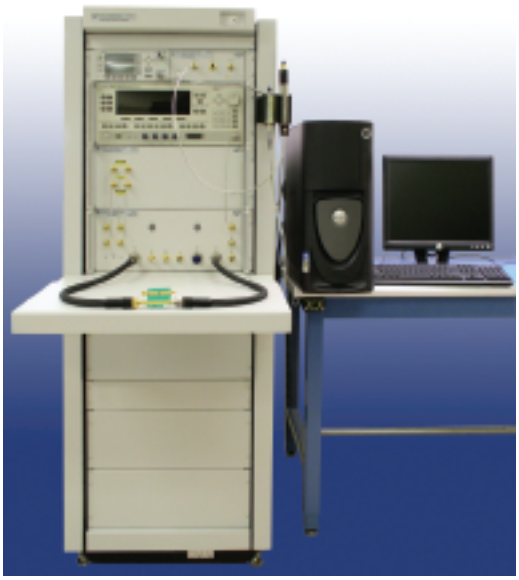

A Network Analyzer for Complete Active Component Characterization and Real-time Harmonic Load Pull

Proper understanding of the nonlinear behavior of transistors, RFICs, power amplifier modules, mixers and other components has become a competitive advantage in the success of the design cycle of almost any system. The cost/performance trade off has forced designers to abandon the comfortable habit of designing for linearity.

Facing the design and test problems of today that involve nonlinear behavior, the use of VNAs is increasingly being enhanced by spectrum analyzer and vector signal analyzer measurements, and the use of high frequency oscilloscopes. To properly characterize and understand active HF components eliminating the assumptions and guesses with existing approaches, one needs to simultaneously measure the voltages and currents at all ports of the component under the excitation of realistic signals and impedances (see ***Figure 1***).

This article presents a model MT4463 network analyzer that overcomes these shortcomings and enables the complete characterization of active components under large-signal conditions.

For researchers and R&D engineers the analyzer gives unprecedented characterization capabilities, going from S-parameters to a complete voltage-current picture under tuning conditions with periodic modulation and periodic switching signals without reconnection of the component. For power amplifier (PA) designers it is now possible to perform

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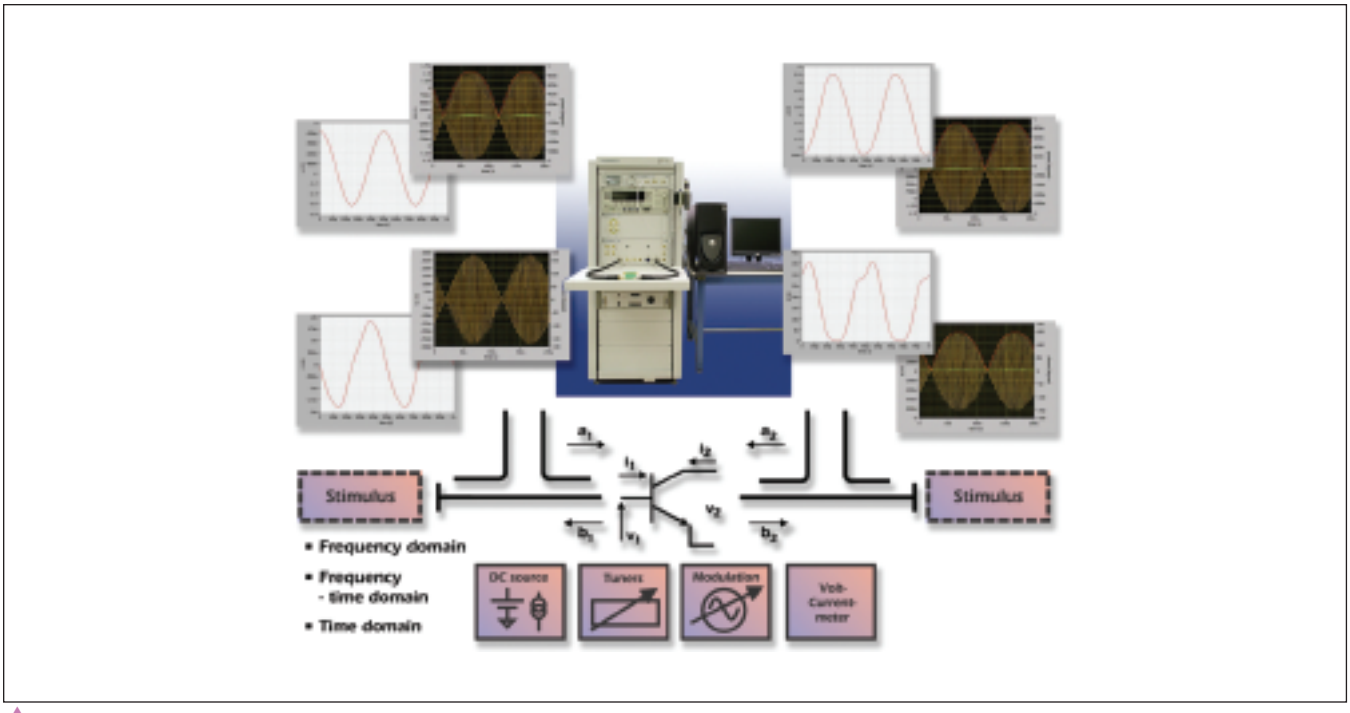

Fig. 1 Measuring voltage/current or incident/reflected waves in the component planes under realistic conditions.

load-pull characterization in a matter of seconds, while both fundamental and harmonics effects are taken into account. This instrument brings real-time power amplifier characterization to reality.

FROM S-PARAMETERS TO COMPLETE LARGE-SIGNAL CHARACTERIZATION

The MT4463 is controlled through a graphical user interface. It is possible to collect the measurements in tools such as LabView and Matlab using the callable DLL. On top of this, a powerful scripting language, provided through Mathematica, makes the possibilities of the system almost unlimited.

The capabilities of the system are illustrated by analyzing step-by-step a FET on wafer after a full calibration. The characteristics measured with one single connection include:

- S-parameters
- Single-tone characterization under optimal terminating conditions at fundamental
- Two-tone characterization under mismatched condition in frequency – time domain
- Dynamic AM/AM, AM/PM and harmonic distortion under mismatched conditions (see ***Figure 2***)
- DC analysis and load-line under one-tone excitation under optimal terminating condition at fundamental (see ***Figure 3***).

REAL-TIME LOAD PULL, INCLUDING FUNDAMENTAL AND HARMONIC EFFECTS

For power amplifier designers the complete characterization of a component with the voltages and currents has been made available in the automated tuner software ATS 4.0. This software allows visualizing the time waveforms occurring at the component ports under different fundamental and harmonic impedance condi-

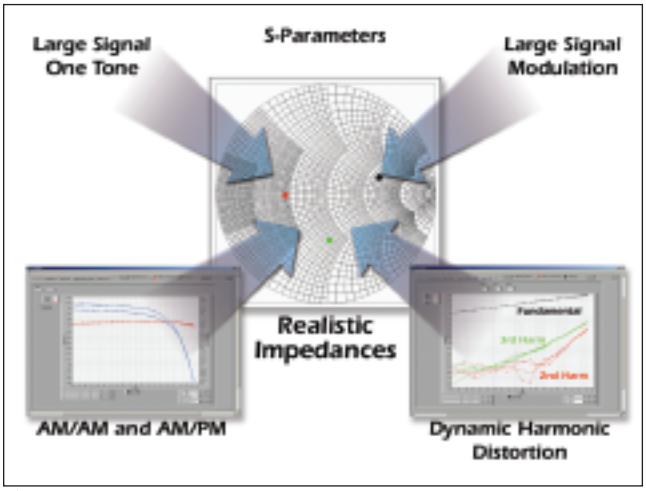

Fig. 2 Measuring AM/AM, AM/PM and harmonic distortion under mismatched conditions.

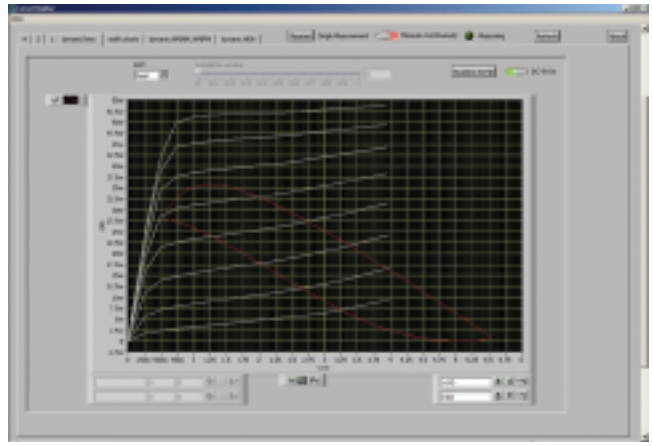

Fig. 3 Displaying load-line (V_d-I_d) with one-tone excitation under optimal termination at the fundamental frequency.

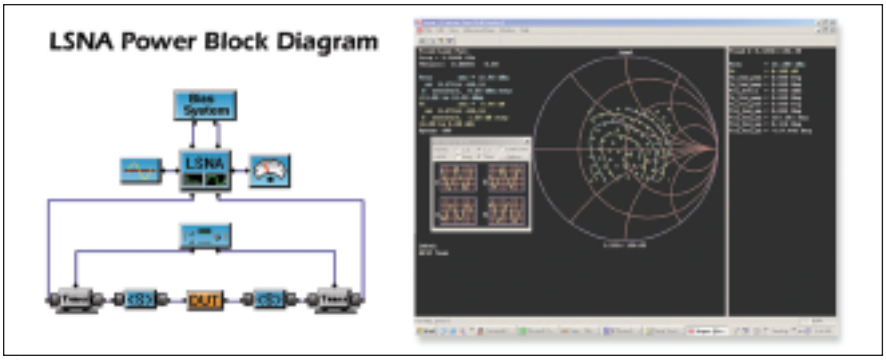

Fig. 4 Load pull with complete voltage-current information.

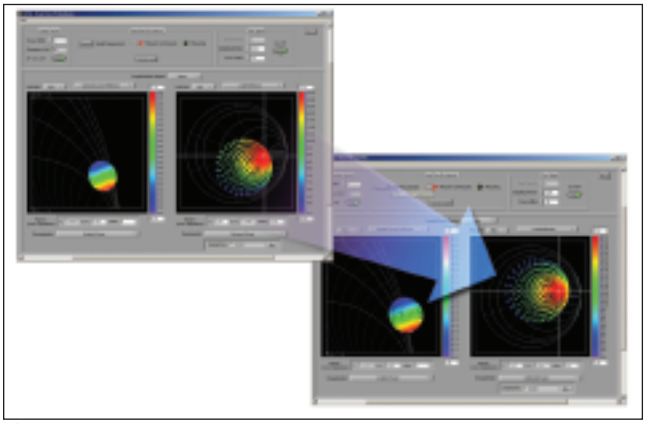

Fig. 5 Real-time tuning for optimal conditions with incident power at the input impedances corresponding to the load impedances and delivered power for the different load impedances.

tions, as shown in ***Figure 4***. Because the waveforms are available, the input and output impedances at the fundamental and harmonics are easily derived among other characteristics. The tuning process by itself, however, is a time-consuming process.

Using active injection in combination with a pre-match tuner, some smart test signals and the MT4463A, it is possible to collect all PA characteristics in one measurement around the impedance enforced by the pre-match tuner. While tuning the tuner in combination with the RF power and bias, the PA performance, including input impedance and harmonic information, is displayed in real-time, thus allowing the operator to find optimal performance very quickly (see ***Figure 5***). This cuts the characterization time drastically. To reduce and even eliminate possible memory effects, once an optimal or near-optimal point is found, the measurement time can be increased while fine-tuning the performance. On top of this major advantage, it is possible not only to use a single tone to perform the PA characterization, but to also use a periodic modulation signal at the input under tuning conditions.

THE MT4463A ANALYZER

Similar to a VNA, a MT4463A (network analyzer) consists of a test set measuring the incident and reflected waves in combination with some basic bias capabilities. The test set contains the necessary hardware to automate the calibration process. The test set can be customized to different needs, including power capability, bandwidth and impedance requirements.

The core of the MT4463A consists of a sampling converter that compresses the HF signals into a low frequency bandwidth for further processing. To measure broadband signals properly, the basic system contains a harmonic phase reference (HPR), which is a new and unique device that enables broadband phase calibration.

To complete the calibration of the system, a VNA-like calibration is required using a regular calibration kit and a power calibration using a power meter and sensor. During the calibration, a microwave synthesizer is required to calibrate the system across the full HF signal bandwidth. The user can select this equipment or use available lab equipment.

LARGE-SIGNAL NETWORK ANALYZER TECHNOLOGY

The MT4463A is based on some large-signal network analysis technology developed by Agilent Technologies. This technology has been licensed to Maury Microwave and sublicensed to NMDG Engineering. The real-time power amplifier technique is being licensed to Maury Microwave by NMDG to complete the MT4463A with PA characterization capability.

CONCLUSION

A large-signal network analyzer is the ultimate tool to characterize HF active components. It provides and expands VNA capability with spectrum analyzer and vector signal analysis features in a mismatched environment using tuners. It provides complete component characterization with one single connection in a mismatched environment from small-signal to large-signal excitation. Finally, equipment load-pull characterization is turned into a real-time process while providing fundamental and harmonic performance information.

For additional information on the MT4463A and the large-signal network analyzer technology, please visit www.nmdg.be and www.maurymw.com, or contact Roy Zohrabian at rzohrabian@maurymw.com or Marc Vanden Bossche at Marc.Vanden_Bossche@nmdg.be.

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