Using Simulation Tools to Debug an Oscillating Amplifier

By Ed Troy

In this particular situation, I had designed an amplifier for a client based on a demo board from the manufacturer of the semiconductor. The demo board worked as predicted by the manufacturer, and simulations of its performance agreed well with measurements. However, when the client layed out the amplifier board and tested it, they complained that it was not working properly and they were having problems. They could not identify the nature of the problems, but I was pretty sure it was probably oscillating, or trying to oscillate. (Normally, I generally perform my own layouts for clients, or at least guide them very carefully, which takes as much, or even more of my time than just doing the layout, but this client insisted on doing the layout on their own without my close supervision. But, when it did not work, they came to me to explain why my design did not work.)

So, the basic schematic is shown in figure 1. I am not showing actual values or part identifications for this example.

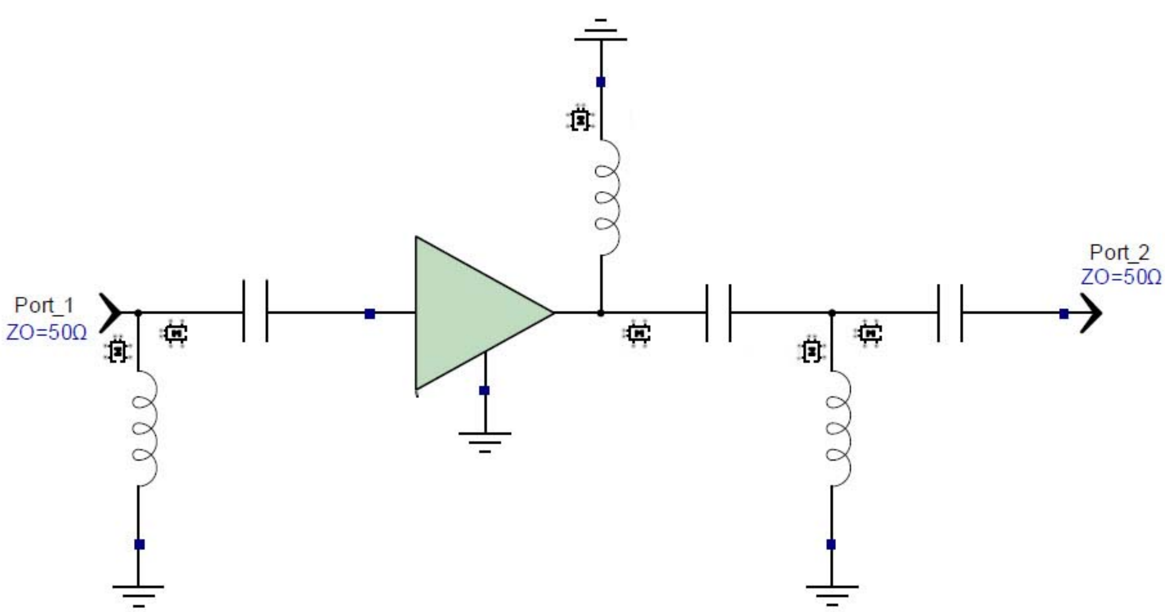

Figure 1 Amplifier circuit as designed

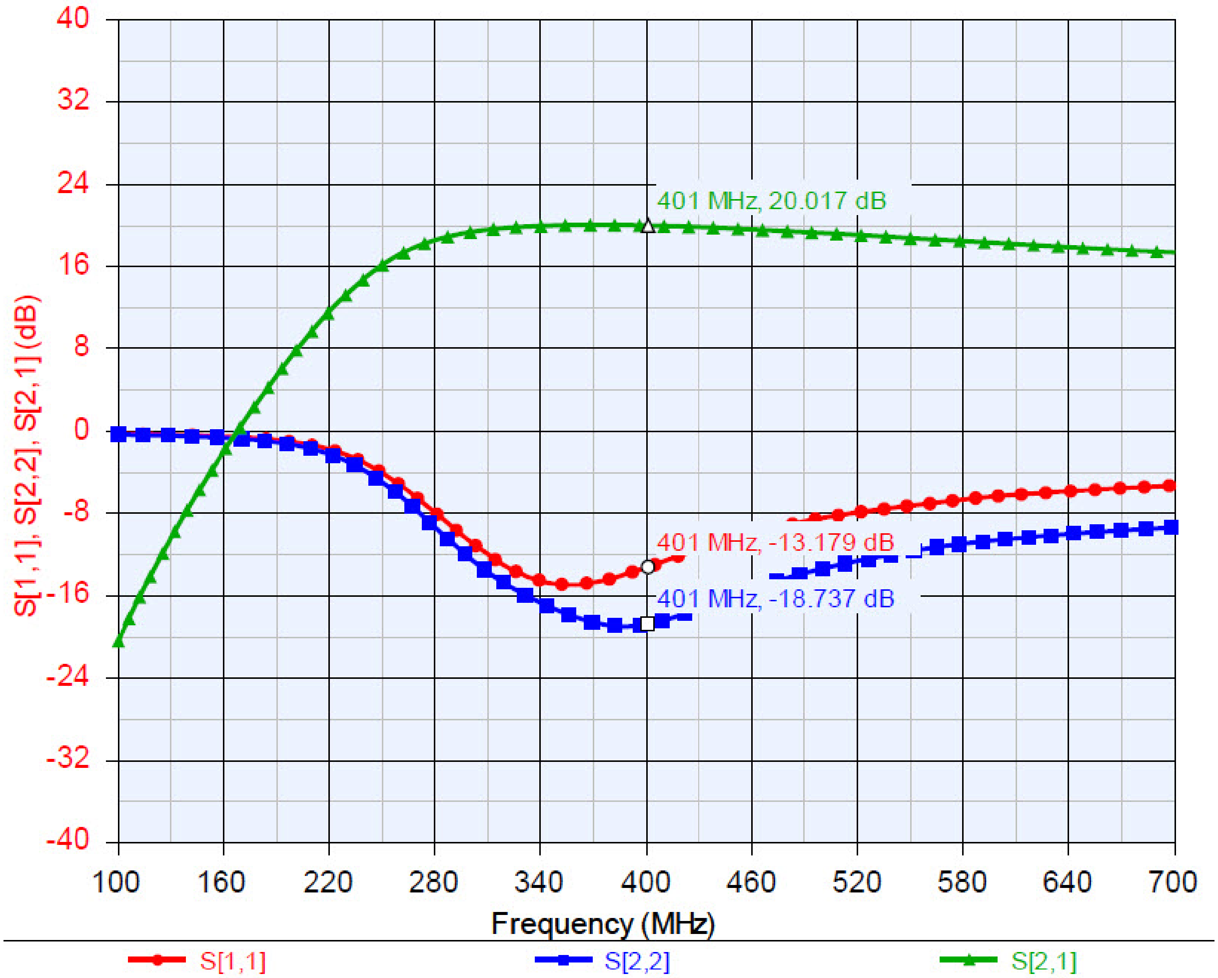

Figure 2 Simulated amplifier performance

However, when I measured the amplifier that was put together by the client on my network analyzer, the result was very different and disturbing, as shown in figure 3. The measured board had a very strong gain peak at about 250 MHz, and the gain at 400 MHz was a few dB less than simulated. This indicates that it may be on the verge of oscillating.

But, why would it oscillate? The simulation looked fine and the measured demo board looked fine, both on the bench and in simulation. I suspected something in the layout and originally thought that I was going to have to perform extensive electromagnetic simulation on the actual layout to identify the problem. (The board consisted of much more than just this amplifier.) But, a quick review of the actual Gerber file used to generate the board showed me something that looked very suspicious and typical of poor RF layout and the cause of many, many circuit problems at these (and higher) frequencies.

Figure 4 clearly shows the problem, if you know what to look for.

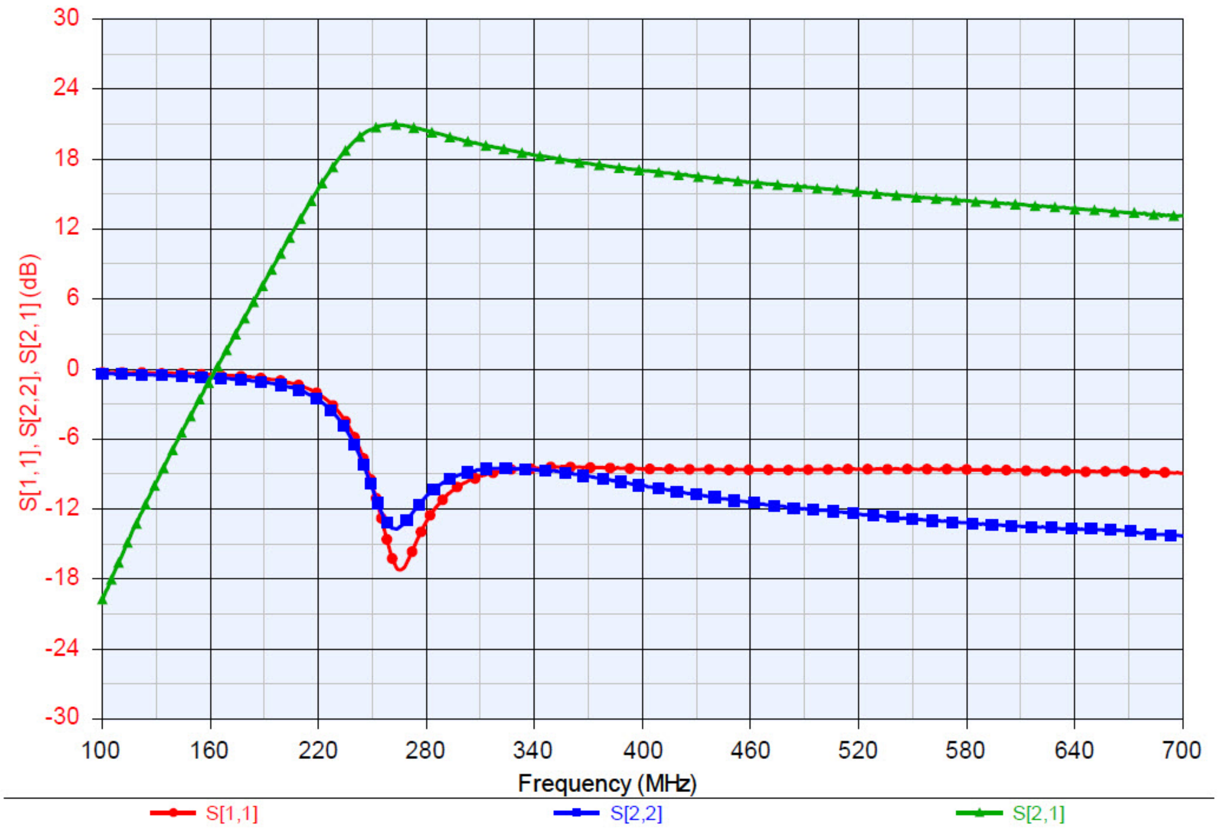

Figure 3 Measured performance of the amplifier as built

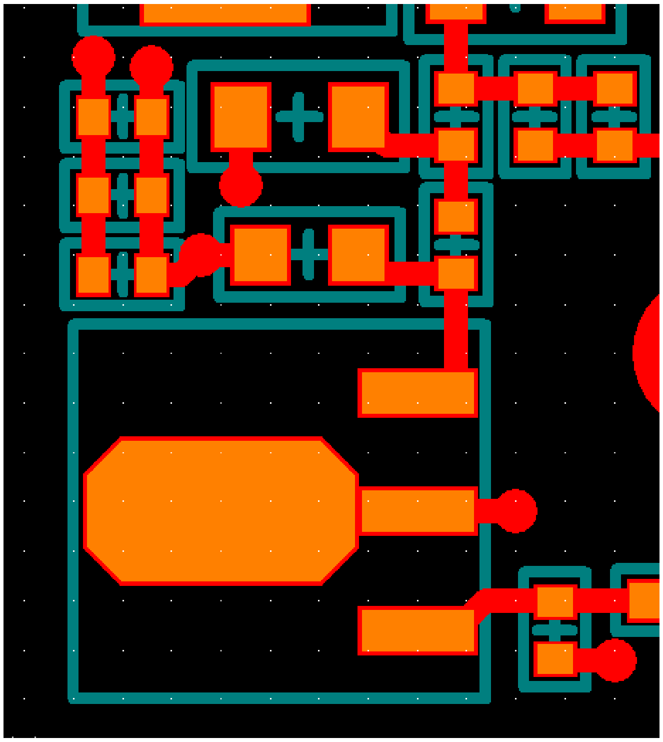

Figure 4 layout of amplifier portion

Notice the small circle to the right of the large pad in the lower left component. That component is the amplifier transistor, and that circle represents a ground via. That is *the only* ground via for the transistor. And, to make it worse, it is at the end of the center pin which is about as far from the bulk of the device, represented by the large octagonal shape to the left of the center lead pad and ground via! Devices like this need multiple ground vias, and they need them located not only where that one ground via is located, but a bunch should also be under and around that ground pad. (Which is the bottom of the actual semiconductor device.) These ground pins are also essential for heat sinking.

So, what we see in this layout is essentially a trace, consisting of the center lead pad and the short trace to the ground via, from the device to the ground. The device, while electrically connected to ground, is connected inductively to ground because of the distance between the actual ground via and the main device pad, which is under the bulk of the device in that octagonal area.

So, with that in mind, lets redo the schematic and add that trace in the ground path of the main device. This results in the schematic shown in figure 5. Note in this case that I put in a short piece (100 mils long and 25 mils wide) of transmission line and a real via between the device ground and actual ground.

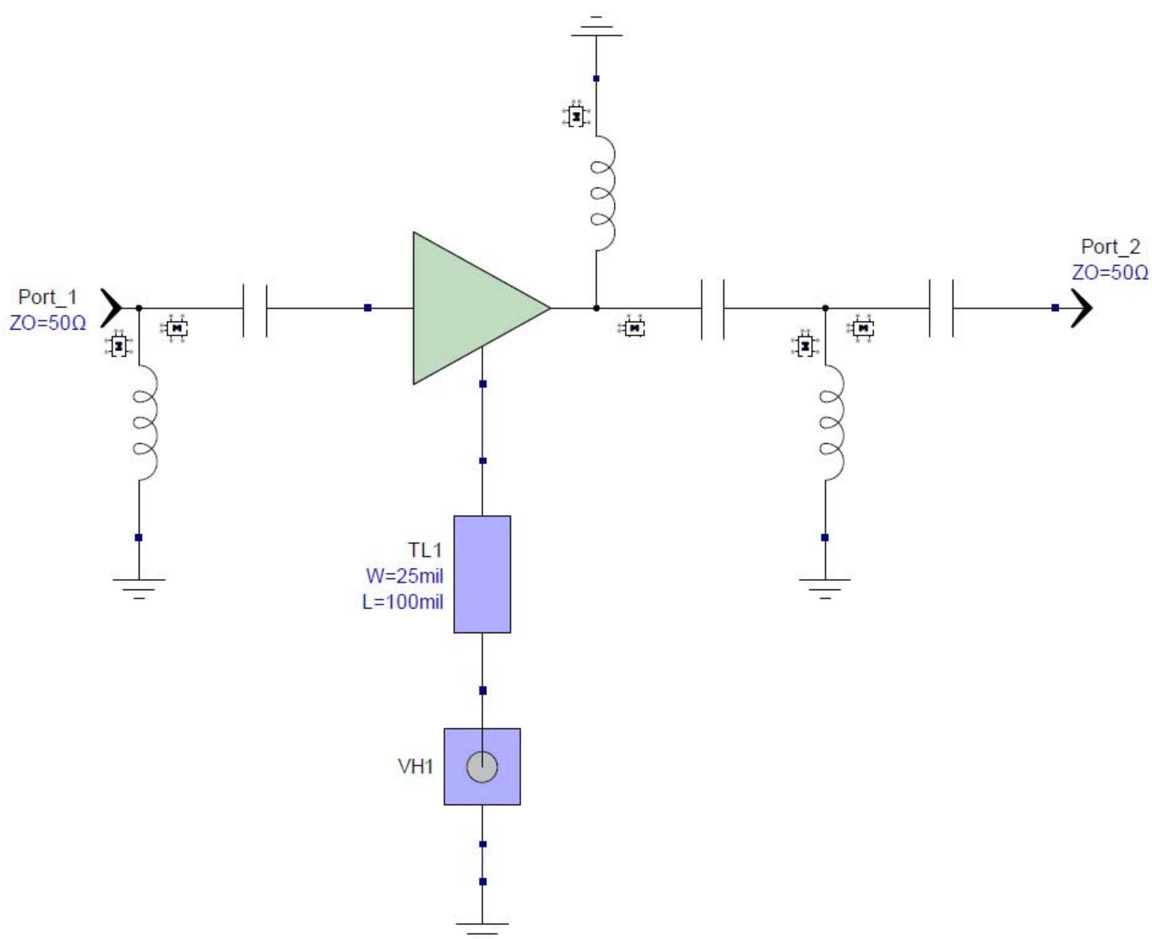

Figure 5 Amplier with inductive ground as in actual layout

Figure 6 shows the simulated performance of this circuit with an inductive ground caused by inadequate grounding of the power transistor along with the actual measured data from the board, as shown earlier. Clearly, you can see that with this slight change, the simulated and measured performance is almost identical.

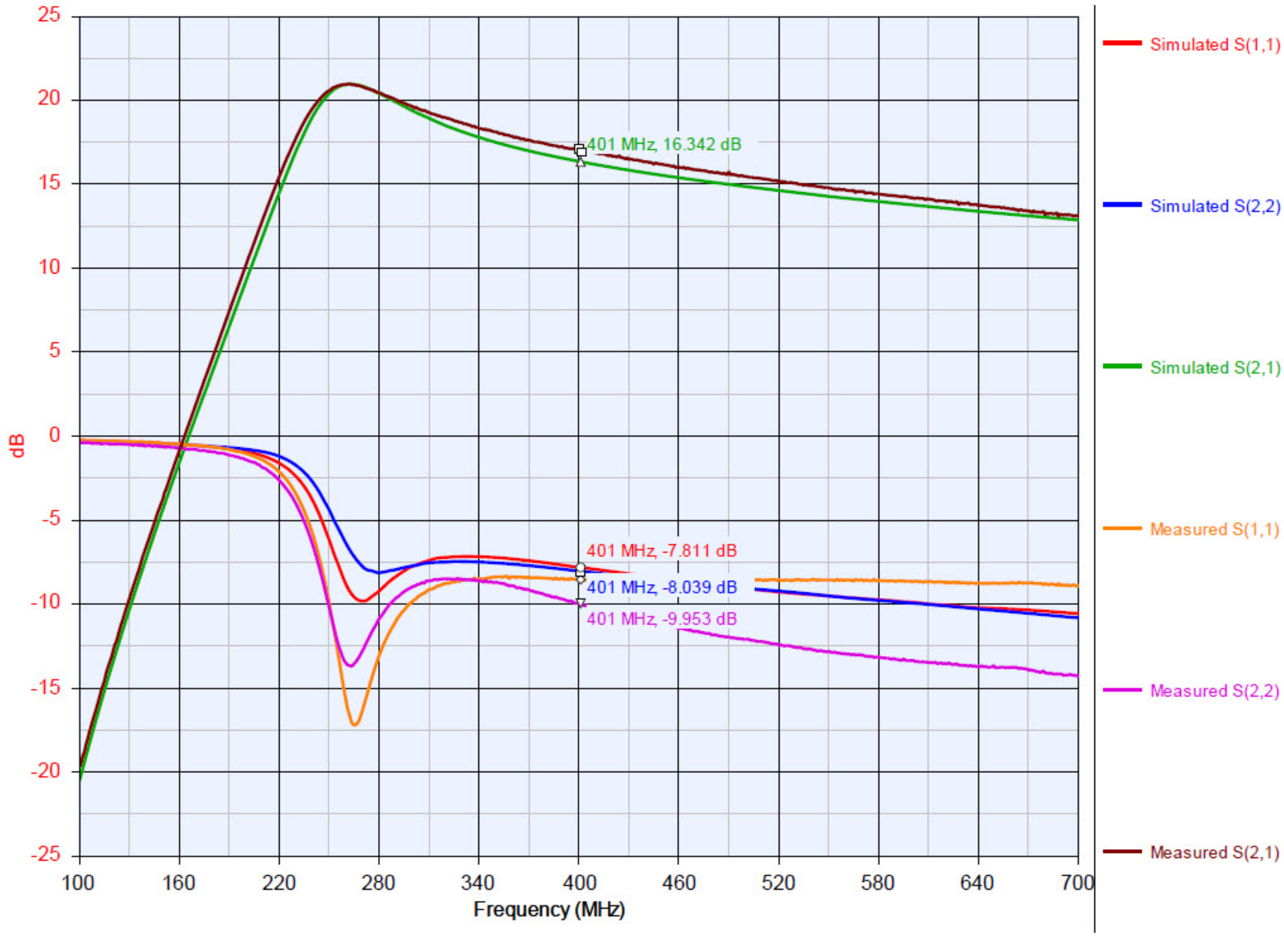

Figure 6 Simulated inductive ground circuit with actual measured board data

Fortunately, in this particular case, the transistor was located right next to the edge of the board. By soldering copper foil to the ground tab of the transistor and wrapping it around the board and soldering it to the ground on the bottom side of the board, a much better ground was achieved. To simulate this, the schematic in figure 7 was developed. Here, the 75 mil wide and 25 mil long trace was added to simulate the copper foil that was wrapped around the board from the ground tab on the device to the bottom side. The bad, inductive ground is still there, as it was on the actual board. But, now, the copper strap will help to lower the inductance between the device and ground.

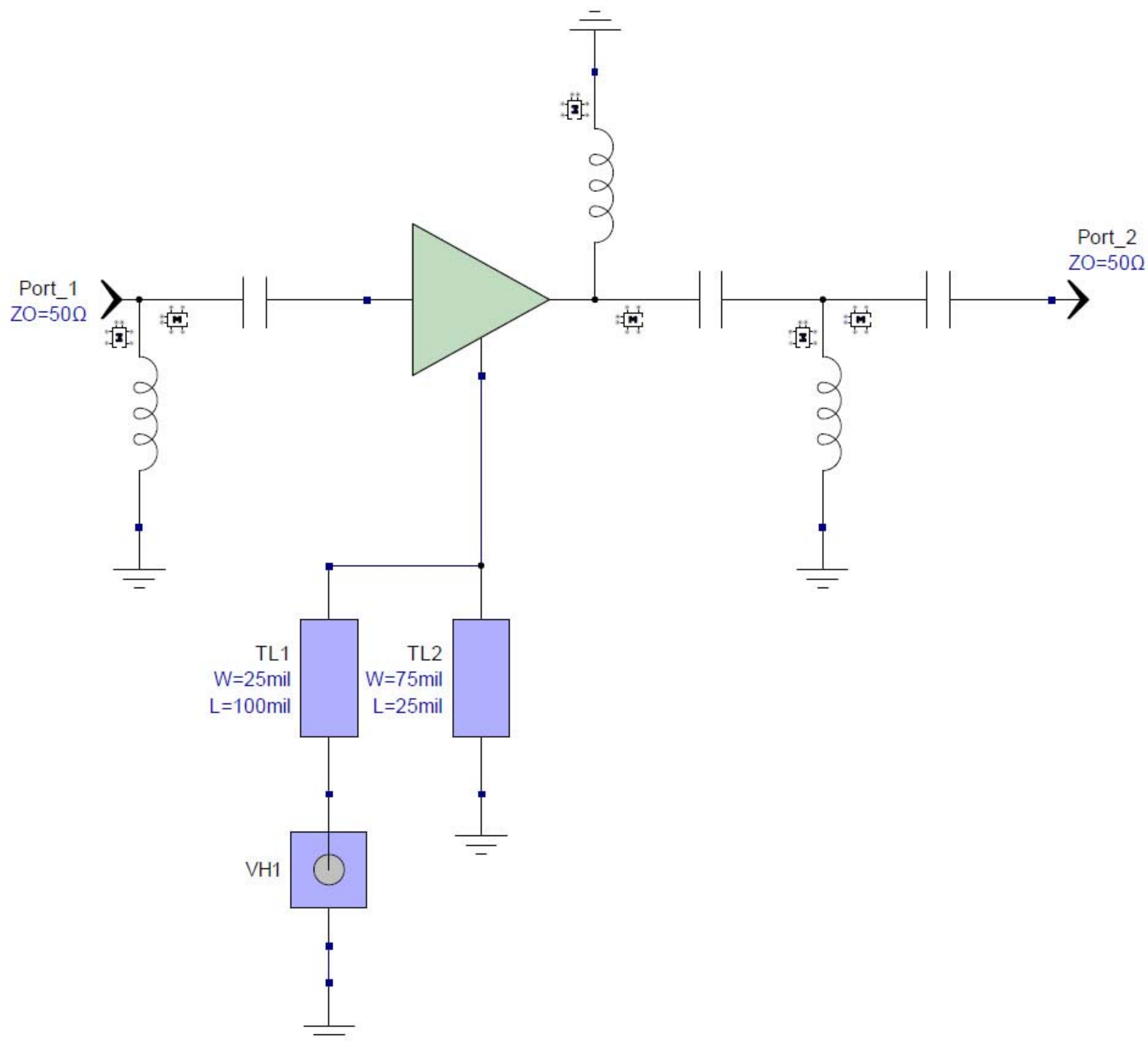

Figure 7 schematic of amplifier with wrap-around ground added

Figure 8 shows the simulated data for the schematic in figure 7 and the measured data for the board with the ground strap added. Clearly the oscillation tendency has been tamed and the conclusion that the problem was caused by bad grounding in the layout was confirmed.

Again, this is another classic case showing not only the extreme importance of excellent grounding for all RF, microwave, and wireless circuits, but it also shows the power of using simulation tools to troubleshoot design problems.

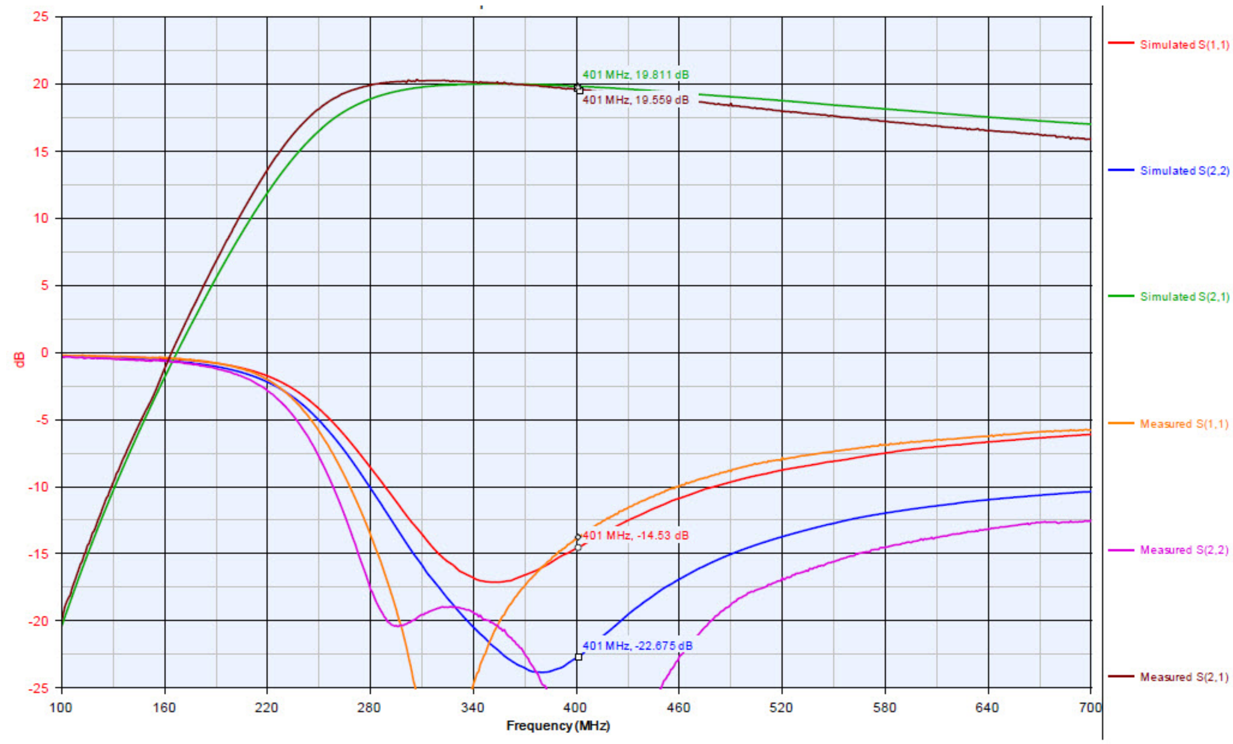

Figure 8 Simulated and measured amplifier with ground strap added

As an additional note, all of the simulated models for the capacitors and inductors were Modelithics (1) models. These provide actual substrate and pad scalable models and thus make modeling much more accurate. Aerospace Consulting LLC uses Modelithics models for all circuit modeling whenever possible.

1) Modelithics http://www.modelithics.com