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Week 2 Labs
2026-01-19

In these labs, we explore matching measured S-parameter models with ideal components in ADS to judge the accuracy of rule-of-thumb estimations and to practice creating digital twins of real systems.

Lab 1: T-line

The DOT is a 2-in transmission line (T-line). Using the bandwidth (BW) rule-of-thumb estimation for lumped circuit models $BW[GHz] = 0.6/Len[in]$, I estimated that the BW of the lumped circuit model would be $\frac{0.6}{2[in]} = 0.3\ [GHz] = 300[MHz]$.

To simulate an open circuit, a capacitor was used. To simulate a closed circuit, an inductor was used. The open-circuit model was accurate to around 200-400MHz, and the closed-circuit model was accurate to around 300-500MHz. This is within an order of magnitude of our estimate, validating it.

Simulated with a T element allows us to simulate the open- and closed-circuit models without varying the element and its model. In other words, the model is independent from the termination, so the termination of the T element and the S-param model should be identical. This model is much more accurate than the lumped models, and it remains accurate to over 10 GHz.

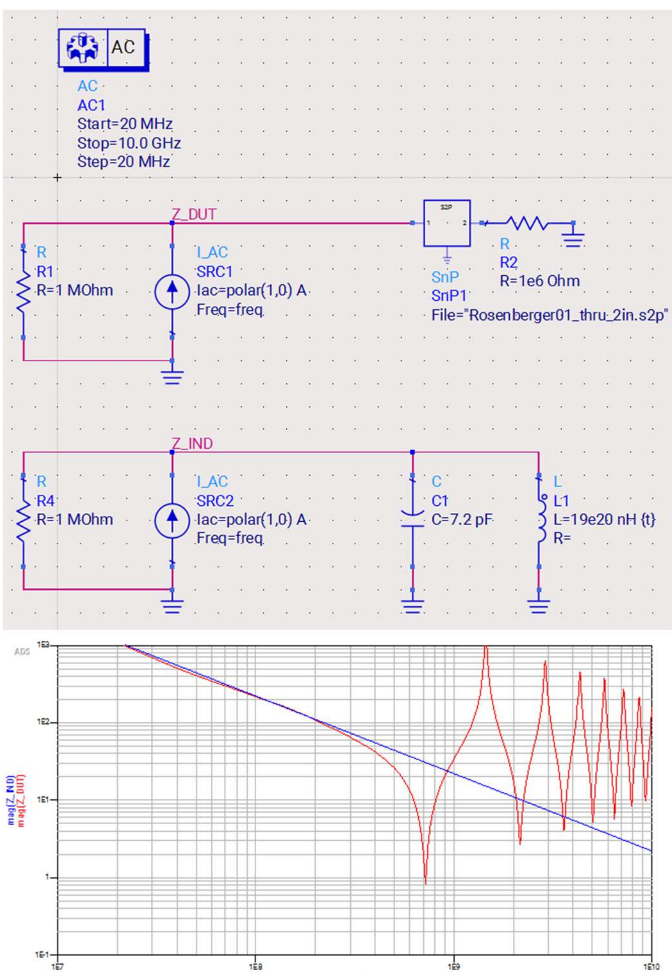

Figure 1: Circuit and simulation for an open T-line using lumped elements.

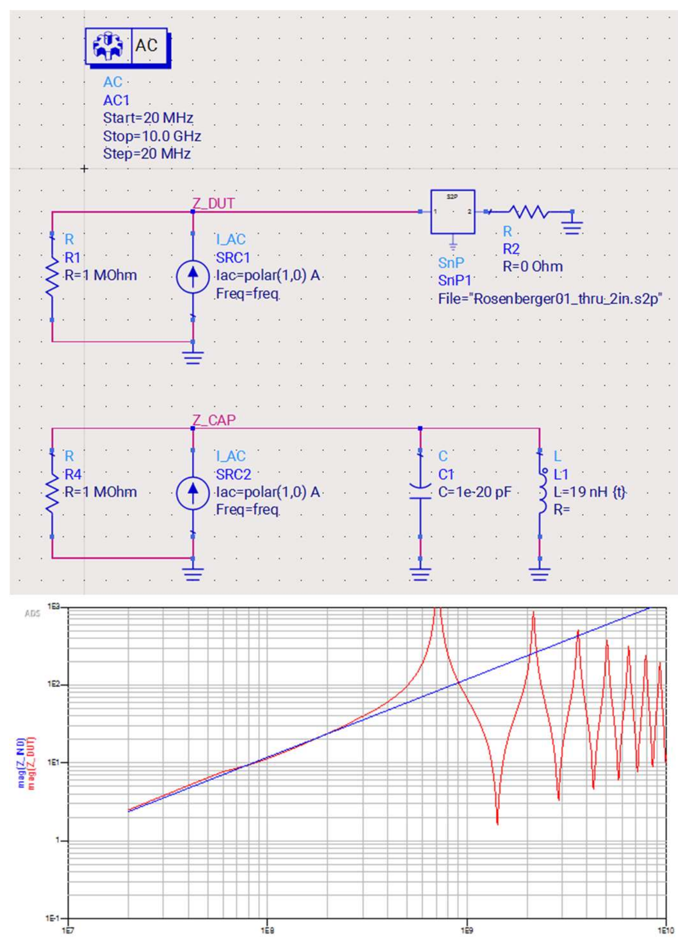

Figure 2: Circuit and simulation for a closed T-line using lumped elements.

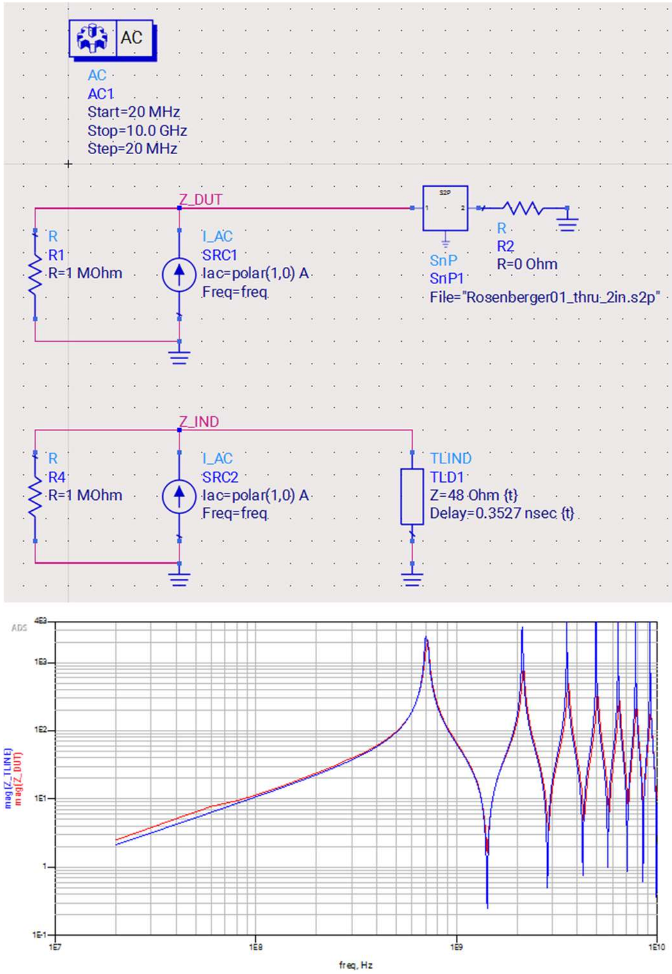

Figure 3: Circuit and simulation for an open T-line using a T element.

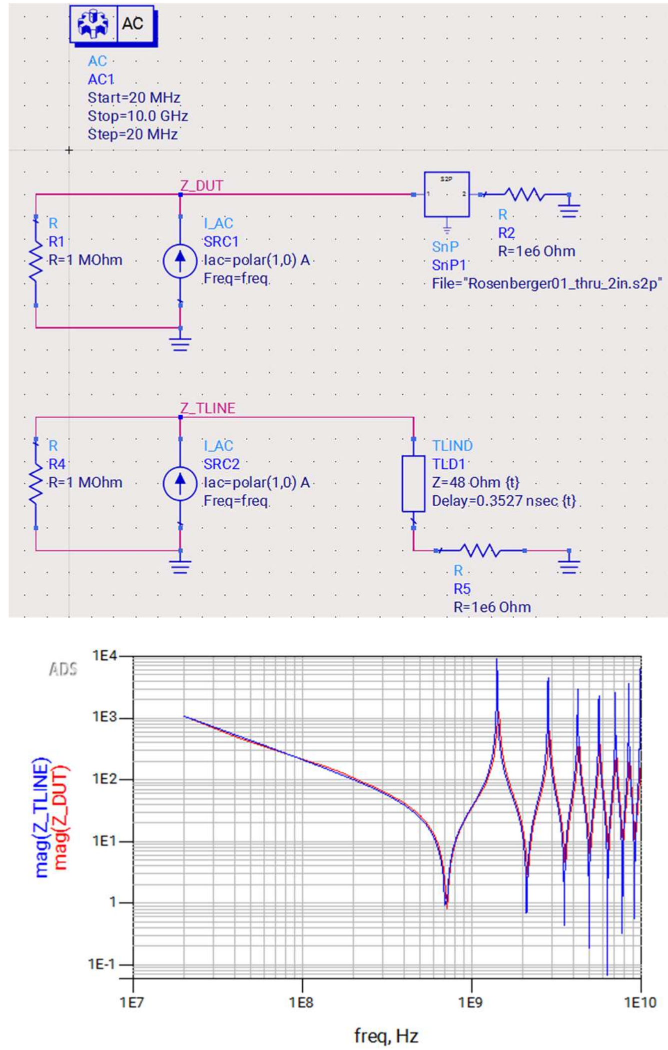

Figure 4: Circuit and simulation for a closed T-line using a T element.

Lab 2: Via

A standard PCB is 1.6mm thick, or about 63 mils. Therefore, I expect a lumped circuit model to work up to $\frac{0.6}{0.063[in]} = 9.5[GHz]$.

The results somewhat line up with my expectations. The open- and closed-circuit results deviate around 3-4 GHz. This is within an order of magnitude of my 9.5 GHz prediction, but the waveform at that point.

Once again, the T element model is more accurate and remains accurate to the maximum frequency in the S-param model of 20 GHz.

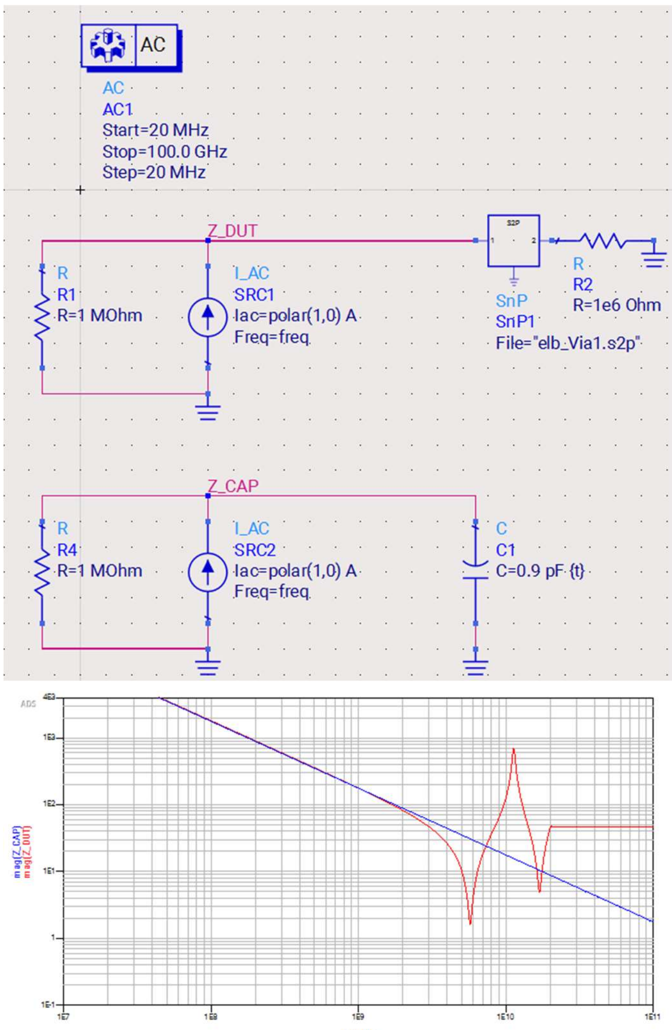

Figure 5: Circuit and simulation for an open via using lumped elements.

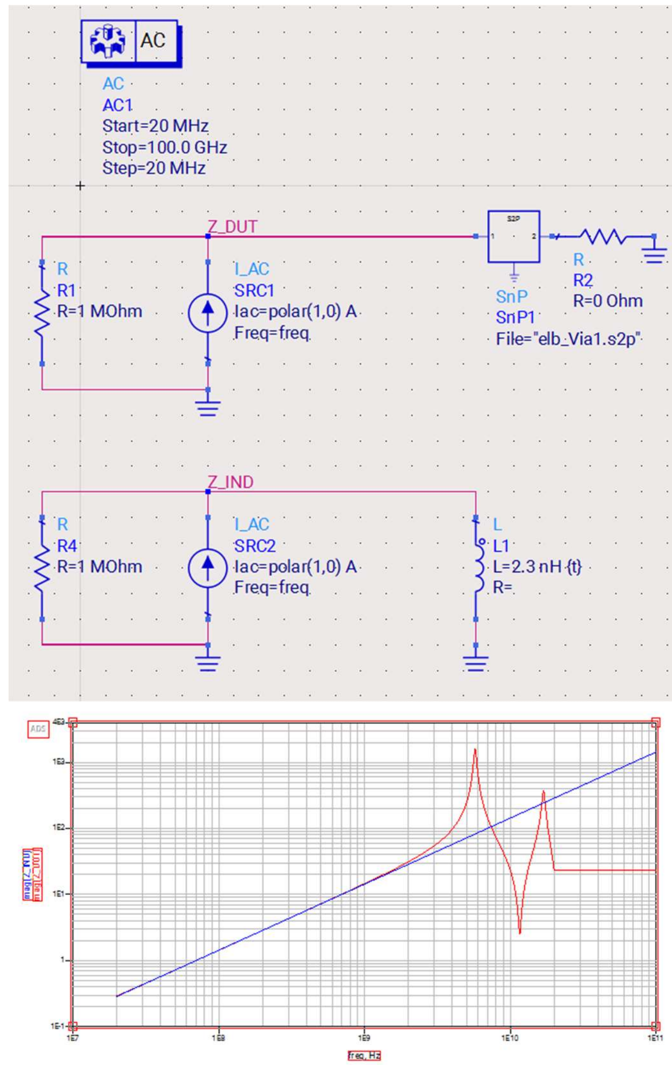

Figure 6: Circuit and simulation for a closed via using lumped elements.

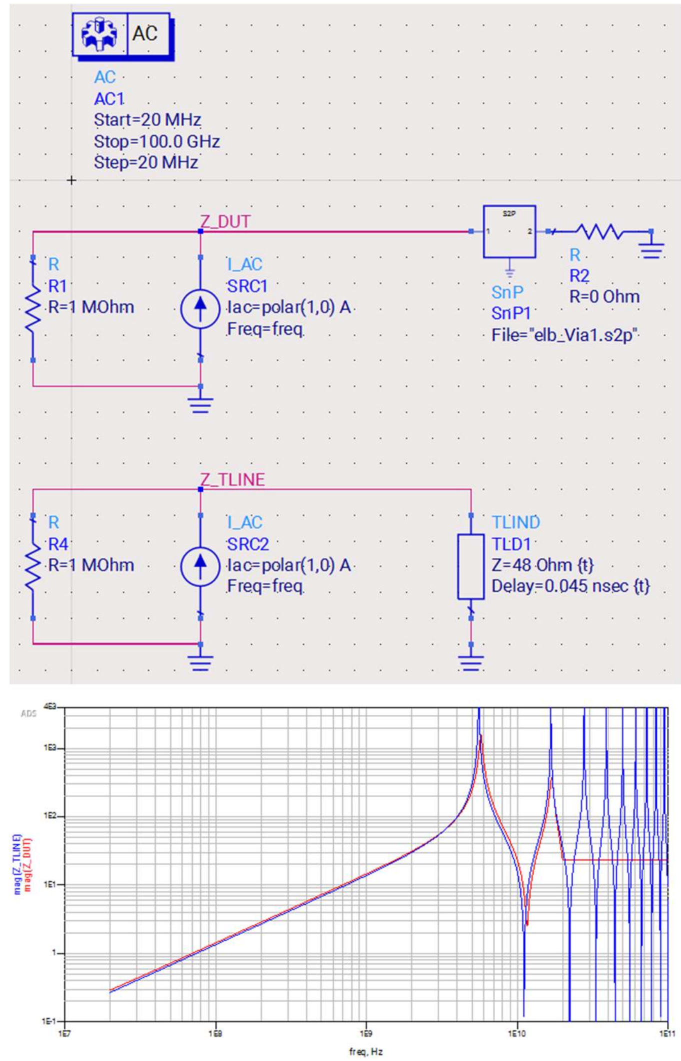

Figure 7: Circuit and simulation for an open via using a T element.

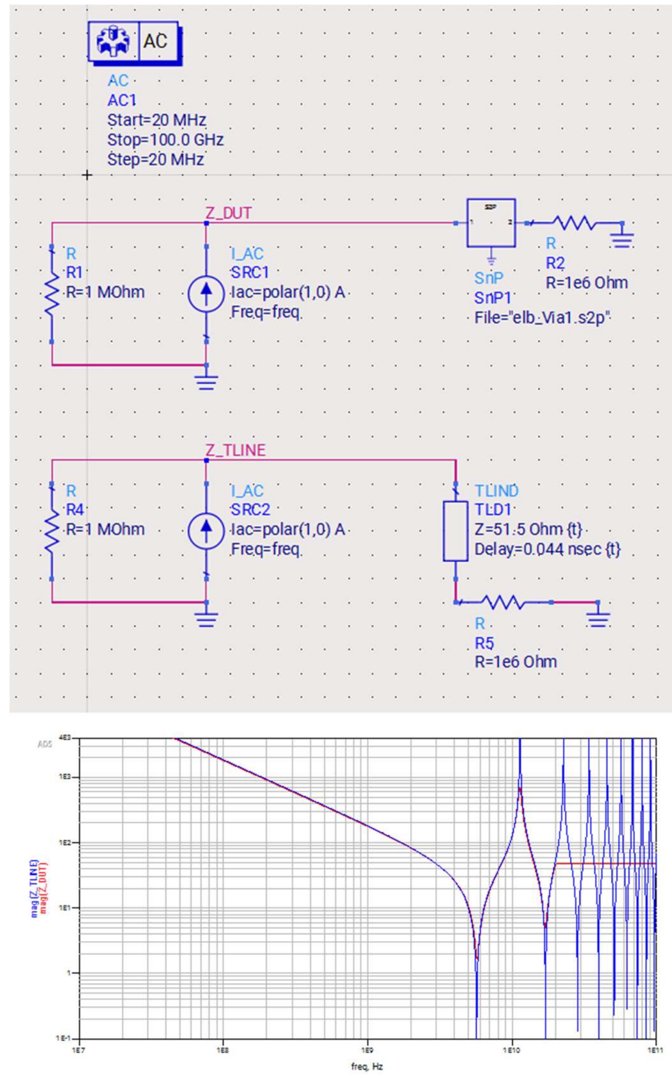

Figure 8: Circuit and simulation for a closed via using a T element.

Conclusions (So what?):

This lab demonstrated that:

- The rule-of-thumb for the bandwidth of lumped element models is useful, though it can only get an estimate within an order of magnitude of the actual bandwidth of the model.
    - This rule-of-thumb was more accurate for the T-line than for the via. This is likely due to the different geometries causing different delays and our rule of thumb being made for lines on 2-layer 1.6mm FR4 boards. The T-line is more similar to an FR4 trace because of its symmetrical geometry, but the via is very short and has a complex 3D geometry.
- A T element model is much more accurate than a lumped element model.
- A digital twin can be created to be a fairly accurate representation of the real world.