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Uncovering the ExpertMode Parameter for Filter Optimization, Part 2

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In Part 1 of this series, we introduced the ExpertMode parameter that's included within Modelithics Microwave Global Models™ for Cadence® AWR Design Environment®. In this post, we'll continue this topic by looking at the design flow of a diplexer example that involves the ExpertMode parameter together with the Equal Ripple Optimization software from DGS Associates.

Figure 1 shows a schematic for the same lumped-element diplexer we saw at the end of Part 1. This design includes Microwave Global Models for the Presidio 0402UP capacitor series and TDK MHQ1005P inductor series. Also, the substrate we'll be using is 20-mil-thick Rogers RO4003C. The goal for this diplexer is a 1-GHz crossover frequency.

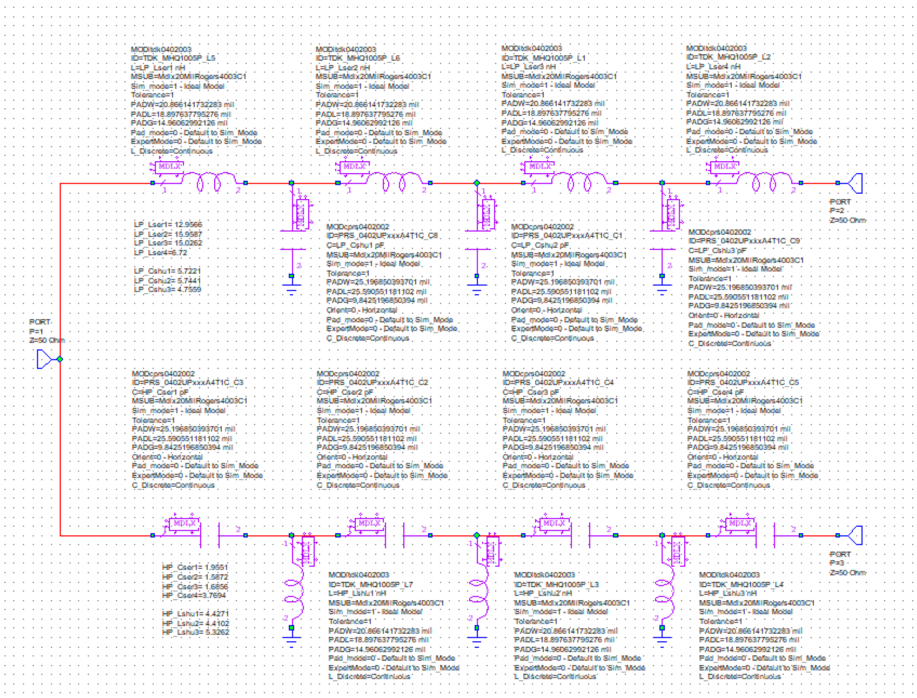

Figure 1. Schematic of the diplexer example.

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Let's begin by just simulating the diplexer with ideal component models. Modelithics Microwave Global Models include a parameter called "Sim_mode" that lets you specify the model's functionality. Setting a model to Sim_mode 1 enables it to simply behave as an ideal model. So, we'll begin by setting all models to ideal mode. The part values have been obtained from a synthesis tool. Note that the 3-dB points are set to 1 GHz for both the lowpass and highpass arms, which does not exactly correspond with optimal return loss. However, this will be corrected in the next step. Figure 2 shows the simulated results.

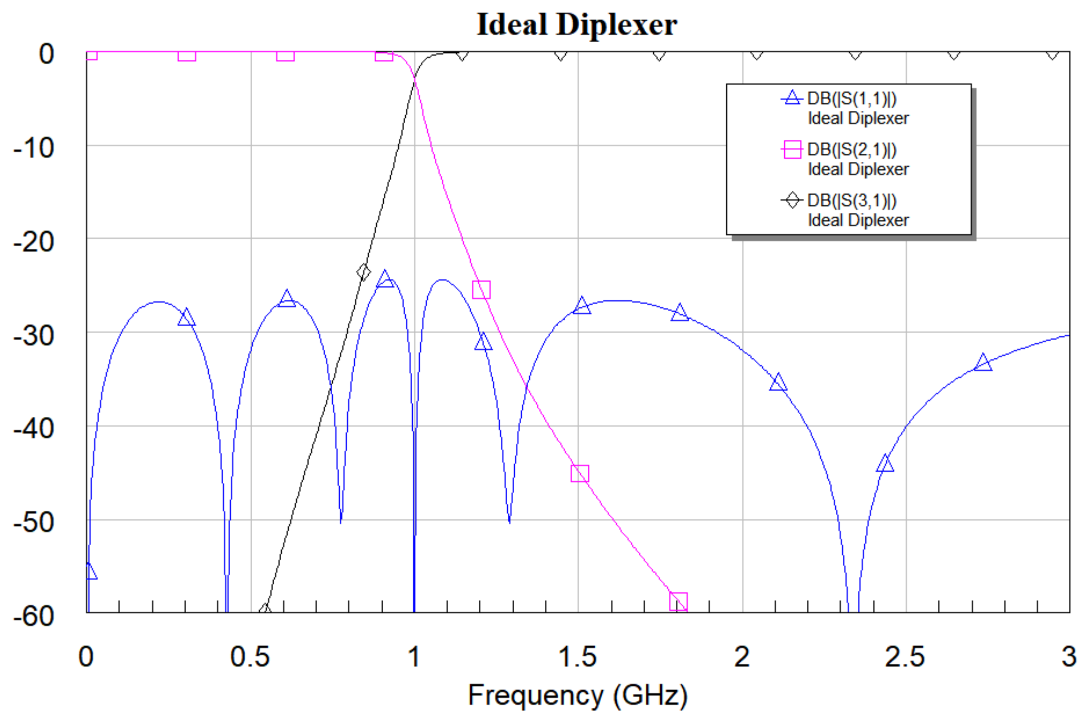

Figure 2. Diplexer performance with ideal component models.

Next, we'll set all models to Sim_mode 0 so that they function as full parasitic models. Now, when we simulate, the diplexer's performance shifts lower in frequency due to using real-life parasitic models instead of ideal component models. So, the next step is to perform an optimization with the Equal Ripple Optimization software. Before optimizing, we'll set the ExpertMode parameter of all models to 1 to remove equivalent series resistance (ESR) from the model. With this setting, the model essentially functions as a lossless model. One additional point is that we'll also make the substrate definition lossless prior to optimizing to ensure that the component models are lossless.

You may be asking if it's still possible to use the Equal Ripple Optimization software for this diplexer if the component models are lossy. The answer is that we cannot in this case because the error function wouldn't be correct with lossy models. So, this design represents a good example of when you would want to take advantage of the ExpertMode parameter.

Now, let's go ahead and run the optimization. Figure 3 shows the simulated results after optimizing. For comparison, Figure 3 also shows the results when using the initial values with Sim_mode set to 0 and ExpertMode set to 1 for all models.

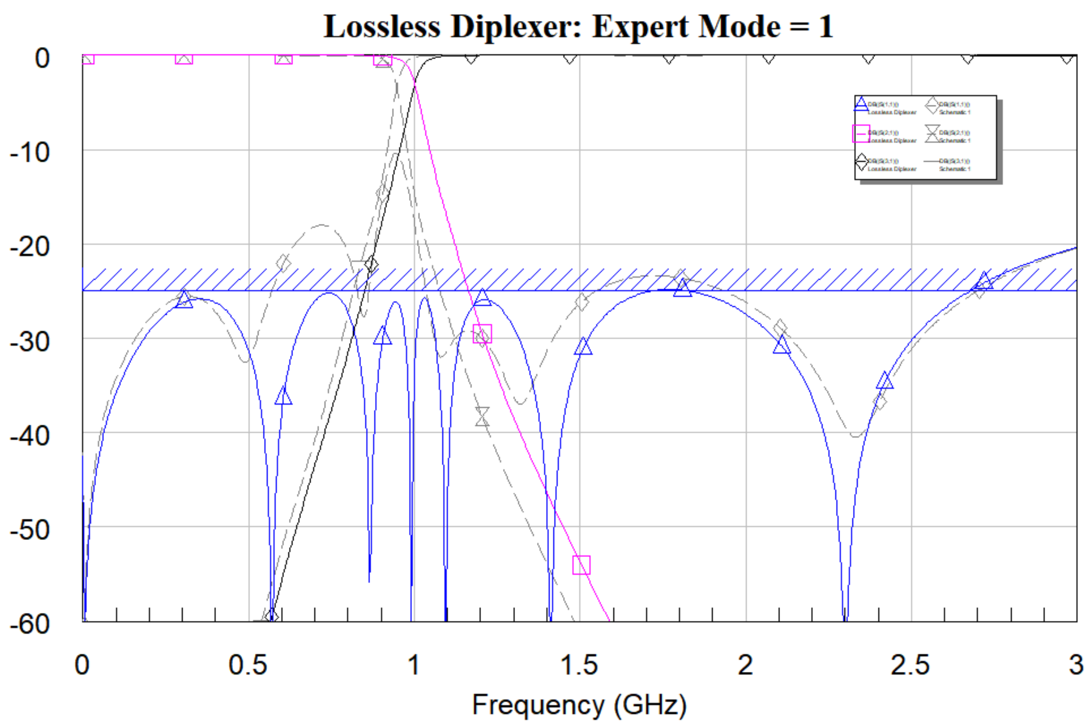

Figure 3. Simulated results after optimizing with the Equal Ripple Optimization software (solid traces). For comparison, the dashed traces show the results after simulating with the initial values with Sim_mode set to 0 and ExpertMode set to 1 for all models.

In Figure 3, notice the additional peak (and null) in the response compared to the response shown in Figure 1. Specifically, the fourth peak that we see here only appears when the lowpass and highpass bandedge frequencies are adjusted correctly. The difference between the bandedge frequencies controls the return-loss level at the crossover frequency. This fine control of the bandedge frequencies is only made possible with the Equal Ripple Optimization software.

Now that we've run the optimization, let's turn loss back on by setting the ExpertMode parameter of all models to 0. We'll also change the substrate definition back to its default lossy condition. After running the simulation with the loss turned back on, we see that the results are very similar to the previous simulation results (Fig. 4). Note that we slightly adjusted some of the component values to better match the lossless performance. For comparison, Figure 4 also shows the previous results obtained when using lossless component models.

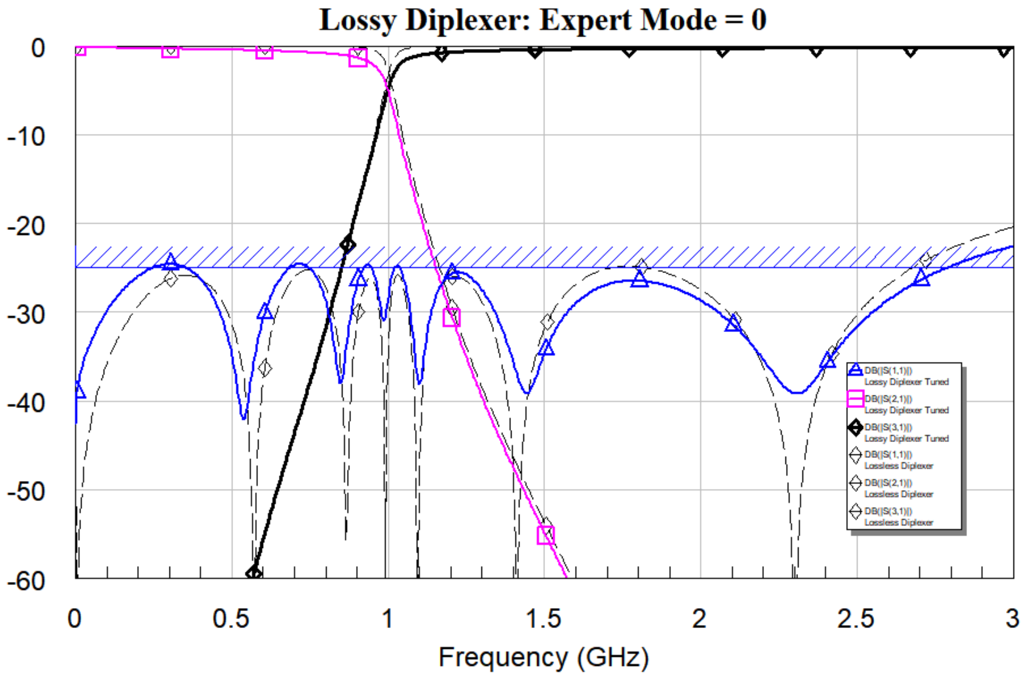

Figure 4. Diplexer performance with lossy component models (solid traces). Note that some component values were slightly adjusted. For comparison, the dashed traces show the previous results with lossless models.

From here, we can go through the process of adding microstrip interconnects and vias. To minimize the impact of the interconnects, the line widths should be as narrow as possible. The lowpass arm is always easier because there's a shunt capacitor at the junctions to absorb parasitic capacitance. The highpass arm is always more difficult because it naturally wants shunt inductance at the junctions.

We'll then set the part values to real-life manufacturer part values that are close to the current values. Since all of this will affect how the diplexer behaves, we'll need to tune the microstrip lengths to retain our desired performance. Readers are encouraged to check out the project file associated with this blog post for more details regarding the diplexer's physical layout. Figure 5 shows the results after simulating the complete diplexer circuit.

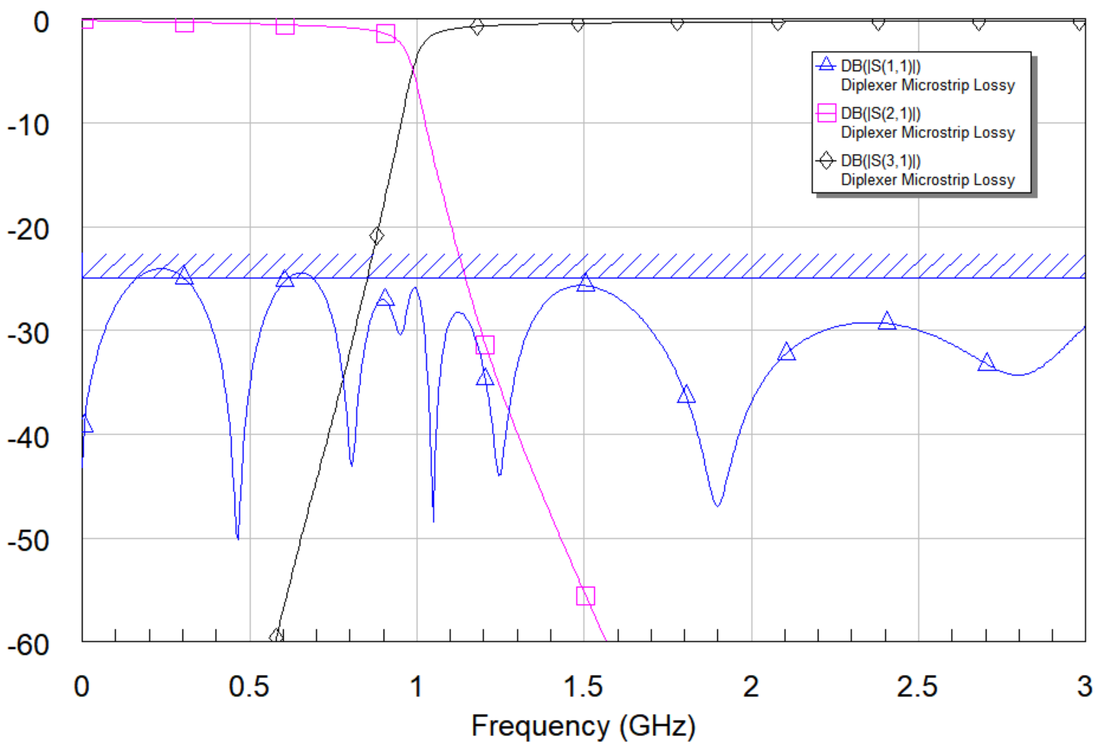

Figure 5. Results after performing a circuit simulation of the complete diplexer circuit.

In Figure 5, we can see that an additional reflection zero appears in the highpass path near 2.75 GHz due to various parasitics in the highpass arm. While you could try to capture this zero with the optimizer, you may end up with a slightly different solution.

Table 1 compares the component values associated with each step of this design flow. Shown are the initial ideal values followed by the values obtained after performing an optimization with the Equal Ripple Optimization software. Remember that this optimization was performed with lossless component models. The third set of part values corresponds to the step following the optimization in which we turned loss back on for all models. At that point, remember that we slighty adjusted some part values to match the lossless performance. These values are shown in the third set of part values in the table. Lastly, the final real-life manufacturer part values used in the complete diplexer design are the fourth and final set of part values listed. Note that there's one capacitor that's not set to a real-life part value due to the best part value not being available within the part series used here. In this case, it would've been more suitable to use a part series with a finer part-value resolution to allow us to select the best component value for the design. This aspect will be taken into account in a future design example.

Table 1

	Initial Ideal Values	Values after optimizing with lossless models	Tuned values after turning loss back on	Final manufacturer part values
Lowpass inductor 1	12.9566 nH	12.79 nH	12.83 nH	13 nH
Lowpass inductor 2	15.9587 nH	15.58 nH	15.58 nH	15 nH
Lowpass inductor 3	15.0262 nH	15.01 nH	14.99 nH	15 nH
Lowpass inductor 4	6.72 nH	6.68 nH	6.68 nH	6.2 nH
Lowpass capacitor 1	5.7221 pF	5.051 pF	5.091 pF	4.7 pF
Lowpass capacitor 2	5.7441 pF	4.891 pF	4.941 pF	4.7 pF
Lowpass capacitor 3	4.7559 pF	3.954 pF	4.174 pF	3.9 pF
Highpass capacitor 1	1.9551 pF	1.873 pF	1.873 pF	1.6 pF
Highpass capacitor 2	1.5872 pF	1.506 pF	1.506 pF	1.384 pF
Highpass capacitor 3	1.6856 pF	1.585 pF	1.585 pF	1.5 pF
Highpass capacitor 4	3.7694 pF	3.4 pF	3.4 pF	3.0 pF
Highpass inductor 1	4.4271 nH	4.299 nH	4.299 nH	4.3 nH
Highpass inductor 2	4.4102 nH	4.359 nH	4.359 nH	4.3 nH
Highpass inductor 3	5.3262 nH	5.15 nH	5.15 nH	5.1 nH

Diplexer part values throughout the design flow.

To wrap this up, we've uncovered the ExpertMode parameter and explained how it can be used with the Equal Ripple Optimization software. We encourage you to give this design process a try for yourself. In addition, be on the lookout for a future application note that will present an even more in-depth look at this topic. This future work will also compare measured data with simulated results.

Finally, if you're not already using Modelithics models, you can request a free trial by visiting www.modelithics.com or emailing sales@modelithics.com.

Note that the example shown here was made possible by support from DGS Associates.