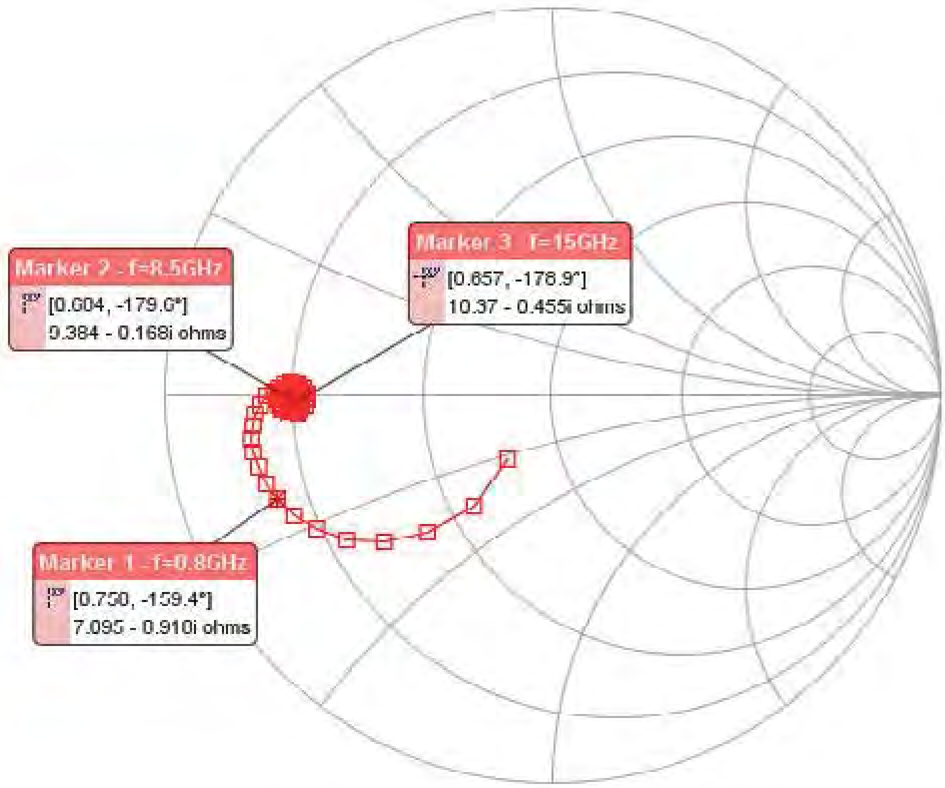
MT964C1-10
7mm Load Pull
Test Fixture

[1] Thru and Reflect standards built into fixture, external Line standard provided.
[2] Proper heat dissipation of DUT is required.
[3] Contact our Sales Staff for biasing option.

Typical S21 Performance of MT964A1-50



Typical S11 Performance of MT964C1-10



Anteverta High-Precision Current Probes

GENERAL INFORMATION

Features & Benefits

- > Resistor-based for simplified long-term use
- > Ideal for low-current measurements
- > Compatible with most commercial oscilloscopes and digitizers
- > Ideal for pulsed measurements

What are Current Probes?

Current probes are active devices which are used in conjunction with an oscilloscope or DMM to determine the current of a device under test. Current probes are either placed directly between a measurement instrument and DUT in order to measure the amplified voltage across an internal resistance or clamped onto a conductor/wire in order to measure the magnetic field created by the current flowing through the wire.

AVCP-Series Overview

AVCP-series current probes are based on a series resistor and differential amplifier which generates an output voltage proportional to the current flowing through the resistor. Large series resistors are used to create a large voltage drop in order to measure extremely low currents in the order of uA and mA. Unlike current probes based on Hall effect sensors, AVCP-series current probes do not need to be demagnetized (degaussed) and can be used more easily over long periods of time. AVCP current probes can be connected by BNC cable to nearly any commercial oscilloscope or DMM and are ideal for measuring active devices with low currents such as transistors under pulsed conditions.

Available Models

	AVCP-1	AVCP-10	AVCP-50
Irange (DC continuous)	+/- 0.2 A	+/- 0.02 A	+/- 0.004 A
Vrange	-5 V to 80 V	-5 V to 80 V	-5 V to 80 V
Gain	10 V/A	100 V/A	500 V/A
Bandwidth	DC - 2 MHz	DC - 2 MHz	DC - 2 MHz
Rise time [1]	175 ns or less	175 ns or less	175 ns or less
DC Accuracy [2]	+/- 3% of reading	+/- 3% of reading	+/- 3% of reading
Lowest measurable current (at ±3% accuracy at DC) [3]	1.4 mA	110 uA	38 uA
Displayed RMS noise, typical (at 20 MHz bandwidth limit)	200 uA rms or less	24 uA rms or less	9.2 uA rms or less
Insertion impedance	0.92 ohm @ 1 MHz 1.88 ohm @ 10 MHz 7.61 ohm @ 50 MHz 14.61 ohm @ 100 MHz	9.94 ohm @ 1 MHz 10.13 ohm @ 10 MHz 12.61 ohm @ 50 MHz 17.91 ohm @ 100 MHz	49.53 ohm @ 1 MHz 49.28 ohm @ 10 MHz 49.43 ohm @ 50 MHz 49.91 ohm @ 100 MHz
Idamage (DC continuous)	1400 mA	500 mA	200 mA

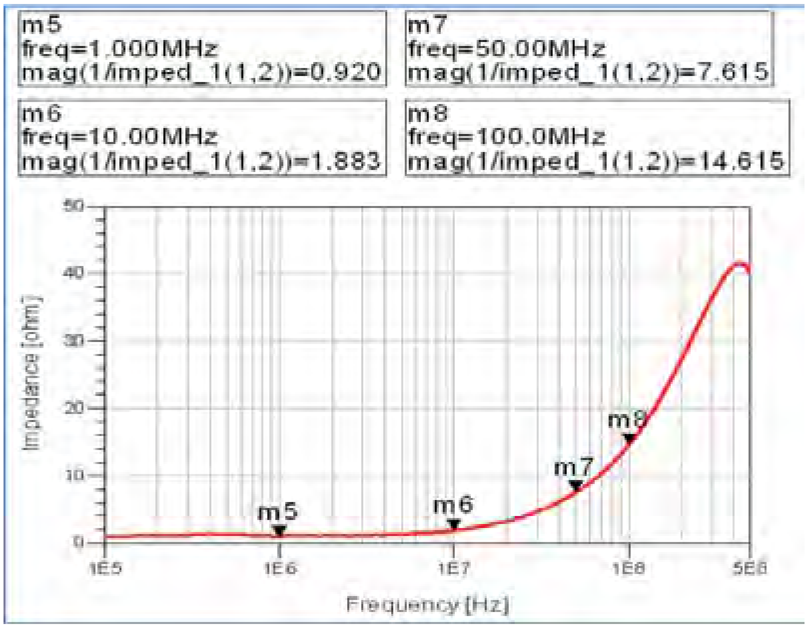
[1] Tr = 0.35/(BW in GHz)

[2] Calibrated with a short and remeasured with 50 ohm

[3] Calibrated with a short and measured 50 times with short on Iout

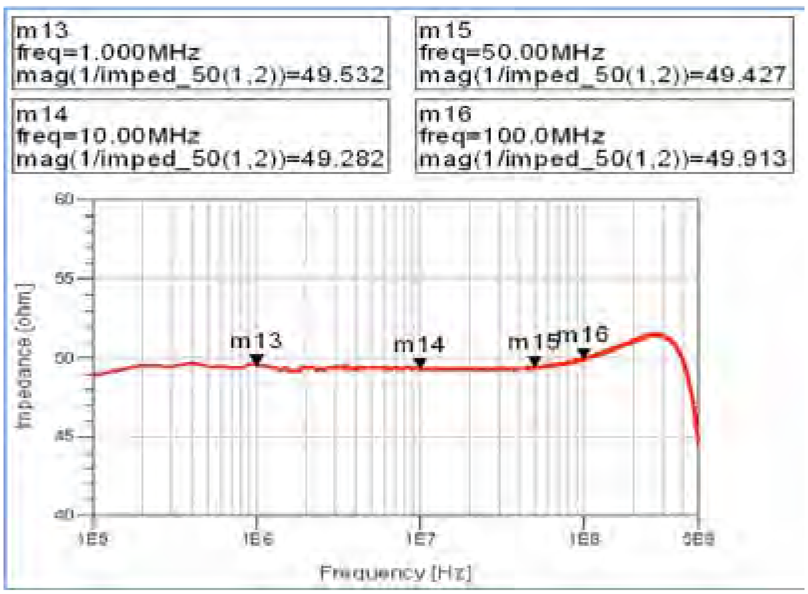
Typical Impedance Plots

AVCP-1

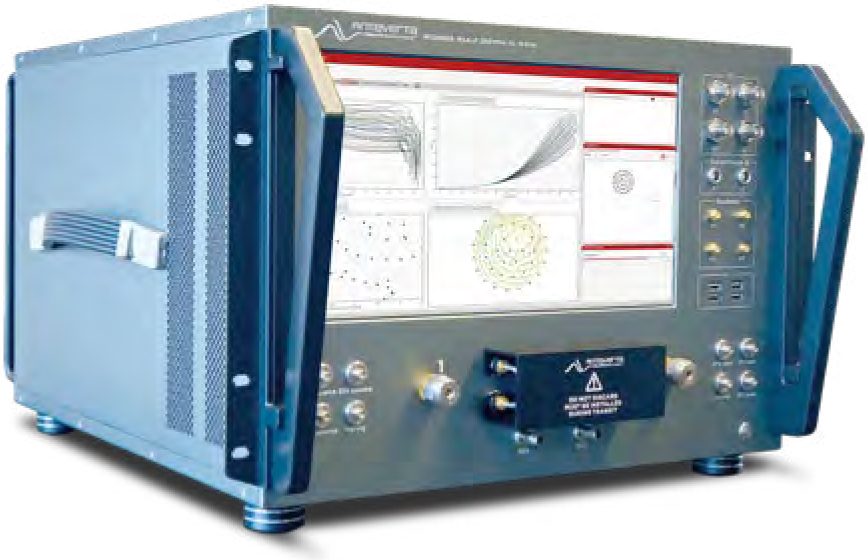


AVCP-10

AVCP-50



MT1000 and MT2000 – Mixed-Signal Active Load Pull System (1.0 MHz to 67.0 GHz) And MT2001 System Software



Powered by

Anteverta
a Maury Microwave company℠

U.S. Patent No. 8,456,175 B2
Several international patents also available

5G Wi Fi

Introduction

The MT1000 and MT2000 mixed-signal active load pull systems are the only commercially-proven solutions[1] capable of performing load pull at high speeds of up to 1000 impedance/power states per minute with no limitation on Smith Chart coverage, under the following conditions:

- Single-tone CW and pulsed-CW RF signal
- DC and pulsed-DC bias
- Time-domain NVNA voltage and current waveforms and load lines
- Fundamental and harmonic impedance control on the source and/or load
- Frequencies between 1 MHz and 67 GHz[2]

High-speed load pull with high magnitudes of reflection coefficients under the above conditions are ideal for:

- Reducing time-to-market due to quicker measurement speed
- Reducing bottlenecks caused by traditional passive mechanical load pull systems without a loss of accuracy
- Validating nonlinear compact models
- Extracting nonlinear behavioral models
- Research and development, design validation test, and on-wafer production test

In addition, the MT2000 is the only commercially-proven solution[1] capable of wideband impedance control of up to 1000 MHz bandwidth at the fundamental, harmonic and baseband frequencies[2] and is ideal for

- Using ACPR and EVM measurement data in the design of wideband PA circuits
- Improving PA linearity based on controlled baseband terminations
- Evaluating the performance of a DUT under realistic antenna load conditions
- Evaluating the performance of DUT under different matching network topologies

The MT1000 and MT2000 are turnkey one-box solutions that replace the functions typically performed by passive fundamental and/or harmonic impedance tuners, VNAs and/or NVNAs, analog signal generators, vector signal generators, vector signal analyzers and oscilloscopes, and add the capabilities of high-speed load pull measurements and wideband impedance control for modulated signals.

[1] as of the publish date of this document
[2] see Available Models on page 204

What is load pull?

Load Pull is the act of presenting a set of controlled impedances to a device under test (DUT) and measuring a set of parameters at each point. By varying the impedance, it is possible to fully characterize the performance of a DUT and use the data to:

> Verify simulation results of a transistor model (model validation)

> Gather characterization data for model extraction (behavioral model extraction)

> Design amplifier matching networks for optimum performance (amplifier design)

> Ensure a microwave circuit's ability to perform after being exposed to high mismatch conditions (ruggedness test)

> Confirm the stability or performance of a microwave circuit or consumer product under non-ideal VSWR conditions (stability/performance/conformance/antenna test)

Figure 1a—Example of load pull measurements with Output Power (Pout) contours plotted on a Smith Chart.

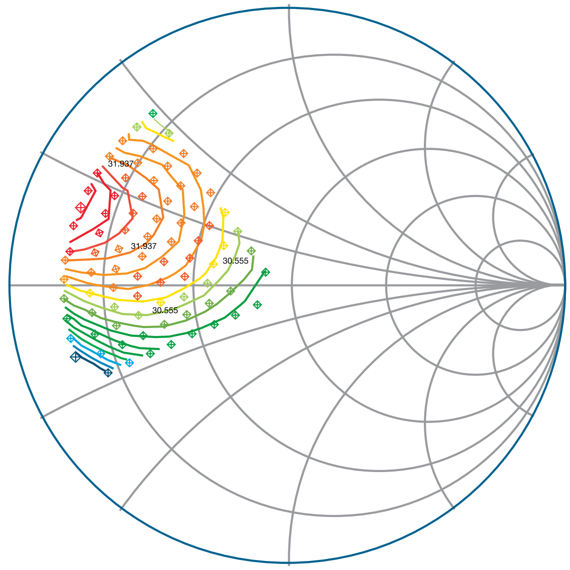


Figure 1b—Iso Pout Contours Measured @ 1.85 GHz

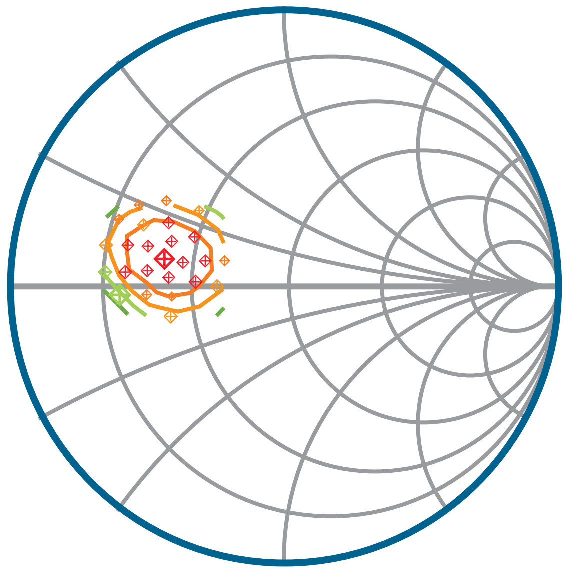
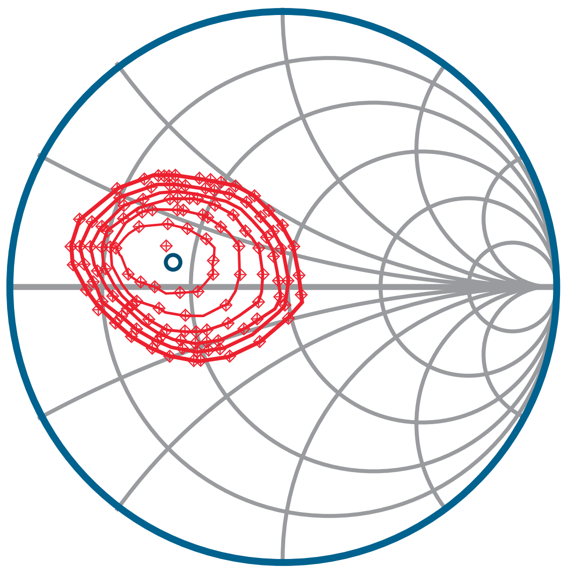


Figure 1c—Iso Pout Contours Simulated @ 1.85 GHz



Active Load Pull

In order to understand how the impedance presented to a DUT is varied, we must first consider the DUT as a two-port network shown in Figure 2.

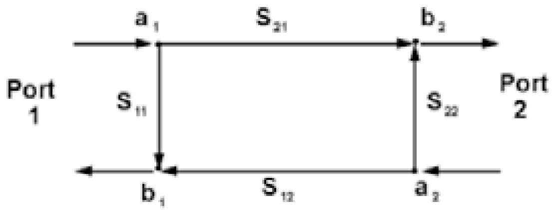


Figure 2. Two-port representation of DUT

The two-port network consists of four waves, a_1, b_1, b_2 and a_2.

- a_1 is the input signal which is injected into port 1 of the DUT
- b_1 is the input signal which is reflected from the input of the DUT due to the mismatch between the DUT's input impedance and the load impedance of the input network
- b_2 is the signal which emerges from port 2 of the DUT
- a_2 is the output signal which is reflected from the output of the DUT due to the mismatch between the DUT's output impedance and the load impedance of the output network

The magnitude of reflection presented to the DUT is calculated as $\Gamma_L = \frac{a2}{b2}$. The magnitude and phase of the reflection presented to the load of the DUT can be varied by changing the magnitude and phase of the signal a_2. In other words, any load impedance $Z = Z_0(\frac{1+\Gamma_L}{1-\Gamma_L})$ can be presented to the DUT as long as the signal a_2 can be achieved.

With regards to active load pull, the signal a_2 is a vector combination of the reflected portion of b_2 due to the mismatch between the DUT's output impedance and the load impedance of the output network, and a new signal created by a signal generator with magnitude and phase variability (referred to as an active tuning loop). An example block diagram of an active tuning loop is shown in Figure 3.

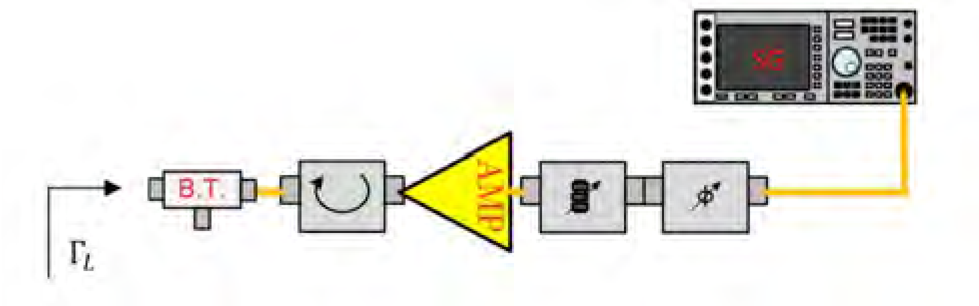


Figure 3. Output network of a simple active load pull setup

In order to perform active load pull, it is necessary to have a vector-receiver capable of accurately measuring the a- and b-waves, as well as signal generator(s) capable of generating output tuning signals.

Mixed-signal active load pull system architecture

A typical mixed-signal active load pull system architecture is shown in Figure 4. Signal analysis of the a1, b1, b2 and a2 waves is achieved by using mixers and local oscillators to down-convert the RF signal to baseband and processed using wideband analog-to-digital converters (ADCs). Signal synthesis of the input drive signal as well as the active tuning signals is achieved by generating signals at baseband frequencies using wideband arbitrary waveform generators (AWGs) and upconverting to RF using mixers and local oscillators.

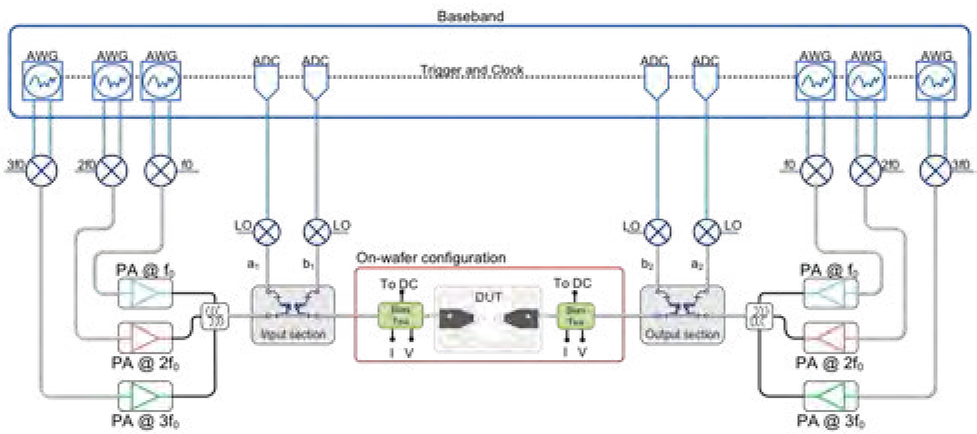


Figure 4 Typical Mixed Signal Active Load Pull System Architecture

A novel calibration and optimization technique correlates the user-desired RF signals at the DUT reference plane with the required baseband signals at the AWG reference plane. This robust technique takes into account the linear and nonlinear characteristics of the internal upconversion/downconversion paths as well as external components including driver amplifiers and bias tees.

Mixed-signal active load pull methodology

First, a wideband signal consisting of hundreds or thousands of frequency components over tens or hundreds of MHz is injected into the input of the DUT. This can be a user-defined signal or a modulated signal compliant to a reference test standard. When driven into nonlinear operating conditions, the resulting b_1 and b_2 waves may have signal distortion as well as baseband and harmonic components.

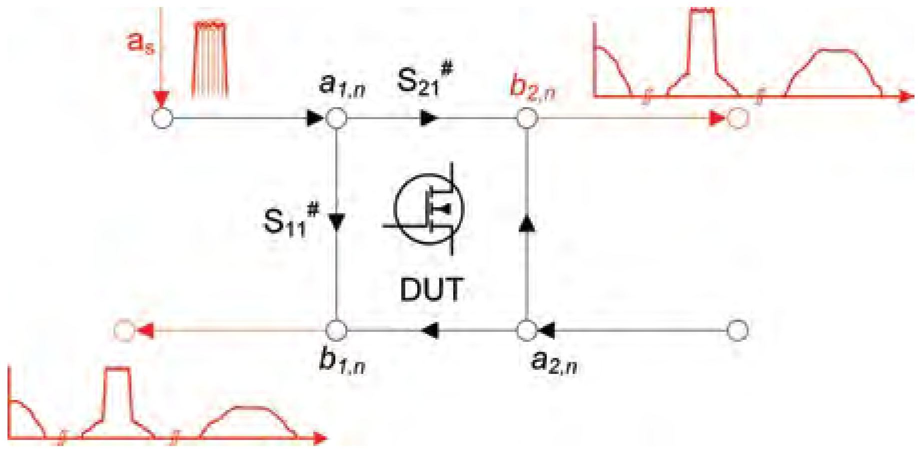


Figure 5 Injected as signal and resulting b_1 and b_2 waves

Second, the b_2 wave is measured at the DUT reference plane and the corresponding a_2 is calculated, generated and injected into the output of the DUT such that each frequency component of a_2 has a magnitude and phase that satisfies the user-desired $\Gamma_L = \frac{a2}{b2}$. Similarly, a second input signal a_1 can be superimposed on as to set the desired source impedances over frequency bandwidth.

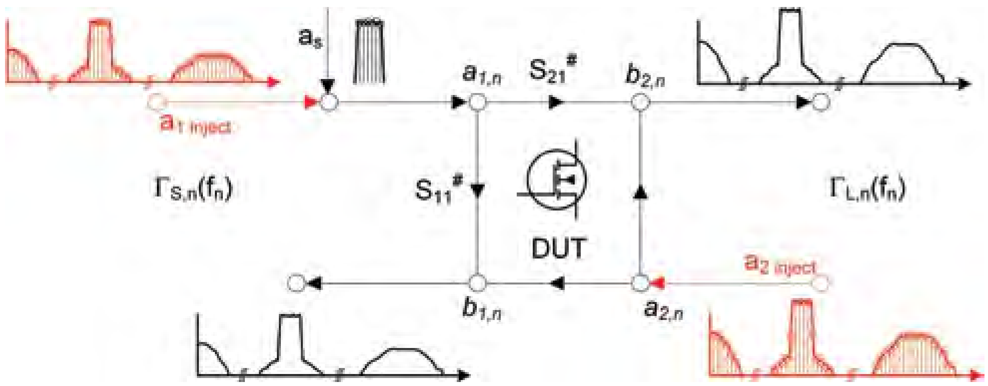


Figure 6 Active tuning a_1 and a_2 signals

Finally, the a- and b-waves are measured at the DUT reference plane, and the tuning signals a_2 and a_1 are modified to converge on the desired reflection coefficients Γ_L and Γ_S.

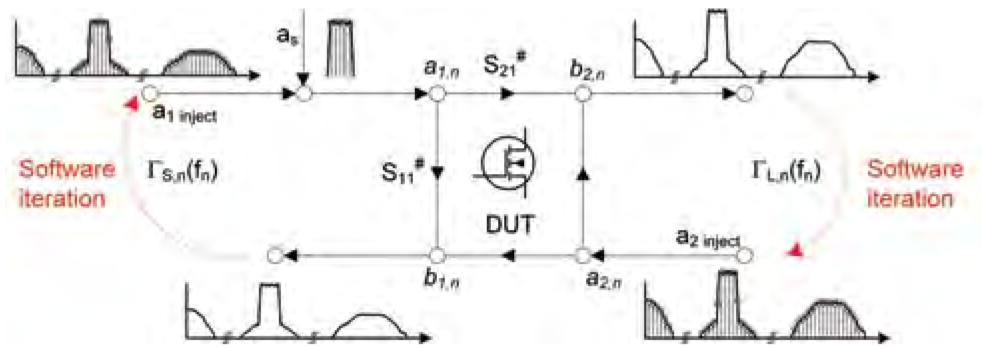


Figure 7 Software iteration of a_1 and a_2 to converge on desired impedances

Due to the use of wideband AWGs and wideband ADCs, it is possible to accurately set user-defined impedances over a bandwidth of hundreds or thousands of MHz (see page 8 for Available Models).

High Speed Single-Tone Active Load Pull Methodology

Wideband modulated signals vary in amplitude and phase over time, such that one repetition of a modulated signal may take 10 ms, as shown in Figure 8 for a LTE-A frame.

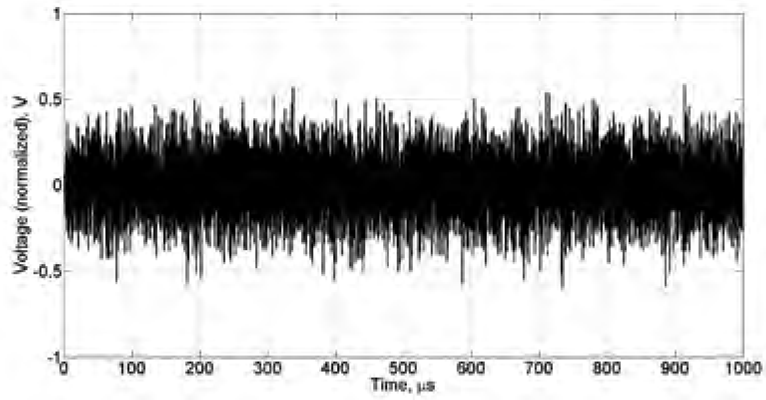


Figure 8 Time-domain representation of an LTE signal

Single-tone signals, on the other hand, can be generated in a much shorter time period, less than 100 us (depending on whether the signal is CW or pulsed-CW, and the pulse width and duty cycle of the pulsed signal). Therefore it is possible to stitch together multiple single-tone a_2 waveforms in order to create a modulated signal, as shown in Figures 9 and 10. The convergence algorithm will treat the stitched modulated waveform in the same manner as a realistic communications modulated signal, but instead of solving $\Gamma_L = \frac{a2}{b2}$ for the individual frequency components of a wideband, it will be solved for many sequential single-tone reflection coefficients. In the time it takes to set the reflection coefficient of a single repetition of a wideband modulated signal, tens or hundreds of single-tone signal impedances can be tuned.

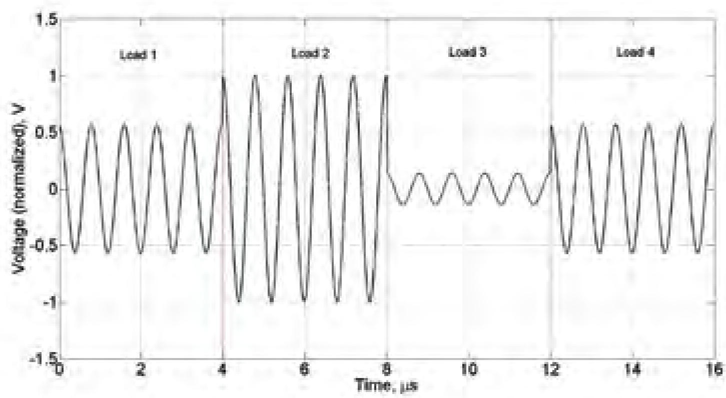


Figure 9 stitched modulated a_2 signal representing multiple single-tone CW reflection coefficients waveforms

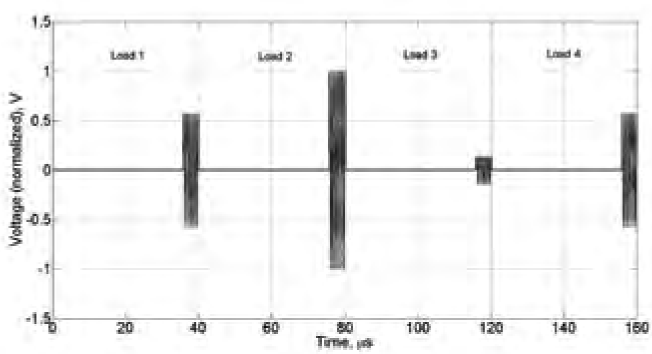


Figure 10 stitched modulated a_2 signal representing multiple single-tone pulsed-CW reflection coefficients waveforms

Available Models / Ordering Information Up To 18 GHz

Model	System RF Bandwidth (GHz)	Number of Active Tuning Loops	Modulation Bandwidth (MHz)	Power Handling CW/Pulsed CW (W)	Typical Detection Dynamic Range (dB)	Typical Active Load Dynamic Range (dB)	Minimum Pulse Width (ns)
MT1000HF2	0.03-2.0	2	N/A	50/500	80	60	2000
MT1000HF4		4					
MT2000HF2-100	0.001-2.0	2	100				200
MT2000HF2-200			200				
MT2000HF2-500			500				
MT2000HF4-100		4	100				
MT2000HF4-200			200				
MT2000HF4-500			500				
MT1000A2	0.2-6.0	2	N/A	100/1000			2000
MT2000A2-100			100				200
MT2000A2-200			200				
MT2000A2-500			500				
MT2000A2-1000			1000				
MT1000B2	0.2-18.0	2	N/A				2000
MT2000B2-100			100				200
MT2000B2-200			200				
MT2000B2-500			500				
MT2000B2-1000			1000				
MT1000B3		3	N/A				2000
MT2000B3-100			100				200
MT2000B3-200			200				
MT2000B3-500			500				
MT2000B3-1000			1000				
MT1000B4		4	N/A				2000
MT2000B4-100			100				200
MT2000B4-200			200				
MT2000B4-500			500				
MT2000B4-1000			1000				
MT1000B5		5	N/A				2000
MT2000B5-100			100				200
MT2000B5-200			200				
MT2000B5-500			500				
MT1000B6		6	N/A				2000
MT2000B6-100			100				200
MT2000B6-200			200				
MT2000B6-500			500				

Available Models / Ordering Information Up To 40 GHz

Model	System RF Bandwidth (GHz)	Number of Active Tuning Loops	Modulation Bandwidth (MHz)	Power Handling CW/Pulsed CW (W)	Typical Detection Dynamic Range (dB)	Typical Active Load Dynamic Range (dB)	Minimum Pulse Width (ns)
MT1000E2	0.7-40.0	2	N/A	20/200	80	60	2000
MT2000E2-100			100				200
MT2000E2-200			200				
MT2000E2-500			500				
MT2000E2-1000			1000				
MT1000E3		3	N/A				2000
MT2000E3-100			100				200
MT2000E3-200			200				
MT2000E3-500			500				
MT2000E3-1000			1000				
MT1000E4		4	N/A				2000
MT2000E4-100			100				200
MT2000E4-200			200				
MT2000E4-500			500				
MT2000E4-1000			1000				
MT1000E5		5	N/A				2000
MT2000E5-100			100				200
MT2000E5-200			200				
MT2000E5-500			500				
MT1000E6		6	N/A				2000
MT2000E6-100			100				200
MT2000E6-200			200				
MT2000E6-500			500				

Available Models / Ordering Information Up To 67 GHz

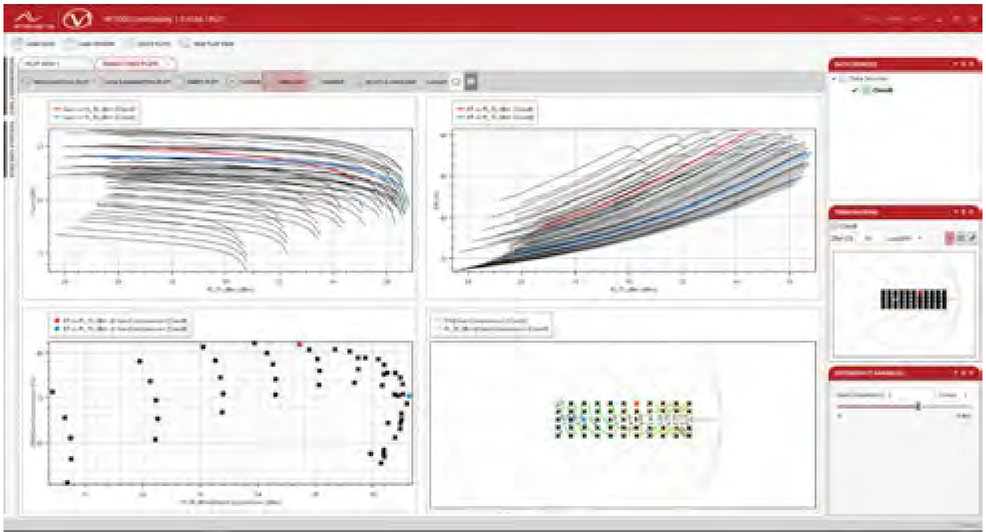
Model	System RF Bandwidth (GHz)	Number of Active Tuning Loops	Modulation Bandwidth (MHz)	Power Handling CW/Pulsed CW (W)	Typical Detection Dynamic Range (dB)	Typical Active Load Dynamic Range (dB)	Minimum Pulse Width (ns)
MT1000F2	0.7-67.0	2	N/A	20/200	80*	60	2000
MT2000F2-500			500				200
MT2000F2-1000			1000				
MT1000F4		4	N/A				2000
MT2000F4-500			500				200
MT2000F4-1000			1000				
MT1000F5		5	N/A				2000
MT2000F5-500			500				200
MT1000F6		6	N/A				2000
MT2000F6-500			500				200

** 70dB between 66-67 GHz*

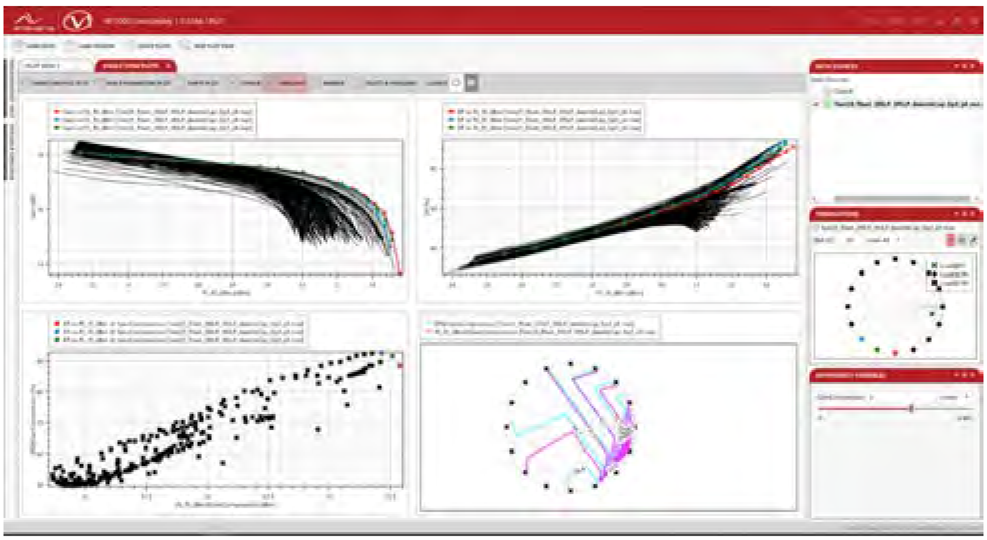
MT2001A Power Measurements

MT2001A is the core software of the MT2000 mixed-signal active load pull system and required for each system. It consists of the following capabilities:

- Fundamental-frequency impedance control at the input and output of the DUT
- Harmonic-frequency impedance control at the input and/or output of the DUT (requires MT2000 hardware with one active tuning loop for each harmonic frequency for each input/output desired)
- Standard single-tone CW and pulsed-CW load pull measurements with an average speed of one impedance state at one power in 1s-3s
- High speed "real-time" single-tone CW and pulsed-CW load pull measurements with an average speed of fifty impedance states at one power in 1s-3s
- Pulsed-bias load pull (requires pulsed power supply or pulse modulator)
- Power sweep / gain compression measurements with both standard and high-speed load impedance control
- Real-time measurement of DUT input and output impedance
- Advanced sweep plan for custom measurements of impedance, power, frequency, input voltage, output voltage
- DC and pulsed current and voltage measurements
- Chronogram / Pulsed configuration with trigger and measurement windows
- Automated impedance tuner control for optional mechanical pre-match for high power load pull measurements
- Probe station control (requires semi-automated probe station)
- CW and pulsed-CW S-parameters measurement
- Standard measurement parameters include Pout, Pin, Pavs, Gt, Gp, Eff, PAE, Vin, Vout, Iin, Iout, AM-AM, AM-PM; custom user-defined parameters



Fundamental-frequency high-speed load pull of 55 impedance states and power sweep at 16 power levels for a total of 880 measurement states in 3 minutes.

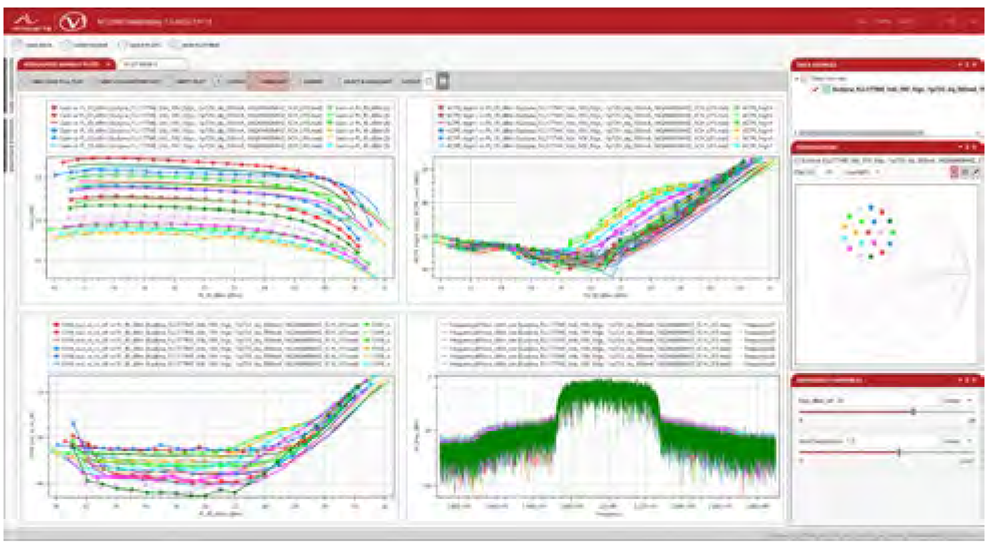


Harmonic-frequency high-speed load pull of 1 Fo impedance state, 16 2Fo impedance states, 16 3Fo impedance states and power sweep at 17 power levels for a total of 4352 measurement states in 15 minutes.

MT2001B Modulated Load Pull Measurements

MT2001B is an add-on option to MT2001A which enables wideband impedance control for modulated signals over the modulation bandwidth of the hardware (see Available Models / Ordering Information). In addition to the capabilities of MT2001A, MT2001B adds the following:

- Library of standard commercially available modulated signals
- Utility to define custom modulated signals
- Automatic signal pre-distortion to create a clean modulated signal at the DUT reference plane
- Wideband impedance control as follows
    - Ability to set all impedance over the modulated bandwidth at a single impedance point (i.e. all frequency components of an 80 MHz 5G signal should be tuned to 5Ω)
    - Ability to set user-defined phase delay of impedance vs frequency over the modulated bandwidth (i.e. a 0.1 degree/MHz phase delay resulting in an overall phase shift of 8 degrees on the Smith Chart for an 80 MHz 5G signal)
    - Ability to load S1P file (user-created, from circuit simulator…) defining impedance vs frequency over the modulated bandwidth. Ideal for evaluating realistic matching network designs (i.e. stub vs transmission line) and evaluating DUT performance under realistic antenna load response
- Vector signal analysis of modulated signals
- Adaptive averaging enhances measurement speed without sacrificing accuracy
- Import and export I and Q baseband waveforms for offline digital pre-distortion load pull (DPD)
- Standard measurement parameters include ACPR, EVM, spectral mask; custom parameters

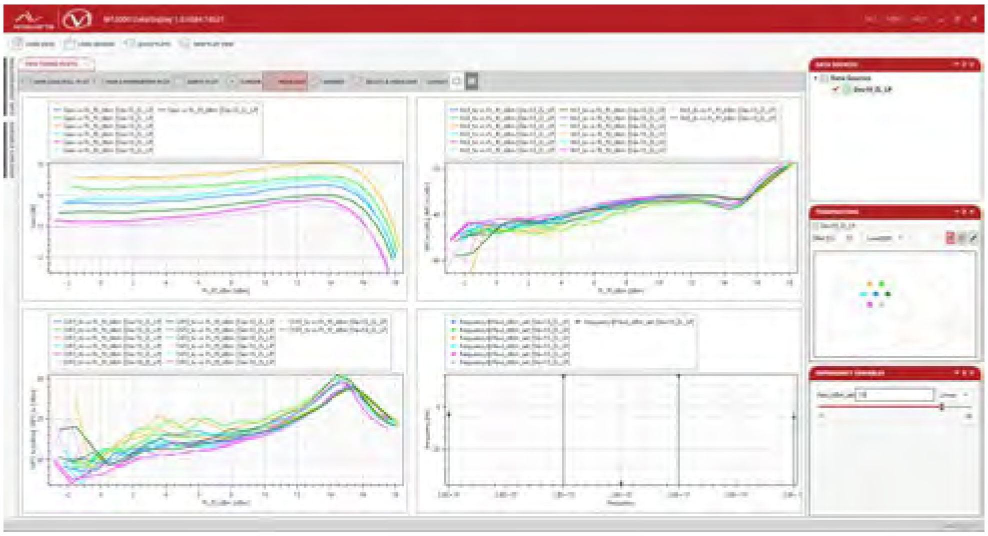


Fundamental-frequency modulated load pull of 20 impedance states and power sweep at 26 power levels, where all impedances over the modulated bandwidth of 200 MHz are set to a single impedance state.

MT2001C Two Tone Load Pull Measurements

MT2001C is an add-on option to MT2001A which enables impedance control for two-tone signals with tone spacing within the modulation bandwidth of the hardware (see Available Models / Ordering Information). In addition to the capabilities of MT2001A, MT2001C adds the following:

- Set tone spacing to user-defined values
- Sweep tone-spacing during load pull measurement
- Automatic signal pre-distortion to create a balanced two-tone signal at the DUT reference plane
- Adaptive averaging enhances measurement speed without sacrificing accuracy
- Standard measurement parameters include IMDx, OIPx; custom parameters



Fundamental-frequency two-tone load pull of 7 impedance states and power sweep at 26 power levels, with a tone spacing of 80 MHz.

MT2001D NVNA and Time-Domain Analysis

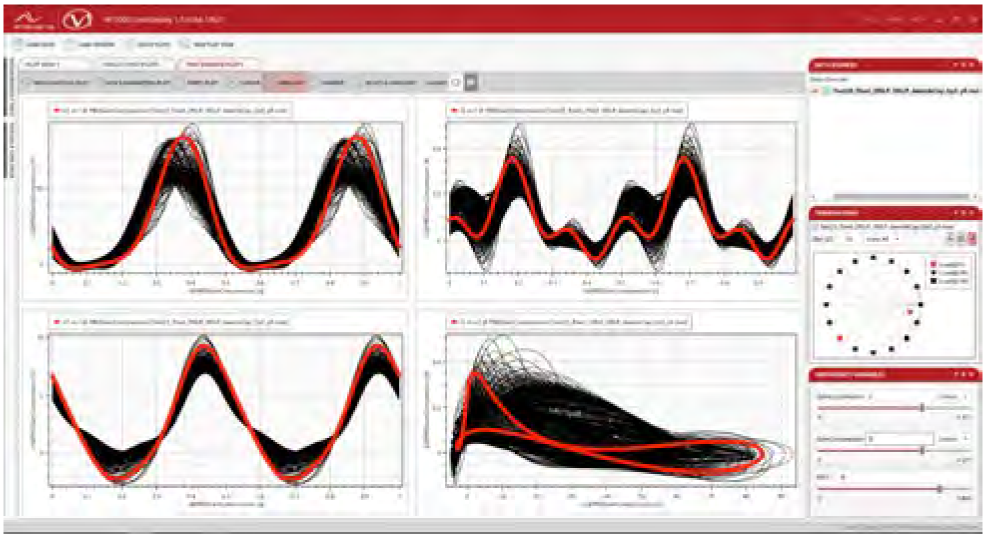
MT2001D is an add-on option to MT2001A which enables Nonlinear VNA (NVNA) time-domain analysis of voltage and current waveforms and load lines for single-tone CW and pulsed-CW signals. In addition to the capabilities of MT2001A, MT2001D adds the following:

> Automatically measure current and voltage waveforms and load lines

> Standard measurement parameters include V1(t), V2(t), I1(t), I2(t); custom parameters

It is important to note that the addition of NVNA time-domain measurements does not increase the overall measurement time and is compatible with both standard and high-speed load pull methodologies.

The MT1000/MT2000 hardware includes a tone-generator which acts as a harmonic phase reference (HPR). A single external harmonic phase reference or comb generator is required for system calibration.



Harmonic-frequency high-speed load pull of 1 Fo impedance state, 16 2Fo impedance states, 16 3Fo impedance states and power sweep at 17 power levels for a total of 4352 measurement states in 15 minutes, with the addition of NVNA time-domain voltage and current waveforms and load lines.

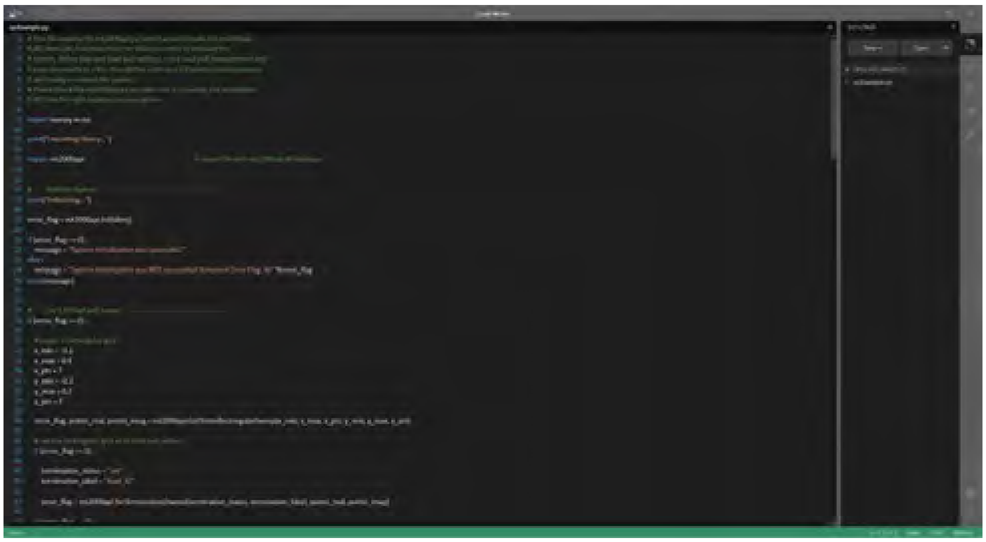
MT2001E External Control

MT2001E is an add-on option to MT2001A which enables external control of the MT2001A software through an API. MT2001E supports the following measurements:

- Single-tone CW measurements
- Single-tone pulsed-CW measurements
- S-parameters measurements

The MT2000 API library has the following functions and are fully documented in the MT2000 API user manual:

- MT2000Initialize
- MT2000Terminate
- MT2000SingleToneLoadPull_Pulsed
- MT2000SingleToneLoadPull_CW
- MT2000SetTerminationsSweep
- MT2000SetBiasSettings
- MT2000SetBiasSearch



Python example of a script calling MT2000 API

MT2001F Visualization and Analysis

MT2001F is standalone software option which enables the visualization and analysis of measurement data taken from MT2001A, MT2001B, MT2001C, MT2001D and MT2001G modules. MT2001F has the following capabilities:

S-Parameters

> Plot S-parameters in standard and custom formats including log magnitude, linear magnitude, phase, polar, Smith Chart

> Overlay multiple S-parameters data sets

Load Pull

> Plot load pull contours on the Smith Chart

> Plot load pull parameters on XY graphs

> Plot power sweep / gain compression curves on XY graphs

> Plot time-domain load pull contours and graphs

> Plot contours and graphs based on dependency parameters (i.e. PAE vs Pout at a fixed gain compression)

> Interconnected plots allow inputs on one plot to executed on all plots (i.e. selecting an impedance on one plot will show the corresponding measurement results for that impedance on all plots)

> Overlay multiple load pull measurement data sets

Export

> Export measurement data in MAT, SPL, CSV, MDF and XLS formats

> Export plots in JPG and PNG graphic formats

Templates

> Save/recall customized visualization plots/graphs, associated parameters and markers

> Save/recall layout for multiple plots/graphs on a single report

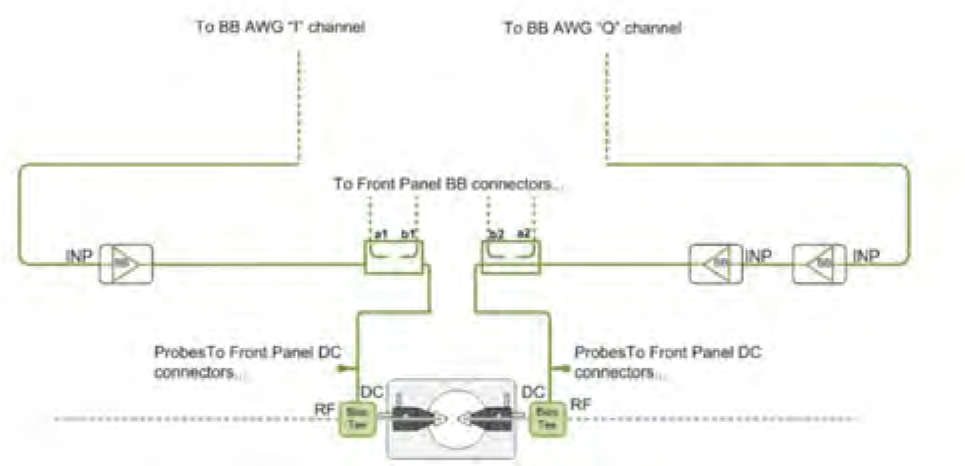
MT2001G Baseband Impedance Control

MT2001G is an add-on option to MT2001B and MT2001C which enables baseband impedance control, which may improve linearity resulting in better IMx and ACPR performance. In addition to the capabilities of MT2001B and MT2001C, MT2001G adds the following:

> Controls impedances at baseband frequencies caused by mixing product of two-tone or modulated signals

> Source and load baseband impedance control

In addition to the MT2000 hardware, external baseband drive amplifiers are required and are selected based on user-required voltages and currents (i.e. ADA4870 baseband amplifier to meet requirements of V=40V, I=1A, BW=80 MHz).



Block diagram of baseband impedance control hardware configuration

Recommended Reading

The following literature is recommended for those who wish to learn more about the MT1000 and MT2000 – Mixed-Signal Active Load Pull System (1.0 MHz to 40.0 GHz) And MT2001 System Software it supports.

5A-044 – Active Harmonic Load Pull with Realistic Wideband Communications Signals.

Abstract – A new wideband open-loop active harmonic load–pull measurement approach is presented. The proposed method is based on wideband data-acquisition and wideband signal-injection of the incident and device generated power waves at the frequencies of interest. The system provides full, user defined, in-band control of the source and load reflection coefficients presented to the device-under-test at baseband, fundamental and harmonic frequencies. The system's capability to completely eliminate electrical delay allows it to mimic realistic matching networks using their measured or simulated frequency response. This feature enables active devices to be evaluated for their actual in-circuit behavior, even on wafer. Moreover the proposed setup provides the unique feature of handling realistic wideband communication signals like multi-carrier wideband code division multiple access (W-CDMA), making the setup perfectly suited for studying device performance in terms of efficiency, linearity and memory effects.

In this work we describe the hardware and signal conditioning of the proposed setup. The high dynamic range, bandwidth and measurement speed of the system, together with its capability to engineer the large-signal operation of an active device, are demonstrated by measuring the improved RF performance of a multi-carrier W-CDMA driven laterally diffused metal–oxide–semiconductor device when the electrical delay in the setup is canceled.

5A-045 – Active Harmonic Load Pull for On-Wafer Out-of-Band Device Linearity Optimization.

Abstract – In this paper,we present an active harmonic load–pull system especially developed for the on-wafer linearity characterization/optimization of active devices with wideband modulated signals using the out-of-band linearization technique. Our setup provides independent control of the impedances at the baseband, fundamental, and second-harmonic frequencies presented to the input and output of the device under test. Furthermore, to enable realistic test conditions with wideband-modulated signals, the electrical delays in the load–pull system are kept as small as possible by implementing a novel loop architecture with in-phase quadrature modulators. We have achieved a phase variation of the reflection coefficient of only 5°/MHz for both the fundamental and second-harmonic frequencies.

We demonstrate the high potential of the system for the on-wafer evaluation of new technology generations by applying out-of-band linearization to heterojunction bipolar transistor (HBT) and laterally diffused metal–oxide–semiconductor (LDMOS) devices. For the HBT, we outline a game plan to obtain the optimum efficiency–linearity tradeoff. Finally, a record-high efficiency–linearity tradeoff was achieved (without digital predistortion) for an inverse class-AB operated Philips Gen 6 LDMOS device, yielding 44% efficiency at an adjacent channel power level of 245 dBc at 2.14 GHz for an IS-95 signal.

5A-046 – A Mixed-Signal Approach for High-Speed Fully Controlled Multidimensional Load Pull Parameters Sweep.

Abstract – A mixed-signal approach for “real-time”, fully controlled, load-pull parameters sweeps is presented. The proposed approach permits high-speed sweeping of any combination of parameters, e.g. input power and fundamental and/or harmonic source or load termination, enabling at the same time full control of all other source and load terminations provided to the device-under-test. Using this method, a very efficient tool is created for high-speed large-signal device characterization, which can mimic realistic circuit conditions not only for singletone signals, but also for wide-band complex modulated signals. The capabilities of the realized system are demonstrated by characterizing a NXP Gen 6 LDMOS device.

5A-047 – Base-Band Impedance Control and Calibration for On-Wafer Linearity measurements

Abstract – This paper introduces a direct and accurate method for controlling and measuring the on-wafer device terminations at the base-band / envelope frequency, using an extension of a conventional network analyzer setup. The base-band impedance can be adjusted manually as well as electronically and is able to (over)_compensate the losses in the measurement setup. This facilitates on-wafer base-band terminations ranging from negative to high Ohmic values. The proposed measurement techniques are particularly useful when characterizing active devices for their linearity.

5A-048 – A Mixed-Signal Load Pull System for Base-Station Applications

Abstract – The capabilities of active load-pull are extended to be compatible with the characterization requirements of high-power basestation applications. The proposed measurement setup provides ultra-fast high-power device characterization for both CW, as well as, pulsed, duty-cycle controlled, operation. The realized system has the unique feature that it can handle realistic complex modulated signals like WCDMA with absolute control of their reflection coefficients vs. frequency.

5C-087 – Active Load Pull Surpasses 500 Watts!

Pulsed IV Systems

AM3200 SERIE 3

AMCAD Engineering
Advanced Modeling for Computer-Aided Design

Systems category: Standard

> Compact and efficient design
> Embedded power supplies
> Flexible and upgradable
> Unrivaled measurement resolution and accuracy
> High reliability pulse generators
> Driven by IVCAD Software

Main Features

> Reliable pulsers with long lasting performances (thermal, SOA and DUT breakdown protections)
> Pulsed or DC operation, pulse width down to 200ns from the generators
> Internal or external synchronization
> Extended stop conditions and built-in protection
> Mix-and-match input and output pulsers
> Connect systems in series for synchronizing 3+ pulsed channels
> Long pulses into the tens of seconds for trapping and thermal characterization
> Direct hardware programmability

System Description

This Pulse IV system is used to bias transistors in quasi-isothermal conditions, it enables accurate compact modeling activities.

Pulser Safe Operating Area

Emergency stop when the operating point exceeds design limits: Ip, Irms, Idc (pulsed, RMS and DC current), Vdc (pulser input voltage, drain pulser only), Pmax (DC power), Fmax (switching frequency), Temperature.

Current Breaker

Programmable thresholds: pulse current and power, quiescent current and power, transient current.

Measurement Sampling Time

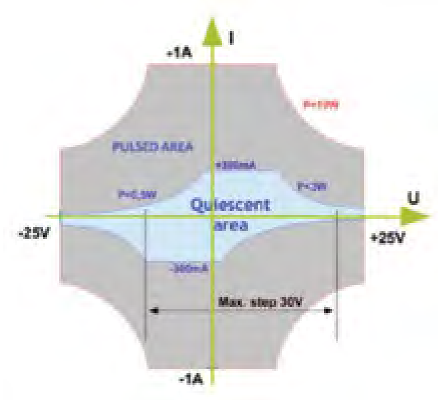
Fully programmable, 20ns resolution, External synchronization Mtrig & Rfpulse.

Modularity

The standard system works with two pulse generators and one control box. External signals permit to combine and synchronize several control boxes (4, 6, 8…).

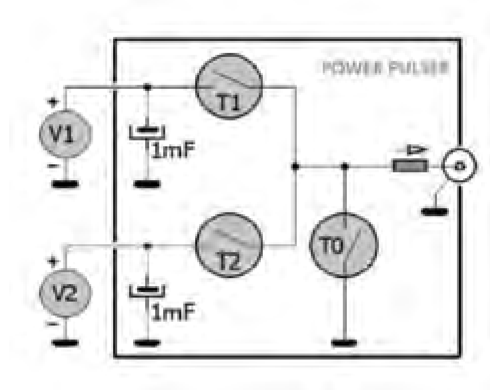
AM3211 Bipolar Probe +/-25V +/-1A

The AM3211 is a low noise floating pulse generator dedicated to bias the transistor gate, optimized to drive quickly and safely all the transistors (RF Devices, MOSFET).



AM3221 Probe +250V +30A

The AM3221 probe is a power probe dedicated to bias the transistor drain, optimized for high power pulsed measurements.



Control Box AM3200 System

Pulsers	AM3211	AM3221
Purpose	Gate	Drain

Operating Range

Switched voltage levels	2	2
Voltage	±25V	+250V
Pulsed current	±1A	+30A
DC & RMS Current	300mA	5A
DC power	3W	100W

Source Performance

Voltage setting resolution	16bit	18bit
Output impedance	I ≤ 0.1mA: 204Ω / I > 0.1mA: 14.5Ω	I ≤ 0.3A: 2Ω / I > 0.3A: 0,4Ω

Pulse Timing

Rise Time (10% - 90%) Fall Time (10% - 90%)	Fast: 33ns[1] (typ. Value) Fast: 32ns[1] (typ. Value)	Fast: 20ns[2] (typ. Value) Fast: 22ns[2] (typ. Value)
Pulse timing	Resolution: 20ns, Width: 200ns to DC (Power limits)	
Fmax	500kHz	

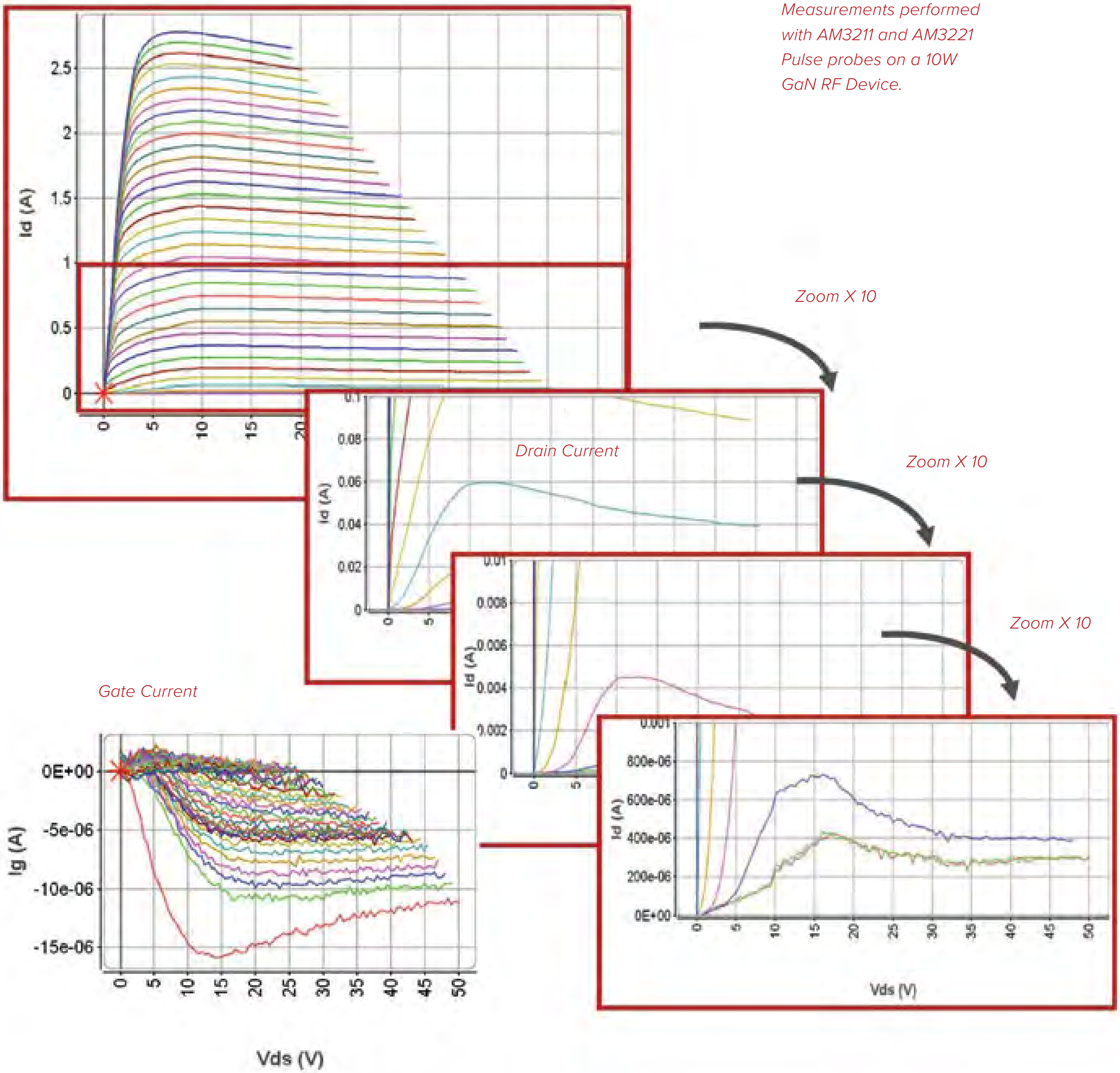
Measurement Performance

V range	25V	250V/5V
I range	1A/10mA/0,1mA	30A/3A/0,3A
V & I ADC resolution	16bit	16bit
Noise free resolution (average filter 128 samples, at 0 voltage and current)	0,5mV	3mV/0,25mV
	30µA/3µA/0,3µA	0,3mA/0,13mA/10µA
Settling time	300ns	300ns
Bandwidth (greatest range)	10MHz	10MHz
Output connector	D-SUB15	2 BNC

[1] *AM3211, speed: fast, no load, 5V step*
[2] *AM3221, speed: fast, no load, 100V step*

Ultimate Measurement Speed and Performances

Measurements performed with AM3211 and AM3221 Pulse probes on a 10W GaN RF Device.



AMCAD Engineering
Advanced Modeling for Computer-Aided Design

System Specifications

Warranty

Any AMCAD product comes with a two-year parts and labour warranty, when returned to our workshops. A phone support service is also available for the same period.

At the end of the initial two-year period, a further contract can be subscribed, including:

> a preventive functional check and calibration of the modules (on site or in our workshop)

> a further two-year warranty period

Quality Regulations & Environment

The PIV System and all modules are compliant to the applicable European directive and hold the CE mark.

> ISO/CEI 17025 compliant calibration for any DC source or measurement module, calibration certificate provided.

> Serial number based life cycle management

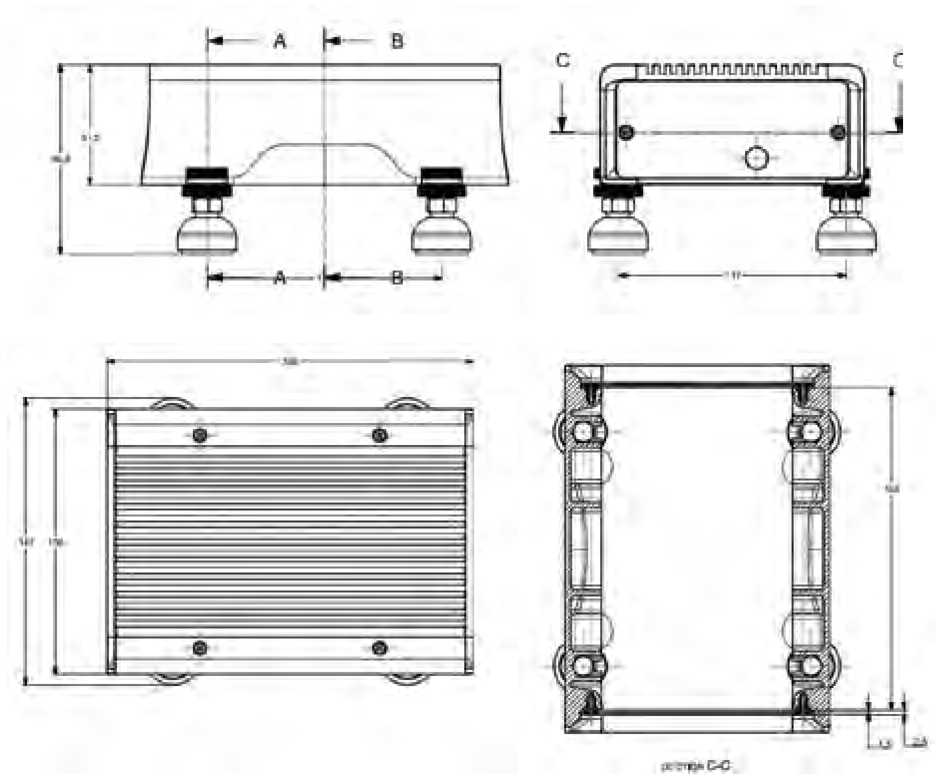
> All products are 100% tested (test reports on demand)

> AMCAD only uses RoHS compliant components and does not use substances banned by the COSHH regulation.

> AMCAD complies with the relevant national regulations related to the safety and health of its employees against hazardous substances.

> The protection degree of the PIV system is IP20 according to CEI 60529.

Probe dimensions (mm)



Pulsed IV Systems

AM3100 SERIE 3

Systems category: Standard

- Compact and efficient design
- Embedded power supplies
- Cost effective pulsed DC supply and measurement solution
- Synchronization capabilities for multiple instrument measurements
- Driven by IVCAD and IQSTAR Software

AM3100 used for pulsed bias of Power Amplifiers

Main Features

- Reliable pulse units with long lasting performances (thermal, SOA and DUT breakdown protections)
- Pulse or DC operation with pulse width down to 1us from the generator and for measurements
- Internal and externalsynchronization
- Extended stop conditions and built-in protection
- Direct hardware programmability (SCPI commands)
- Embedded measurement units providing wide bandwidth and high accuracy for simultaneous current and voltage measurements
- Embedded fast short-circuit current breaker, performing the protection of the external pulse unit as well as external components such as Bias Tees
- Remote control through LAN or USB
- Compatible with IVCAD and IQSTAR Software's

System Description

The AM3100 is a standalone Pulsed IV system for Pulse Load Pull and general-purpose test pulsed applications. AM3100 PIV systems are used to bias transistors or circuits in pulsed conditions to avoid self-heating and ensure quasi-isothermal conditions during the measurements.

Pulsed DC and RF Load Pull bench architecture

Power amplifiers are often driven by pulsed RF signal combined with continuous or pulsed DC bias conditions. This brings some complexity to the bench configuration. Indeed, even when continuous DC voltages supplies are used, the pulsed RF signal magnitude will drive the transistor consumption in pulsed mode also, if the PA operates in saturated area.

In order to measure the peak current to evaluate the peak efficiency, there is a need for synchronized pulsed IV and pulsed RF measurements.

In term of measurement speed and system integration, the AM3100 PIV system will replace advantageously complex measurement architectures made of DC multimeters or external oscilloscope combined with external DC supplies.

AM3111 Pulse SMU +/-25V +/-0.2A

Embedded inside the AM3103 Main controller, the Gate Pulse SMU presents the following characteristics:

> 4-quadrant DC or Pulse voltage source.

> Down to 1µs pulse width, 20ns time resolution.

> Simultaneous voltage and current sampling.

> Pulse and Quiescent level sampling time points can be chosen automatically by the source or manually by the user.

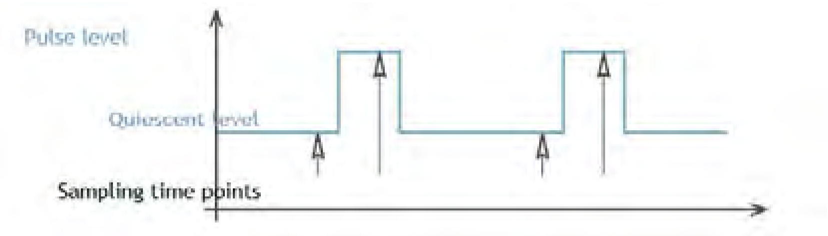
> 1 voltage range: ±25V

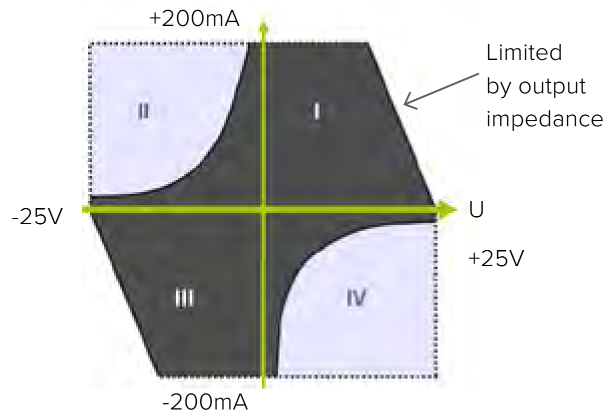
> 2 current ranges: ±5mA and ±200mA

> No transient when powering on/off or switching on/off

> Output on isolated BNC connector

> Operating range: DC: Gray area, Pulse: Gray + Lilas areas





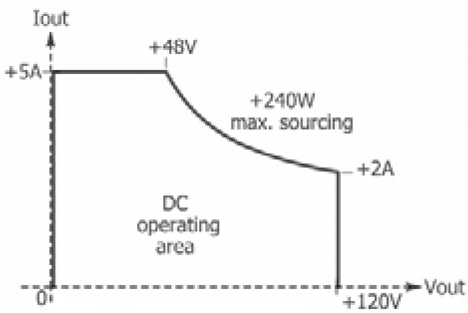
Parameters	Conditions/Comments	Min	Max
Voltage prgramming range		-25V	25V
Output current	Guaranteed: source stops if +/-260mA is exceeded	-200mA	200mA
Output power	Source, DC		3W
	Sink, DC		0.5W
Pulse	Width	1.1 µs	10s
	Frequency	0.1Hz	200KHz
	Duty cycle	0%	100%
Temperature	Ambient temperature in front of the chassis rear opennings	10°C	30°C

AM3121 Pulse SMU +120V +30A

The AM3121 Pulse SMU is a power probe dedicated to bias the transistor drain (Positive voltages). Optimized for high power pulsed measurements applications (120V, 30A), this probe head embed a current breaker and can be used either for Load Pull applications or general-purpose pulsed SMU.

The Strig signal performs overall synchronization of start, stop, and emergency stop.

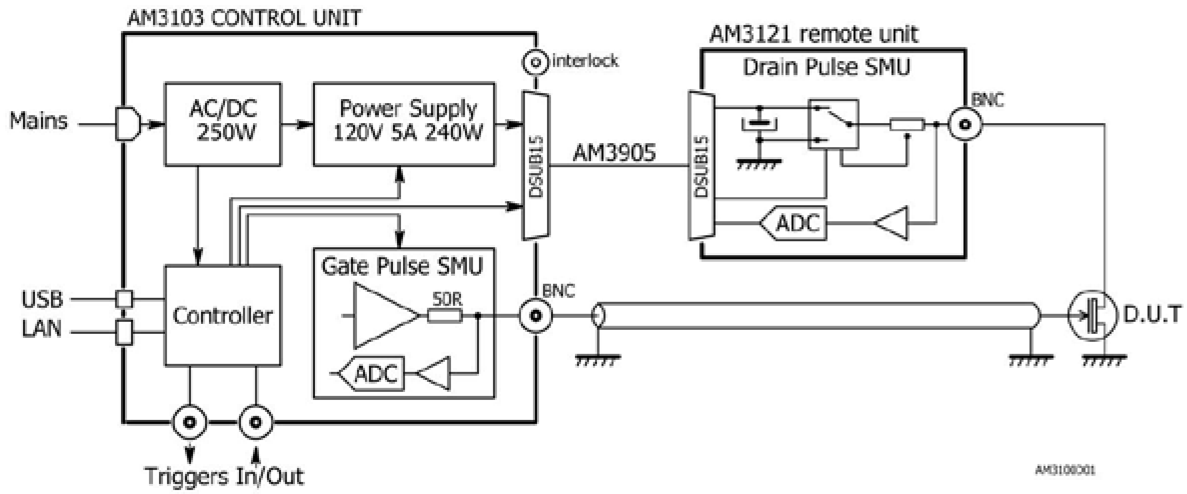
Using either constant level or pulsed mode, the Ptrig signal performs overall synchronization of the power pulse, the measurement sampling time and the transient mask.

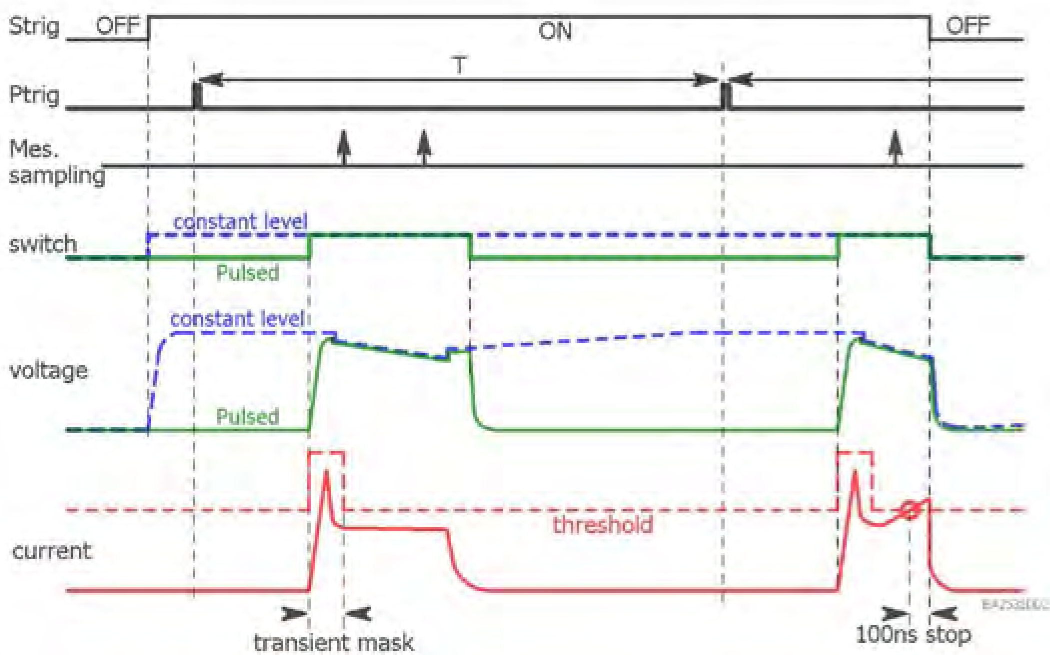


- Isolated DC voltage source
- Fast toggling current and power limitation
- 2-quadrant, source & sink operating area
- 18-bit voltage programming, no missing code
- Safe charging and discharging of any load capacitor
- Programmable voltage slope
- No transient when powering on/off

Parameters	Conditions	Value
Input voltage		120V
Pulsed current		30A
Average current		5A
RMS current		10A
Pulsed current		3000W
DC power		220W
Earth isolation	Between power gnd. and earth	220kΩ 120V

System Schematic and measurements specifications





AM3111 Measurement specifications

Parameters	Conditions/Comments	25V Range	200mA Range	5mA
ADC resolution	15-bit	0.9mV	7µs	170nA
Noise		+/-2mV	+/-30µs	+/-5µs
Setting time	To 95% To ADC resolution	0.5µs 2µs	0.5µs 2µs	1µs 4µs
Absolute accuracy	Offset + % reading, 2-year	7.5mV + 0.1%	100µs + 0.2%	10µs + 0.2%

AM3121 Measurement specifications

Parameters	Conditions/Comments	Voltage	Current
Measurement range		125V	33A
ADC resolution	16 bits	2.1mV	550µs
Setting time	To 95% To ADC resolution	0.5µs 2µs	0.5µs 2µs
Noise		+/-15mV	+/-2mA
Absolute accuracy	Offset + gain	20mV + 0.1%	20mA + 0.3%

AM3100 Pulse Timing definition

Parameters	Conditions/Comments	Spec	Min	Max
Time jitter	Ptrig to any output			+/-2.5ns
Minimum time delay from ptrig	Fixed delay ptrig to any output	200ns	190ns	210ns
Time delay calibration error	Parameter isnide each pulse	+/-10ns		
Time resolution	Delay and duration counting	20ns		
Pulses duration setting range			1µs	10s
Pulses delay setting range			1µs	10s
Sample clock delay setting range			-1µs	10s
Internal ptrig range	Period (timer resolution 1µs) Frequency		5µs 200KHz	10s 0.1Hz

Warranty

Any AMCAD product comes with a two-year parts and labour warranty, when returned to our workshops. A phone support service is also available for the same period. At the end of the initial two-year period, a further contract can be subscribed, including:

> • a preventive functional check and calibration of the modules (on site or in our workshop)

> • a further two-year warranty period

Quality Regulations & Environment

The PIV System and all modules are compliant to the applicable European directive and hold the CE mark.

> ISO/CEI 17025 compliant calibration for any DC source or measurement module, calibration certificate provided.

> Serial number based life cycle management

> All products are 100% tested (test reports on demand)

> AMCAD only uses RoHS compliant components and does not use substances banned by the COSHH regulation.

> AMCAD complies with the relevant national regulations related to the safety and health of its employees against hazardous substances.

> The protection degree of the PIV system is IP20 according to CEI 60529.

RF Device Characterization System Integration

FULLY INTEGRATED COAXIAL AND MILLIMETER-WAVE DEVICE CHARACTERIZATION SYSTEMS, 250 MHZ TO 110 GHZ

Features

> Power and noise parameter measurements

> Packaged and On-Wafer measurements

> Modulated, pulsed and CW signals

> Automated in-situ calibration

> Fewer connections

> Reliable and fast RF switching

> Saves time and money

> Turnkey systems available – Works "out of the box"

MT900N Series Fully Integrated 2.4mm 50 GHz LSNA Measurement System.

Description

Maury's mission is to meet its customers' device characterization needs regardless of the level of complexity. Maury has and continues to provide solutions covering the entire measurement spectrum; from the simplest stand-alone tuner to fully integrated turnkey systems.

Integrated systems are offered between 250 MHz and 110 GHz, in-fixture and on-wafer, and are capable of measuring the following:

> S-Parameters

> X-Parameters

> DC-IV and Pulsed-IV measurements

> Power Measurements: Pout, Pin-delivered, Gain, Compression, Efficiency, Harmonic Powers...

> Multi-Tone Measurements: IMD, TOI...

> Modulated Measurements: ACPR, EVM, CCDF...

> Noise Parameters: NFmin, Γopt, Rn, Noise and Gain contours

> Time-domain Analysis: a-b waves, I-V waves, load lines...

> Thermal Microscopic load pull

Maury will integrate these features into an easily assembled and calibrated system that is straightforward to use, saving time as well as money. Furthermore, the results will display greater accuracy and repeatability. Less time and less money means a more profitable design cycle.

In-situ Calibration

The power of a Maury integrated system begins with its proprietary in-situ calibration method, which allows for a complete system-level calibration without disconnecting any of the core system components. The majority of calibration and measurement errors occur for the following reasons; multiple VNA calibrations with improper reference-plane shifting, probes that are connected/disconnected multiple times or measured on their own, and multiple small measurement errors that cascade into very large errors. Unlike the above situations, in-situ calibration requires only one single connection, makes use of highly-repeatable and reliable RF switches and automates the calibration procedure through the use of a graphic wizard. Overall system level verification procedures built into the ATS software result in average deltaGT values of less than 0.2 dB at all magnitudes and phases, when performing an in-situ calibration.

Turnkey Measurement Systems

Maury works very closely with instrument and component manufacturers to offer complete turnkey noise parameters as well as large-signal test systems for both on-wafer and packaged device measurements. Recognized as the global leader in microwave and millimeter-wave tuners and DC systems, Maury has partnered with numerous multinational companies who are also leaders in their respective fields. Examples include Keysight Technologies for RF Instruments (Network Analyzers, Spectrum Analyzers, Power meters, Power supplies), Cascade Microtech (on-wafer probe stations, probes and positioners), Intercontinental Microwave (test fixtures and jigs), Quantum Focus Instruments (Thermal IR cameras), Auriga Measurement Systems (Pulsed IV), as well as component and cabling manufacturers. Turnkey measurement systems are available for sign-off and acceptance at Maury's corporate office.

MT900-series integrated on-wafer millimeter-wave s-parameters, noise parameters and load pull system, including swept two-tone measurements.

MT900-series integrated on-wafer millimeter-wave s-parameters, noise parameters and load pull measurement system.