



Precision Measurements and Models You Trust

Application Note 49

ANALYSIS OF A 30 W POWER AMPLIFIER UTILIZING MODELITHICS' TRIQUINT T2G6003028-FS MODEL IN AGILENT ADS

Introduction

This note provides insight into the performance predictability of a design simulation for a single-stage microwave power amplifier (PA) reference design, based on the use of a non-linear model for the TriQuint T2G6003028-FS packaged GaN HEMT device. The example studied in this application note is a 30 W device utilized in a reference amplifier board that uses distributed and surface mount components for matching and bias networks. The bias and operating information for the design is as follows: $V_{ds} = 28V$, $I_{ds} = 200mA$, design frequency = 5.9 GHz. For the simulations, a Modelithics developed nonlinear model for the T2G6003028-FS device is used along with Modelithics CLR models for the passive lumped surface mount components. The modeling and analysis tool used in this work includes Agilent Technologies' Advanced Design System (ADS).

The treatment within this note includes exploration of the measured to model agreement for small-signal as well as large signal analysis, including careful analysis of the passive matching network representations. The objectives of this work include the validation of the transistor model as well as an understanding of the impact of the matching and bias circuit modeling on the overall simulation to measured data agreement of the amplifier.

Assembly and Small Signal Analysis

We will begin with a study of how each section of the PA contributes to the overall small signal performance of the amplifier. With this objective, two measurement scenarios were developed: 1) measuring the fully assembled PA and 2) measuring each of the three sections separately.

Due to the transistor grounding and heat-sinking requirements, copper carriers are required. In order to produce an accurate and dependable transistor performance, a trench was milled in the carriers to provide just enough depth so the conducting pins at the gate and drain of the transistor rest 1 mil above the transmission lines on the substrate. An image indicating the measurement reference planes of the assembled transistor can be seen in Figure 1. Figure 2 provides a side view image of the assembled transistor.

The individually measured input and output matching networks are shown in Figure 4.

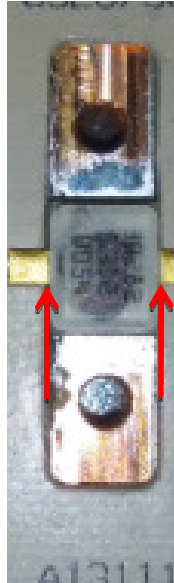


Figure 1. Assembled transistor. The **red arrows** indicate the measurement reference planes on a 25-mil Rogers 3210 board.

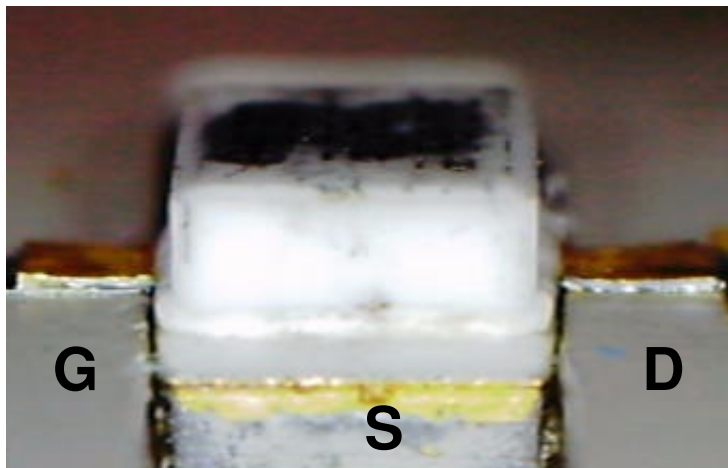


Figure 2. Assembled transistor side view.

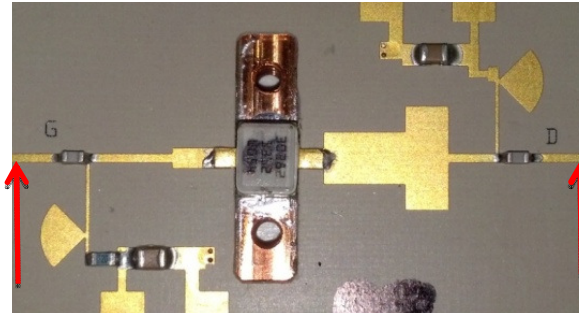


Figure 3. Assembled PA. The **red arrows** indicate calibration reference planes.

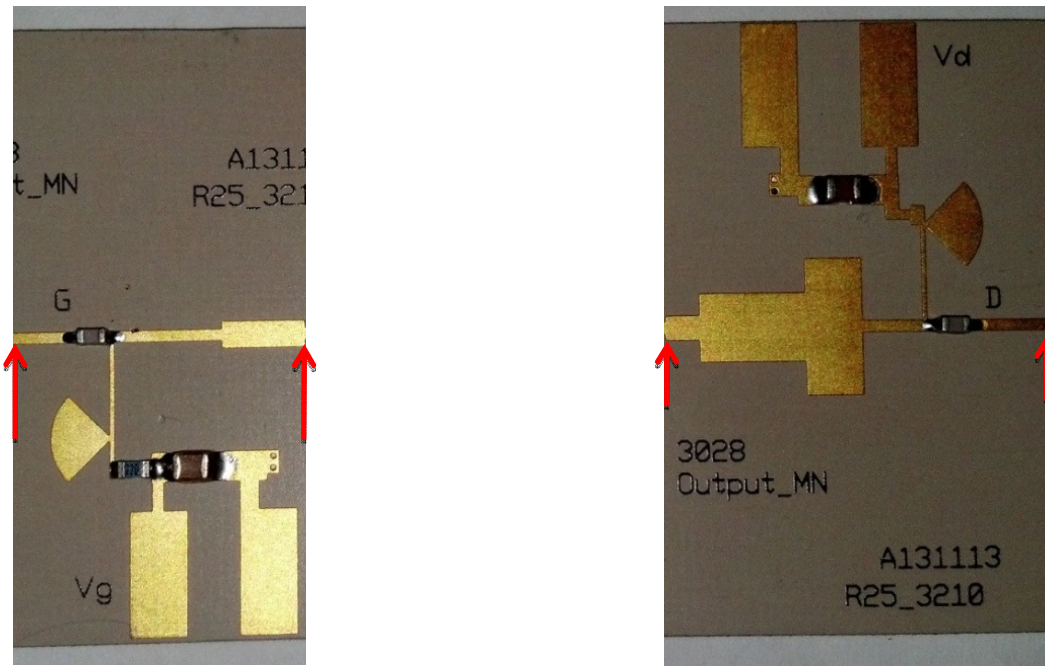


Figure 4. Input and output matching networks. The **red arrows** indicate calibration reference planes.



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The first set of measurements to be presented will be those of two samples of the T2G6003028-FS transistor; the two samples of the individual transistor were measured at 28 Vds with an Ids of 200 mA. The nonlinear Modelithics model for the transistor was originally developed using measured data obtained on a microstrip test fixture using 20 mil Rogers 4350B board (R20) with an Er of 3.75 while the 25 mil Rogers 3210 board (R25) used in this PA design has an Er of roughly 10.2; a comparison of the data is shown in Figure 5. Fortunately, two transistor samples that were measured on the 20 mil boards were available for the 25 mil board measurements. Although the measurement reference planes are located at the ceramic package edges, 4.064 mm apart, test fixture-related effects are apparent above 3GHz. Figure 6 shows the comparison between the Modelithics transistor model and the measured data, after some minor parasitic adjustment for improved fit to the R25 fixture data.

In an attempt to accurately predict the behavior of the PA over a broad-band, the input and output matching network (MN) models were created to emulate the fabricated matching networks as closely as possible; also modeled were the transmission lines (TL) and passive lumped elements used to make up the bias networks. The purpose of this detailed modeling attempt is to fully understand every aspect of the assembled PA. Figure's 7 and 8 show the ADS transmission line model representations for the input and output matching networks.

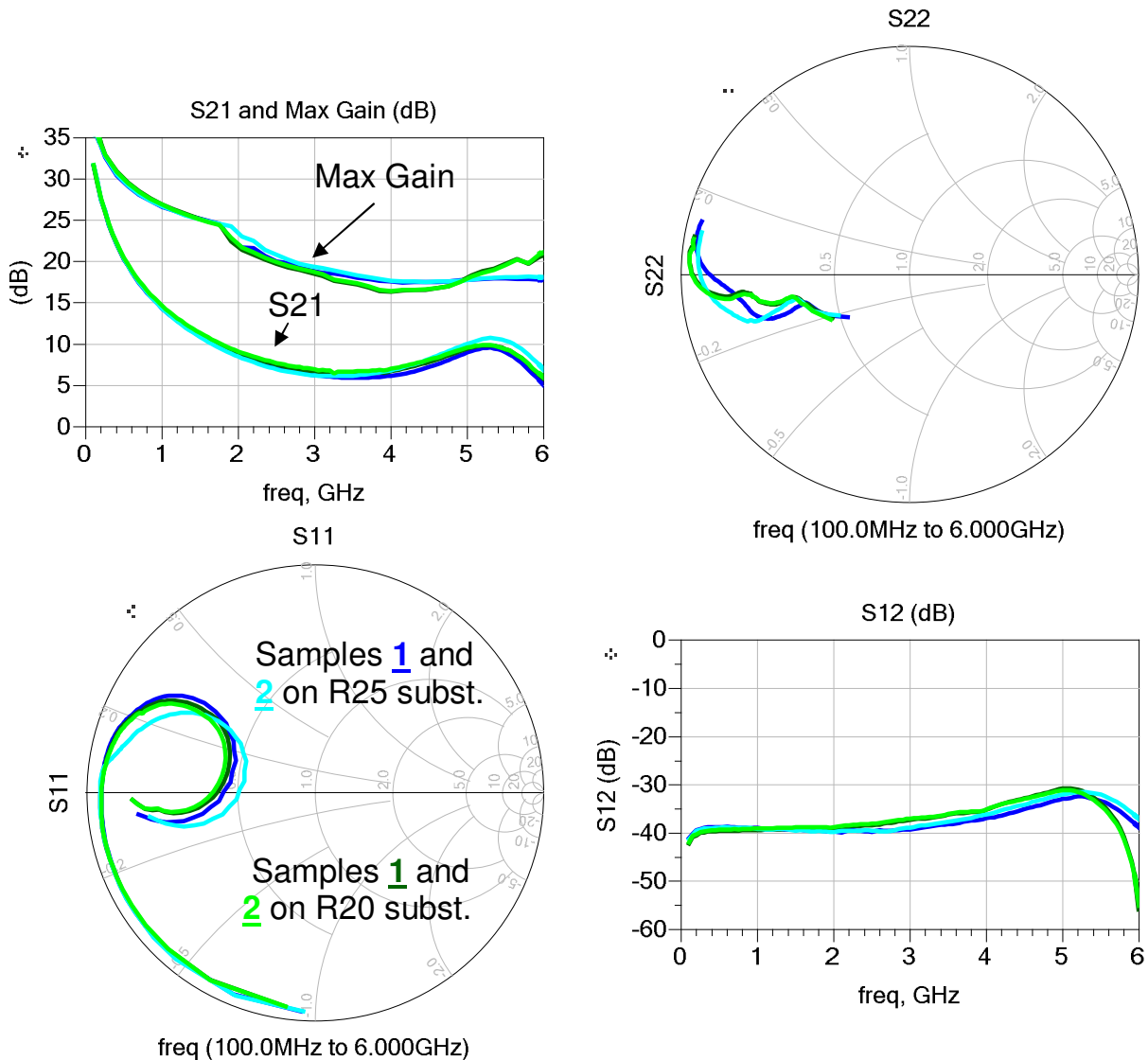


Figure 5. $V_{ds} = 28$ V, $I_{ds} = 200$ mA. Transistor 3028-FS sample #1 measured on R25 substrate (**dark blue line**), transistor sample #2 measured on R25 substrate (**light blue line**), transistor sample #1 measured on R20 substrate (**dark green line**), transistor sample #2 measured on R20 substrate (**light green line**).



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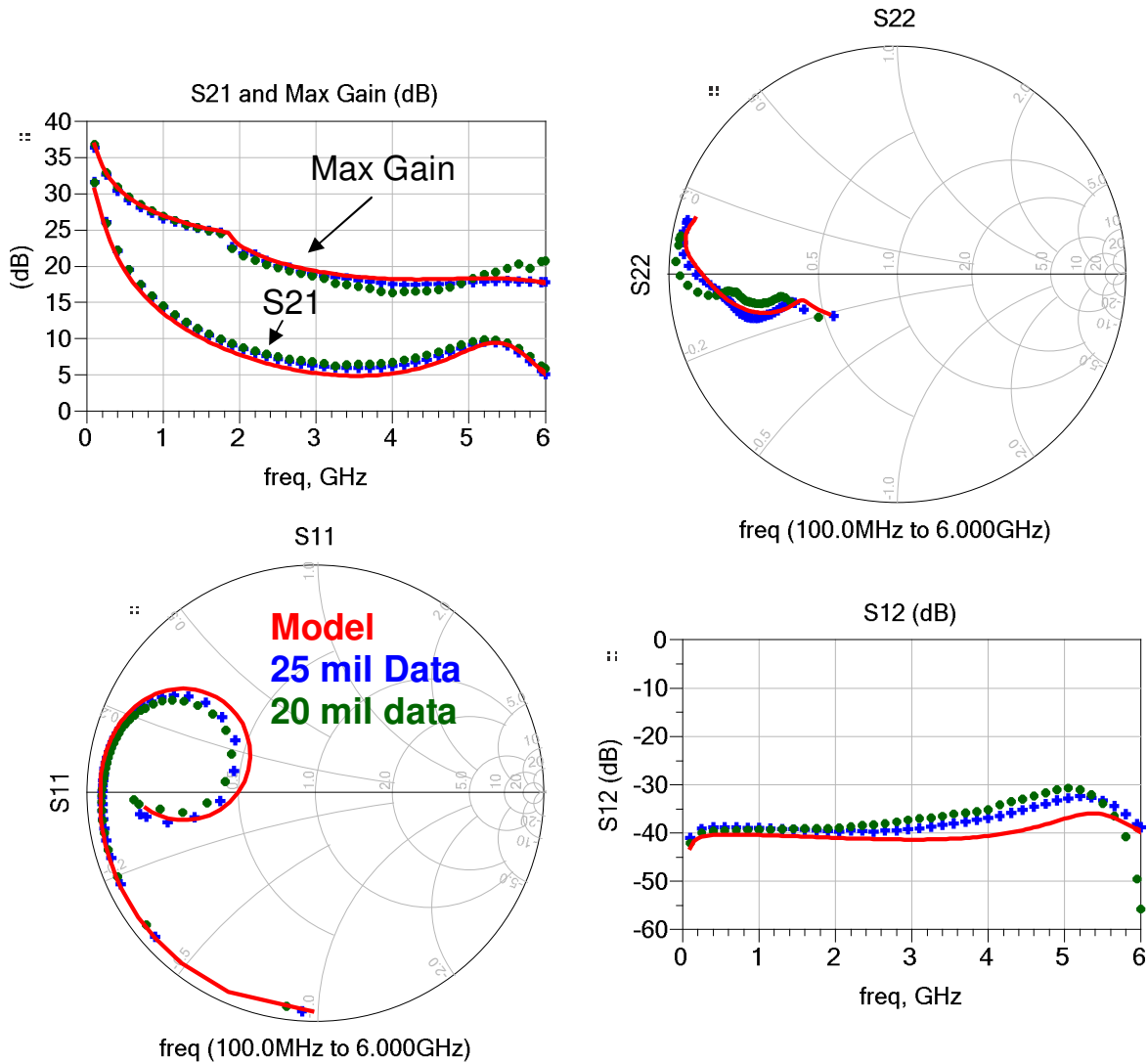


Figure 6. $V_{ds} = 28\text{ V}$, $I_{ds} = 200\text{ mA}$. Model (red line), 3028 transistor sample #1 measured on R25 substrate (blue symbols), 3028 transistor sample #1 measured on R20 substrate (green symbols).



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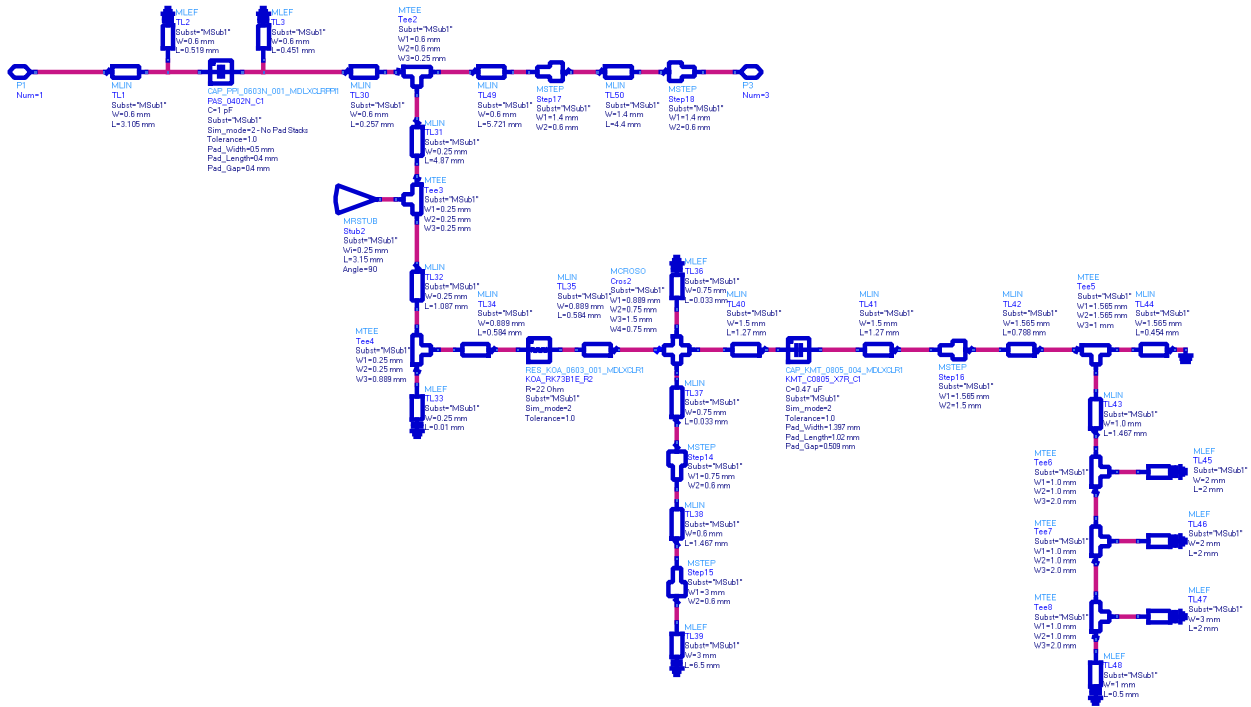


Figure 7. ADS input matching network TL representation. All the passive surface mount elements are represented by Modelithics CLR Library models.



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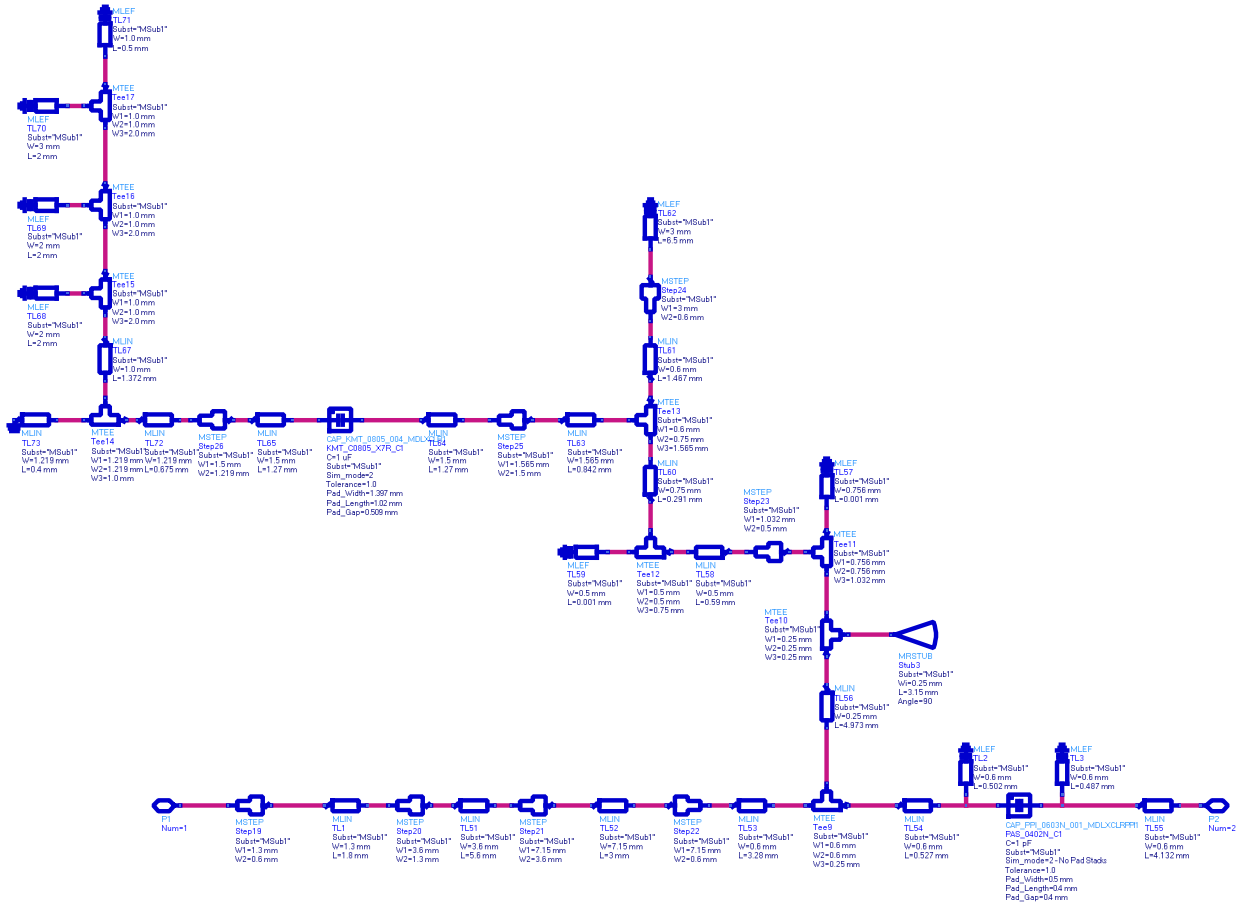


Figure 8. ADS output matching network TL representation. All the passive surface mount elements are represented by Modelithics CLR Library models.

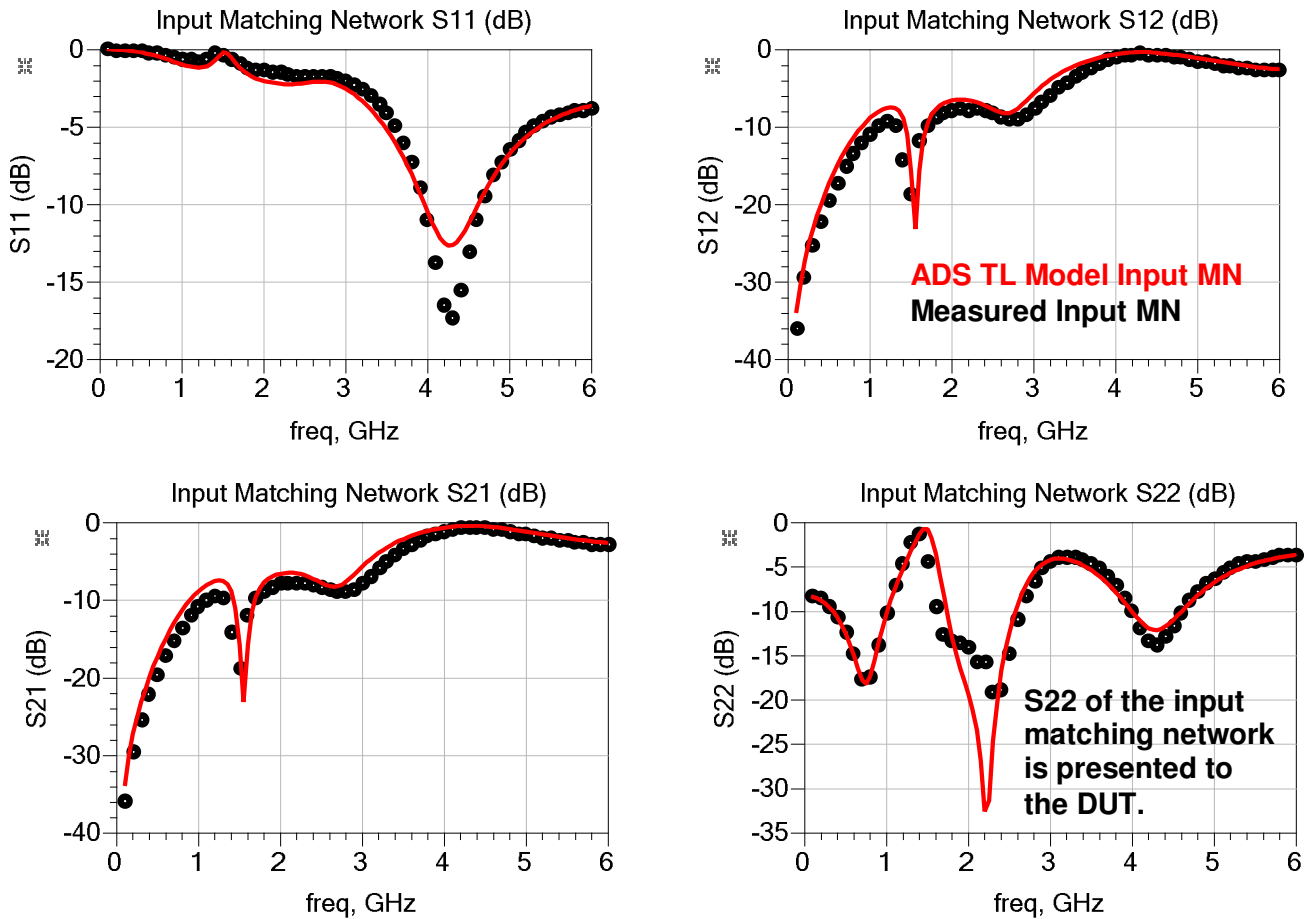


Figure 9. Modeled versus measured input matching network S-Parameters: ADS TL model (red line) and measured data (black symbols).

Figures 9 and 10 provide a comparison between the modeled input and output matching networks illustrated in Figures 7 and 8 and the measured data for the input and output matching networks seen in Figure 4.

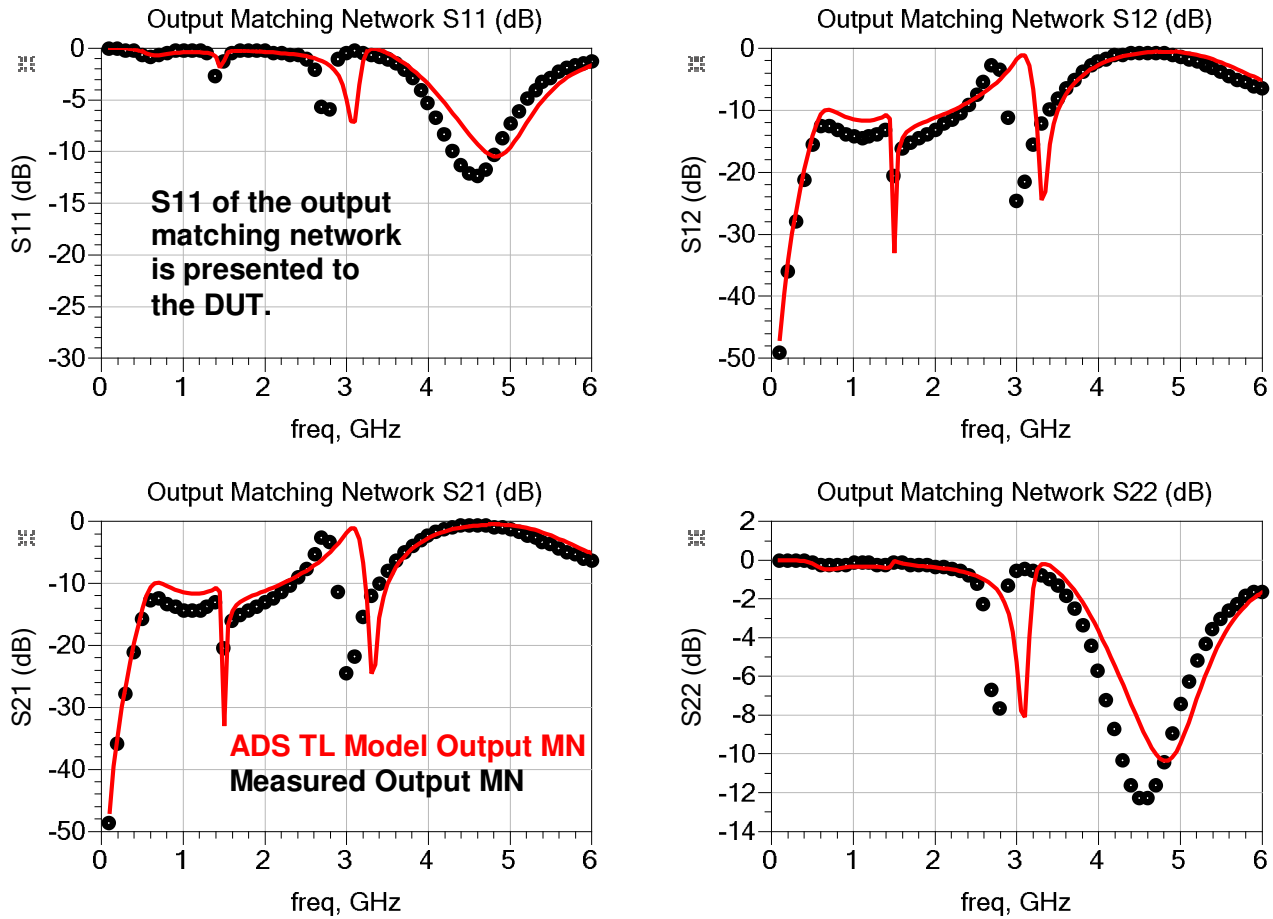


Figure 10. Modeled versus measured output matching network S-Parameters: ADS TL model (red line) and measured data (black symbols).



Figures 12 and 13 show broad-band and narrow-band comparisons between the measured data for the PA seen in Figure 3, the measured transistor seen in Figure 2 cascaded with the TL modeled matching networks seen in Figure 7 and 8, and the Modelithics nonlinear transistor model cascaded with the TL modeled matching networks seen in Figure 7 and 8. Figure 11 provides a conceptual representation of the comparisons shown in Figures 12 and 13; the colored labels seen to the left of the figures below help clarify the information plotted in Figures 12 and 13.

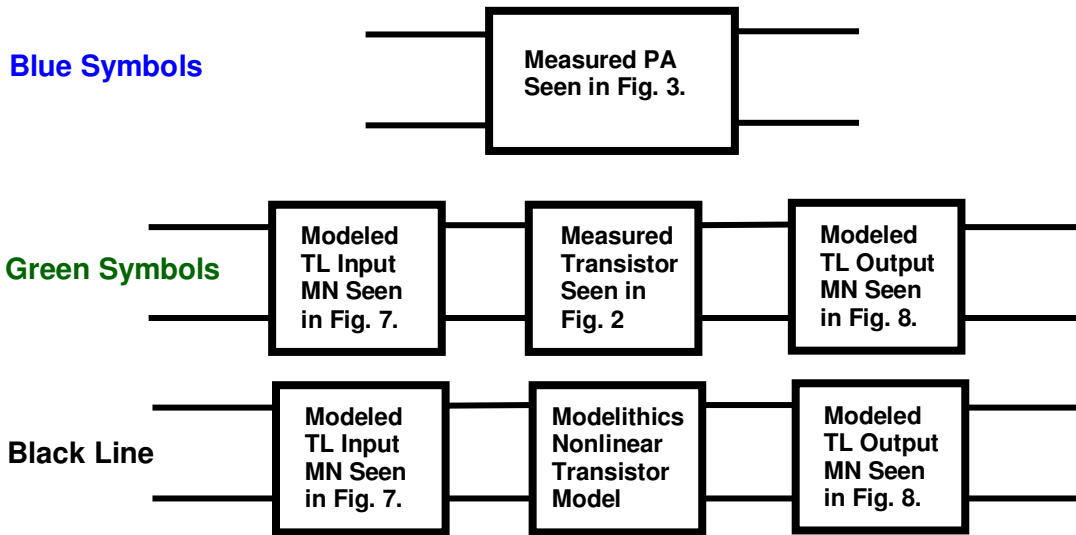


Figure 11. Conceptual representation of the data comparisons seen in Figures 14 and 15.

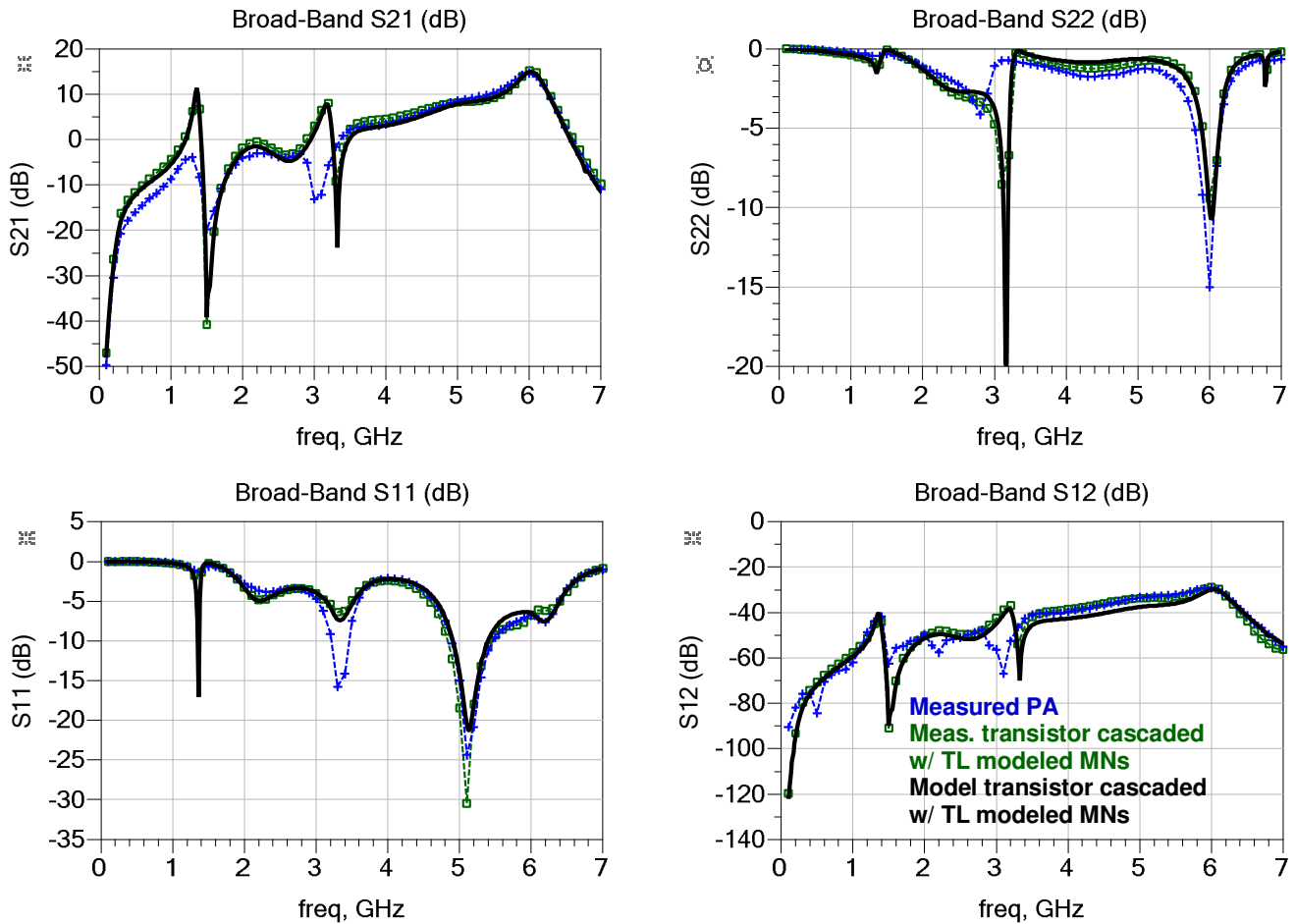


Figure 12. $V_{ds} = 28\text{ V}$, $I_{ds} = 200\text{ mA}$. Broad-band comparison between the measured PA (blue symbols), measured transistor cascaded with the TL modeled matching networks (green symbols), Modelithics nonlinear transistor model cascaded with the TL modeled matching networks (black line).

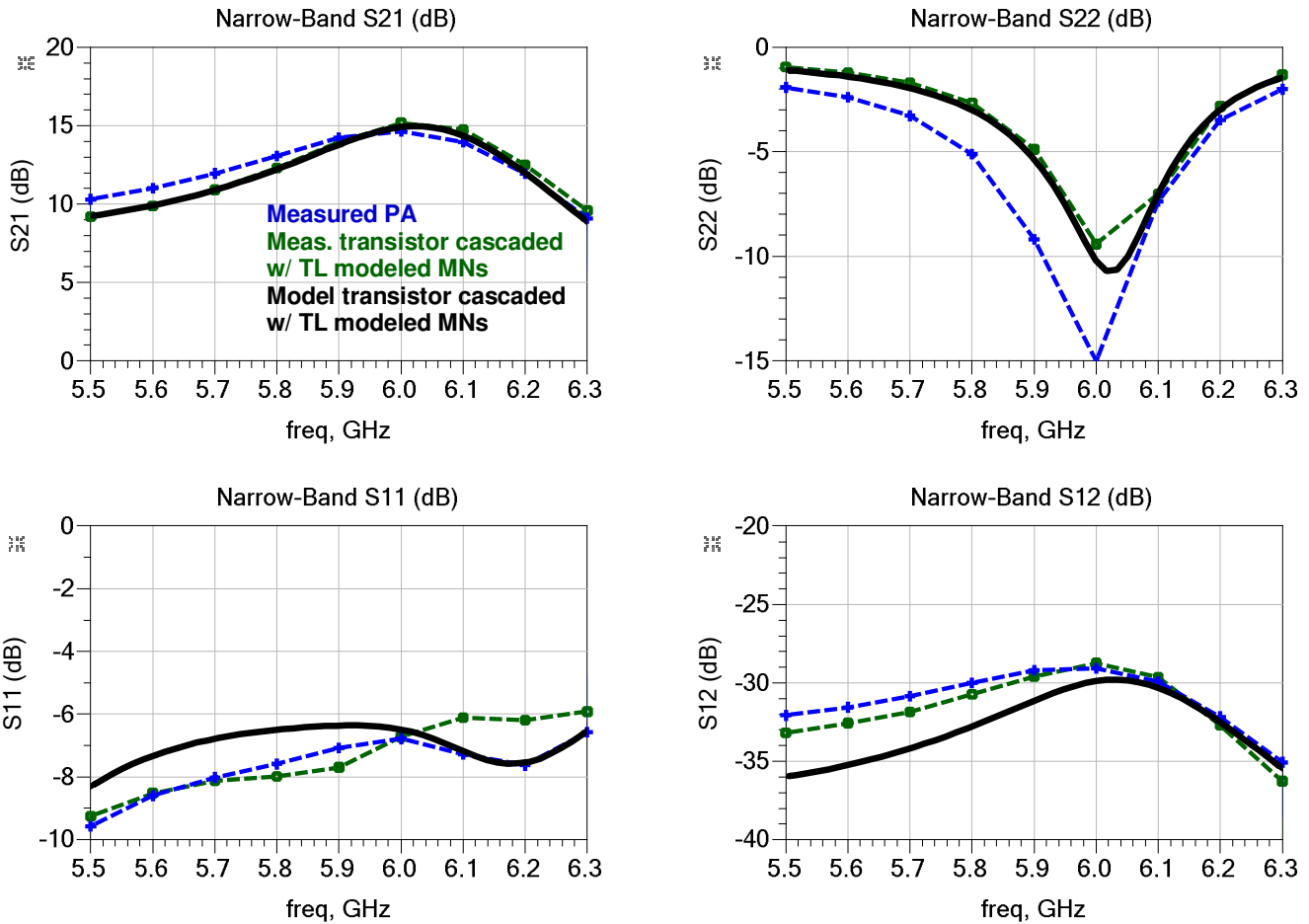


Figure 13. $V_{ds} = 28\text{ V}$, $I_{ds} = 200\text{ mA}$. Narrow-band comparison between the measured PA (blue symbols), measured transistor cascaded with the TL modeled matching networks (green symbols), Modelithics nonlinear transistor model cascaded with the TL modeled matching networks (black line).

Large Signal Analysis

Figure 14 provides a view of the model transistor power sweep simulation setup in ADS. Figure 15 shows the comparison between the measured data and model performance using the source and load reflection coefficients presented to the device during the power sweep measurements. The bias information includes: $V_{ds} = 28\text{ V}$, $I_{ds} = 200\text{ mA}$, frequency = 5.9 GHz. The PA power measurement is the response of the PA circuit as built; no tuning was done on the test bench in order to maximize performance.

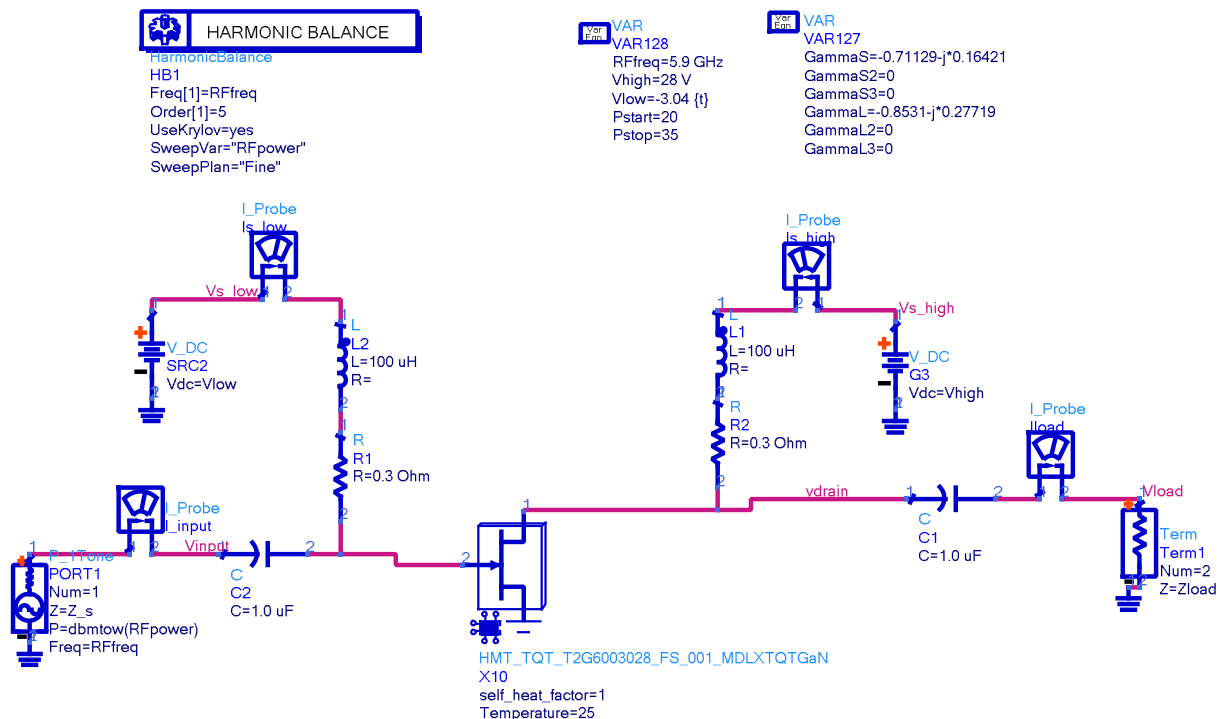


Figure 14. ADS power sweep simulation. The source and load reflection coefficients as presented to the device in the power bench measurement set-up are represented by the GammaS and GammaL variables.

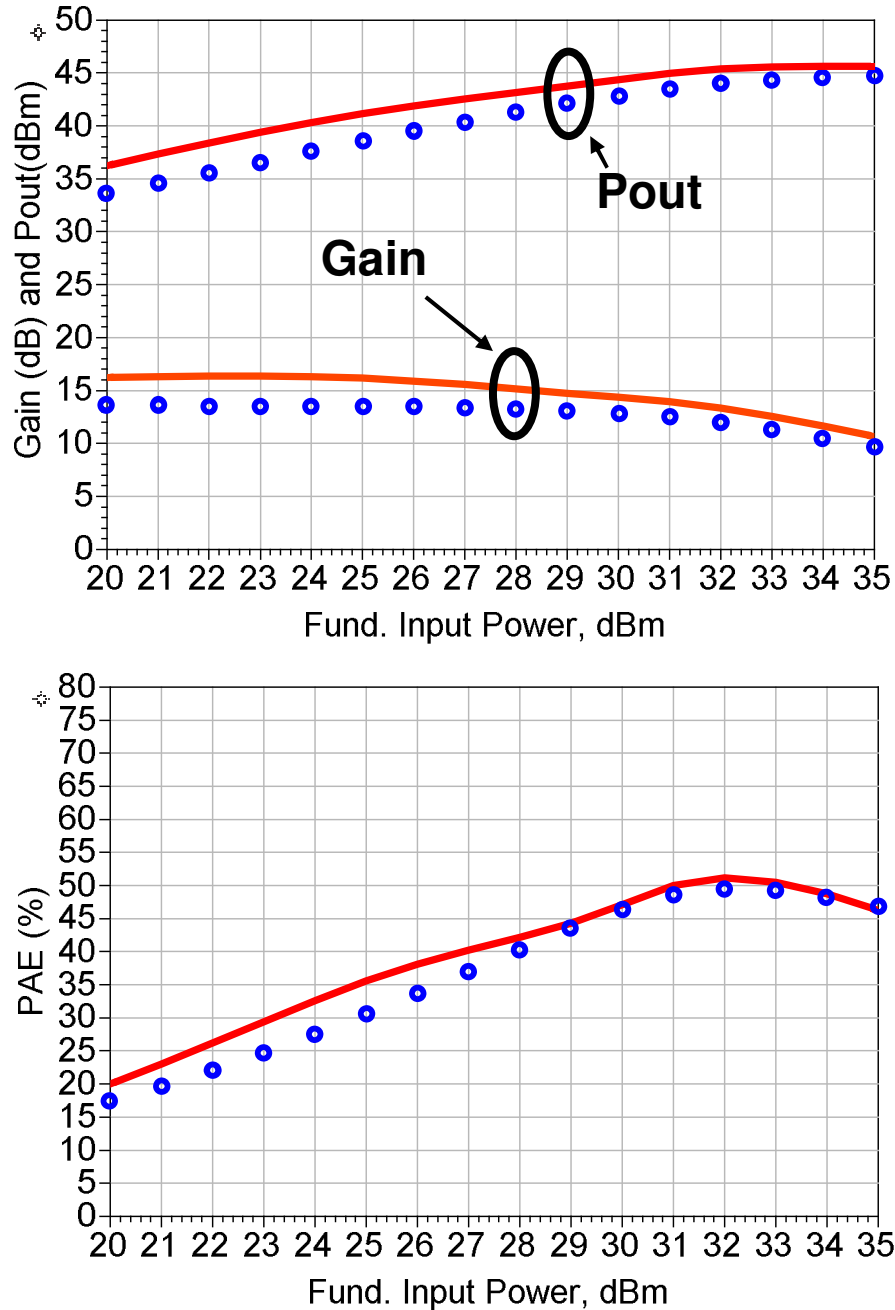


Figure 15. $V_{ds} = 28\text{ V}$, $I_{ds} = 200\text{ mA}$, frequency = 5.9 GHz. Modeled (red lines) vs measured (blue symbols) power amplifier power sweep.



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Summary and Conclusions

In this note, a 5.9 GHz Power Amplifier designed by TriQuint was studied; the TriQuint T2G6003028-FS transistor was the active device used in this power amplifier. The study began with a discussion about the assembly process and high frequency device performance differences due to test fixture, and subsequently progressed to include the small and large signal analysis of the amplifier. While the study provided insight into the amplifier, it also served to validate the Modelithics HMT-TQT-T2G6003028-FS-001 non-linear model of the TriQuint T2G6003028-FS device. Among the lessons learned was that test fixture and mounting differences can cause significant differences in measured performance at these frequencies. Careful attention to modeling all aspects of the passive matching and bias, as well as the transistor is required for predictable design results.

About this note

The initial design was provided by Dr. Charles Suckling of TriQuint semiconductor. The analysis work described in this note was performed by Hugo Morales, Scott Skidmore and Scott Muir of Modelithics, Inc..

The ADS input files associated with the amplifier shown here are available upon request.

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