Are 3D EM Models a Necessity or a Redundancy?

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When designing RF/microwave circuits, measurement-based equivalent-circuit models have traditionally been the best solution in terms of simulating the components used in the design. However, one limitation of these models is that they are developed for isolated single components and generally cannot capture the coupling effects that can arise when components are located close to other components or objects. This is where 3D electromagnetic (3D EM or 3D) models come into play because, unlike equivalent-circuit models, 3D models can capture coupling interactions.

So how can you know when to use 3D models? After all, there's no doubt that equivalent-circuit models work great for many design scenarios. With that being the case, 3D models may seem like more of a redundancy rather than a necessity.

But don't be too quick to dismiss 3D models because they may be more necessary than you think. To explain, let's say you have a design that includes components that are densely packed onto a printed-circuit board (PCB). If you choose to simulate such a design using only equivalent-circuit models, you may be in for a surprise when you see how the circuit actually performs on the bench. Let's try to prove this point by looking at an example.

Figure 1 shows a schematic and the corresponding layout of a bandpass filter design in Ansys® Electronics Desktop. For the components, we are using Modelithics Microwave Global Models™ for the TDK MHQ1005P inductor series and the Johanson R07S capacitor series. Microwave Global Models are measurement-based, highly scalable equivalent-circuit models. The substrate used for this design is 4-mil-thick Rogers RO4350B. Notice from the layout how the components are located very close to one another. Of course, this arrangement allows for a smaller size, but it also creates the possibility that the components will couple to one another.

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Chris DeMartino is a Sales and Applications Engineer at Modelithics. His experience includes developing and testing RF/microwave components and assemblies for various applications. In addition, Chris spent several years working as a technical editor for an industry publication, making him well equipped to create useful technical content. Some of his roles at Modelithics include designing application circuits, writing technical articles and application notes, and creating demonstration and tutorial videos. Chris has a B.S. in Electrical Engineering from the State University of New York at Binghamton and an M.S. in Electrical Engineering from Polytechnic University.

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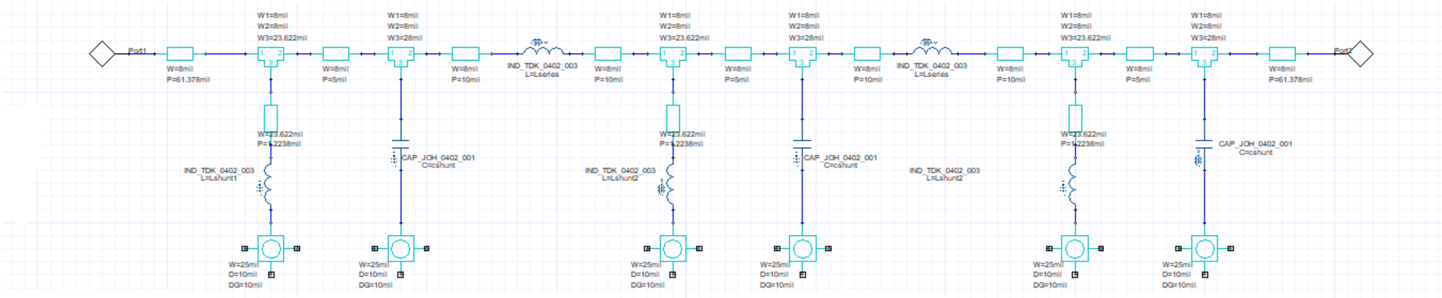

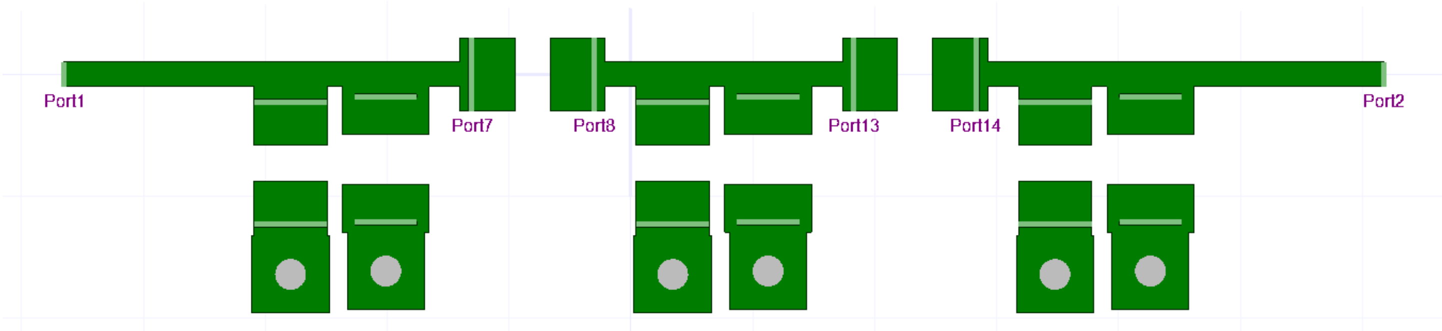

Figure 1. Filter schematic (top) and the corresponding layout (bottom) in Ansys Electronics Desktop.

Let's perform a planar EM/circuit co-simulation using Ansys' 2.5-D Method of Moments (MoM) EM solver to simulate the layout shown. This simulation approach is very effective for many design scenarios.[1] But for this example, we'll see later that performing a planar EM/circuit co-simulation with equivalent-circuit models is actually not the best way to accurately predict real-life performance.

We'll also create a 3D version of this same design. Figure 2 shows the same filter in Ansys HFSS™. By performing a 3D EM simulation of this project, we can compare the results of the planar EM/circuit co-simulation with the results of this 3D EM simulation. For this 3D project, we are using 3D EM geometry models for the same TDK inductors. We are also using what are known as 3D Brick Models™ for the same Johanson capacitors. For more on 3D Brick Models, we recommend reading Application Note 78 from the Modelithics website titled, "Using 3D Brick Models for Full-wave EM/Circuit Model Co-simulation of MLCC Capacitors in Ansys HFSS."

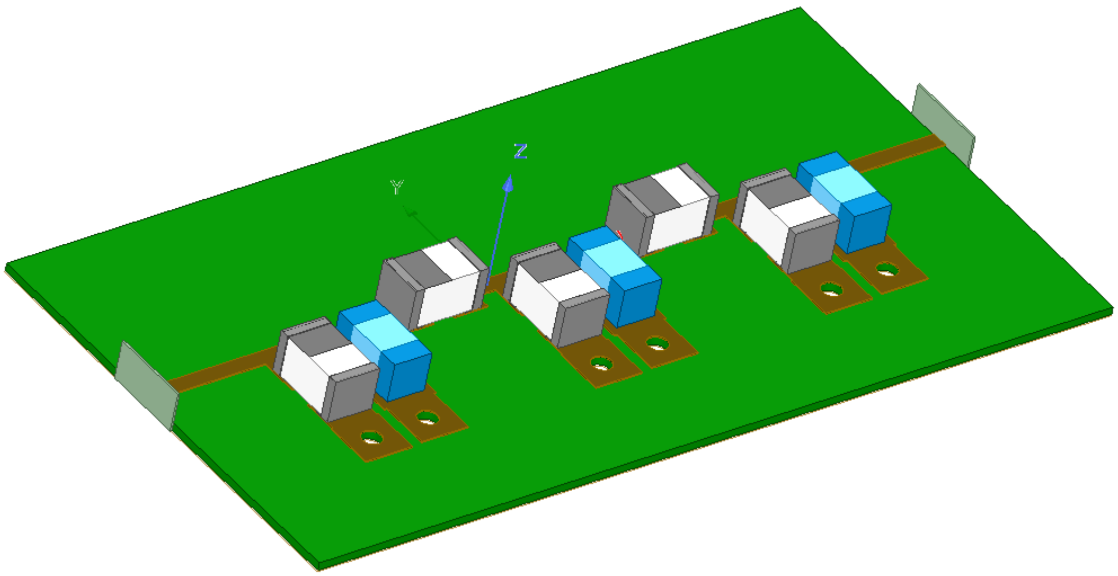

Figure 2. Shown is the same filter design in HFSS that includes 3D EM geometry models for the TDK inductors and 3D brick models for the Johanson capacitors.

Now, let's see how the results of the planar EM/circuit co-simulation and the 3D EM simulation compare with one another. Figure 3 shows the results of both simulations. Notice the discrepancy between the two sets of results. Figure 4 shows a close-up view of the S_{21} results from both simulations. We can clearly see that the 3D EM simulation produces a frequency response that's shifted higher in comparison to the planar EM/circuit co-simulation results. To be more specific, the two simulations produce lower 3-dB bandwidths that differ by about 100 MHz and upper 3-dB bandwidths that differ by just under 80 MHz.

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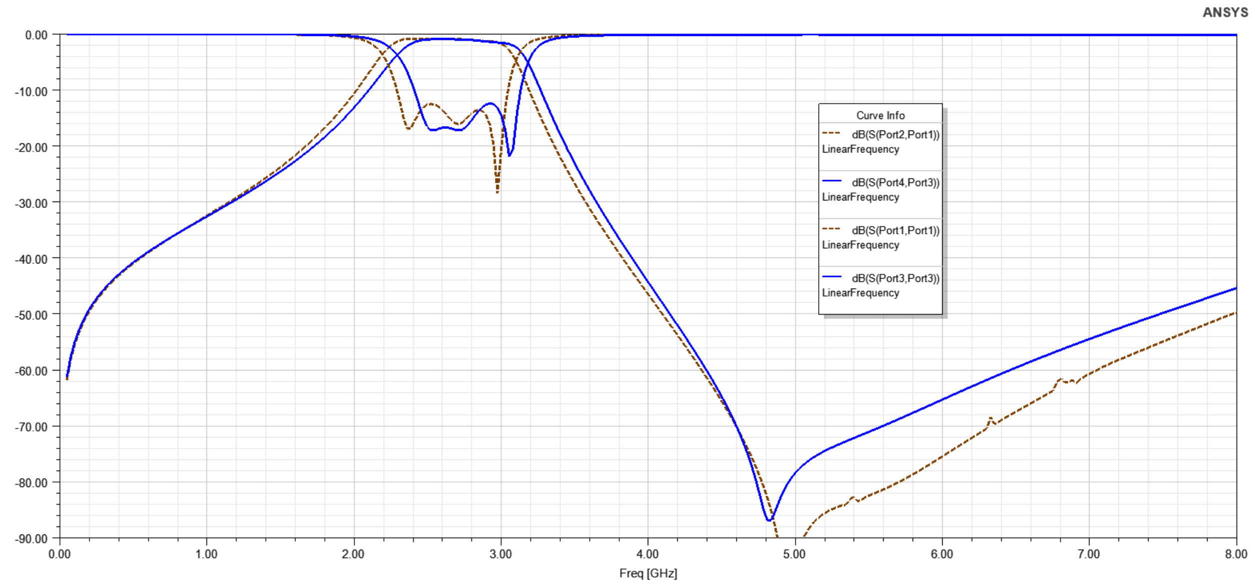

Figure 3. Simulated S_{21} and S_{11} of the filter design. Solid blue traces represent the 3D EM simulation results, while the dashed brown traces represent the planar EM/circuit co-simulation results.

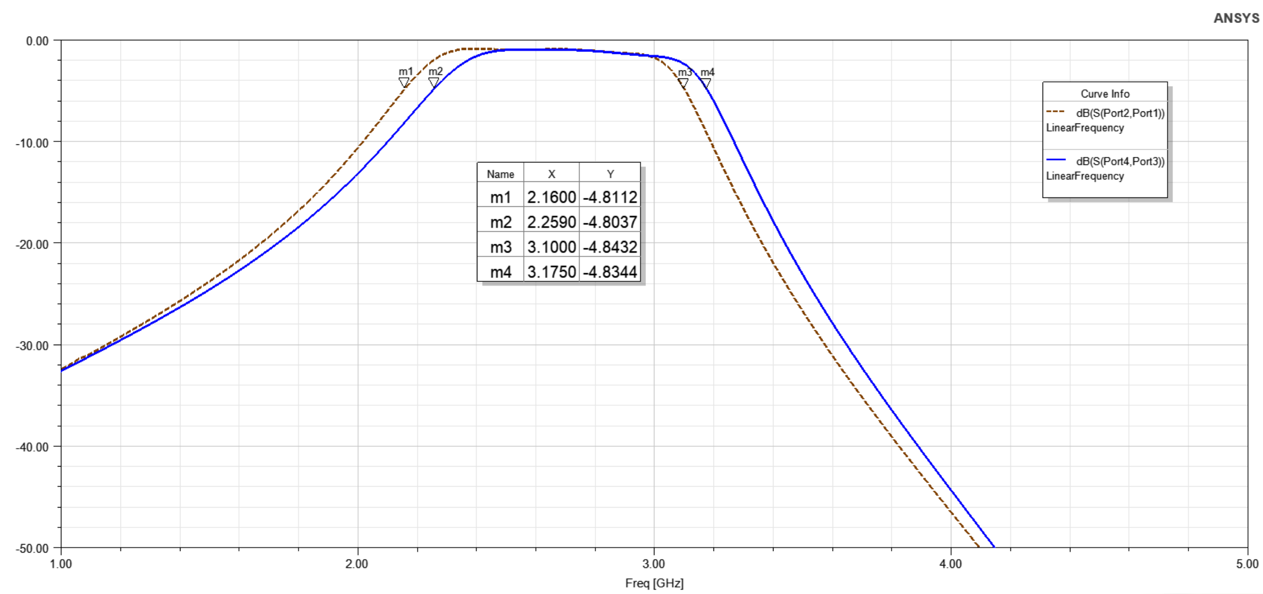

Figure 4. A closer look at the S_{21} results of both simulations. Again, the solid blue traces represent the 3D EM simulation results, while the dashed brown traces represent the planar EM/circuit co-simulation results.

So we've demonstrated how performing a planar EM/circuit co-simulation and a 3D EM simulation of the same design can produce different results. Now you might be asking, "Which of the two simulations truly predicts real-life performance?" The answer, we can safely say, is the 3D EM simulation. To prove this point, you can check out an upcoming article in which a similar filter design is simulated with the same two methods shown here. A similar discrepancy is also shown between the two sets of results. The article also presents measured data of the filter. So which of the two simulations really predicted real-life performance? The answer, as you can see in the article, is the 3D EM simulation.

So are 3D models a necessity or a redundancy? The answer really lies in the application at hand. Equivalent-circuit models are perfectly fine for many design scenarios, thus removing the need for 3D models. However, for densely packed designs, such as the one shown here, it would be a good idea to take advantage of 3D models to ensure that you avoid any unwanted surprises when it's time to measure your circuit in the lab. Do keep in mind that 3D models are associated with longer simulation times. Another factor that should be determined beforehand is whether a 3D model is available for a given component.

References

1. C. DeMartino, "Application Note 079: Filter Design Flow in Ansys Electronics Desktop with Modelithics Substrate Scalable Models." Modelithics literature: https://www.modelithics.com/Literature/AppNote.

2. I. Bedford, E. Valentino, L. Dunleavy, "Application Note 063: Intoduction to Modelithics 3D Models in HFSS." Modelithics literature: https://www.modelithics.com/Literature/AppNote.

3. I. Bedford, "Application Note 078: Using 3D Brick Models for Full-wave EM/Circuit Model Co-simulation of MLCC Capacitors in Ansys HFSS." Modelithics literature: https://www.modelithics.com/Literature/AppNote.