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Passive RF
20dB Coupled Line Coupler Design

The first step in producing the 20dB coupled line coupler was to calculate even and odd impedances for the desired coupling at port 3. This was done below and input into an ideal transmission line simulation. Transmission line outputs were matched to the characteristic impedance of the system ($50\,\Omega$) and arbitrarily made $180°$ in electrical length to account for connector installation later. Figure 1. depicts the layout of the ideal transmission line design and Figure 2. depicts the reflection and transmission coefficients at all ports of the system.

- 20dB coupling = 0.1 magnitude = C
- $Z_{even}=\sqrt{\frac{1+C}{1-C}}\times Z_C=55.2770798\,\Omega$
- $Z_{odd}=Z_{even}\times\frac{1+C}{1-C}=45.22670179\,\Omega$

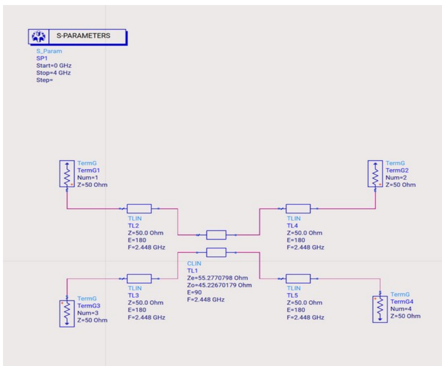



Figure 1. Ideal Transmission Line Design

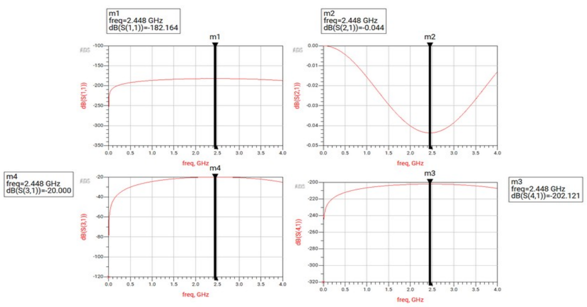



Figure 2. S-Parameter Outputs

As shown above, the ideal transmission line design soundly reaches $20\,dB$ coupling on the coupled port (port 3), has well below 0.2dB excess loss on the through port (port 2), has incredibly low rejection (port 4), and incredibly low return loss (port 1). The above results provide validation in inputting the ideal parameters into ADS LineCalc as a basis for a physical design.

The design approach from this point forward was to create a substrate with physical transmission lines, use LineCalc to determine initial dimension values, and then optimize the system with the system optimizer tool to reach all desired specifications. Figure 3. depicts the base setup of the component.

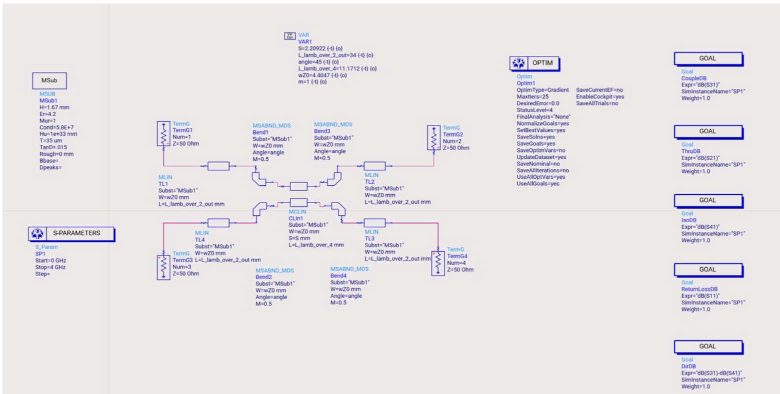


Figure 3. Physical Design

The variables tuned in the physical design are the physical coupling distance (S), characteristic impedance width (wZ0), output T-line lengths (l_lamb_over_2_out), coupler length (l_lamb_over_4), elbow angle (angle), and elbow M value (m). Figure 4. depicts the optimization goals designed to meet system specifications.

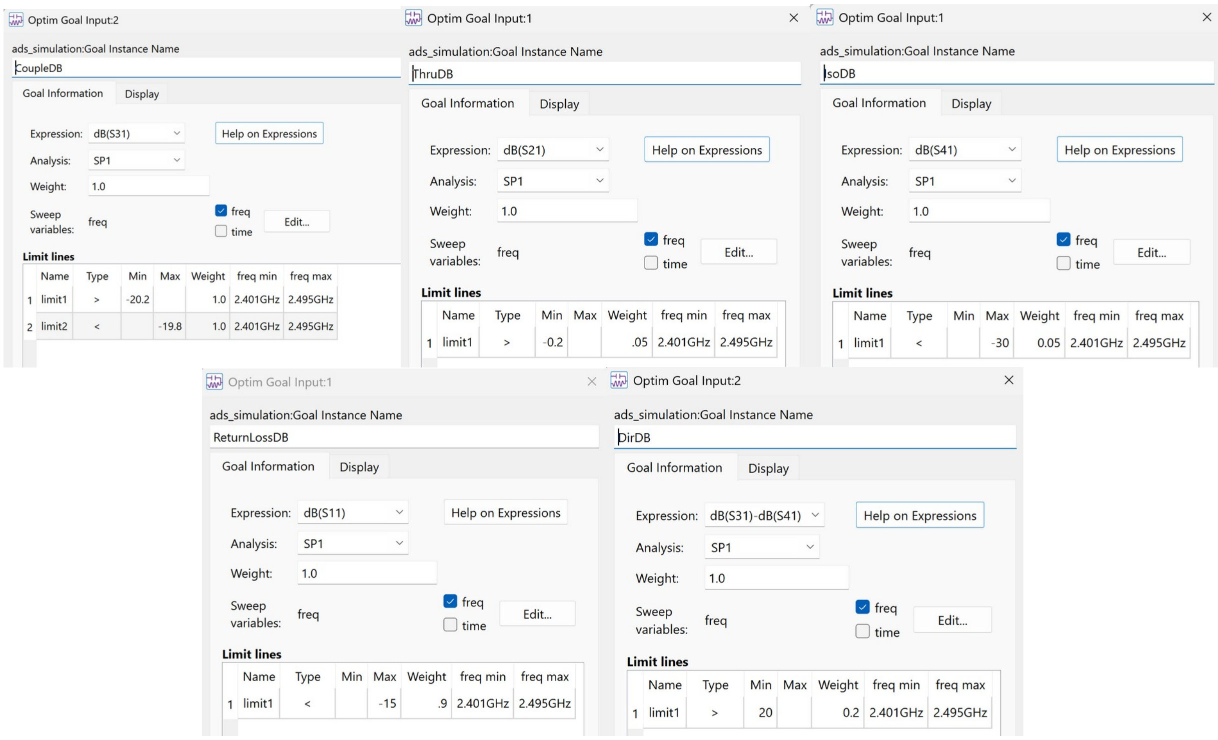



Figure 4. Goals for Optimization

After trial and error, it was determined that the through port goal weight had to be decreased to minimize error the most. The measurement spec is the most important specification for this component, so reducing error for the CoupleDB goal was the chief priority. It was determined that it was unlikely for this component to meet each specification simultaneously. Figure 5. depicts an optimization run and subsequent error contributions from the individual goals.

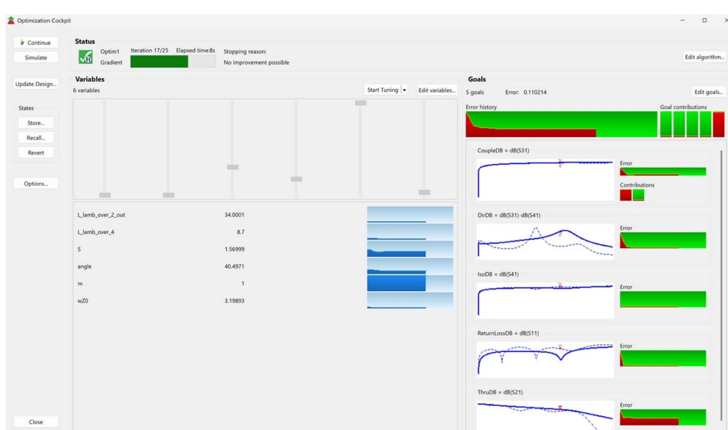


Figure 5. Initial Optimizer Run

Figure 6. depicts the system performance after the optimizer reached a state of no improvement.

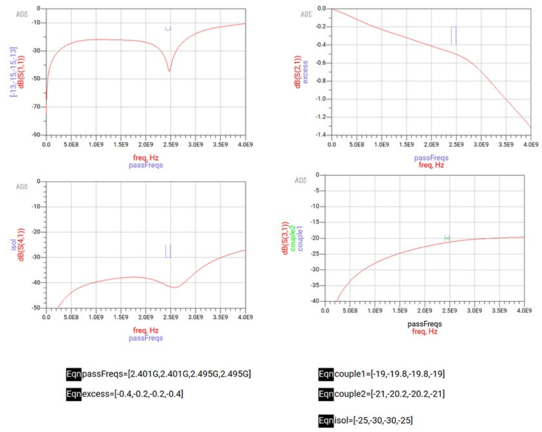



Figure 6. System Performance at Maximum Optimization

Going forward, tests were conducted to determine if loosening the design constraints on the less important goals could boost performance on the more important constraints. For this component, measurement, and through loss are the most important factors in the functionality of the design, and these goals were prioritized.

Even after loosening the isolation and directivity constraints by 10dB and 5dB respectively, the metrics for coupling and excess loss were not met (see Figure 7.).

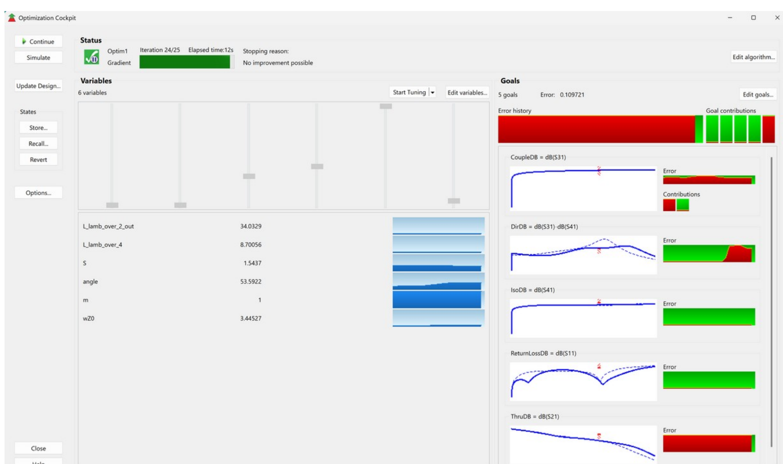


Figure 7. Loose Constraints Optimization Run

Errors appear to go down significantly. For this reason, as a last resort, constraints for the excess loss were increased to < 0.5dB and the coupling constraints were increased to +/- 1dB. All other original criteria can be met if these constraints are changed. S-Parameter results can be found in Figure 8.

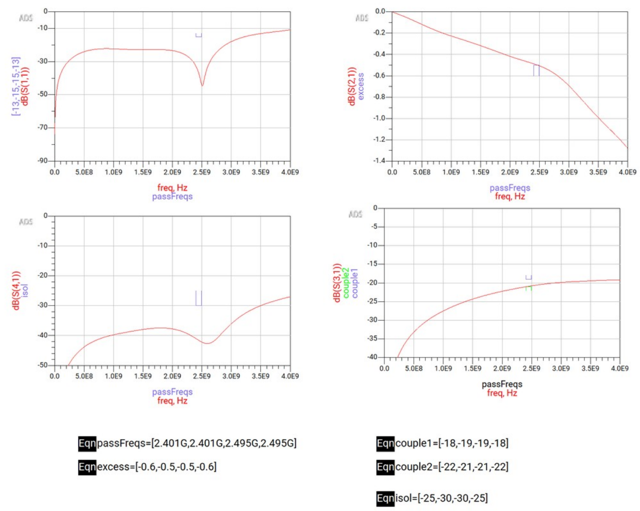



Figure 8. Final Design S-Parameters

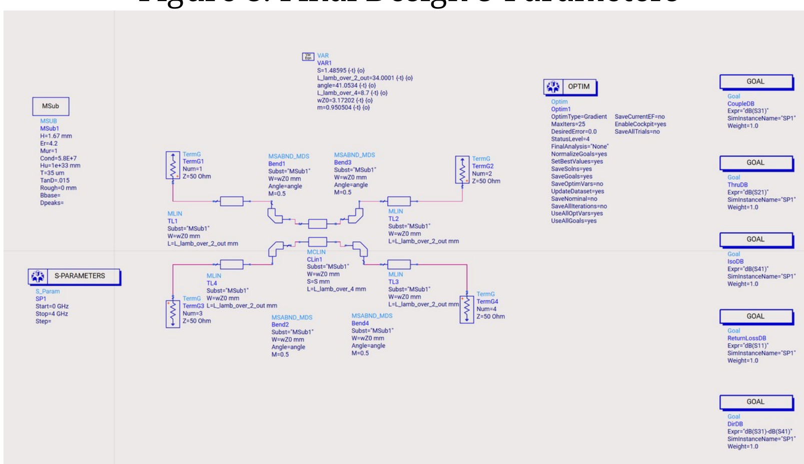



Figure 9. Final Design

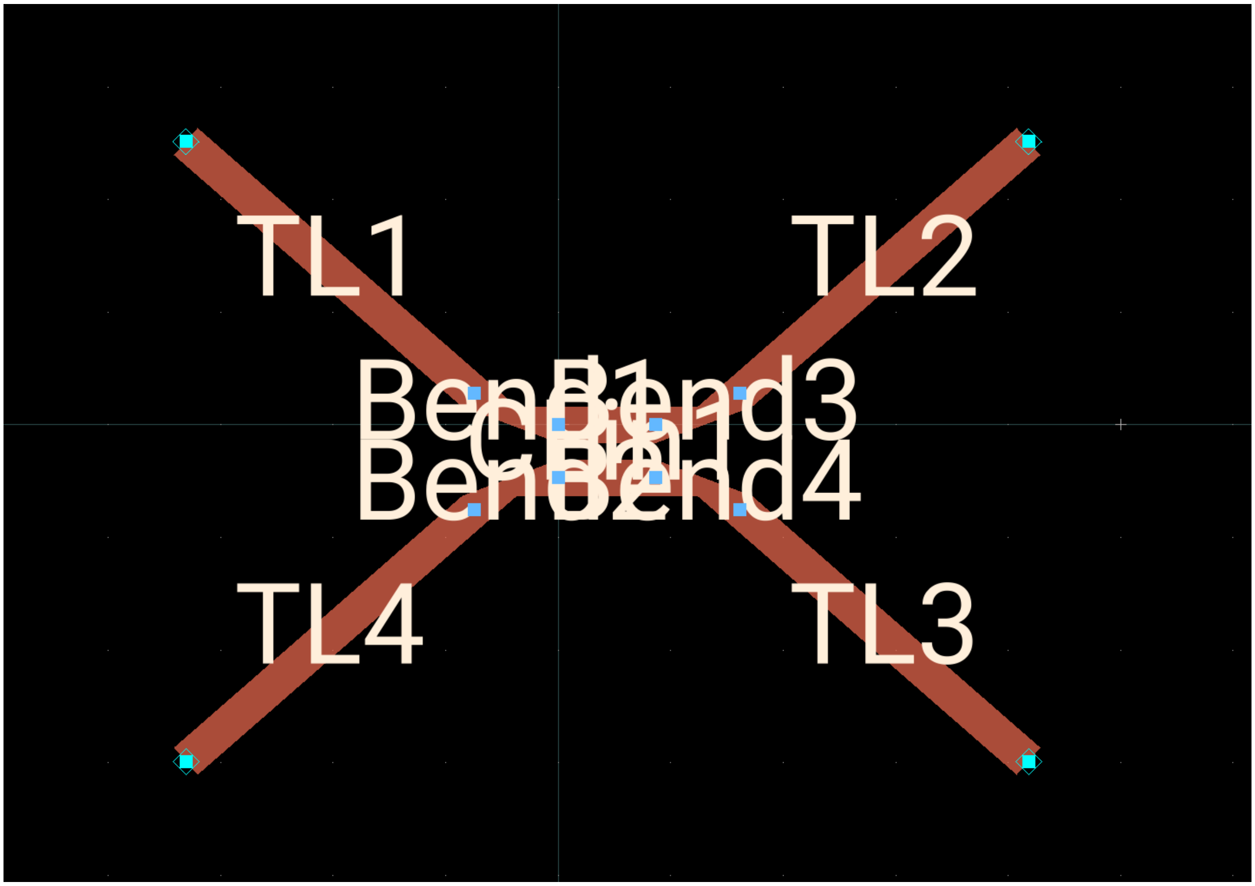



Figure 10. Layout

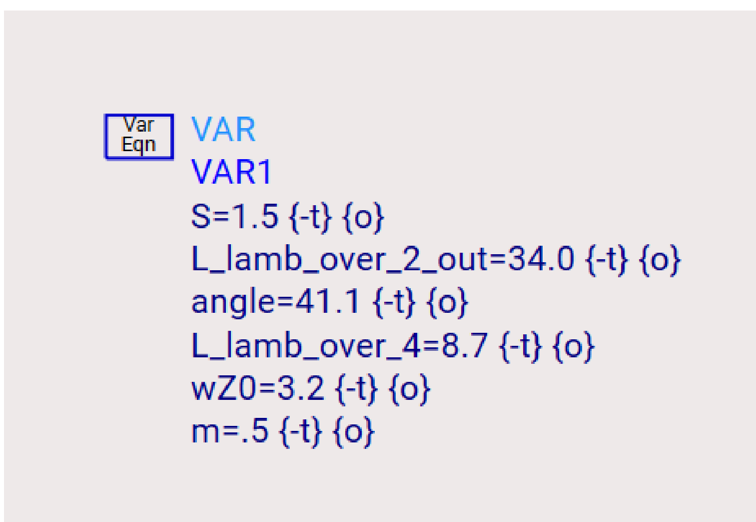
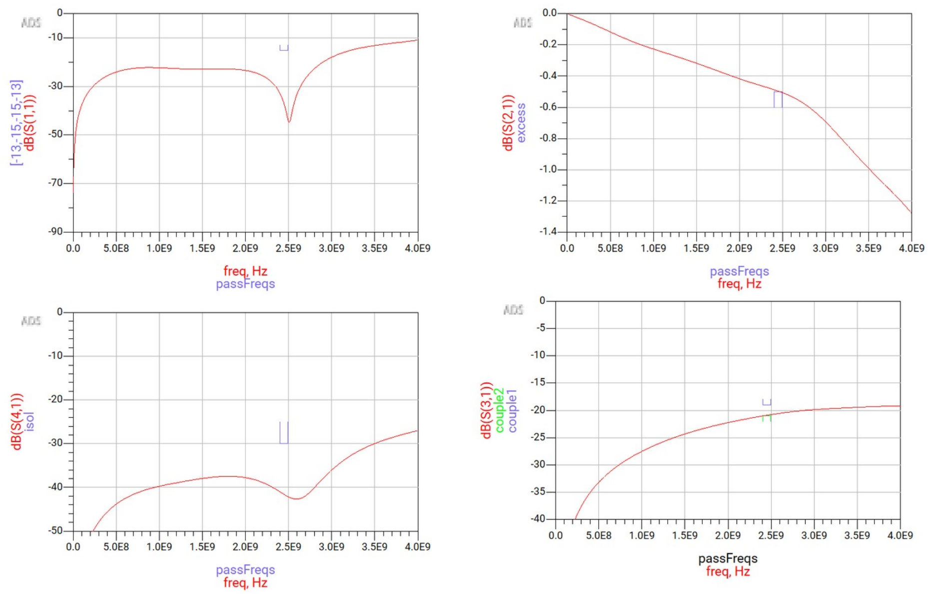



Figure 11: Final Rounded Values




Eqn passFreqs=[2.401G,2.401G,2.495G,2.495G]

Eqn excess=[-0.6,-0.5,-0.5,-0.6]

Eqn couple1=[-18,-19,-19,-18]

Eqn couple2=[-22,-21,-21,-22]

Eqn isol=[-25,-30,-30,-25]

Figure 12: Final Performance with Rounded Values