Closing the Loop on Reference Design Simulations

Accurate simulation requires component models that represent true RF/microwave performance

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Reference design "evaluation boards" provide a starting point for RF design engineers; however, accurate reference design simulation setups, inclusive of parasitic models for all passive and active devices, are not usually provided by vendors. Accurate reference design simulations enable the ability to modify the design and rapidly achieve success for new applications, with specifications differing from the original reference design.

Overview

This article shows the procedure used to develop accurate reference design simulations using models from Modelithics, Inc. The reference design example used in this article is for a power amplifier, operating at 900 MHz, using TriQuint's TGF2960-SD 0.5 watt transistor. The simulation schematics shown throughout this article were developed using Agilent's Advanced Design System (ADS). Procedures and issues related to correcting the differences between simulated and measured results are explained and implemented. Data from each simulation in the procedure is provided to show the impact that Modelithics models have on the overall performance of the design.

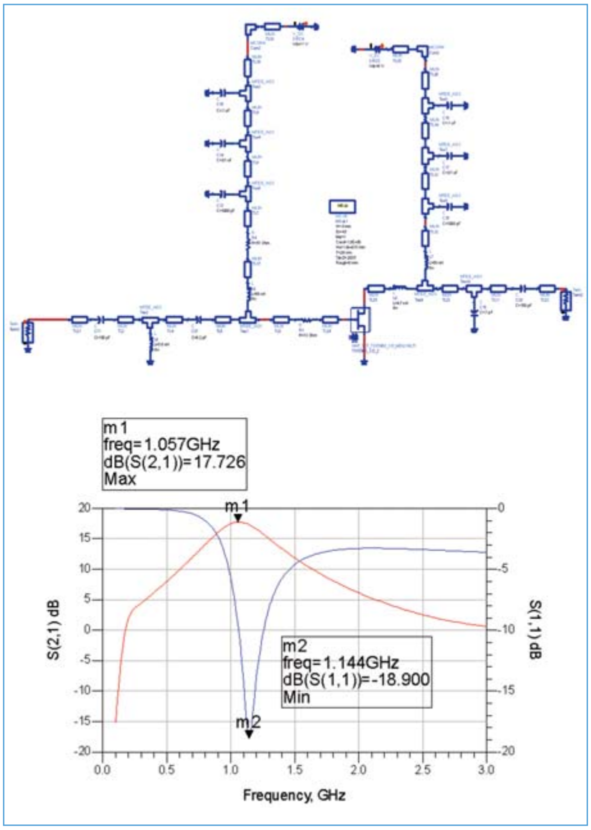

FIGURE 1
Schematic and results from initial simulation of the 900 MHz reference design using ideal passive components and Modelithics non-linear transistor model in ADS.

Project Goals

The project design goals were developed using TriQuint's datasheet for the TGF2960-SD transistor. The datasheet shows a successful amplifier design along with measured data for this transistor at 900 MHz. Using the values from the datasheet as the project design goals provides the opportunity to validate the results against TriQuint's data. The simulation-to-measurement goals were created to account for inconsistencies in the components and the performance of the board.

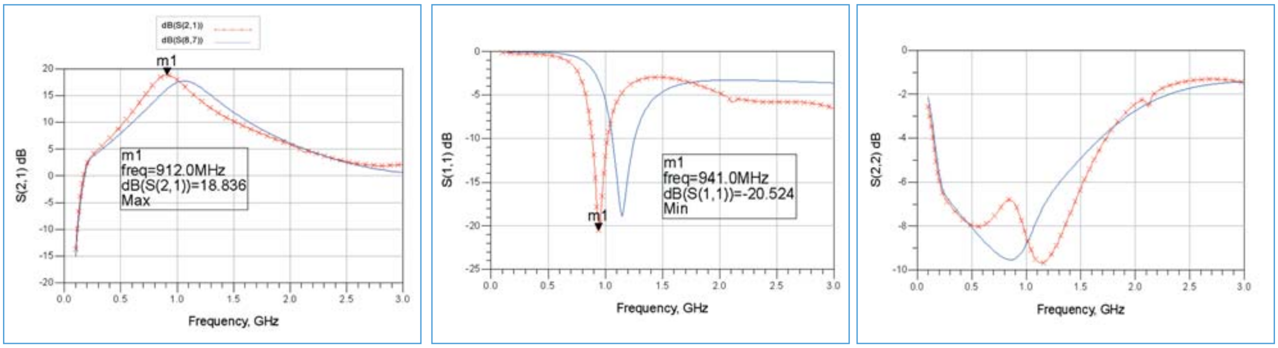

FIGURE 2

Results from simulations using ideal models (Initial – blue lines) and full parasitic models (Modeled – red lines with markers) for all surface mount components along with the Modelithics non-linear transistor model. The simulated data confirms that the design goals were met.

Design Goals

- Maximum gain 18 dB
- Peak gain center frequency 900 MHz
- 3 dB bandwidth 400 MHz
- Input return loss greater than 10 dB
- 1 dB compression at 27 dBm output power

Simulation-to-Measurement Comparison Goals

- Peak gain level within 1 dB
- Gain peak center frequency within 5%
- 3 dB bandwidth within 10%

About the Non-Linear Model Used

The non-linear model used in this design was developed at Modelithics. The model is extracted from pulsed IV and multi-bias *S*-parameters. This model is capable of performing power and intermodualtion behavior simulations. Detailed information about the Modelithics non-linear model for this part can be found in the Modelithics HMT-TQT-TGF2960-SD model information datasheet. The model for this part is contained in Modelithics NLT Library version 4.0 and later versions and can be used in ADS and AWR's Microwave Office.

Design Procedure

The design process used for creating the reference design follows. Each step during the simulation stage provides an opportunity to tune the circuit to ensure the design goals are being met.

1. Simulate small signal gain and input return loss for the reference design in ADS using ideal components.
2. Simulate reference design replacing the ideal components with models from the Modelithics CLR Library.
3. Assemble the 900 MHz reference design.
4. Measure small signal gain and input return loss using a network analyzer.
5. Simulate and measure 1 dB compression point at the center frequency.
6. Close the loop—compare simulation results to measurement results and investigate/resolve discrepancies.

900 MHz Design

The initial design in ADS was created using ideal passive components, microstrip lines and the Modelithics model for the transistor. The evaluation board provided by TriQuint came with a fixed layout. The dimensions of the microstrip lines on the evaluation board were measured and entered into the schematic, along with the substrate parameters. The transistor in the simulation was biased by setting the drain voltage equal to 8 V and setting the gate voltage equal to –0.93 V. This provided a drain current equal to 100 mA, which is the recommended operating current listed in the datasheet. Figure 1 shows the schematic and the simulation results for the initial design using ideal passive components. Note the peak gain center frequency is not centered at the desired goal of 900 MHz. This does not match

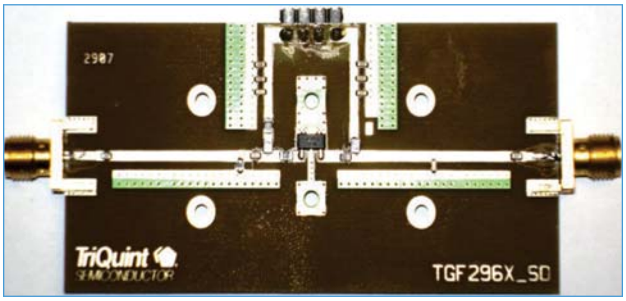

FIGURE 3

Assembled 900 MHz reference design board.

the measured results in the TriQuint datasheet, showing that the simulation lacks the necessary accuracy.

Using Modelithics models for all surface mount components provided results much closer to the targeted goals. The ideal components in ADS were replaced with a Modelithics model of the same part value. The simulation results from the new design containing Modelithics models are shown in Figure 2. The gain increased from 17.7 dB to 18.8 dB. The center frequency accuracy improved from 1.057 GHz to 912 MHz. The results are closer to the targeted goal because the models account for the resonant effects and the impact of component-substrate interaction.

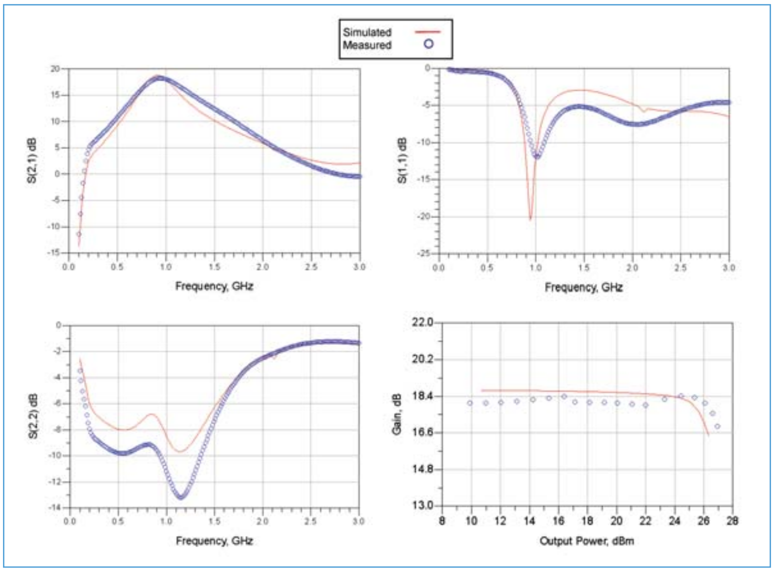

FIGURE 4

Results from *S*-parameter and gain compression measurements compared to model-enabled simulations. Note the shift in the input return loss. The 50 ohm power sweep frequency is 900 MHz.

Verification

The reference design circuit was assembled on a 20 mil GETEK, FR-4, board provided by TriQuint. *S*-parameter measurements were taken and compared to the simulation results. Figure 3 shows the assembled board. The results from the *S*-parameter measurements are shown in Figure 4 with the simulation results. A 50 ohm power sweep was simulated and measured and is also shown in Figure 4. The frequency used for the power sweep was 900 MHz. To bias the transistor for measurements, the drain voltage was set to 8 V and the gate voltage was adjusted until the drain current equaled 100 mA. The same procedure was used for the simulation. The final schematic is shown in Figure 5.

The agreement between the measured data and the simulated data does not meet the desired goals. The measured peak gain center frequency occurs at 941 MHz, but the simulated results show the center frequency at 912 MHz. The measured gain is 18.24 dB and is within 0.5 dB of the simulated gain. The agreement between the measured and simulated data can be improved by investigating the cause of the differences.

Closing the Loop

After observing the differences between the measured data and simulated data, the simulation schematics were revisited. First to be considered was the precise placement of the components. During assembly, some components were not placed in the exact location specified in the schematics. The design used in the simulations placed the matching network 9 mm from the transistor. However, when the evaluation board was assembled, the matching network was only 5.3 mm from the transistor. As a result, the measured peak gain center frequency was 40 MHz

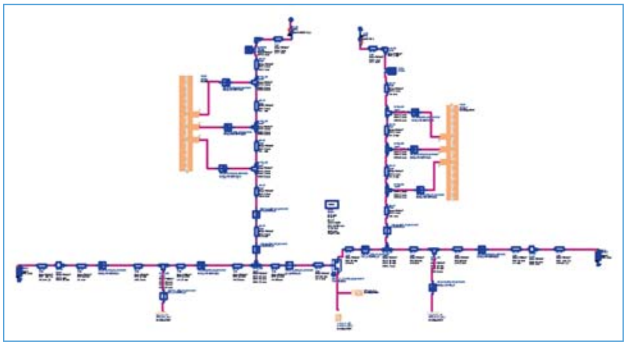

FIGURE 5

Final schematic for ADS simulation of the 900 MHz reference design.

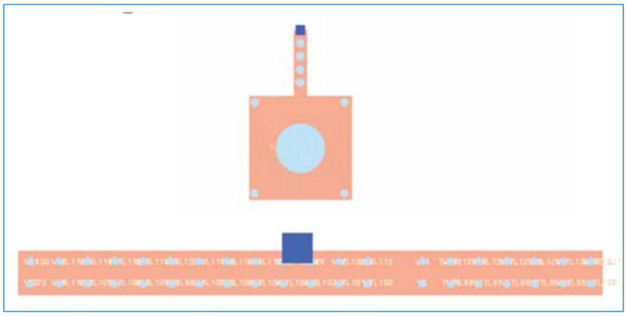

FIGURE 6

Example via models created in Momentum. These models were used to improve the simulated to measured agreement.

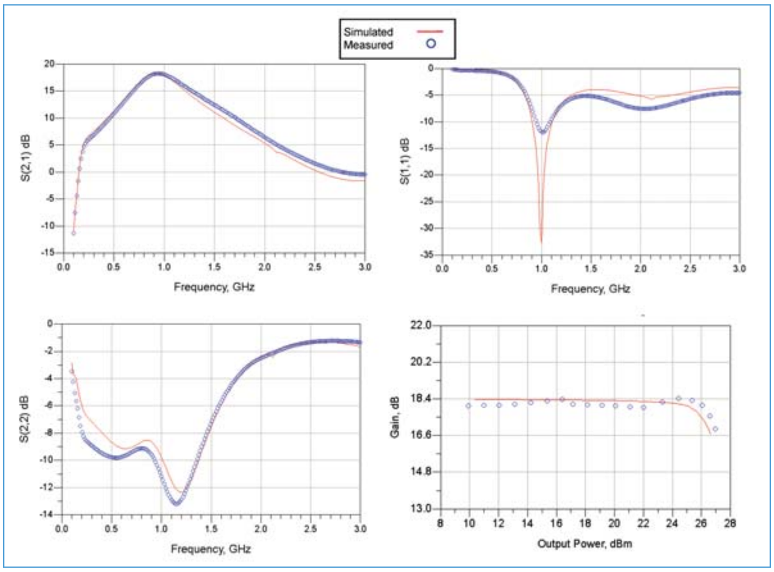

FIGURE 7

Final simulation results from schematic with via models and corrected location of surface mount components, compared to measurements. 50 ohm power sweep frequency is 900 MHz.

	Simulated	Measured	Goal	Difference
Maximum Gain	18.17 dB	18.24 dB	+/- 2 dB	-0.07 dB
3 dB Bandwidth	507 MHz	551 MHz	+/- 10%	8%
Peak Gain Frequency	926.5 MHz	941 MHz	+/- 5%	1.6%

Table 1

Comparison of simulated and measured data after closing the loop; identifying differences between assembly and simulation.

higher than the goal. The schematic was corrected to account for the physical location of the components on the evaluation board.

It was also discovered that the via holes to ground had not been represented in the simulations. In an effort to account for the effects of the vias, electromagnetic simulations were run using Momentum. The physical dimensions of the vias were measured and used to create models using Momentum. Figure 6 shows two examples of the via models that were created. The results from the electromagnetic simulations show a response similar to a series inductor.

Using the via models and accounting for the actual physical placement of the surface mount components, the simulations were run again. The results in Figure 7 show a much better agreement between the measured and modeled data. The deep, narrow response in the simulated S_{11} is often not so dramatic in measurements. It is primarily the frequency where the minimum occurs that demonstrates agreement. Power compression was simulated and measured to demonstrate the ability to perform accurate nonlinear simulations. These results can also be seen in Figure 7.

Conclusion

This article shows the successful development of a reference design schematic and simulation for a power amplifier operating at 900 MHz. Using accurate models from Modelithics CLR and NLT libraries along with proper circuit representation, accurate reference design simulations can be created. Reference design simulations like the one described in this article enable the design engineer to reduce the time required to achieve targeted design goals.

About This Article

This article was created at Modelithics, Inc. The reference design example shown was part of a BSEE senior project completed by David Wright, with funding and technical support provided by Modelithics, Inc.

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For information about Modelithics products and services, or to request a downloadable version of the reference design presented in this article, please contact :

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