

# Performing EM/Circuit Co-Simulation With Modified Standard Models

By Luis M. Ledezma and Thomas M. Weller  
Modelithics, Inc.

Here are guidelines for de-embedding the mounting pads in standard component models to achieve accurate EM simulation

By default, Modelithics library models include mounting pad effects. Hence, when performing full wave electromagnetic (EM) analyses the pad geometries should not be included in the geometry setup used to define the EM analysis. However, there are reasons to include the pads in the EM simulation instead of having them inside the components models. Some of these reasons are:

- Use of a pad size different from the one included with the model, or outside the range of pad dimensions if using a pad-scalable model.
- Including the step effect when the feed line is different from the pad width. This step can also be included using an analytical model in a circuit simulation.
- Including the effects of coupling between the pads and another part of the circuit.
- Desire to simulate the pads along with other printed circuit patterns as a standard practice.

Modelithics models include a feature that allows the pads to be deembedded from the model, thus leaving the part effectively without the pads. This feature, named *simulation mode 2*, is useful in the case that the pads need to be included in an EM simulation.

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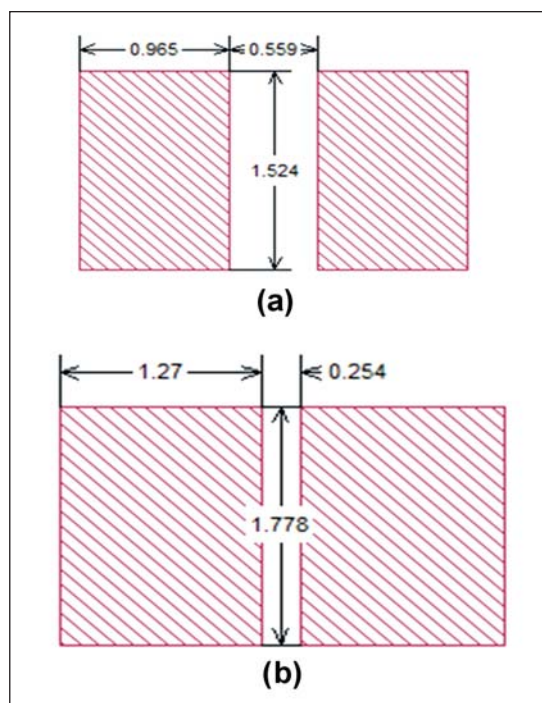


Figure 1 . (a) the mounting pad used to extract the model; (b) different mounting pad used for validation. (Dimensions in mm)

Sonnet Software Suites [1].

## Using Simulation Mode 2

Using simulation mode 2 along with EM simulation allows the use of pad geometries tailored to the specific circuit at hand. As an example, let's consider including an AVX-AQ12 capacitor, from the Modelithics CLR library, within an EM-circuit co-simulation with Sonnet. The model for this capacitor was extracted using the pads shown in Figure 1(a). The objective is to predict the response with

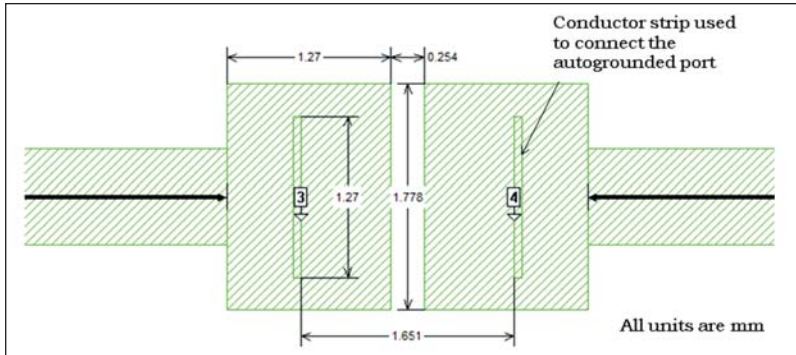


Figure 2 · Simulation set up in Sonnet. Note that the feeding transmission lines are deembedded leaving just the pads. Also note that the distance between the internal ports is equal to the length of the component.

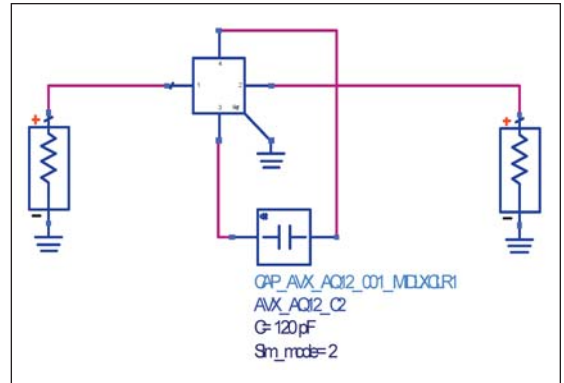


Figure 3 · Capacitor model connected to the result of the EM simulation. Note that simulation mode is set equal to 2.

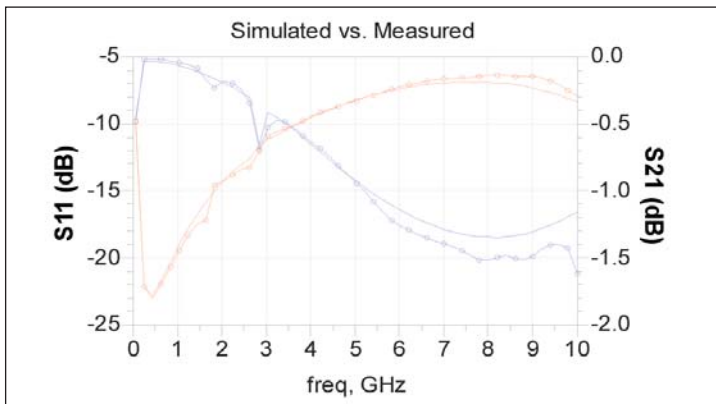


Figure 4 · Comparison between measured data (line with markers) and EM co-simulation (continuous line). Red lines are for  $S_{11}$  and blue lines for  $S_{21}$ . Note the different scales for each parameter.

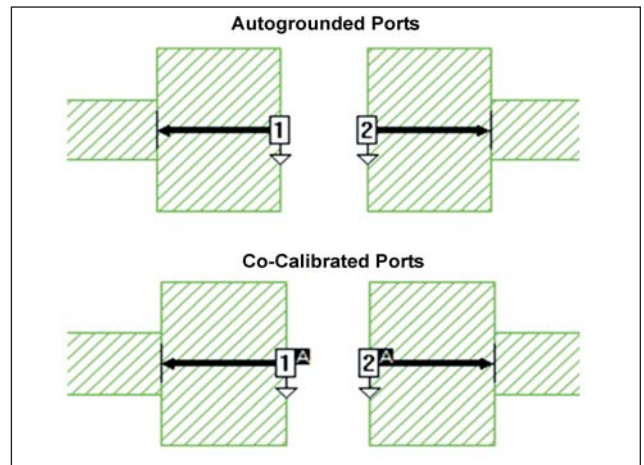


Figure 5 · Autogrounded and co-calibrated ports with pad deembedding.

the capacitor mounted on the pads shown in Figure 1(b).

The setup in Sonnet is shown in Figure 2. Note that the feeding transmission lines are deembedded leaving just the pads. The goal is to compare the capacitor and pads directly without introducing any other variable. Autogrounded ports are located at the component boundaries. To enable the use of these ports inside the pads, a redundant conductor stripe is located where the component boundaries are supposed to be. In this case the size of the component is  $1.27 \times 1.651$  mm.

The s4p file obtained from this simulation may be used in any circuit simulation software together with the Modelithics model of the capacitor. The capacitor is then connected between ports 3 and 4 of Figure 2. An illustration of this, using Agilent ADS, is depicted in Figure 3. Recall that simulation mode equals 2.

The comparison between the simulation of Figure 3 and measured data is shown in Figure 4. Note that the results show close agreement and differ primarily near

the edge of the valid range of the model (10 GHz). The difference is small (note the scale in the right hand axis), about 0.3 dB above 8 GHz for  $S_{21}$ . The capacitor used here had a nominal value of  $C = 120$  pF. However, other comparisons against measured data were done for several values of capacitance obtaining very similar results. The substrate used in all the simulations and for fabrication was 10 mil-thick Rogers 4350.

### Using Simulation Mode 0

If the pad size that is going to be used is already available in the model of the component, it is possible to include just part of the pad effect in the EM simulation. As illustrated in Figure 5, we can use internal ports (either autogrounded or co-calibrated [1]) at the edge of the pads and deembedded them. Note that by doing this we are including the step in width from the line to the pad in the EM simulation. Since the pads are deembedded, they need to be included in the components model when per-

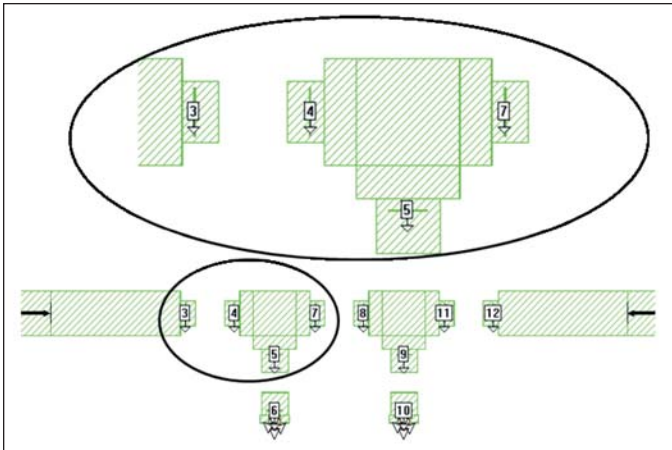


Figure 6 · Low pass filter in Sonnet using autogrounded ports. A different calibration group is used for each component.

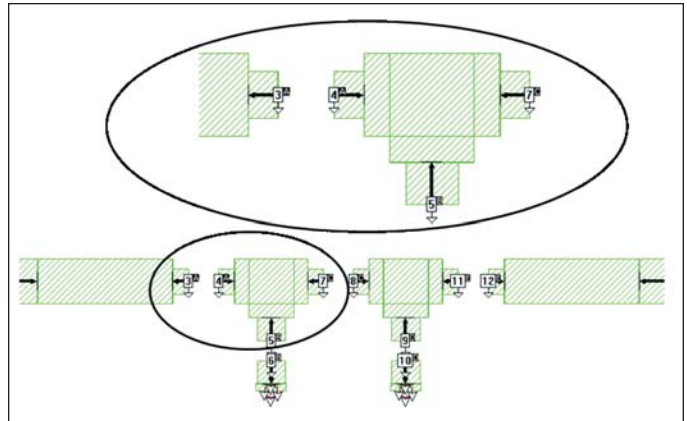


Figure 7 · Low pass filter in Sonnet using co-calibrated ports. A different calibration group is used for each component.

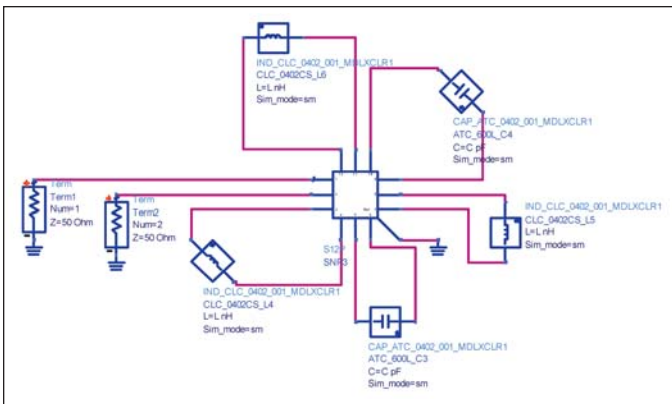


Figure 8 · Schematic connection of the EM simulation results and the lumped components of the filter. Agilent ADS was used in this example.

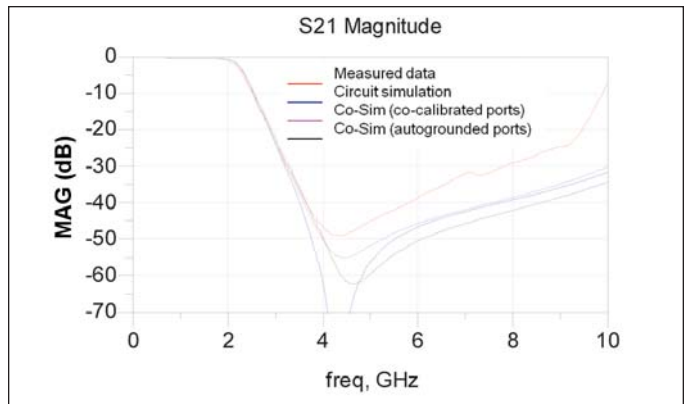


Figure 9 · Results from the co-simulation, circuit simulation and measured data for the low pass filter of AN-17 (2).

forming a subsequent circuit simulation; thus simulation mode 0 must be used.

Another option available in Sonnet is the “component” feature. Since this is technically equivalent to using co-calibrated ports we won’t cover it here. We refer you to the Sonnet’s user manual for more detailed information about this feature.

### Example 1: Low Pass Filter

As an application example consider the benchmark low pass filter from Modelithics AN-17 [2]. This is a fifth-order Chebyshev filter with 0.25 dB ripple in the pass-band and a cutoff frequency of 2.2 GHz. The layout in Sonnet is shown in Figures 6 and 7 using autogrounded ports in one case, and co-calibrated groups in the other. Note that in the case of autogrounded ports a different calibration group is used for each component.

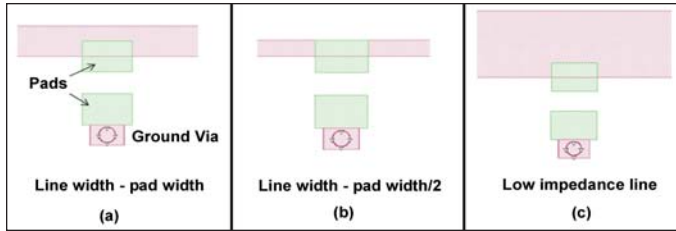
The output of the Sonnet simulation is an S14p file (12 internal ports, and 2 external ports not shown in the fig-

ures). The schematic configuration for the co-simulation is shown in Figure 8 using Agilent ADS.

The results of these co-simulations along with the circuit simulation and the measured data are shown in Figure 9. The co-simulation with co-calibrated ports gives results nearly identical to those of the circuit simulation as expected. The deep resonance predicted just above 4 GHz by the circuit simulation is likely due to the equivalent lumped models of the microstrip discontinuities, and the coupling through the substrate that is ignored. We conclude this because this behavior is not predicted by the co-simulation, nor it is present on the measured data.

### Example 2

Let’s explore the case of shunt connections used in many applications. To save circuit real estate, designers often put the mounting pads of the components above the transmission lines when realizing shunt connections. Three examples illustrating this practice are illustrated



**Figure 10** · Three possible configurations for shunt connections with mounting pads overlapping transmission lines. (Pads shown in a different color for clarity)

in Figure 10. A simple way of modeling this situation is simulating the geometry in an EM simulator, including internal ports at the boundaries of the component, and using simulation mode = 2. With Sonnet, autogrounded ports may be used as discussed before.

As an example, a comparison between measured data and co-simulation results is presented in Figure 11. The configuration used was the one depicted in Figure 10(a) with a 20 mil-thick Rogers 4003 substrate. The part mounted was an ATC 600F capacitor with a nominal value of 20 pF.

## Conclusions

Guidelines for performing EM co-simulation using Modelithics library models and Sonnet suites were presented. The main strategy is to use simulation mode = 2 along with internal ports in the EM simulator. The results from the simulation presented good agreement with measured data for the different experiments and examples presented.

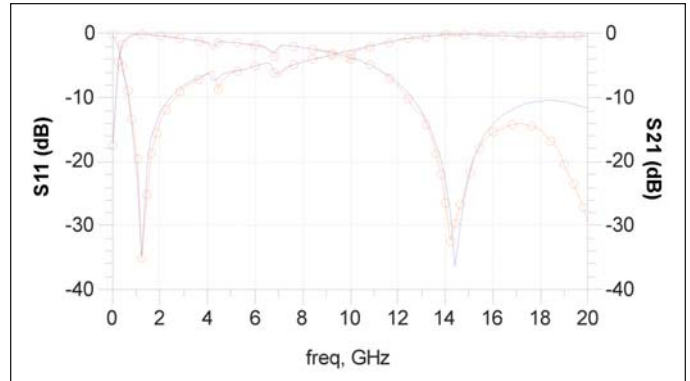
## References

1. J. C. Rautio, "Deembedding the effect of a local ground plane in electromagnetic analysis." *IEEE Tran. Microwave Theory Tech*, 53(2), Feb. 2005, pp. 770-776.
2. "Lumped Element Filter Design and Optimization," Application Note AN-17, [www.modelithics.com](http://www.modelithics.com)

## Author Information

Luis M. Ledezma received the BSEE degree from the University of Carabobo, Venezuela, in 2008. He is currently a graduate student in the Wireless and Microwaves Information Systems (WAMI) group at the University of South Florida. In 2010 he completed internships with Modelithics, Inc. His research interests include applied and theoretical electromagnetics, as well as design and modeling of microwave and millimeter-wave circuits. He can be reached at [luisledezma@mail.usf.edu](mailto:luisledezma@mail.usf.edu)

Thomas M. Weller received the B.S., M.S. and Ph.D. degrees in Electrical Engineering in 1988, 1991, and 1995, respectively, from the University of Michigan. From 1988-1990 he worked at Hughes Aircraft Company. He



**Figure 11** · Results of the co-simulation (in blue) and the measured data (in red with dots) for the shunt connection of Figure 10a.

joined the University of South Florida in 1995 where he is currently a professor in the Electrical Engineering Department and Associate Dean for Research in the College of Engineering. He co-founded Modelithics, Inc. in 2001. His current research interests are in the areas of RF micro electromechanical systems, development and application of microwave materials, and integrated circuit design. He can be reached at: [tweller@modelithics.com](mailto:tweller@modelithics.com)