

*Solutions for*

## **Sharing Accurate, IP-Protected Nonlinear RF Behavioral Models**

### **Generating X-parameters from Circuit-level Designs**

#### **Application Note**



#### **Overview**

X-parameters<sup>†</sup> represent a new category of nonlinear network parameters for high-frequency design and are used for characterizing the amplitudes and relative phase of harmonics generated by the nonlinear behavior of components. Developed and introduced by Agilent Technologies, X-parameters are applicable to both large-signal and small-signal conditions, and for linear and nonlinear components. They correctly characterize impedance mismatches and frequency mixing behavior to allow accurate simulation of cascaded nonlinear X-parameter blocks (e.g., amplifiers and mixers), in wireless design. X-parameters play a key role in the development of active devices like the power amplifier (PA) and mixers—critical components in today's wireless designs.

#### **Problem**

Designing and testing wireless communications systems like the wireless handset at the system level can be challenging. Using circuit-level designs and models in hierarchical RF-system simulation and trade-off analysis, for example, is slow and cumbersome. Further complicating matters, behavioral models do not accurately represent a circuit's nonlinear behavior in phase and magnitude at all harmonics. The challenge is no less complex for the component/device designer supplying their Intellectual Property (IP) to the system designer/integrator. Traditionally, the designer would have to wait until a physical hardware prototype of their circuit-level design was available before sending it to the system designer/integrator for evaluation within their system. It may take several months for the chip to be manufactured and several more to properly characterize it across different operating parameters. Finding a way to share the performance of their circuit-level design with the system designer/integrator, instead of waiting for a physical prototype, represents a significant competitive advantage not only for the designer vying for an early design win, but also for the system designer/integrator hoping to deliver their product to market ahead of the competition.



**Agilent Technologies**

## Solution

A fast, accurate behavioral model based on X-parameters generated from a circuit-level design, offers an ideal way for the designer to share the performance of their circuit-level design with the system design/integrator, prior to the availability of a physical prototype. Using these models, the system designer/integrator can evaluate overall system performance and conduct trade-off analysis—earlier in the design cycle and much faster than if they were working with circuit-level designs. Because the X-parameter-based models are accurate and characterized over the same set of parameters that would be used to characterize the actual physical device, system designers/integrators also have a higher degree of confidence that the chip will work within the system the first time. Some of the key benefits of this approach include:

- **Simulation speed up and accuracy.**

X-parameter models enable faster hierarchical design analysis, and system simulation and verification than circuit-level models. They also provide unprecedented accuracy of nonlinear behavior in phase and magnitude at all harmonics. Fully functional behavioral models with the ability to accurately simulate measurements like IMD (IP3/TOI), PAE, spurs, and higher-order harmonics can be cascaded, load-pulled and account for mismatches.

- **Sharing IP-protected designs.**

X-parameter models provide a convenient way for design houses to protect their IP. The models essentially encapsulate the composite design, modeling it in an X-parameter representation that offers more protection of the design information than encrypting. The ability to share IP in real time speeds ongoing communication between design houses and system designers/integrators, enabling design houses to secure design wins before physical parts are available. It also significantly reduces chip, package and system design iterations. Minimizing hardware respins saves cost and speeds time-to-market for products with increased accuracy and therefore better specifications.

## Generating X-parameters

Until recently, the ability to create fast, accurate behavioral models based on X-parameters generated from a circuit-level design did not exist. X-parameters could only be obtained through Agilent's Nonlinear Vector Network Analyzer (NVNA) software running inside its PNA-X microwave network analyzer. Now though, X-parameters can also be generated from a circuit-level design in Agilent's Advanced Design System (ADS) software—an Electronic Design Automation (EDA) platform specifically engineered to generate X-parameter models of multi-port, nonlinear components or devices under load-pull conditions (Figure 1).

X-parameters are generated using the ADS X-Parameter Generator, which takes an ADS circuit-level design and creates X-parameters that can be used in an ADS linear, harmonic balance or circuit envelope simulation. The resulting X-parameter-based, nonlinear behavioral models are fast, drop-in useable and accurate.

The process for generating X-parameters is simple and straightforward. It begins with the creation of a circuit-level schematic in ADS. Once the schematic is complete, information regarding frequency, bias, temperature, and other important parameters is entered into the X-Parameter Generator. In turn, it creates X-parameters. ADS simulation of the X-parameters then extracts the corresponding X-parameter-based behavioral model.

A key benefit of using the X-Parameter Generator in ADS is that with no limits on the number of ports, power or frequency it can handle, it is able to deal with complicated designs involving multiple ports and biases (e.g., mixers), as well as arbitrary topology.

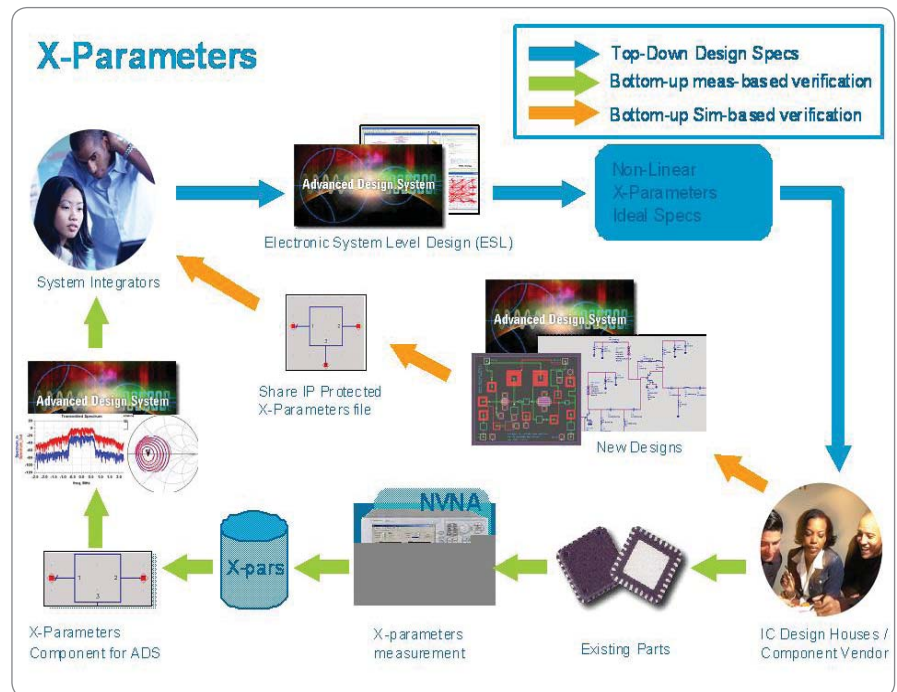


FIGURE 1: X-parameters can now be created from measurement or ADS simulation with the same speed and convenience as the well-known linear S-parameters. When generated from ADS circuit-level models, the resulting nonlinear behavioral models can be confidently used to speed system-level design.

## Active Device Example

Using the ADS X-Parameter Generator, it is a straightforward process to create X-parameter models that can be analyzed and quickly distributed as secure IP to system designers/integrators. Consider the example of an LTE PA design as shown in Figure 2. To extract the X-parameters model for the device from simulation, the designer must first set up the ADS X-Parameter Generator (Figure 3). X-parameters are then created, producing an X-parameter-based model that can be distributed as IP (Figure 4). In one real-life scenario, this process allowed a designer to go from software download to a distributable X-parameter model in less than 10 minutes. The simulation of the amplifier with a complex LTE signal took just a few seconds. Without ADS and the X-Parameter Generator, the design would not have had IP protection and, at the system level, would have taken much longer to simulate—making it very difficult for the system engineer to conduct multi-simulation trade-off analysis.

## Summary of Results

X-parameters represent a very useful and competitive technology for both design houses and system designers/integrators alike. This technology is now all the more powerful given the ability to generate X-parameters from circuit-level designs using Agilent's X-Parameter Generator in ADS. This critical capability enables design houses to secure early design wins and system designers/integrators to deliver products to market ahead of the competition.



### The Power of X

The Agilent X-Parameters and PNA-X Microwave Network Analyzer are key

products in Agilent's comprehensive Power of X suite of products. These products grant engineers the power to gain greater design insight, speed manufacturing processes, solve tough measurement problems, and get to market ahead of the competition.

Offering the best combination of speed and scalability, and created and supported by renowned worldwide measurement experts, Agilent's X products are helping engineers bring innovative, higher-performing products to emerging markets around the globe. To learn more about Agilent's suite of X products please visit:

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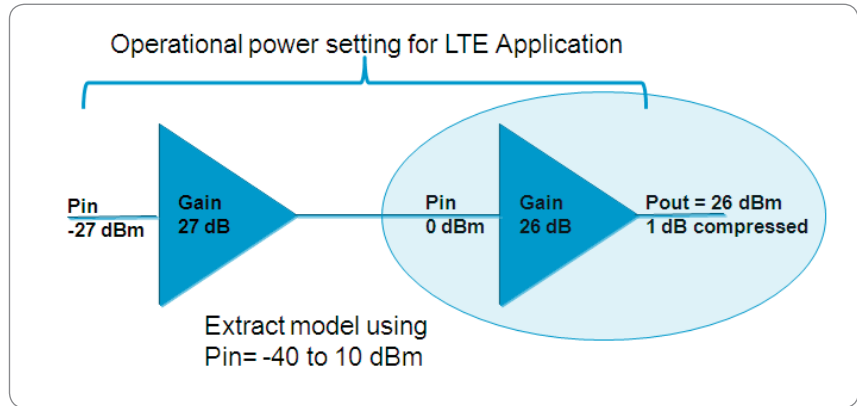


FIGURE 2: Agilent's ADS and X-Parameter Generator can be used to extract an X-parameters model for the second stage of two cascaded MMIC PAs.

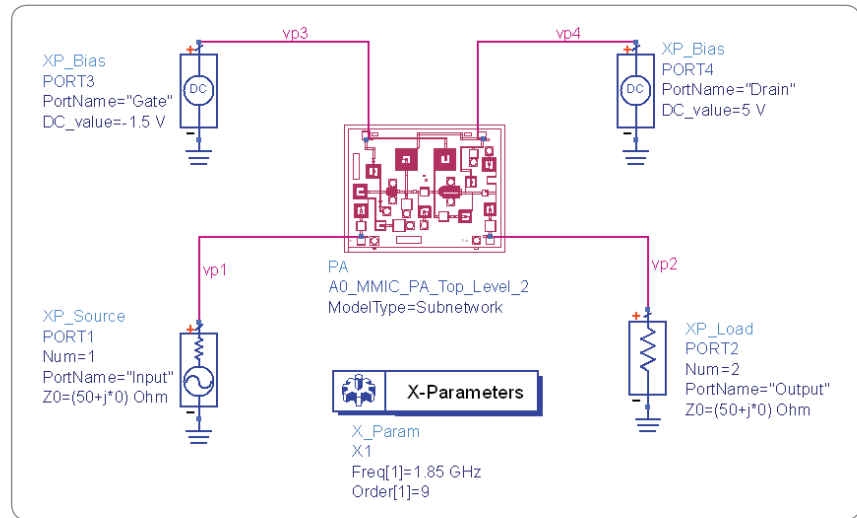


FIGURE 3: Prior to simulating the parameters, the engineer must set up the different parameters, such as bias, frequency and temperature.

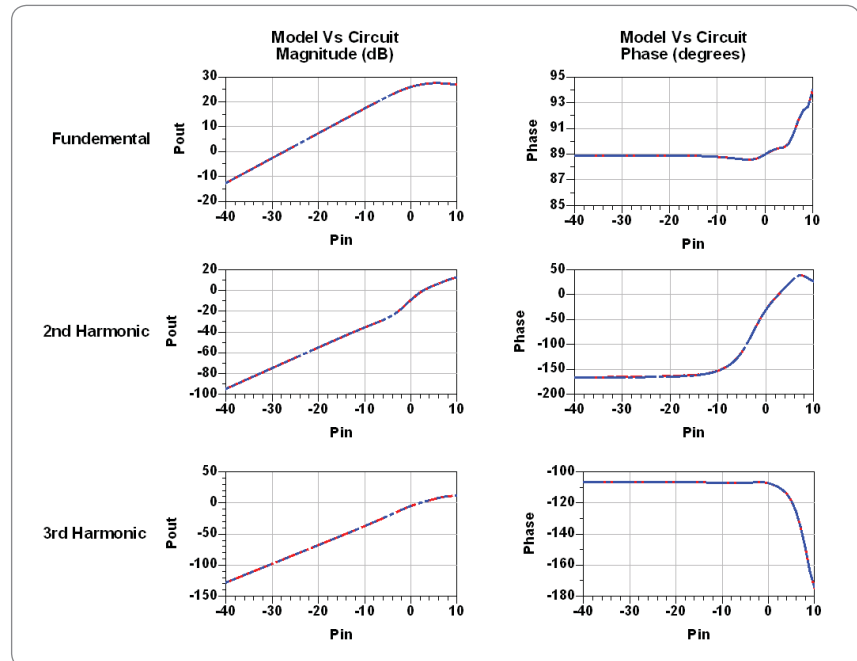


FIGURE 4: The X-parameter-based model is shown here overlaid on actual circuit-level PA results.

## Related Applications

- Aerospace/defense
- Consumer wireless
- Generate X-parameters for handset/basestation PAs
- Generate X-parameters for amplifiers, mixers or any nonlinear device

## Related Agilent Products

- W2305 X-Parameter Generator
- W2200 ADS Core
- Nonlinear Vector Network Analyzer

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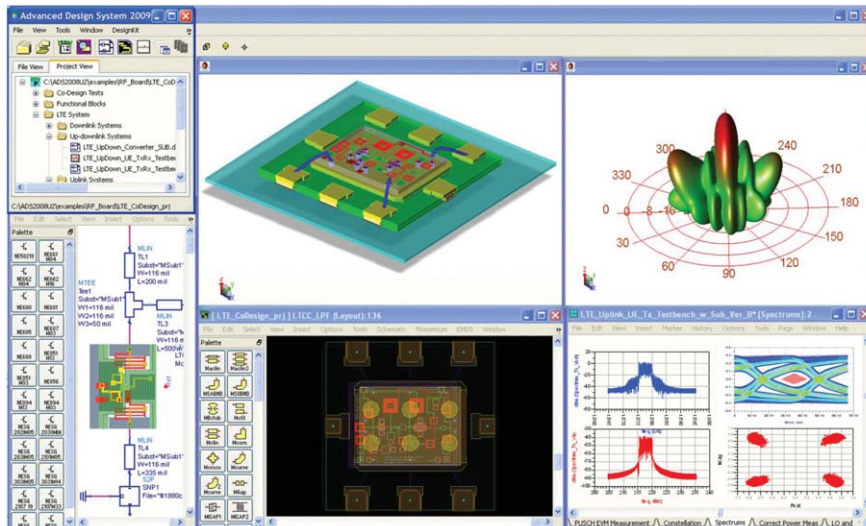
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W2200 ADS Core

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