Scattering Parameters for Nonlinear Devices, Measurement and Simulation

William A. Davis* (wadavis@vt.edu), Virginia Tech Antenna Group
Bradley Dept. of Elec & Comp Engr, Virginia Tech, Blacksburg, VA 24061-0111
John B. Call, Silicon Semiconductor Corp, Durham, NC 27713

A three-port representation of a nonlinear device as a function of drive level can be obtained with a few relatively simple measurements. This characterization is used to analyze and simulate device performance for a range of large-signal drive levels. Using the three-port model, designers may make use of the results in their circuit simulations rather than depend solely on manufacturer data. The technique is applied to high power transistors in this paper.

The Reflect-Thru-Line (RTL) measurement system was developed by Davis (URSI/USNC, Boulder, 1993) as a 1-way two-port alternative to TRL for scattering parameter measurements on nonlinear devices under high drive-level conditions. This system was used to obtain *S*-parameter measurements on several commercially available power transistors that previously had been considered unmeasurable because of their high gain and capability for large output levels.

Using the three-port model, a device can be characterized using *S*-parameter measurements as a function of drive level. Advantages of a three-port device representation are 1) any two-port nonlinear device dominated by a single non-linearity can be represented — ideal for characterizing devices using new physical structures or exotic materials and RFIC or MMIC devices which are not adequately handled by existing models; 2) most functional RF design labs have the measurement equipment required to extract a three-port model. The extracted three-port model parameters were found to provide an excellent fit to measured power sweep data with only minor limitations. Though the effort required to obtain a three-port model is minimal, the information and insight available from the model make it possible for high-power amplifier designers to adopt tools and techniques that have previously been available only to small-signal circuit designers. The current system does not account for harmonic loading, but no serious variations were found due to this omission.

A simulation of load-pull measurements was run using the three-port model for two high-power devices and compared to measured load-pull data. Gain contours were compared with measured gain contours for three different power levels. At low drive levels the simulation and measured contours were in close agreement. As the power levels increased, the simulated and measured contours began to diverge, most likely due to device heating. The latter device heating problem must also be overcome with existing modeling approaches to account for the thermal properties of the device separately from the RF properties.